Publication 839

Guide to Vegetable Production in Ontario

Ministry of Agriculture, Food and Rural Affairs

Ontario

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Guide to Vegetable Production in Ontario

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Publication 839: Ontario Field Vegetable Guide

This guide features production information for commercial field vegetable production in Ontario. Features of this guide include crop-specific information on production requirements as well as common pest and pathogens of field vegetables grown in Ontario. This guide and the *Vegetable Crop Protection Guide* (Publication 838) replace *Vegetable Production Recommendations* (Publication 363). This publication does not contain specific information on pest control products registered for Ontario field-grown vegetables. For updated lists of available pest control products, please consult Publication 838 or the online Ontario Crop Protection Hub at ontario.ca/cropprotection.

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Chapter 1

Vegetable Crop Fertility and Nutrient Use

Soil fertility is an important component in the production of high-yielding, top-quality vegetable crops. A good soil fertility program balances:

- the requirements of the crop being grown
- the nutrients already available in the soil
- the correct rate, timing, source and placement of nutrient additions

Soil fertility is only one part of a crop management program. The effectiveness of a soil fertility program depends on good soil and water management, as well as crop protection.

For a complete guide to soil fertility, see OMAFRA Publication 611, *Soil Fertility Handbook*.

Assessing Vegetable Crop Nutrient Needs

There are three ways to assess soil and crop fertility:

- visible deficiency symptoms
- soil testing
- plant tissue analysis

Visible Deficiency Symptoms

Leaf symptoms are helpful for evaluating some nutrient deficiencies. Unfortunately, by the time deficiency symptoms are visible, yield losses may have already occurred. Visible deficiency symptoms may also be easily confused with other production problems, such as herbicide injury, leaf and root diseases, nematodes, insect damage, compaction or air pollution. Suspected visual deficiencies can often be confirmed with plant tissue analysis and an accompanying soil sample. It is important to note that the primary cause of a nutrient deficiency may not be due to a lack of nutrients in the soil, but due to something like damaged roots, compaction or vascular disease.

Soil Testing

Soil testing is the most accurate tool available to determine nutrient requirements for a crop (Figure 1–1). It consists of three steps:

1. Collecting a representative sample from the field or specific areas within a field.
2. Analyzing the sample using OMAFRA-accredited soil tests.
3. Relating the results to the nutrient requirements of the crop.

Interpreting the Soil Test Reports

In a soil test report, each nutrient is given a numerical value, a letter rating and a suggested fertilizer application rate. The suggested fertilizer rate is usually listed in kg/ha or lb/acre. The soil test nutrient ratings reflect the likelihood of a yield response to applied fertilizer in the year of application. The yield benefits to an application should exceed the value of the fertilizer and the associated application costs.

The rating system is explained in Table 1–1.

Table 1–1. Soil Test Nutrient Ratings

Response Category (from the soil test report)	Level of Soil Fertility	Probability of Profitable Crop Response to Applied Nutrients
High response (HR)	low	high (most of the cases)
Medium response (MR)	medium	medium (about half the cases)
Low response (LR)	high	low (few of the cases)
Rare response (RR)	very high	rare (very few of the cases)
No or negative response (NR)	excessive	not profitable to apply nutrients

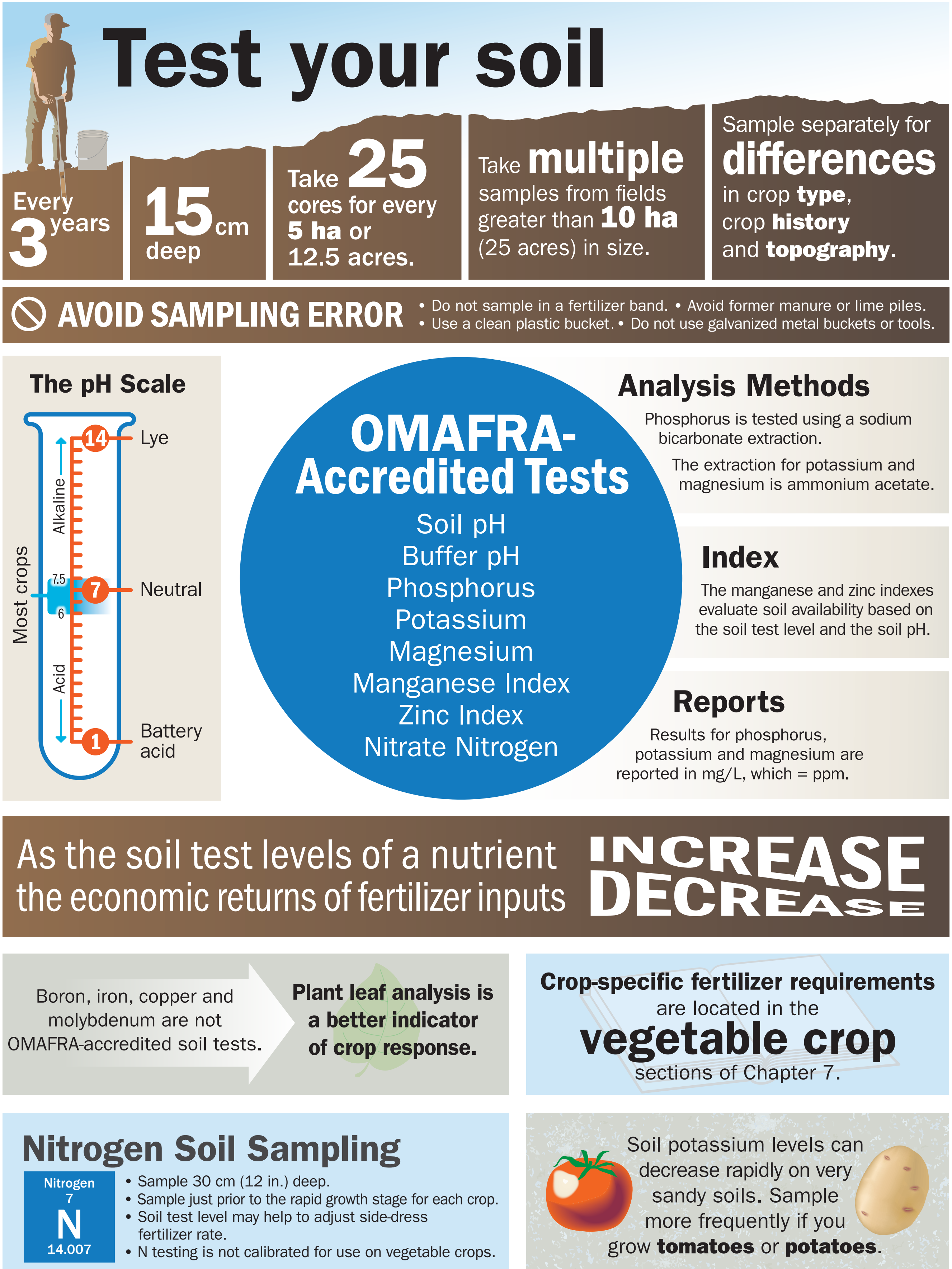


Figure 1–1. Test your soil — sampling information and accredited tests in Ontario.

There are four systems used to help decide fertilizer application rates based on the soil test report:

- sufficiency approach (OMAFRA-accredited)
- build-up and maintenance
- base saturation ratios
- crop removal

Sufficiency Approach

The sufficiency approach aims to minimize the risk of profit loss from over-fertilization. In other words, it aims to maximize net returns to fertilization in the year of application. It recommends to fertilize only when there is a good chance that a profitable yield response will be realized. As a result, it keeps the soil test levels lower and within responsive ranges. This approach is normally adopted on land leased for short periods of time or when cash flow is limited.

OMAFRA recommendations are based on sufficiency. The OMAFRA-accredited program uses field trials to determine the optimal application nitrogen, phosphorus and potassium rates. These rates are most likely to maximize profit in the year of application. Applying nutrients according to OMAFRA guidelines will maintain or gradually increase soil fertility (Figure 1–2).

The OMAFRA-accredited nitrogen, phosphorus and potassium rates for each crop are listed in Chapter 7.

Build-up and Maintenance Approach

The nutrient build-up and maintenance approach intends to minimize the risk of yield loss from nutrient deficiency. It removes nutrient as a yield-limiting variable and emphasizes soil fertility levels rather than crop response. In other word, fertilizers are applied at rates higher than those determined by crop response to keep the soil test levels higher, usually in non-responsive ranges. This approach is normally adopted on owned land or land leased for longer periods of time. Fertilizer recommendations based on the build-up and maintenance approach are always higher than the recommendations based on the sufficiency approach.

There is no economic advantage to maintaining soil test levels in the rare response (RR) or no response (NR) range. High levels of some nutrients may interfere with the uptake of others and cause yield reductions. For example, high levels of soil phosphorus may limit the uptake of zinc. High levels of potassium may reduce magnesium uptake.

The build-up and maintenance concept does not apply to nutrients that readily leach from the soil, such as nitrogen and sulphur.

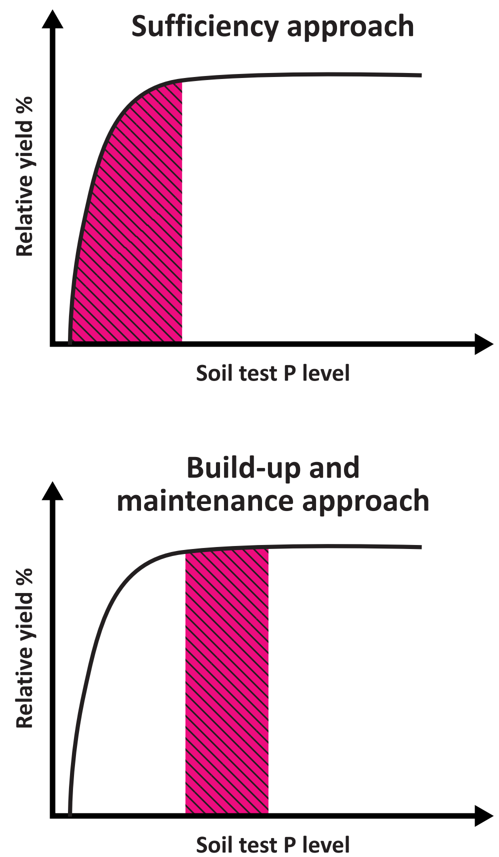


Figure 1–2. Soil test phosphorus (P) levels under two approaches: the sufficiency approach (top) and the build-up and maintenance approach (bottom).

Base Saturation Ratio

This concept addresses cation interactions and aims to achieve "ideal" proportions of potassium, calcium and magnesium cations in relation to each other. This system suggests that calcium should occupy 65% of the cation exchange sites, magnesium 10% and potassium 5%. However, research has shown that crops can grow at a wide range of potassium-calcium-magnesium ratios or percentages, provided one of the nutrients is not clearly deficient.

Base saturation ratios do not include an economic analysis of the fertilizer application rates. Many Ontario soils have high levels of calcium and magnesium, leading to a large imbalance between these nutrients and the potassium levels. The rates of potassium needed to balance the system are often uneconomical. Ontario research has not found any significant effect of cation exchange capacity on the amount of potassium required for optimal crop growth. This approach does not apply for nitrogen and phosphorus recommendations.

Crop Removal

Crop removal fertilizer rates are calculated using the average amount of each nutrient removed from the soil in the harvested portion of the crop. This system does not account for naturally occurring levels of nutrients supplied by the soil. As a result, the suggested fertilizer rates for phosphorus and potassium are often uneconomically high. On soils with a rating of low response (LR), rare response (RR) or no response (NR), the increase in yield may not pay for the additional fertilizers applied using crop removal calculations.

Alternately, many vegetable crops have comparatively low nutrient removal values. In these instances, the fertilizer rates determined by crop removal may actually be lower than the amount needed to support crop growth and quality. On soils with a high response rating (HR), fertilizer rates based on crop removal may result in an insufficient fertilizer application.

Plant Tissue Analysis

Plant tissue analysis measures the nutrient content within the plant tissue. These results are compared against established normal ranges for the crop, identifying if a specific nutrient is excessive, adequate or deficient. Tissue analysis sufficiency ranges are listed for many individual vegetable crops in Chapter 7.

There are advantages and disadvantages to using plant tissue analysis to manage crop fertility.

Advantages:

- Accredited soil tests are not available for boron, copper, iron or molybdenum. Plant tissue analysis can provide information to help manage these nutrients.
- Plant tissue analysis provides growers with an opportunity to evaluate phosphorus, potassium, magnesium and manganese fertility programs during the growing season.
- Plant tissue analysis is a valuable tool for diagnosing nutrient-related problem areas in the field for future corrective measures.
- If the soil levels of a nutrient are known to be adequate, plant tissue analysis may indicate other problems that are reducing nutrient uptake.

Disadvantages:

- Plant tissue analysis is unreliable for evaluating nitrogen and zinc.
- The test results do not indicate the cause of a deficiency or the amount of fertilizer required to correct it.
- The timing of tissue analysis on many vegetable crops is difficult. Rapid growth and a relatively short growing season mean that yield loss may have already occurred by the time sample results are available.
- Rapid growth may result in temporary deficiencies unrelated to actual soil deficiency or even yield potential.

Plant tissue analysis is most useful when it is combined with:

- a current soil test to provide information about soil nutrient levels and soil pH
- a visual inspection of the crop and soil conditions
- knowledge of past management in the field

There is no OMAFRA accreditation process for plant tissue analysis. However, OMAFRA-accredited soil laboratories that perform plant tissue analysis are monitored and provide quality analysis and interpretation of plant tissue samples.

Plant Tissue Sampling

Time of sampling and the plant part sampled both have a major effect on the results of plant tissue analysis. Nutrient levels within a plant vary considerably with age and physiological growth stage. Recommended sampling stages have been developed for most vegetable crops. These are listed in the nutrient sufficiency range tables found in the individual crop sections of Chapter 7. Results are difficult to interpret if samples are taken at times other than the recommended timing.

For most crops, sample the most recently mature leaf from each plant. Very old and very young leaves often provide misleading results.

To diagnose a specific crop problem:

- Take tissue samples from the problem area and a separate sample from an adjacent, non-affected part of the field, for comparison purposes.
- Take leaves from at least 20 plants or petioles from at least 50 plants (approximately 250 g of fresh weight samples), distributed throughout the area being sampled.
- Store tissue samples in paper bags. Plant tissues will rot more quickly if they are stored in plastic bags.
- Wash any soil from the leaves prior to shipping them to the laboratory.
- Deliver fresh plant samples directly to the laboratory or air dry them at a low temperature (no greater than 65°C (149°F)) to prevent spoilage.
- Collect and submit a soil sample from both affected and non-affected areas to accompany the tissue sample.

Tissue sampling procedures (leaves, petioles) for different crops are also described in OMAFRA Publication 611, *Soil Fertility Handbook*. Plant tissue analysis may be obtained from several laboratories in Ontario. See *Appendix C. Accredited Soil-Testing Laboratories in Ontario*.

Soil Acidity and Liming

The pH scale is used to indicate acidity and alkalinity. A pH value of 7 is neutral. As pH values decrease from 7 to 1, acidity increases. Alkalinity increases as the pH values increase from 7 to 14.

On mineral soils, most vegetable crops grow well in a soil pH range from 6.0–7.5. A range of 5.0–6.0 is acceptable on muck soils. For specific vegetable crop pH requirements, see the individual crop sections of Chapter 7.

Maintaining a soil's pH within the appropriate range is important. Some nutrients become less available at a soil pH outside the crop's ideal range, while others become more available. Either situation could result in the potential for nutrient deficiencies or toxicities.

Where a crop is grown in rotation with other crops requiring a higher pH, lime the soil to the higher pH. Crops with significantly different pH requirements (e.g., brassicas and potatoes) may not be a suitable rotation.

To correct soil acidity, broadcast ground limestone and work it into the soil at rates determined by a soil test. Use dolomitic limestone on soils with a magnesium soil test of 100 ppm or less.

Macronutrients

Macronutrients are required by the plants in large quantities for basic plant growth and development. They include the primary nutrients: nitrogen, phosphorus and potassium, as well as the secondary nutrients: calcium, magnesium and sulphur.

For information on macronutrient deficiency symptoms and their causes, as well as the effects of excessive amounts of macronutrients in the soil, see Figure 1–3 and Table 1–2.

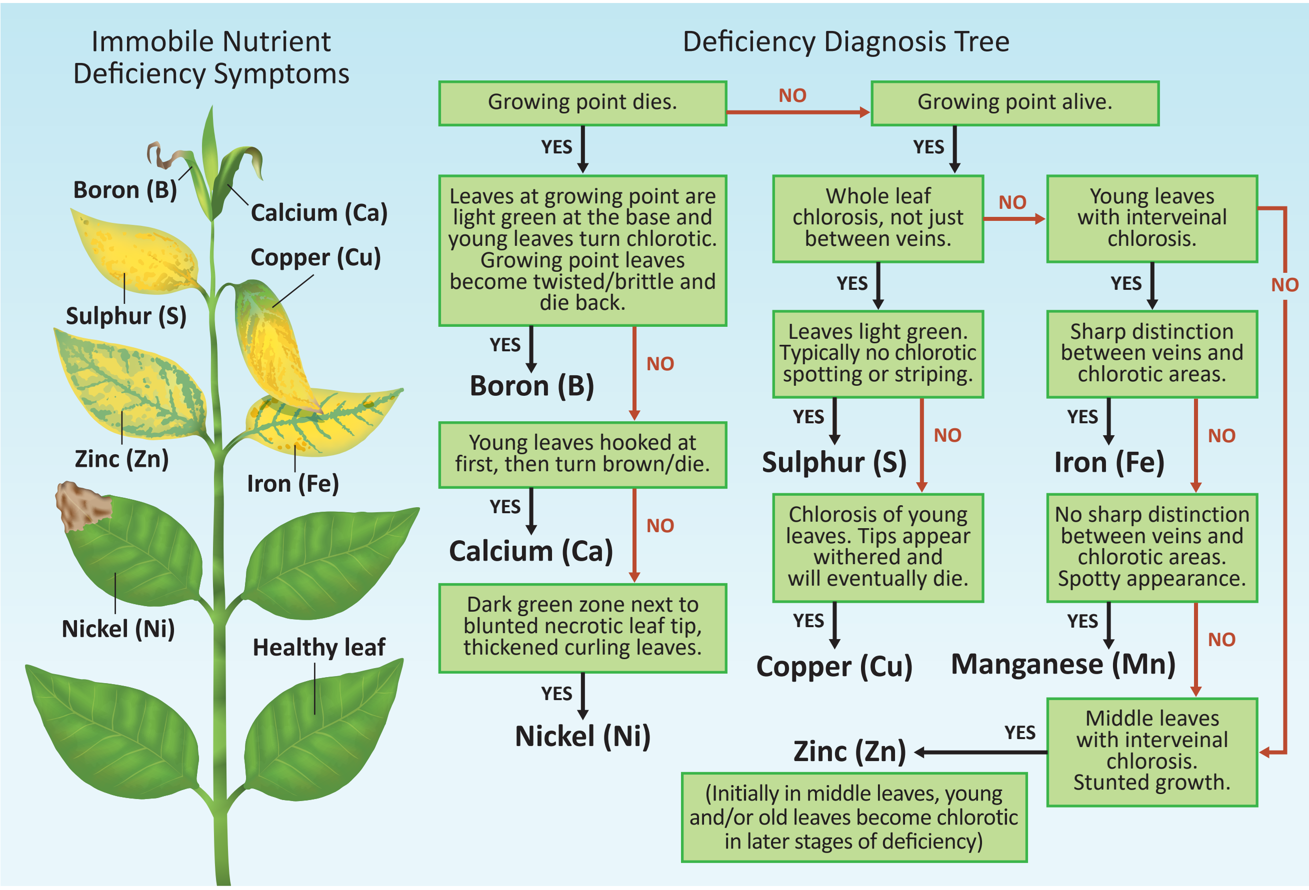


Figure 1–3. Nutrient deficiency symptoms.

Table 1–2. Macronutrients in Soil and Plants

Nutrient	Form Taken up by Plants	Deficiency Symptoms	Soil or Environmental Conditions Most Often Deficient	Effects of Excess Amount
Nitrogen	nitrate (NO_3^-) ammonium (NH_4^+)	◦ reduced growth, yield or quality ◦ general yellowing of older leaves first	◦ underfertilized soils ◦ waterlogged soils ◦ cool growing conditions ◦ impeded root development	◦ excessive vegetative growth ◦ reduced flower development ◦ increased insect or disease pressure
Phosphorus	phosphate ($H_2P0_4^-$) ($HP0_4^{2-}$)	◦ reduced growth, yield or quality ◦ purplish-red leaves ◦ older leaves impacted first ◦ often on the underside of the leaf	◦ underfertilized soils ◦ marl soils ◦ low pH soils ◦ cool growing conditions	◦ reduced uptake of zinc
Potassium	potassium (K+)	◦ reduced growth, yield or quality ◦ yellow leaves, beginning at edges ◦ colour disorders (tomatoes) ◦ fruit abortion or misshapen fruit	◦ sands and loams	◦ reduced uptake of magnesium
Calcium	calcium (Ca_2+)	◦ buds do not develop properly ◦ young leaves emerge twisted and yellow ◦ blackheart in celery and potato ◦ tip burn in lettuce and cabbage ◦ cavity spot in carrots ◦ blossom end rot in tomatoes and watermelon	◦ acidic sandy soils ◦ under-irrigated soils ◦ uncommon in Ontario	N/A
Magnesium	magnesium (Mg_2+)	◦ yellowing between leaf veins ◦ older leaves impacted first ◦ may occur in corn, tomatoes, potatoes, carrots, celery and spinach	◦ acidic soils ◦ sandy soils ◦ following high rates of potassium	N/A
Sulphur	sulphate ($S0_4^{2-}$)	◦ reduced growth, yield or quality ◦ general yellowing of leaves	◦ see *Sulphur*	N/A

Adapted from BMP20, *Managing Crop Nutrients*, 2008.

Nitrogen, phosphorus and potassium fertilizer application rates for specific crops are noted in the individual crop sections in Chapter 7. For phosphorus and potassium recommendations for muck and mineral soils, see Table 1–3, Table 1–4, Table 1–5, Table 1–6.

The phosphorus and potassium rates used in this publication are based on soil test results. Where a soil test is not available, use the following guidelines to obtain a rough estimate of the fertilizer requirements:

- If the field has received fertilizer regularly for a number of years, heavily in recent years or received manure regularly, use a rate suggested for the medium response (MR) soil test rating.
- If the field has received very little fertilizer or manure in the past, use one of the rates provided for a high response (HR) soil test rating.

Where soil test results indicate the need for additional magnesium, see Table 1–7.

Table 1–3. Phosphorus Requirements: Vegetables on Mineral Soils

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

Sodium Bicarbonate Phosphorus Soil Test (ppm)	Phosphate (P_2O_5) Required kg/ha (lb/acre)								
	Beans (lima & snap) Peas	Radishes	Sweet corn Asparagus (est.)	Sugarbeets	Beets Carrots Lettuce Onions Parsnips Rutabagas Spinach Horseradish	Potatoes	Cucumbers Muskmelons Pumpkins Squash Tomatoes[1] Watermelons	Celery Rhubarb	Broccoli[2] Brussels sprouts[2] Cabbages[2] Cauliflower[2] Eggplant[1] Peppers[1] Asparagus (nursery & new plantings)
0–3	80 (71) HR	80 (71) HR	110 (98) HR	150 (134) HR	180 (161) HR	200 (178) HR	230 (205) HR	230 (205) HR	270 (241) HR
4–5	60 (54) HR	70 (63) HR	100 (89) HR	140 (125) HR	170 (152) HR	200 (178) HR	230 (205) HR	230 (205) HR	260 (232) HR
6–7	50 (45) HR	60 (54) HR	90 (80) HR	140 (125) HR	170 (152) HR	190 (170) HR	220 (196) HR	220 (196) HR	250 (223) HR
8–9	40 (36) HR	60 (54) HR	70 (63) HR	130 (116) HR	160 (143) HR	190 (170) HR	220 (196) HR	220 (196) HR	240 (214) HR
10–12	30 (27) MR	50 (45) MR	50 (45) HR	130 (116) MR	160 (143) HR	180 (161) HR	210 (187) HR	220 (196) HR	230 (205) HR
13–15	20 (18) MR	50 (45) MR	20 (18) MR	120 (107) MR	150 (134) HR	170 (152) HR	190 (170) HR	210 (187) HR	220 (196) HR
16–20	0 LR	40 (36) LR	20 (18) MR	100 (89) LR	140 (125) HR	160 (143) HR	170 (152) HR	190 (170) HR	200 (178) HR
21–25	0 LR	40 (36) LR	20 (18) LR	90 (80) LR	120 (107) MR	140 (125) MR	140 (125) MR	160 (143) MR	170 (152) HR
26–30	0 RR	30 (27) LR	20 (18) LR	70 (63) RR	100 (89) MR	120 (107) MR	110 (98) MR	140 (125) MR	140 (125) MR
31–40	0 RR	30 (27) LR	0 RR	50 (45) RR	80 (71) MR	90 (80) MR	80 (71) MR	110 (98) MR	110 (98) MR
41–50	0 RR	20 (18) LR	0 RR	30 (27) RR	50 (45) LR	50 (45) MR	50 (45) MR	80 (71) MR	80 (71) MR
51–60	0 RR	0 LR	0 RR	0 RR	30 (27) RR	30 (27) LR	30 (27) LR	50 (45) LR	50 (45) LR
61–80	0 NR	0 RR	0 NR	0 RR	0 RR	30 (27) LR	0 RR	0 RR	0 RR
80+	0 NR	0 NR	0 NR	0 NR	0 NR	30 (27) LR	0 NR	0 NR	0 NR

[1] For transplanted tomatoes, peppers and eggplants, apply a starter solution, such as 1 L of 10-34-0 per 100 L of water, or 1 L of 6-24-6 per 75 L at planting.

[2] For transplanted broccoli, Brussels sprouts, cabbages and cauliflower, if no insecticide is used in the planting water, apply a starter solution high in nitrogen such as 20-20-20 at 1 kg/200 L. Under high temperatures and in dry, sandy soils, use half the concentration of fertilizer.

Table 1–4. Phosphorus Requirements: Vegetables on Muck Soils

LEGEND: HR = high response MR = medium response
LR = low response RR = rare response
NR = no response

Sodium Bicarbonate Phosphorus Soil Test (ppm)	Phosphate (P_2O_5) required kg/ha (lb/acre)	
	Beets Broccoli[1] Brussels sprouts[1] Cabbages[1] Carrots Cauliflower[1] Lettuce Onions[2] Parsnips Potatoes Radishes Spinach	Celery
0–3	100 (89) HR	120 (107) HR
4–5	100 (89) HR	120 (107) HR
6–7	100 (89) HR	120 (107) HR
8–9	100 (89) HR	120 (107) HR
10–12	90 (80) MR	120 (107) HR
13–15	90 (80) MR	110 (98) MR
16–20	80 (71) MR	100 (89) MR
21–25	70 (63) MR	90 (80) MR
26–30	60 (54) MR	80 (71) MR
31–40	50 (45) LR	70 (63) LR
41–50	30 (27) LR	50 (45) LR
51–60	20 (18) LR	40 (36) LR
61–80	0 RR	0 RR
80+	0 NR	0 NR

[1] For transplanted broccoli, Brussels sprouts, cabbages and cauliflower, if no insecticide is used in the planting water, apply a starter solution high in nitrogen, such as 20-20-20 at 1 kg/200 L. Under high temperatures and in dry, sandy soils, use half the concentration of fertilizer.

[2] If maturity of onions is a problem on organic soils less than 40 cm (16 in.) deep, additional phosphate may be required.

Table 1–5. Potassium Requirements: Vegetables on Muck Soils

LEGEND: HR = high response MR = medium response
LR = low response RR = rare response
NR = no response

Ammonium Acetate Potassium Soil Test (ppm)	Potash (K_2O) required kg/ha (lb/acre)		
	Broccoli Brussels sprouts Cabbages Cauliflower	Carrots Celery Onions Parsnips Potatoes	Beets Lettuce Radishes Spinach
0–15	200 (178) HR	230 (205) HR	100 (89) HR
16–30	190 (170) HR	220 (196) HR	100 (89) HR
31–45	170 (152) HR	210 (187) HR	90 (80) HR
46–60	150 (134) HR	200 (178) HR	80 (71) HR
61–80	120 (107) MR	170 (152) MR	60 (54) MR
81–100	90 (80) MR	150 (134) MR	40 (36) MR
101–120	70 (63) MR	120 (107) MR	30 (27) MR
121–150	50 (45) MR	80 (71) MR	20 (18) MR
151–180	40 (36) MR	40 (36) MR	20 (18) MR
181–210	0 LR	0 LR	0 LR
211–250	0 RR	0 RR	0 RR
250+	0 NR	0 NR	0 NR

Table 1–6. Potassium Requirements: Vegetables on Mineral Soils

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

Ammonium Acetate Potassium Soil Test (ppm)	Potash ($K_2$0) Required kg/ha (lb/acre)									
	Radishes	Beans (snap & lima) Peas	Sweet corn	Sugar-beets[1]	Tomatoes (paste & fresh market) Cucumbers Muskmelons Pumpkin Squash Watermelons	Beets Carrots Lettuce Onions Parsnips Potatoes Spinach Horseradish	Broccoli Brussels sprouts Cabbages Cauliflower Eggplant Peppers	Celery Rhubarb Rutabagas[2]	Asparagus	Tomatoes[2] (whole pack)
0–15	60 (54) HR	120 (107) HR	170 (152) HR	180 (161) HR	230 (205) HR	230 (205) HR	270 (241) HR	340 (303) HR	420 (375) HR	660 (589) HR
16–30	60 (54) HR	110 (98) HR	160 (143) HR	170 (152) HR	220 (196) HR	220 (196) HR	250 (223) HR	330 (294) HR	400 (257) HR	640 (571) HR
31–45	50 (45) HR	90 (80) HR	140 (125) HR	160 (143) HR	200 (178) HR	210 (187) HR	230 (205) HR	310 (277) HR	360 (321) HR	600 (535) HR
46–60	50 (45) HR	80 (71) HR	110 (98) HR	140 (125) HR	180 (161) HR	190 (170) HR	200 (178) HR	280 (250) HR	320 (286) HR	560 (500) HR
61–80	40 (36) MR	60 (54) MR	80 (71) HR	120 (107) HR	140 (125) HR	160 (143) HR	170 (152) HR	250 (223) HR	280 (250) HR	480 (428) HR
81–100	30 (27) MR	40 (36) MR	50 (45) MR	90 (80) MR	100 (89) HR	130 (116) HR	130 (116) HR	200 (178) HR	250 (223) HR	400 (357) HR
101–120	30 (27) MR	30 (27) MR	30 (27) MR	70 (63) MR	70 (63) MR	100 (89) MR	100 (89) MR	150 (134) MR	220 (196) HR	340 (303) MR
121–150	20 (18) MR	0 LR	0 LR	20 (18) MR	50 (45) MR	80 (71) MR	80 (71) MR	90 (80) MR	190 (170) MR	300 (268) MR
151–180	20 (18) MR	0 RR	0 RR	0 LR	40 (36) MR	50 (45) MR	50 (45) MR	50 (45) MR	160 (143) MR	280 (250) MR
181–210	0 LR	0 RR	0 RR	0 LR	0 LR	0 LR	0 LR	0 LR	130 (116) MR	140 (125) MR
211–250	0 RR	0 RR	0 RR	0 RR	0 RR	0 RR	0 RR	0 RR	80 (71) MR	70 (63) MR
250+	0	0	0	0	0	0	0	0	0 LR	0 LR

[1] Excess application of potassium will lead to luxury consumption by the sugarbeet plant. This has a negative effect upon clear juice purity.

[2] For rutabagas and tomatoes on soils with magnesium tests less than 100, the required amount of potash is adjusted downward from the amounts shown in this table to a minimum of 50% at 50 ppm Mg.

Table 1–7. Magnesium Soil Test Ratings and Interpretations for All Crops

LEGEND: HR = High Response MR = Moderate Response LR = Low Response

Soil Magnesium[1] mg/L of Soil (ppm Mg)	Rating	All Vegetables
below 20 [2]	HR	Apply magnesium for all crops. If pH is below 6.5, apply dolomitic lime. At higher pH values, apply 30 kg soluble magnesium (Mg) per hectare (27 lb Mg/acre). Potassium applications in excess of those recommended by a soil test will increase the probability of Mg deficiency.
21–39 [2]	MR	If lime is required, use dolomitic. Magnesium is recommended if potassium soil test is above 250. Potassium applications in excess of those recommended by a soil test will increase the probability of magnesium deficiency.
41–100 [2]	MR	If lime is required, use dolomitic.
100+ [2]	LR	If lime is required, use either dolomitic or calcitic.

[1] 1 M ammonium acetate extraction method.

[2] For tomatoes and rutabagas on soils with magnesium tests of less than 100 ppm, adjust the potassium rate downward to a minimum of 50% at a magnesium test of 50 ppm. For example, a soil testing 75 ppm magnesium should receive only 75% of the usual potassium recommendation for that soil. On soils testing 50 ppm magnesium or less, apply 50% of the total potassium recommendation.

Sulphur

There is no OMAFRA-accredited soil test for sulphur. Soil sulphur levels fluctuate over the course of the growing season depending on soil temperature, moisture and organic matter. Historically, sulphur was a component of many synthetic fertilizers. Modern production methods have removed much of the sulphur found in fertilizer. Nevertheless, many Southwestern Ontario farms still receive considerable amounts of sulphur in the form of acid rain. Each year, 8–13 kg/ha (7–12 lb/acre) of sulphur are deposited in rainfall. Additional fertilizer sulphur may be required for crops with high sulphur requirements such as brassica crops and onions.

Micronutrients

Micronutrients include boron, copper, iron, manganese, molybdenum and zinc. Although a plant requires these elements in smaller amounts than the macronutrients, they are still important to a plant's overall nutrition.

Crops vary in their response to micronutrients. Highly responsive crops will often benefit from additional micronutrients applied to the soil or plant, if the concentration is low. Medium-responsive crops are less likely to respond, and low-responsive crops do not usually respond to fertilizer additions, even at low soil micronutrient levels. See Table 1–8.

For information on micronutrient deficiency, sources of micronutrients and toxicity symptoms, see Table 1–9.

Use caution when applying mixtures of several foliar micronutrients, as crop injury may occur. Always follow the product label. Do not combine micronutrients with insecticide, fungicide or herbicide sprays unless the manufacturer of each product indicates that the mixtures are compatible. Many chelated micronutrients will consolidate in the spray tank if mixed with pesticides. Boron fertilizers will react with solupaks.

Use caution when applying micronutrients through fertigation systems. Certain micronutrient blends may cause the emitters to plug.

The use of micronutrients in the starter fertilizer is generally not recommended, as this often increases the amount of phytotoxicity, especially in adverse weather conditions.

For manganese and zinc requirements, see Table 1–10 and Table 1–11.

Table 1–8. Response of Crops to Micronutrient Fertilizers[1]

LEGEND: **high** = crop likely to benefit from fertilizer application of this nutrient if soil or plant concentrations are low
medium = crop less likely to respond to fertilizer applications of this nutrient
low = crop unlikely to respond to fertilizer applications of this nutrient
– = information not available

Crop	Mn	B	Cu	Zn	Mo	Fe
Asparagus	low	low	low	low	low	medium
Beans, snap	high	low	low	high	medium	high
Beets, table	high	high	high	medium	high	high
Broccoli	medium	high	medium	–	high	high
Cabbages	medium	medium	medium	low	medium	medium
Carrots	medium	medium	medium	low	low	–
Cauliflower	medium	high	medium	–	high	high
Celery	medium	high	medium	–	low	–
Cucumbers	high	low	medium	–	–	–
Lettuce	high	medium	high	medium	high	–
Onions	high	low	high	high	high	–
Parsnips	medium	medium	medium	–	low	–
Peas	high	low	low	low	medium	–
Peppers	medium	low	low	–	medium	–
Potatoes	high	low	low	medium	low	–
Radishes	high	medium	medium	medium	medium	–
Spinach	high	medium	high	high	high	high
Sugarbeets	high	medium	medium	medium	medium	high
Sweet corn	high	medium	medium	high	low	medium
Tomatoes	medium	medium	high	medium	medium	high
Turnips	medium	high	medium	–	medium	–

[1] Taken, with permission, from the Michigan State University Cooperative Extension Publication E486 *Secondary and Micronutrients for Vegetables and Field Crop* (Table 3, Relative response of selected crops to micronutrient fertilizers).

Table 1–9. Micronutrients in Soil and Plants

Nutrient	Fertilizer Sources	Deficiency Symptoms	Soil Conditions Most Often Deficient	Effect of Excess Amount
Zinc (Zn)	zinc sulphate	◦ white stripes or patches near base of young leaves ◦ stunted or twisted growth ◦ may occur in corn, legumes and onions	◦ sandy or eroded soils ◦ high ph soils ◦ soils high in phosphorus	◦ may interfere with uptake of other micronutrients
Manganese (Mn)	manganese sulphate, manganese chelates	◦ yellowing between veins on young leaves ◦ veins stay dark green ◦ may occur in beans, beets, cucurbits, lettuce, onions, peas, potatoes, spinach, corn, tomatoes and muck crops	◦ soils that were previously poorly drained: muck, marl ◦ eroded, sandy, high pH soils	◦ on acid soils, excess manganese may reduce root growth ◦ leaf spotting on older leaves
Boron (B)	borate	◦ new growth is stunted and discoloured ◦ flower buds may abort ◦ hollow or cracked stems ◦ may occur in brassica crops, celery, beets and spinach	◦ sandy soils ◦ dry soil conditions	◦ necrosis of leaf margins ◦ new growth pale or whitish and blotchy
Copper (Cu)[1]	copper sulphate	◦ limp or discoloured leaves ◦ twisted leaf tips ◦ thin pale scales on onions ◦ poor colour in carrots	◦ muck soils ◦ coarse sandy soils	◦ foliar sprays that are too concentrated will damage leaf tissue
Molybdenum (Mo)	sodium molybdate	◦ leaves twist and become whip-like ◦ edges of leaves appear scorched ◦ may occur in cauliflower	◦ muck soils ◦ acidic sandy soils	◦ excess molybdenum may cause symptoms that appear like iron deficiency
Iron (Fe)	iron chelates	◦ leaves become yellow between the veins	◦ rarely seen in Ontario	◦ uncommon

Adapted from BMP20, *Managing Crop Nutrients*, 2008.
[1] See *Subsidence of Peat and Muck Soils*.

Table 1–10. Manganese Rates

Manganese Index[2]	Manganese (Mn) Required[1]	
	Onions, Lettuce, Beets	Other Crops
0–7	2.0 kg/ha (1.8 lb/acre)	The manganese soil test is low, however manganese deficiency is not expected on crops other than onions, lettuce and beets. If deficiency symptoms appear, make a foliar application of 2 kg Mn/ha in 200 L water (1.8 lb Mn/acre in 18 gal water).
8–15	2 kg/ha (1.8 lb/acre)	0
16–50	0	0
50+ above Normal	0	0

[1] Apply as a foliar spray of manganese sulfate; soil applications are ineffective.
[2] Manganese Index = 498 + 0.248 (phosphoric acid extractable Mn in mg/L of soil) – 137 (soil pH) + 9.64 (soil pH)^2.

Table 1–11. Soil-Applied Zinc Rates

Zinc Index[1]	Zinc (Zn) Rates	
	Corn, Onions	Other Crops
0–7	4–14 kg/ha[2] (3.6–12.5 lb/acre)	The zinc soil test is low, however, zinc deficiency is not expected on crops other than onions and sweet corn. If zinc deficiency symptoms appear, make a foliar application.
8–14	4–14 kg/ha[2] (3.6–12.5 lb/acre)	0
15–100	0	0
100+ above normal	0	0

[1] Zinc index reported = 203 + 4.5 (DTPA extractable soil zinc in mg/L of soil) – 50.7 (soil pH) + 3.3 (soil pH)^2.
[2] The 14 kg Zn/ha rate should be sufficient up to 3 years. Do not apply more than 4 kg Zn/ha as a banded application.

Subsidence of Peat and Muck Soils

Cultivated peat and muck soils decompose or subside (oxidize) gradually at rates of 1–3 cm/year. Maintaining a high water table and a pH of 5.1–5.5 reduces the rate of subsidence to less than 0.05 cm/year.

A very wet (or very acidic) soil does not give maximum yields and is likely to be flooded when rainfall is intense. Wet spots may also be difficult to work and may result in uneven crop growth. Keeping fields well drained during the growing season will ensure optimal crop growth. Raising the water table in the fall and winter will help reduce the rate of subsidence.

Copper (Cu) applied as fertilizer has the residual effect of slowing down degradation (subsidence) by about 50%. Apply 14 kg of Cu/ha (12.5 lb Cu/acre) annually to peats and mucks in the first 3 years of cultivation and up to 5 kg of Cu/ha (4.5 lb Cu/acre) every second year thereafter, particularly when onions, carrots or lettuce are grown on the soils.

Table 1–12. Average Amounts of Available Nutrients for Different Types of Manure

Nutrient values based on average analysis results for over 12,000 samples[1]. There are large variations between manures, so a manure analysis is your best guide to nutrient availability.

Manure	Average Dry Matter	Available[2] N Fall applied	Available[2] N Spring applied	Available[3] P_2O_5	Available[4] K_2O
Liquid manure					
Liquid cattle	8.1%	1.0 kg/1,000 L (10 lb/1,000 gal)	1.6 kg/1,000 L (16 lb/1,000 gal)	1.5 kg/1,000 L (15 lb/1,000 gal)	2.6 kg/1,000 L (26 lb/1,000 gal)
Liquid hog	3.2%	1.4 kg/1,000 L (14 lb/1,000 gal)	2.5 kg/1,000 L (25 lb/1,000 gal)	2.0 kg/1,000 L (20 lb/1,000 gal)	2.0 kg/1,000 L (20 lb/1,000 gal)
Anaerobic digestate[5]	4.2%	1.7 kg/1,000 L (17 lb/1,000 gal)	3.0 kg/1,000 L (30 lb/1,000 gal)	1.4 kg/1,000 L (14 lb/1,000 gal)	1.7 kg/1,000 L (17 lb/1,000 gal)
Solid manure					
Solid poultry (chicken)	58.6%	13.9 kg/tonne (27.9 lb/ton)	15.4 kg/tonne (30.8 lb/ton)	22.3 kg/tonne (44.6 lb/ton)	15.3 kg/tonne (30.6 lb/ton)
Solid dairy	27.3%	2.2 kg/tonne (4.4 lb/ton)	2.3 kg/tonne (4.7 lb/ton)	3.6 kg/tonne (7.1 lb/ton)	6.5 kg/tonne (13.0 lb/ton)
Composted (cured)	46.2%	3.3 kg/tonne (6.4 lb/ton)	1.0 kg/tonne (2.0 lb/ton)	4.9 kg/tonne (9.7 lb/ton)	4.7 kg/tonne (10.0 lb/ton)
Solid beef	30.9%	2.7 kg/tonne (5.5 lb/ton)	3.4 kg/tonne (6.8 lb/ton)	5.6 kg/tonne (11.2 lb/ton)	6.8 kg/tonne (13.7 lb/ton)
Sheep	32.8%	2.7 kg/tonne (5.5 lb/ton)	2.9 kg/tonne (5.8 lb/ton)	5.8 kg/tonne (11.6 lb/ton)	9.2 kg/tonne (18.4 lb/ton)
Horse	38.1%	1.6 kg/tonne (3.2 lb/ton)	0.5 kg/tonne (1.0 lb/ton)	2.8 kg/tonne (5.4 lb/ton)	4.9 kg/tonne (9.8 lb/ton)

kg/1,000 L = kg/m³

1 Data from manure analysis provided from Ontario Labs collected between 2000 and 2021.
2 Nitrogen spring application assumes incorporated within 24 hr. Nitrogen fall-applied assumes mid-October and incorporated within 24 hr.
3 Phosphate from manure is assumed to be 80% as available as phosphate (40% in the year of application (another 40% of the phosphorus is available the following year)).
4 Potassium from manure is assumed to be 90% as available in the year of application as potassium from commercial fertilizer.
5 Anaerobic digestate often has high pH, which increases N loss. Injection/immediate incorporation will help retain nitrogen.

Adjustments to Fertilizer Recommendations

The general fertilizer recommendations in this book apply to situations where no organic sources of nutrients have been applied to the field. If manure is applied to the land, or if legumes are plowed down, reduce the fertilizer rates to adjust for the nutrients applied in the organic form.

See Table 1–12 and Table 1–13. More precise estimates of available nutrients can be made by accounting for the actual timing and conditions for manure application, and the lag time before incorporation. The OMAFRA nutrient management software (NMAN) can help with this process.

Note: for food safety reasons, do not apply manure to fresh vegetable crops within 4 months of harvest.

Table 1–13. Adjustment of Nitrogen Requirements Where Crops Containing Legumes are Plowed Down

Crop Type	For All Crops, Deduct from N Requirement
Less than one-third legume	0
Less than one-third to half legume	55 kg/ha (49 lb/acre)
Half or more legume	100 kg/ha (90 lb/acre)
Clover cover crop (thick stand over 40 cm (16 in.) high)	45 kg/ha (40 lb/acre)
Soybean and field bean residue	0

Fertilizer Recommendations for Transplant Production

Vegetable transplants are usually fertilized with soluble fertilizer, applied in the irrigation water. See Table 1–14, for a list of fertilizers commonly used in transplant production. Use fertilizers that supply most of the nitrogen in nitrate form. Avoid fertilizers with a high concentration of urea, as they may cause burning of the roots and crop injury.

Table 1–14. Analysis for Various Soluble Fertilizers

Fertilizer Analysis	Rate for 100 ppm N	Parts per Million			EC [1]
		N	P	K	
20-20-20	50 g/ 100 L water	100	43	83	0.40 mmho/ cm
20-10-20	50 g/ 100 L water	100	21	83	0.60 mmho/ cm
20-8-20	50 g/ 100 L water	100	17	83	0.75 mmho/ cm
17-5-19	59 g/ 100 L water	100	12	92	1.00 mmho/ cm
15-5-15	67 g/ 100 L water	100	14	83	0.70 mmho/ cm
14-0-14	71 g/ 100 L water	100	0	83	0.85 mmho/ cm

[1] Electrical conductivity of a 100 ppm solution in micromhos. The EC values were determined with a conductivity meter using distilled water. The EC values obtained will vary depending on the background EC of the water source.

A high concentration of phosphate (P_2O_5) may promote excessive stem elongation. Use a fertilizer with a low-to-medium phosphate concentration, or use a fertilizer with no phosphate for most feedings and apply a high-phosphate fertilizer once every four or five feedings to promote growth. Do not withhold phosphate completely, as this will delay field establishment.

Vegetable crops vary in their response to fertilizer. The feeding program must be designed for each crop. Adjust the fertilizer program based on the nutrient content of the growing media, the water analysis and the cell size (larger cells require less fertilizer). See Table 1–15.

Table 1–15. Vegetable Transplants Fertility Guidelines

Crop	Fertility Guidelines
Tomatoes	◦ Very responsive to fertilizer. ◦ Excess fertility will reduce transplant quality. ◦ If feeding at every watering, use a fertilizer concentration of 50–100 ppm N, depending on the stage of development. ◦ There may be some advantage to feeding less often at a higher concentration.
Peppers	◦ Require more fertilizer than tomatoes. ◦ If feeding at every watering, use approximately 100 ppm N; increase the concentration if feeding less often.
Onions	◦ Require moderate fertility. ◦ Apply 100–200 ppm N weekly. Fertilize less frequently under cool, cloudy conditions.
Brassica crops	◦ Low fertilizer requirement. Do not require as much fertilizer as other crops. One application per week of 100–150 ppm N should be sufficient under most conditions.
Cucurbit crops	◦ Low fertilizer requirement. Use 100–150 ppm N at weekly intervals for a total of 2–4 applications.

Toxicities and Deficiencies in Transplant Production

Nutrient deficiencies are more common than nutrient toxicities. Many growers are very cautious about overfertilizing for fear of "burning" the roots or stems.

Phosphorus-deficient transplants show very definite purple colouration along the stem and underside of leaves. Plants that have too little nitrogen will have pale-green foliage. Too much nitrogen will result in very white stems and dark-green leaves. See Table 1–2 and Table 1–15.

Soluble salts in the fertilizer water may prevent germination or damage the young seedlings. On older seedlings, salt-injured plants are often stunted and dark green. Burning of the leaf margins and tan-coloured roots are other common symptoms of salt injury. Salts are measured by the electrical conductivity (EC) of the water. See Table 1–16.

Table 1–16. Acceptable Ranges of Water Quality and Correction Methods

Factor	Range	Correction
pH	5.5–6.5	Use acid to lower the pH.
Bicarbonate level	60–100 ppm	Use acid to lower the bicarbonate reading. For each 60 ppm of bicarbonate above this range, add 7 L of phosphoric acid (85%)[1] or nitric acid (67%)[2] per 100,000 L of water. For example, a bicarbonate level of 220 ppm would require 14 L of acid to correct the problem.
EC (electrical conductivity)	<0.6 mmho/cm in straight water 1.0–2.0 mmho/cm with fertilizer added	The fertilizer program can be adjusted to maintain a safe EC.
Nitrate levels	normally less than 20 ppm	Adjust the fertilizer program accordingly.
Sulfates	normally 150–250 ppm	If levels exceed the normal range, do not add sulfates to the fertilizer solution.
Chlorides	normally 20–400 ppm	If levels exceed the normal range, do not add chlorides to the fertilizer solution.
Boron	0.5 ppm	If levels exceed the normal range, do not add boron to the fertilizer solution.

[1] Use no more than 7 L of phosphoric acid per 100,000 L of water to avoid crop problems (stretching). Use nitric acid for neutralizing more than 60 ppm bicarbonate.
[2] Each 7 L of nitric acid will contribute 14 ppm of nitrate nitrogen to the irrigation water. Adjust the nitrogen fertilizer rate accordingly.

Starter Fertilizers for Vegetable Crops

Phosphorus availability and root growth are reduced in cool soils. As a result, many early-season vegetable crops may benefit from having small amounts of phosphorus applied to the rooting zone at seeding or transplanting. For crops planted later in the season, under more favourable soil conditions, there is little benefit to adding extra phosphorus at planting.

Although the most important starter nutrient is phosphorus, small amounts of nitrogen are often included to improve early growth and vigour. Ammonium-nitrogen enhances the absorption of phosphorus by the plant. On low-potassium soils, there may be a response to potassium in the starter fertilizer, but in most cases starter potassium will not provide a benefit.

The most common method of applying starter nutrients to transplanted vegetables is through liquid fertilizers applied with the planter water. For some seeded vegetables, starter fertilizers may be banded 5 cm (2 in.) below and 5 cm (2 in.) to the side of the seed. Seed-placed (or “pop-up”) fertilizers are generally not recommended for use with vegetable crops. See *Avoid Fertilizer Burn*, for general information on the safe use of nutrients in starters. See the individual crops sections in Chapter 7, for specific recommendations for the safe rates of starter fertilizers.

Avoid Fertilizer Burn

All fertilizers are salts. If a germinating seedling or young transplant comes into contact with a concentrated fertilizer band, the seed may not germinate or the roots may become seriously damaged. For this reason, ensure that the correct fertilizer, the appropriate rate and the right placement are selected for each application.

Urea is not suitable for use in starter fertilizers or banded applications because of ammonia toxicity.

Ensure that starter or transplant fertilizers contain only as much nitrogen as necessary to get the crop started. Fertilizers containing more than half as much nitrogen as phosphate frequently contain urea and will have a greater chance of causing crop damage. Under dry soil conditions, the amount of nitrogen in the starter should be reduced or eliminated.

In general:

- Fertilizers of the same grade may vary in salt levels depending on the raw material used to formulate them.
- Nitrogen and potassium salts are more injurious than phosphorus salts.
- Fertilizers that contain micronutrients (boron, copper, iron, manganese, zinc) are more phytotoxic than the same grades of fertilizer without micronutrients. The use of micronutrients in the starter fertilizer is generally not recommended.

Which to Choose: Soil or Foliar Fertilizers?

Foliar uptake occurs through the leaf's cuticle and the stomata. The amount of nutrients that can enter the plant through these means is quite limited, and increasing the application rates may lead to crop injury. The macronutrients (nitrogen, phosphorus, potassium, calcium and magnesium) are required in relatively high amounts for crop growth. As a result, soil application is almost always the most efficient and economical method of getting the major nutrients into the plant.

Micronutrients, which are required by the crop in much lower quantities, can often be efficiently delivered through foliar applications, especially when soil conditions impact the nutrient's availability. Depending on the micronutrient and the timing at which the deficiency is identified, either soil-applied or foliar fertilizers may be recommended. Specific recommendations regarding application methods are discussed in the individual crop sections of Chapter 7.

Foliar-applied nutrient uptake can be improved through the timing of the application and the use of surfactants. Younger leaves generally have a less well-developed cuticle and are able to take in nutrients more readily than older leaves. Early-morning applications may favour foliar uptake. Avoid applying foliar nutrients during the heat of the day when leaves will dry quickly; this will reduce the effectiveness of uptake. Ensure good leaf coverage, particularly on the lower leaf surfaces.

Fertigation

Fertigation is the application of crop nutrients through a drip irrigation system. The advantage of fertigation is the ability to match nutrient applications with crop requirements and uptake. Apply small amounts of fertilizer regularly, increasing the rates as the crop develops. Once harvest begins, rates can be leveled off or even decreased.

> Do not use fertilizers containing calcium, phosphate or sulphate, as these elements may plug the emitters.

Nitrogen and Potassium

Where crops are grown under fertigation, apply approximately half the crop's total nitrogen and half the total potassium requirement to the soil prior to planting. The remainder can be injected through the fertigation system. Recommended weekly fertigation application rates for tomatoes, peppers and cucurbit crops appear in the crop sections of Chapter 7.

Phosphorus

Many common forms of phosphorus are not suitable for use in fertigation systems. Most phosphate fertilizers will form salts when mixed with other nutrients. These salts plug the emitters, rendering the whole system useless. Water-soluble forms of phosphorus have been developed for the greenhouse industry. However, in field conditions, there is no yield advantage associated with the application of phosphorus through drip irrigation. The presence of phosphorus may also encourage the growth of algae in the drip tape, consequently plugging the emitters. Soil applications remain the most cost-effective method of delivering phosphorus to the crop.

Micronutrients

Use caution when applying micronutrients through fertigation systems. Certain micronutrient blends may cause the emitters to plug.

Chapter 2

Soil Management

Vegetable production is an intensive process, usually involving a lot of tillage and numerous passes over a field. Most prime vegetable-growing soils are light in texture; maintaining soil organic matter levels and soil health is a challenging and ongoing process.

Soil Health

Soil health can be considered as a measure of a soil's ability to resist erosion, compaction and other stresses, while maintaining economic productivity. A healthy soil:

- produces uniform crop growth and quality
- has optimal ranges of nutrient levels, pH and organic matter
- is resistant to wind, water or tillage erosion
- has good drainage, water infiltration and water-holding capacity
- supports seedling emergence and root growth

Soil organic matter contributes to soil structure and drainage, enhances the soil's capacity for holding moisture, increases the soil's ability to hold nutrients and improves drainage. Recent research has highlighted the role of living roots and microbes in supporting organic matter accumulation. Maintaining adequate soil organic matter levels will help support crop yields, particularly under adverse conditions (e.g., too dry or too wet).

Tracking soil organic matter levels is part of managing soil health over time. Soil organic matter is an indicator of soil health, where more is better. The target soil organic matter level varies, depending on soil type. See Table 2–1.

Table 2–1. Soil Organic Matter Levels Based on Soil Type

Soil Type	Target Soil Organic Matter Level
Sandy	2.5%–4%
Sandy-loam	3%–4.5%
Loam	4%–6%
Clay-Loam	4%–6.5%
Clay	4.5%–6.5%

Assessing soil health for each field can be as simple as tracking soil organic matter levels and basic fertility or can involve a suite of other tests. Costs will vary greatly depending on the analysis. Currently, soil health testing is being refined with a variety of tests on the market. For now, the best approach is to select a test or a suite of tests from a lab that will provide management direction and select a season or time of year for sampling. Be consistent in the sampling and analysis and ensure that changes over time are tracked with management practices. For soil health analysis, take soil samples at the same depth as your soil fertility samples (15 cm (6 in.)). Keep the samples cool, as soil health tests may involve assessing biological processes.

Maintaining soil health is a continuous process. Some measures are easy and relatively inexpensive, while others require more effort and commitment. Table 2–2 describes a variety of measures that can be used to help maintain or improve various aspects of soil health.

Table 2–2. Maintaining or Improving Soil Health

Measure	Comments
Easy/Less Expensive	
Use of cover crops	Use cover crops with fibrous root systems (grasses) to improve soil structure, particularly in the seedbed. Use cover crops with taproots (broadleaf plants) to penetrate dense soil layers.
Soil testing and accurate application of fertilizer and lime	Adequate pH and fertility will improve crop growth. Monitor organic matter over the years.
Reducing tillage and using residue management	Using fewer tillage passes to prepare the seedbed will: ◦ leave more residue on the surface to protect against wind and water erosion ◦ reduce soil organic matter loss by leaving soil aggregates intact ◦ reduce crusting and compaction
Adding organic materials in the form of manure or compost (where appropriate in the crop rotation)	Regularly adding organic materials to the soil will help increase organic matter levels in the soil, improve soil structure, increase the water-holding capacity and make the soil less prone to erosion. Organic amendments can also be a valuable source of nitrogen, phosphorus, potassium and many micronutrients. Excessive rates over the long term could lead to increased levels of heavy metals. Human pathogens, such as *E. coli*, are often a concern. Do not apply manure in the same season as a vegetable crop.
Erosion control measures	Simple measures such as grass waterways, buffer strips, drop structures (rock chutes or drop pipes), tile outlet protection and strip cropping greatly reduce soil erosion. Structures such as water and sediment control basins and terraces help slow water movement across fields, preventing major soil loss. Erosion control measures work best in combination with basic conservation practices such as reducing tillage, managing residue, crop rotation and cover crops.
Significant Management Changes or Investment Required	
Minimum tillage	Switching to minimum or no-till systems will leave more residue on the soil surface and help prevent erosion. It will also improve soil structure. This requires investment, equipment and management changes.
Strip tillage	Strip till supports the use of targeted tillage where the crop is planted while leaving much of the soil surface undisturbed. This requires significant investment in equipment and adjustments to herbicides. The strip warms more quickly in spring while the undisturbed area modulates moisture and temperature through the summer. Strip till can be used in combination with cover crops to ensure ground cover.
Controlled traffic or other compaction-reducing options	Reducing tire pressure and equipment loads and adjusting equipment spacing to support controlled traffic will help reduce compaction.
Crop rotation, including a mix of cereal, perennial legumes or forage crops	Rotating vegetable crops over a period of 2–4 years with cereals, perennial legumes or forages will improve soil structure, improve the water-holding capacity and make the soil less prone to erosion. Include crops that leave large amounts of high-carbon crop residues such as grain or sweet corn and small grains.
Planting windbreaks	Treed windbreaks protect the soil and prevent sandblasting and desiccation of the crop. They may also provide the benefits of a microclimate. Results are seen in a few years after planting, and the benefits can last a lifetime.
Planting windstrips	Established each year, grass windstrips can be adapted to many different crops. Like windbreaks, windstrips protect the soil and prevent sandblasting and desiccation of the crop and may provide microclimate benefits.
Improving drainage	Tile drainage will remove excess water, allowing for more timely field operations, reduced compaction potential and improved crop growth. If compaction is limiting drainage, deep ripping can break up compacted layers. Make sure soil conditions are not too wet at the depth of the implement. Deep tillage can alleviate compaction, but if the cause is not addressed, the compacted zone is likely to return, possibly deeper.

Tillage Systems

Traditional tillage systems were used to:

- provide weed control
- bury crop residues to mitigate insects and diseases
- prepare a seedbed that will give good crop stands and high yields

More recently, tillage and cropping systems have been changed to accomplish the same goals while reducing soil erosion through less intensive or no cultivation. Crop residue on the soil surface, especially across sloping fields, slows water movement and helps reduce the movement of soil. Newer, more effective herbicides have reduced the need for aggressive mechanical weed control programs. Savings on fuel and labour are other factors favouring reduced tillage.

Base any decision to switch to a different tillage system on the system's compatibility with the farm's soil types, slopes, drainage, spring soil temperatures, crop rotation and harvest equipment. Tillage impacts erosion control as well as the timeliness of field work and the potential for controlling weeds, insects and diseases. For some machine-harvest vegetables, the success of a reduced tillage system will depend on the amount of residue left after the previous crop. For example, snap beans require a level surface without large amounts of residue to prevent the uptake of foreign material by the harvester.

No one system is best for all Ontario conditions. Variability in soils, crops, climate and management mean tillage systems must be fine-tuned for each farm operation. In fact, the tillage system may rotate with the crop, allowing for the use of the most appropriate tillage for each crop.

Conventional Tillage

Conventional tillage is any system that attempts to bury most of the previous crop residue, leaving less than 30% of the soil surface covered with residue after planting. Usually, a moldboard plow is used in conjunction with a variety of other tillage implements.

The principal advantages of the moldboard system are that the machinery is familiar and widely available, and the system is adaptable to a wide range of soil conditions. Moldboard plowing increases soil porosity temporarily, allowing for air exchange, root proliferation and water infiltration, especially when rainfall is above average. However, the increased porosity can be lost with excessive secondary tillage, soil compaction or in soils with poor structural stability.

The main weaknesses of the moldboard plow system include high costs of equipment, fuel and additional labour associated with seedbed preparation. Plowing will often leave the field uneven. Secondary tillage will be required to prepare a suitable seedbed. With little or no residue cover, there is a high risk for soil erosion by wind and water. Adjusting the moldboards so that the soil is not completely inverted, and some residue is left on the surface can help reduce some of these problems.

Conservation Tillage

Conservation tillage systems are designed to leave residue from the previous crop on the soil surface, providing more protection against erosion than conventional tillage. A variety of implements can be used for conservation tillage. The chisel plow has been the most widely adopted conservation tillage tool in Ontario. Tandem and offset discs are also used extensively in some areas of the province.

Fall chisel plowing with twisted shovel teeth will often leave ridges in the field the following spring. This can lead to extra costs in secondary tillage (more passes), uneven seed beds and occasionally excessive soil drying. Many of these problems can be overcome by:

- using sweep teeth on all or part of the chisel plow
- adding a levelling bar or harrows to the rear of the chisel plow
- practising timely secondary tillage in the spring

Zone or Strip Tillage

Strip tillage combines the best of both no-till and conventional tillage systems. It uses both shanks and coulters to create a narrow (15–20-cm (6–8 in.) wide) zone of tilled soil that acts as a conventionally prepared seedbed. Each zone of tillage corresponds to the width of the planter units. The area between the rows is left undisturbed. This dramatically increases the amount of surface residues left on the field, while still creating the fine seedbed desired by many vegetable growers.

Zone tillage may be done in the fall, to aid in the timeliness of field work the following season, or in the spring, immediately before planting, depending on the soil type. Crops such as sweet corn and pumpkins are well suited to this system.

No-Till Systems

No-till systems provide the greatest opportunity to leave protective crop residues on the soil surface. They also have the greatest potential for reducing the cost of labour and fuel on the farm.

Numerous options exist, both in the original design and in the modifications available for row crop planters or seed drills to be considered capable of "no-till." Several Ontario equipment companies have been leading the industry in the development of no-till vegetable planters.

No-till is a technique that can be used relatively easily with some vegetable crops. Maintaining surface crop or cover crop residues offers several benefits, including:

- the potential for weed suppression
- interference with the movement of some pests, e.g., Colorado potato beetle
- reduction of sandblasting and wind dessication
- reduction of soil water losses

Concerns with no-till systems include:

- an increased reliance on "burndown" herbicides
- crop residues on the surface may harbour insects and disease
- crop debris interfering with (trans)planting or machine harvest

Tillage serves a slightly different purpose in organic vegetable production. Organic growers may rely heavily on timely tillage (cultivation, harrowing, scuffling, tine weeding) to provide weed control. In certain organic crops, combining weed-suppressing cover crops such as cereal rye with no-till practices and roller crimping may provide suitable weed suppression.

Vegetable crops grown successfully in no-till, zone till or conservation tillage systems include:

- tomatoes
- sweet corn
- pumpkins
- squash
- brassica crops
- peppers
- sugarbeets
- snap beans

Cover Crops

Cover crops take on many roles in vegetable production, from wind abatement, to pest management, to basic soil maintenance.
Some examples:

- Pumpkins or squash are planted into rye cover crop residue to suppress weeds and protect the fruit from soil contact. This reduces the labour required to clean the fruit.
- Carrots and onions are often planted with a short-term cover crop of barley to protect the emerging seedlings from wind damage.
- Pepper, melon and fresh market tomatoes are often planted between wide windstrips of rye or barley. These windstrips provide wind protection and microclimate enhancement. Later in the season, the windstrips can be used as drive rows for the sprayer and harvest equipment.
- Some potato growers use specific types of mustard or other cover crops as biofumigant crops to reduce plant parasitic nematode populations or soil-borne diseases.

Cover crops can fit into most vegetable production systems with care and planning. When planting cover crops after the commercial crop, plant them immediately after harvest to get the most benefit from the cover crop investment. While broadcast application and incorporation of cover crop seed often work well to establish cover crops, direct-seeding or drilling will ensure faster and more even establishment.

Each different type of cover crop has its own strengths and weaknesses. See Table 2–3 and Table 2–4.

Table 2–3. Selecting a Cover Crop

Function	Cover Crop Options
Wind abatement	Broadcast or drilled barley with carrots or onions. Plant before transplanting tomatoes.
Nitrogen production	Red clover or vetch
Nitrogen scavenging	**Fall uptake:** radish and other brassicas, oats, phacelia **Winter/spring uptake:** rye, winter wheat
Weed suppression	Radish and other brassicas, winter rye, buckwheat
Nematode suppression	Nematode suppression is specific to the variety of cover crop and the species of nematode. Certain cultivars of these cover crops have nematode-suppressing properties: ◦ leaf and heading mustards ◦ pearl millet ◦ sorghum-sudan grass ◦ marigold ◦ radish
Soil structure building	Cereals such as oats, cereal rye, buckwheat, phacelia
Compaction busting	Alfalfa, sweet clover, radish (limited)
Biomass return to soil	**Fall:** oats, oilseed radish **Summer:** millets, sorghum-sudan
Erosion protection (wind or water)	Winter rye, winter wheat, ryegrass (well established)

Cover crops can be divided into five groups based upon plant types: grasses, legumes, brassicas, other (non-legume broadleaves) and mixes (Figure 2–1). Consider your entire crop rotation to add diversity to your system and to minimize insects and diseases.

Grasses

Grasses have fine, fibrous root systems that are well suited to holding soil in place and improving soil structure. Grass species suitable for cover crops are fast growing and relatively easy to kill (either chemically, mechanically or by winter temperatures). Grasses do not fix nitrogen out of the atmosphere but they can scavenge quantities of residual nitrogen left in the field after harvest. Windstrips are usually created from overwintering grass cover crops.

Spring Cereals

Spring cereals are planted in the early spring. When grown as a commercial crop, they mature later in the same season and do not require vernalization to produce grain heads. As a cover crop, spring cereals can be grown before late-planted vegetable crops, where they provide wind abatement and protection to the crop as the canopy develops.

For early-harvested vegetable crops, spring cereals are a valuable ground cover. They can produce a large amount of biomass and scavenge nutrients. Once well established, spring cereals are relatively tolerant of frost. Do not attempt to establish late in the fall as the growth will be limited. Spring cereals are typically killed over the winter.

Winter Cereals

Winter cereals are highly versatile cover crops. They can be planted in the spring, summer or fall for soil cover. Winter cereals usually survive the winter, providing erosion protection the following spring. These grasses can be used to create windstrips and residue mulch, or killed early to minimize residue cover at planting. Consider winter cereals such as cereal rye for use on vegetable crop headlands. If planted in the spring or early summer, the rye will stay short and not go to head. When used for weed suppression, winter cereals will require a high planting rate and may also benefit from fertilizer applications, depending on the previous crop and soil fertility levels.

Warm-Season Grasses

Warm-season grasses such as sorghum-sudan and millet are best suited for planting into the warmer soils of late June, July and early August. They are very sensitive to frost. Root growth is extensive and the top growth lush. Be prepared to mow these grasses to keep stalks tender, encourage tillering and prevent heading. Do not mow closer than 15 cm (6 in.) to ensure re-growth. Optimal growth may require additional fertilizer nitrogen.

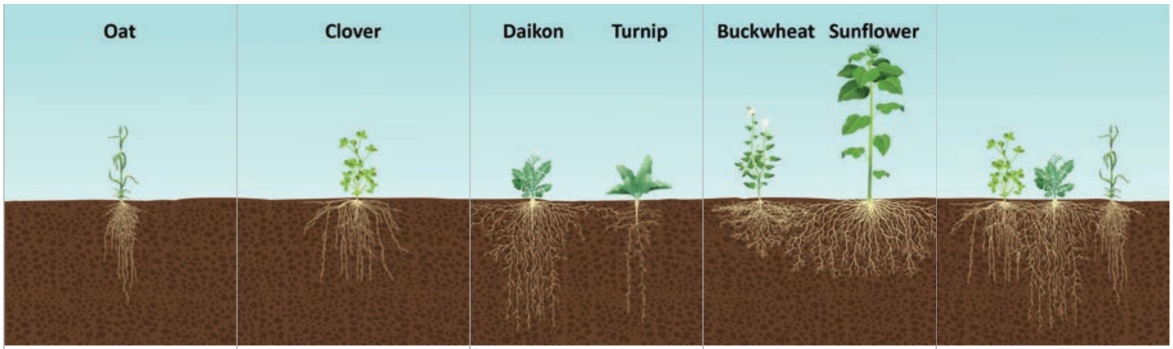
Table 2–4. Characteristics of Cover Crops Grown on Ontario Vegetable Farms after Harvest

LEGEND: Nematode Rating Codes: – = poor or non-host + = ability to host
D = certain cultivars may help decrease soil nematode populations
Nitrogen: F = fixed S = scavenged

Species	Seeding Rate (kg/ha)	Common Seeding Time	Nitrogen[1]	Over-Wintering Characteristics	Building Soil Structure	Weed Suppression	Nematode Rating: Root Lesion	Nematode Rating: Root-knot	Quick Growth	Root Type
Grasses										
Spring cereals: oats, barley	100–125	early spring, mid-Aug–Sept	S	killed by freezing usually	good	good	+	–	very fast	fibrous
Winter cereals: barley, wheat	60–130	Sept–Oct	S	overwinters very well	good	good	+	–	fast	fibrous
Winter rye	30–130	Sept–Oct	S	overwinters very well	very good	very good	+[2]	D	very fast	fibrous
Sorghum sudan	25–40	June–Aug	S	killed by frost	good	good/fair	+	D	very fast	coarse fibrous
Pearl millet	10–15	June–Aug	S	killed by frost	good	good/fair	D	–	fast	coarse fibrous
Broadleaves – Legumes[3]										
Hairy vetch	15–25	Aug	F/S	overwinters	good	fair/poor	++	+	slow to establish	tap with secondary fibrous
Red clover	8–10	March–April	F/S	overwinters	good	fair	++	+++	slow to establish	weak tap/ fibrous
Sweet clover	8–10	March–April	F/S	overwinters	good	fair	–	–	slow to establish	strong tap
Peas, field, forage, winter	40–100	Aug	F/S	killed by heavy frost	poor	good/fair	–	–	fast	weak tap/ fibrous
Broadleaves – Non-Legume										
Buckwheat	20–40	June through Aug	S	killed by first frost	very good	very good	+++	–	fast	weak tap/ fibrous
Radish[4] (tillage, oilseed)	4–10	early spring, mid-Aug–early Sept	S	killed by freezing usually	fair	very good	D	D	fast	moderate tap
Other brassicas, i.e., forage radish	Varies with species	early spring, mid-Aug–early Sept	S	species dependent	fair	very good	D	D	fast	moderate tap
phacelia	8–10	mid-Aug–early Sept	S	killed by freezing usually	good	poor	D	++	slow to establish	fibrous

100 kg/ha = 90 lb/acre

[1] The potential for nitrogen uptake is influenced by seeding date, stand establishment and growing conditions. Nitrogen-fixing legumes are less likely to take up residual nitrogen.
[2] The rating for a full season rye crop would be higher (+++).
[3] Diseases caused by *Pythium* and *Phytophthora* species can be more severe after legume cropping.
[4] Radish residues can be toxic or allelopathic to subsequent crops if the following crop is planted too closely after green manuring. Allow the green manure residues to break down or desiccate before planting the next crop.



	Grasses	Legumes	Brassicas	Other (non-legume broadleaves)	Mixes
Crops	oats, rye, wheat, sorghum, millet	clovers, peas, beans, vetch	radish, rape, canola, kale, collards, camelina	sunflowers, flax, phacelia buckwheat	variety of species
Roots	fibrous roots	weak tap root with fibrous	prominent tap root	root type varies, some extensive but fragile	a range of root types recommended
Nitrogen	scavenges nitrogen	nitrogen fixing (some may need inoculant)	heavy nitrogen feeder	nitrogen scavenging	dependent on the mix composition
Mycorrhizae	supports mycorrhizae	supports mycorrhizae	does not support mycorrhizae	usually supports mycorrhizae	select mixes with some species that support mycorrhizae
Soil	builds soil structure	builds soil structure; some with tap roots may reduce compaction over time	breaks up moderate (shallow) soil compaction; improves infiltration	builds soil structure, particularly in the upper 10–15 cm (4–6 in.)	builds soil structure, especially with varying root architecture
Erosion/ ground cover	usually fast to establish and provide ground cover and erosion protection	many are slow to establish and provide little early ground cover	rosette-forming habit, fast growth and large leaves provide ground cover and reduces erosion	varies with species; may also support pollinators	dependent on species in mix and seeding rate
Weeds	suppresses weeds	many are slow to establish, not competitive with weeds	rosette-forming habit inhibits weeds	may suppress weeds, depending on species	dependent on mix and seeding rate

Figure 2–1. Root zones and characteristics of common cover crop types.

Legumes

Legume cover crops can fix nitrogen from the air. They then supply it to the succeeding crop as well as protecting the soil from erosion and adding organic matter. The amount of nitrogen fixed varies from species to species. Generally, abundant top growth is an indicator of more nitrogen fixation. Ontario research has suggested that legume cover crops, such as red clover, are also effective at scavenging residual nitrogen from the soil.

Nitrogen release from legumes can be inconsistent. This must be accounted for when calculating fertilizer needs. See Table 1–13, Chapter 1, for more information. Excess nitrogen release late in the season could lead to excessive vegetative growth in fruiting vegetables, such as tomatoes, peppers and melons.

Some legume species, such as alfalfa and red clover, have aggressive taproots that can break up subsoil compaction, but this requires more than one season's growth.

Non-Legume Broadleaves

These broadleaf crops cannot fix nitrogen from the air, but they may absorb large quantities from the soil. Growth will be poor if soil nitrogen levels are low or if compaction is severe. Most of these crops are not winter-hardy, so additional control measures are not normally required. Do not allow these crops to go to seed, as the volunteer seed can become a significant weed problem.

New and Emerging Cover Crops

New crops are frequently evaluated as cover crops. Often these species are from different parts of the globe and may not be well adapted to Ontario growing conditions. For more information on new and well-known cover crop species, see the Soil Management section of the OMAFRA website at www.ontario.ca/crops or look at the Ontario pages from the Midwest Cover Crop Council at www.mccc.msu.edu.

Cover Crop Mixes

In recent years there has been interest in using a mixture of cover crop species. This increases the diversity of plant species across the field, providing different root systems and growth habits. For example, a simple cover crop mix of oats and radish provide a fibrous (horizonal) and a taproot (vertical) growth habit. By selecting a variety of cover crops that thrive under a range of conditions, cover crop mixes can improve establishment across the field, especially under adverse conditions. Consider mixing one from each category: legume, broadleaf, warm- and cool-season grasses. A caution with cover crop mixes: consider the species in the mix when selecting the termination method. For example, do all the plant species winter kill? Will any of the species go to seed before termination?

Tillage Systems Following Cover Crops

In conservation and no-till cropping systems, cover crops can greatly increase the surface residue cover. While this adds to the potential benefits of the system, it also can require adjustments in management.

Here are some management factors to consider when reduced tillage follows cover crops:

- Some regrowth of winter annual, biennial or perennial cover crops will occur in the following crop year. Consider the herbicide program and adjust it as needed to control the overwintered cover crops. A controlled amount of regrowth (e.g., windstrips) can provide some spring wind protection.
- The first tillage operation with overwintering cover crops should occur at least 2 weeks prior to planting the main crop to allow for the breakdown of the residue to start, and minimize the risk of problems with soil insects such as seed corn maggot.
- Seedbed preparation may be difficult if persistent cover crops are not tilled until spring or if they grow too large.
- Cover crops that do not survive over winter may be a good option, especially on more poorly drained soils, or for crops that are planted very early in the spring. Adjust seeding dates and rates to adapt for the potential cover crop residue (earlier seeding and higher rates result in more growth). Also consider that under mild winter conditions, some cover crops such as radish, oats or barley may partially overwinter and would then require spring termination.
- Consider burndown herbicides before conservation tillage of overwintering cover crops such as rye. Careful timing, rate and application of herbicides can help keep enough residue on the surface to prevent wind damage to tender crops while allowing crop establishment.

Subsidence of Peat and Muck Soils

Muck or peat soils are very different from mineral soils. They are fragile and prone to soil losses from wind erosion and subsidence. Cultivated peat and muck soils decompose or subside (oxidize) gradually at rates of 1–3 cm/year. Maintaining a high water table and a pH of 5.1–5.5 reduces the rate of subsidence to less than 0.05 cm/year. A very wet (or very acidic) soil does not give maximum yields and is likely to be flooded when rainfall is intense. Wet spots may also be difficult to work and may result in uneven crop growth. Keeping fields well drained during the growing season will ensure optimal crop growth. Raising the water table after harvest n the fall and winter will help reduce the rate of subsidence.

Copper (Cu) applied as fertilizer has the residual effect of slowing down degradation (subsidence) by about 50%. Apply 14 kg of Cu/ha annually to peats and mucks in the first 3 years of cultivation and up to 5 kg of Cu/ha every second year thereafter, particularly when onions, carrots or lettuce are grown on the soils.

Chapter 3

Cooling and Storage

Vegetable Storage Conditions

The expected duration of storage varies greatly between the different types of vegetables. Highly perishable crops, such as sweet corn, leafy greens and cucumbers may last less than a week in storage, while crops such as carrots, cabbage and onions last for many months.

Optimum storage life requires optimum storage conditions. Table 3–1, outlines the ideal ranges in temperature and relative humidity required to maintain desirable eating quality. It also lists the expected storage duration for each crop.

The expected storage life is approximate and will depend on many factors including the quality and maturity of the produce entering the storage, insect or disease pressure, the rate at which the produce was cooled and the type of cold storage facility. For more information on the different types of cold storages, see *Low Temperature Management*, in this chapter.

Table 3–1. Storage Life for Fresh Vegetables in Commercial Storage

Commodity	Temperature	Relative Humidity	Approx. Storage Life
Asparagus	0°C–2°C (32°F–36°F)	95%–100%	2–3 weeks
Beans, green or snap	7°C–10°C (45°F–50°F)	95%–100%	8–12 days
Beans, lima	3°C–5°C (37°F–41°F)	95%	5–7 days
Beets, topped	0°C (32°F)	98%–100%	4–6 months
Broccoli	0°C (32°F)	95%–100%	21–24 days
Brussels sprouts	0°C (32°F)	95%–100%	3–5 weeks
Cabbage, Chinese	0°C (32°F)	95%–100%	3–6 months
Cabbages, early	0°C (32°F)	98%–100%	3–4 weeks
Cabbages, late	0°C (32°F)	98%–100%	3–7 months
Carrots, bunched	0°C (32°F)	95%–100%	2 weeks
Carrots, immature	0°C (32°F)	98%–100%	4–6 weeks
Carrots, mature	0°C (32°F)	90%–98%	7–9 months
Cauliflower	0°C (32°F)	95%–98%	3 weeks
Celeriac	0°C–2°C (32°F–36°F)	97%–99%	6–8 months
Celery	0°C (32°F)	95%–100%	2–3 months
Chard	0°C (32°F)	95%–100%	10–14 days
Chicory, witloof	0°C (32°F)	95%–100%	2–4 weeks
Collards	0°C (32°F)	95%–100%	10–14 days
Corn, sweet	0°C (32°F)	95%–98%	5–8 days
Cucumbers	10°C–13°C (50°F–55°F)	95%	10–14 days
Eggplants	7°C–12°C (45°F–54°F)	90%–95%	1 week
Endive and escarole	0°C (32°F)	95%–100%	2–3 weeks
Garlic	0°C–1°C (32°F–34°F)	60%–70%	6–7 months
Greens, leafy[1]	0°C (32°F)	95%–100%	10–14 days
Horseradish	–1.0°C–0°C (30°F–32°F)	98%–100%	10–12 months
Kale	0°C (32°F)	95%–100%	1–2 weeks
Kohlrabi	0°C (32°F)	98%–100%	2–3 months
Leeks	0°C (32°F)	95%–100%	2–3 months
Lettuce	0°C (32°F)	98%–100%	2–3 weeks

[1] Leafy greens may be stored for 2–3 weeks if they have been hydro-cooled immediately after harvest.

Table 3–1. Storage Life for Fresh Vegetables in Commercial Storage

[1] Leafy greens may be stored for 2–3 weeks if they have been hydro-cooled immediately after harvest.

Table 3–1. Storage Life for Fresh Vegetables in Commercial Storage

Commodity	Temperature	Relative Humidity	Approx. Storage Life
Melons: Honey dew	7°C–10°C (45°F–50°F)	90%–95%	3 weeks
Melons: Muskmelons (¾-slip)	2°C–5°C (36°F–41°F)	95%	15 days
Melons: Muskmelons (full slip)	0°C–2°C (32°F–36°F)	95%	5–14 days
Melons: Watermelons	10°C–15°C (50°F–59°F)	90%	2–3 weeks
Mushrooms	0°C (32°F)	95%	5-7 days
Okra	7°C–10°C (45°F–50°F)	90%–95%	7–14 days
Onions, dry	0°C (32°F)	65%–70%	6-9 months
Onions, green	0°C (32°F)	95%–100%	3–4 weeks
Onions, sets	0°C (32°F)	65%–70%	6–8 months
Parsley	0°C (32°F)	95%–100%	2–3 weeks
Parsnips	0°C (32°F)	98%–100%	2–4 months
Peas, green	0°C (32°F)	95%–98%	1–2 weeks
Peppers, chili (dry)	0°C–10°C (32°F–50°F)	60%–70%	6 months
Peppers, sweet	7°C–10°C (45°F–50°F)	85%–95%	2–3 weeks
Potatoes, chipping	10°C (50°F)	90%–95%	10 months
Potatoes, early crop	4°C (39°F)	90%–95%	7 days
Potatoes, late crop	4°C (39°F)	90%–95%	5–10 months
Potatoes, seed	2°C–4°C (36°F–39°F)	90%–95%	7 months
Pumpkins	10°C–13°C (50°F–55°F)	50%–70%	2–3 months
Radishes	0°C (32°F)	95%–100%	3–4 weeks
Rhubarb	0°C (32°F)	95%–100%	2–4 weeks
Rutabagas	0°C (32°F)	98%–100%	4–6 months
Salsify	0°C (32°F)	95%–98%	2–4 months
Spinach	0°C (32°F)	95%–100%	10–14 days
Squashes, summer	5°C–10°C (41°F–50°F)	95%	1–2 weeks
Squashes, winter	10°C–13°C (50°F–55°F)	50%–70%	1–6 months
Sweetpotatoes	13°C–16°C (55°F–61°F)	85%–90%	4–7 months
Tomatoes, firm-ripe	7°C–10°C (45°F–50°F)	85%–95%	3–5 days
Tomatoes, mature-green	13°C–16°C (55°F–61°F)	85%–95%	3–6 weeks
Turnips	0°C (32°F)	95%	4–5 months

[1] Leafy greens may be stored for 2–3 weeks if they have been hydro-cooled immediately after harvest.

Table 3–1. Storage Life for Fresh Vegetables in Commercial Storage

[1] Leafy greens may be stored for 2–3 weeks if they have been hydro-cooled immediately after harvest.

Low Temperature Management

Low temperature management (controlling product temperature and reducing the amount of time that the product is at less than optimal temperatures) is the most effective tool for slowing the loss of quality in fresh vegetables. This begins with the rapid removal of field heat by using one of the following cooling methods (see Table 3–2):

Room Cooling (RC): Containers of produce are placed into a refrigerated room and cold air from the evaporator coils slowly cools the product. The main advantage of RC is that produce can be cooled and stored in the same room, whereas the major disadvantage is that it is too slow for most commodities.

Forced-Air Cooling (FA): This method is the most widely adaptable and fastest cooling method for small-scale operations. Cold air is forced to move rapidly through the containers (versus around the containers as in RC), allowing the cold air to be in direct contact with the warm produce. In forced-air evaporative cooling (FA-EC), the air is cooled with an evaporative cooler instead of with mechanical refrigeration, resulting in high-humidity cooling air.

Hydrocooling (HC): Cold water is an effective method for quickly cooling a wide range of vegetables in container or bulk. Hydrocoolers use either an immersion or a shower system to bring products in contact with the water. HC avoids product water loss and may even add water to a slightly wilted commodity, as is often done with leafy green vegetables.

Package Icing (PI): Some vegetables are cooled by filling the packed containers with crushed or flaked ice. Initially, the direct contact between the ice and product causes fast cooling. However, as the ice in contact with the product melts, the cooling rate slows considerably. PI is less efficient than FA or HC. Liquid-ice, a slurry of ice and water, distributes ice throughout the container, achieving better contact with the product.

Table 3–2. Vegetable Cooling Methods

LEGEND: RC – room cooling; FA – forced-air cooling; HC – hydro-cooling; PI – package icing; VC – cacuum cooling

	RC	FA	HC	PI	VC
Asparagus		X	X		
Bean		X	X		
Broccoli		X	X	X	
Brussels sprouts		X	X	X	
Cabbage		X			X
Carrot (with tops)		X	X	X	X
Carrot (without tops)		X	X	X	
Cauliflower		X			X
Celery/rhubarb		X	X		X
Cucumber	X	X	X		
Eggplant	X	X			
Garlic	X	X			
Leafy greens		X	X		X
Muskmelon	X	X			
Onion (dry)	X	X			
Onion (green)/leek			X	X	X
Pea		X		X	X
Pepper	X	X			X
Potato	X				
Squash (summer)	X	X			
Squash (winter)	X				
Sweet corn		X	X	X	X
Tomato	X	X			
Watermelon	X	X	X		

Vacuum cooling (VC): This method involves water evaporation at very low atmospheric pressure. Vegetables that have a large surface area to volume ratio, such as lettuce and leafy greens, are best suited for VC. There is approximately 1% product weight loss (mostly water) for every 6°C (43°F) of cooling, and thus some coolers are equipped with a water spray system that adds water to the product surface during cooling (WVC).

Table 3–3. Potential Benefits of Controlled Atmosphere Storage on Vegetables

	Low O_2	High CO_2	Temp	Benefits
Asparagus	Not beneficial	10%–14%	0°C–1°C (32°F–34°F)	maintains tenderness, retains green colour and retards soft rot development
Beans, snap	2%–5%	3%–7%	5°C–8°C (41°F–46°F)	retains green colour and reduces discolouration due to mechanical injury
Broccoli	1%–2%	5%–10%	0°C–1°C (32°F–34°F)	delays yellowing of flower buds, suppresses decay growth, reduces negative effects of ethylene, and may preserve vitamins C and A
Cabbage	3%–5%	3%–6%	0°C–2°C (32°F–36°F)	maintains colour and flavour, and reduces leaf abscission, sprouting and decay development
Garlic	Not beneficial	5%–10%	0°C–1°C (32°F–34°F)	reduces sprouting and slows decay development
Tomato, mature green	3%–5%	2%–3%	12°C (55°F)	delays ripening and development of surface moulds

Controlled Atmosphere (CA) Storage

Controlled atmosphere (CA) storage is currently used worldwide on many fresh fruits and vegetables. It extends their storage life by slowing the metabolic processes associated with aging.

CA refers to enclosure within an air-tight environment, in which the O_2 is lower and/or the CO_2 is higher than the concentrations found in fresh air. The atmosphere is most often created by injection of desired gas concentrations but can also be influenced by respiration of the product. Nitrogen is usually used to replace O_2 when concentrations below 21% are desired. Gas levels must be precise and accurately maintained to prevent injury to the product.

Newer CA equipment, such as pallet covers and portable gas analyzers, are making it easier to use this technology. Table 3–3 shows a list of vegetables that can benefit from CA storage, along with suggested atmospheres.

Chilling Injury

Chilling injury can develop in certain vegetables when temperatures are less than 15°C (59°F). This phenomenon is especially important in post-harvest handling and storage, as the use of low temperature is the most effective method of extending the storage life of many products.

The degree of chilling injury incurred depends on the temperature, the duration of low temperature exposure and the sensitivity of the species to chilling temperatures. The lower the temperature, the greater the severity of the eventual injury. Upon removal to non-chilling temperatures, the full manifestation of the stress becomes apparent. The longer the duration of exposure to chilling temperatures, the greater the injury. The sensitivity of a vegetable to chilling stress depends on several factors, of which species, cultivar, plant part, and morphological and physiological condition at the time of exposure are of critical importance. Chilling stress and injury do not only occur in storages. Chilling temperatures may also be encountered in the field, during handling or transit, during wholesale distribution, in the retail store, and/or in the home.

Table 3–4 lists the vegetables that are sensitive to chilling temperatures, as well as the lowest safe storage/handling temperature and the symptoms of chilling injury for that vegetable.

Table 3–4. Chilling Injury-Sensitive Vegetable Crops

Commodity	Lowest Safe Temperature	Chilling Injury Symptoms
Asparagus	0°C–2°C (32°F–36°F)	darkened, water-soaked tips leading to bacterial soft rot
Basil	7°C–10°C (45°F–50°F)	wilting, darkening, water-soaked appearance
Beans (snap)	7°C–10°C (45°F–50°F)	russetting, pitting, corky centres
Cantaloupe	2°C–5°C (36°F–41°F)	pitting, surface decay
Cucumber	10°C (50°F)	pitting, water-soaked lesions, surface decay
Eggplant	7°C–13°C (45°F–55°F)	flesh browning, pitting, decay of cap, fruit rot
Okra	7°C–10°C (45°F–50°F)	pitting, discolouration, decay
Pepper	7°C–13°C (45°F–55°F)	pitting, water-soaked appearance, darkening, fruit rot
Potato	2°C–10°C (36°F–50°F)	browning, sweetening
Pumpkin	10°C (50°F)	pitting, decay
Sweetpotato	10°C–12°C (50°F–54°F)	flesh discolouration, surface pitting, off-flavours, hard core, increased decay
Tomato (ripe)	7°C–10°C (45°F–50°F)	softening, watery flesh, seed browning, decay
Tomato (mature green)	13°C (55°F)	irregular ripening, poor texture
Watermelon	10°C (50°F)	surface pitting, loss of flavour, fading of red colour
Winter squash	10°C (50°F)	pitting, poor flavour, increased rot
Zucchini (summer squash)	5°C–10°C (41°F–50°F)	surface pitting, rapid decay

Ethylene

Ethylene is naturally produced by many fruit and vegetables. It acts as a growth regulator and is known as the ripening hormone. Ethephon is a synthetically produced ethylene product, which is commercially available. It is widely used in the processing tomato industry.

Ethylene gas increases the rate of ripening in mature fruits and vegetables, and shortens shelf-life. The effects of ethylene gas depend upon the stage of produce maturity, temperature and relative humidity of the storage room, concentration of ethylene and exposure time.

Ethylene is an invisible and odourless gas. However, it can be detrimental to produce and the effects can be easily misdiagnosed. Some of the undesirable effects of ethylene are:

- accelerated ripening of fruits (i.e., tomatoes)
- loss of green colour in some immature fruits (i.e., cucumbers, summer squash) and leafy vegetables
- russet spotting on lettuce
- bitterness in carrots
- sprouting of potatoes
- abscission of leaves (i.e., cauliflower, cabbage)
- toughening in asparagus

Ethylene can be used to your advantage when controlled and careful ripening of fruits and vegetables is desired. In this case, commercially available ethylene generators are used.

Food Safety

For detailed food safety information, e-mail OMAFRA food safety staff at foodinspection@ontario.ca.

Regulations:

- *Food and Drugs Act* and Food and Drug Regulations (www.law-lois.justice.gc.ca/eng/regulations/C.R.C._C._870)
- Safe Food for Canadians regulations (www.laws-lois.justice.gc.ca/eng/regulations/SOR-2018-108)
- O. Reg. 493/17 Food Premises under the *Health Protection and Promotion Act* (www.ontario.ca/laws/statute/90h07?search=health+protection+act)
- Good Agriculture and Collection Practices (GACP) certification: www.chsnc.ca/g-a-c-p-s/

Chapter 4

Field Scouting and Monitoring

Field Scouting

Field scouting involves walking through a field and stopping at a number of locations to make observations. Regular field examinations help to accurately identify yield-limiting problems and pest outbreaks. Every cropping season should begin with the recording of vital field information (soil fertility and crop inputs) on a field record form. Example field record forms are available on the OMAFRA website at ontario.ca/crops. This information, combined with regular field scouting, accurate identification and diagnosis of problems and a record of those observations, makes for a successful crop monitoring program. In addition to dealing with immediate issues, scouting information is used for future reference to avoid problems in subsequent years.

Thresholds

An integrated pest management program uses control guidelines (thresholds) that indicate when control measures should be taken to prevent economic losses.

For insect pests, spray guidelines are based on an economic threshold where the lost income from not applying a control will be higher than the cost of applying a control. In other words, some damage to the crop is tolerated, as long as this damage does not exceed the cost of the control. Thresholds for many insect pests are listed in Chapter 5. Nematode thresholds are listed in Chapter 6.

Depending on the disease, control measures are largely preventive. Fungicide programs may be triggered based on crop staging, weather conditions, regional forecasts or reports of disease outbreaks in neighbouring growing regions. Scouting for disease symptoms provides the information necessary to select the appropriate control measures, adjust fungicide spray timing and, in some instances, time harvest activities accordingly.

Timing of Field Scouting Operations

Early recognition and control of pest problems will minimize the economic impact on a crop. In the commodities sections of Chapter 7, pest activity calendars illustrate the timing associated with the common vegetable crop pests found in Ontario. It is important to monitor fields consistently and frequently, since pest dynamics change rapidly throughout the season.

Evaluate crop stands within 1–2 weeks of transplanting or plant emergence. This helps determine the many causes of early-season plant losses, while the pests or symptoms are still present.

Plan to scout most vegetable crops weekly throughout the growing season. More frequent scouting may be necessary during periods of peak pest activity or if a specific pest population is nearing its threshold level. Pest-specific scouting guidelines are outlined in Chapter 5 and Chapter 6. See the individual commodity sections in Chapter 7 for pest activity calendars.

Scouting Tools and Techniques

Tools used to monitor crop development and pests vary with the crop and the pest. Basic field scouting equipment includes:

- a clipboard with field scouting forms or field pocket guide to record observations
- field maps
- a shovel or a trowel
- a pocket knife
- containers and bags for collecting specimens
- a 10x hand lens

Professional scouts often carry other tools that could include a camera, labels for identification, reference guides, a sweep net, vials and isopropyl alcohol, sticky cards or traps to detect insect pests, a GPS unit to mark the location, flagging material, etc.

It is also wise to wear appropriate clothing for protection from the sun and from unknown risks such as poisonous plants and mosquitoes. Be aware of recent pesticide treatments applied to the field and obey restricted entry intervals indicated on product labels. Always consult the spray records before entering a field.

Number of Sampling Locations

The number of sampling locations in a field depends on factors such as field size, crop, pest type and stage of development, level of infestation, timing, etc. Where a specific protocol exists for scouting a particular pest, it is outlined in Chapter 5 or Chapter 6. Otherwise, a general recommendation is to carefully inspect 10 plants at each of 10 locations across the field. Split fields larger than 16 ha (40 acres) into units of 16 ha (40 acres) or less.

Scouting Pattern

When scouting, cover all parts of the field. Vary the observation locations each time the field is scouted, to ensure that all areas of the field are represented. Revisit any hot spots identified during the previous week's scouting activity. When determining a scouting pattern, take into account factors such as:

- changes in cultivar or planting date
- differences in past cropping history or cultural practices
- changes in fertilizer rates or manure application
- pest biology and behaviour

Do not scout fields solely on the basis of crop appearance or problem areas. For pests that are typically distributed uniformly across a field, randomly select sampling locations evenly across the field (Figure 4–1). Airborne diseases and winged insects (or the larvae of winged insects) frequently have a uniform field distribution. This pattern is also appropriate for soil sampling.

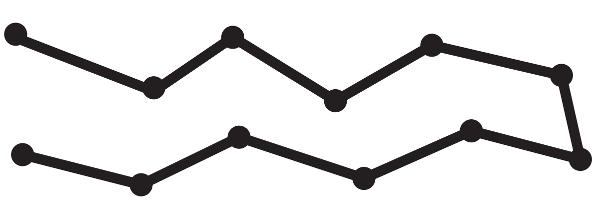


Figure 4–1. Random scouting pattern for uniformly distributed pests.

For pests expected in headlands or outside rows, randomly select sampling locations evenly around the edges of the field (Figure 4–2). Pests and problems that fit this scouting pattern include armyworm, spider mites and soil compaction. Certain insects such as cucumber beetles and Colorado potato beetles may appear as border pests before they penetrate the entire field.

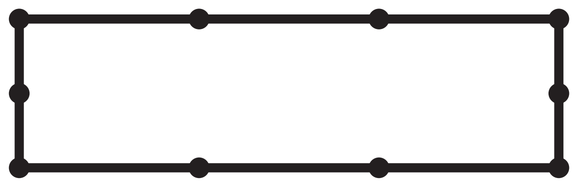


Figure 4–2. Border scouting pattern.

For pests developing in specific areas of the field, concentrate sampling locations in areas where the problem or pests are most likely to be found (Figure 4–3). Pests that tend to be specific to certain areas of the field include seed-borne diseases, nematodes, cutworms and certain soil-borne diseases such as *Phytophthora*.

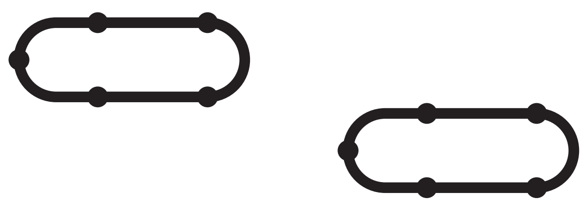


Figure 4–3. Specific scouting pattern.

Many vegetable crops are host to a wide range of insects and diseases. As a result, a combination of the above scouting strategies is often the most effective method to gage all potential pest populations.

Trapping

Traps are useful for indicating the presence or absence of certain insects. However, they often catch only the adult stage of the pest and may not provide specific information on the damaging, immature pest stages. Not all traps are used to indicate the potential pest population in the field. Many trapping programs are used solely to track the development of a population and to identify peak activity.

Weather monitoring and the use of growing degree days can improve trapping efficiency by predicting insect emergence and development. See *Growing Degree Days*, in this chapter.

Traps are usually placed in the field 1–2 weeks prior to the estimated emergence of the insect. Both pheromone traps and visual traps are commonly used in vegetable crops. Pheromone traps use a female sex hormone lure to attract male adults and for some insects like stink bugs, an aggregation lure can be used. The lure is specific to each insect species, which makes insect identification easier. Visual traps rely on a visual lure, such as a bright yellow sticky card, to attract the pest.

It is critical to the success of the trapping program that the correct type of trap is used for each target pest. The number of traps and the location within the field will also depend on the crop and insect. Specific monitoring guidelines are outlined in the individual commodities sections in Chapter 7. For more detailed information on scouting and trapping visit www.ontario.ca/cropIPM.

Keep in mind that pheromone lures are specific to the pest being trapped. They are very sensitive to contamination if they come into contact with other types of pheromones. If your trapping program involves using different types of pheromones, wear disposable latex or nitrile gloves to prevent cross-contamination during handling.

Recording Field Observations

Field scouting records are an essential tool for making current and future management decisions. Using a field scouting form will facilitate and standardize the recording of field observations. Computer software is also available to record and summarize data from field observations.

Information to be recorded during scouting events includes:

- field name/code, location and scouting date
- condition of the crop
- hybrid/cultivar
- crop growth stage
- weather conditions
- soil conditions
- weed species
- diseases
- insects
- crop damage
- field map
- results of scouting procedures performed
- action required

Sample Handling and Submission

It is often difficult to identify a pest or field problem. Disease symptoms, nutrient disorders and physiological problems can look remarkably similar. Crop specialists, agri-business professionals and diagnostic laboratories can help narrow down and identify specific crop problems. However, when submitting samples, the quality of the sample can make a big difference to how easily and accurately the problem is isolated.

For more information on how to take proper samples, and a sample submission form, see *Appendix F. Diagnostic Services*.

Growing Degree Days

Growing degree days (GDDs) are used to estimate the growth, development and maturity of plants and insects during the production season. This system tends to be more accurate than “days to maturity.”

The development of most crops and insects is closely related to the daily accumulation of heat. A certain amount of heat is required to provide enough energy for a plant or insect to move to its next development stage. For example, it takes 300 GDDs for the first emergence of European corn borer moths to occur in Southwestern Ontario. The GDD heat requirements do not change from year to year. But, depending on weather conditions, the amount of actual time (calendar days) can vary between years.

Each species of plant and insect has a minimum base temperature or threshold below which development does not occur. These base temperatures are different for each organism.

To calculate GDD, first determine the mean daily temperature. This is done by taking the maximum and minimum temperatures for the day, adding them together and dividing by two. The base temperature is then subtracted from the mean temperature to give a daily GDD. If the resultant daily GDD is a negative number, count it as zero. Each daily GDD is then added up (accumulated) over the growing season.

$$\frac{\text{daily maximum temperature} + \text{daily minimum temperature}}{2} - \text{base} = \text{Growing Degree Days}$$

GDD models are available for most vegetable crops and several insect pests. See Table 4–1 and Table 4–2 for examples of specific GDD base temperatures.

Table 4–1. Insect Growing Degree Days Base Temperatures

Insect	GDD Base Temp
General insects	15°C
Aster leafhopper	9°C
Cabbage maggot	6°C
Carrot rust fly	3°C
Carrot weevil	7°C
European corn borer	10°C
Cutworms	7°C
Onion maggot	4°C
Seedcorn maggot	4°C
Tarnished plant bug	9°C

There are four factors to consider when comparing GDD accumulations from various sources or regions.

- **Are the base temperatures used in the equations the same?** Different organisms have different base temperatures used to calculate growing degree days. 150 GDDs at base 10 does not equal 150 GDDs at base 0.
- **Are the start dates for the accumulations the same?** Generally, GDD accumulations start on April 1 each year, but some insect GDD models start at the emergence of a specific life stage. This is referred to as a biofix.
- **Are the equations used to calculate the daily GDDs the same?** Many modifications to the simple GDD calculation have been developed over the years and may still be referred to as degree days.
- **Are the temperatures used in degrees Celsius or Fahrenheit?** GDD accumulations will vary significantly, depending whether they are being tracked in Celsius or Fahrenheit. GDD models have been designed specifically for use in Celsius or in Fahrenheit and cannot be interchanged without making conversions.

Confusion has been created over the years by the terminology used to describe growing degree days. In Ontario, the terms “growing degree days” (GDDs) and “crop heat units” (CHUs) represent two very different development models. The crop heat units calculation used in Ontario is identical to the traditional corn heat units calculation. Its name was changed to reflect its now broader application to other crops.

Growing degree days are sometimes referred to as “degree days” or “degree days averaging method.” Some other jurisdictions use the term “heat units” interchangeably with degree days.

Table 4–2. Vegetable Growing Degree Days Base Temperatures

	Base Temperature					
	2.2°C	4.4°C	7°C	10°C	13°C	15.5°C
Crop	onion spinach	asparagus beet broccoli carrot lettuce pea potato	squash	bean (snap) cantaloupe pepper sweet corn tomato	cucumber watermelon	eggplant sweetpotato

Disease Prediction Models

Disease prediction models utilize environmental data collected from a network of weather stations across a specific growing area. Depending on the disease, the weather variables include factors such as daily average temperature, leaf wetness and relative humidity. The weather data is used to calculate disease severity values (DSVs) throughout the growing season. Growers are advised to spray when a critical number of DSVs have accumulated since planting or since the last fungicide application. The rate of DSV accumulation and the spray thresholds vary based on the crop and the specific model.

A number of disease prediction models are available for use in vegetable crops in Ontario. These include:

- BEETcast for cercospora leaf spot in sugarbeets
- BOTCAST for botrytis leaf blight onions
- BREMCAST for downy mildew in lettuce
- DOWNCAST for downy mildew in onions
- TOMcast for early blight, septoria leaf spot and anthracnose in tomatoes

A predictive model is also used for downy mildew in cucurbit crops across North America. This model tracks the development of the disease in the various cucurbit-growing regions. It then uses weather forecasts to predict the spread of the disease from areas with known infections into other growing regions. For more information, visit the ipmPIPE website: http://cdm.ipmpipe.org.

In Southwestern Ontario, Weather INnovations Consulting LP offers TOMcast and BEETcast programs to tomato and sugarbeet growers. For more information, contact WIN at 519-352-5334 or visit their website: www.weatherinnovations.com.

The University of Guelph, Muck Crops Research Station, also offers a number of disease prediction models for growers in the Holland Marsh region. For more information, visit their website: www.uoguelph.ca/muckcrop/ipm.html.

Growers may also choose to establish and maintain their own on-farm weather station. Software for many of the disease prediction models is often available for purchase from the manufacturers or distributors of weather monitoring equipment.

Chapter 5

General Entomology

Aphids

Aphididae family

Identification: There are several aphid species affecting vegetable crops in Ontario. Aphids are small, soft-bodied, pear-shaped insects, with cornicles or "tail-pipes" near the tip of their abdomen. They have relatively long legs and prominent antennae. Colour may vary depending on the species and the host plant. A few species found in vegetable crops have a waxy or woolly appearance.

Wingless aphids establish colonies in the field, on the underside of the leaves or along the stems or petioles. Some species, including the sugarbeet root aphid, are associated with roots.

Winged aphids form under crowded conditions, allowing them to migrate to new food sources.

Damage: Aphids often congregate on new growth. They pierce the leaves and suck the sap from the plant, causing leaf distortion, stunting, delayed maturity and wilting. Feeding damage interferes with the uptake of water and nutrients. It also opens the plant up to other insect and disease problems.

While feeding, aphids exude a sticky substance called "honeydew." Honeydew, and the moulds associated with it, may affect the marketability of the harvested product. Sugarbeet root aphids exude waxy, whitish strands that are likely to be noticed more readily than the aphids themselves.

Aphids also act as a primary vector of several economically significant virus diseases in either a persistent or non-persistent manner (see Chapter 6). The soybean aphid does not form colonies on vegetable crops; however, it often moves through vegetables in its search for soybeans, spreading non-persistent viruses as it travels. The control of aphid populations with conventional insecticides does little to prevent the spread of non-persistent viruses.

Biology: Most aphids overwinter as eggs on perennial hosts, such as weeds, and migrate to vegetable crops in the summer. Other species, such as the corn leaf aphid, migrate northwards on weather systems from more southerly regions. Sugarbeet root aphid overwinter in the soil.

Aphids are present throughout most of the growing season. Populations increase rapidly under favourable conditions, including hot, dry weather. Natural predators (lady beetles, lacewings, minute pirate bugs, etc.) or parasitoids (*Aphelinus* and *Aphidius* spp.) often help keep aphid populations below threshold levels.

Scouting and Thresholds: Aphid distribution may be patchy within a field. Populations are often higher along field margins and hedgerows. Inspect the underside of leaves from the top, middle and bottom of plants. Note the presence of aphid honeydew on the foliage and fruit. Look for beneficial insects (aphid predators or parasites) as well. Look closely to distinguish live aphids from dead aphids and moulted skins. To scout for sugarbeet root aphids, dig up and inspect the roots of wilted plants. Aphids may also be found on the roots of weed hosts such as lamb's-quarters and pigweed.

Lettuce:	1% infestation 7–10 days prior to harvest
Peppers:	No threshold is established, but more than 10 aphids per leaf could be potentially damaging.
Potatoes:	4 aphids per leaf (check 1 lower leaf on 50 plants). Keep seed potato fields free of aphids at all times.
Sugarbeet (roots):	No threshold is established, but less than 10% infestation may result in reduced yield.
Sweet corn:	10% of ears infested (ears with more than 20 aphids are considered infested)
Tomatoes:	5 aphids per 10 leaflets per plant

Management Notes: When controlling other insect pests, select pest control products that are safer for beneficial insects. Broad-spectrum insecticides may also control natural enemies, resulting in higher aphid populations. Note that the sunflower aphid and the green peach aphid may have developed resistance to insecticides in some areas.

Lamb's-quarters and pigweed are alternative hosts of some root aphids; crop rotation and weed management may help reduce their numbers. Destruction of infested crops following harvest may prevent excessive dispersal. In sugarbeets, cultivars with resistance to root aphid are available.

Aster Leafhopper

Macrosteles quadrilineatus

Crops Affected: Carrots, celery, leafy greens, herbs

Identification: Aster leafhoppers are small, greenish-grey insects with six spots arranged in pairs on top of the head. Its wings are transparent and heavily veined.

Damage: Aster leafhoppers transmit aster yellows to carrots, celery and leafy greens by feeding on these crops. See *Aster Yellows*, *Carrots*, Chapter 7.

Biology: The aster leafhopper overwinters as an egg in the leaf tissue of winter grains such as wheat and rye. Approximately 130 growing degree days (GDDs), base 9°C, are required for egg maturation. An additional 270 GDDs are required for development to adulthood. See *Growing Degree Days*, Chapter 4.

As the winter grains mature in late May and early June, local first-generation leafhoppers disperse into vegetable crops. Leafhopper populations from the U.S. are also carried into Ontario on weather systems. Both local dispersal and long-distance movement influence the incidence and severity of the aster leafhopper and aster yellows.

Scouting and Thresholds: The Aster Yellows Index (AYI) determines the need to treat a crop. To use the AYI, monitor aster leafhoppers with a sweep net. Multiply the number of aster leafhoppers captured in 100 sweeps by the percentage of leafhoppers carrying aster yellows in your area (4%–5% is the currently recommended percent infectivity in Ontario). Use this formula:

Infectivity rate (4%–5%) x # of leafhoppers/100 sweeps) = AYI

Use the AYI thresholds for each crop listed below. In carrots, the threshold varies depending on varietal tolerance. If a carrot cultivar has not been evaluated for aster yellows tolerance, use an AYI threshold of 70. See Table 5–1.

Table 5–1. Aster Yellows Index

Crop	Aster Yellows Index
Carrots — resistant	100
Carrots — intermediate	70
Carrots — susceptible	50
Celery	30–35
Lettuce — head	20–25
Lettuce — cos/romaine	30–35

Management Notes: Grow resistant cultivars and remove perennial weeds from fields that may act as reservoirs.

Brown Marmorated Stink Bug

Halyomorpha halys

Crops Affected: Reported vegetable crops attacked include asparagus, bean, sweet corn, cucumber, eggplant, okra, pea, pepper, tomato, summer squash, other.

Identification: The brown marmorated stink bug (BMSB) is easily confused with other types of stink bugs. The adults are shield-shaped, 12–17 mm (½–⅔ in.) long, and a mottled brownish-grey colour. They have several important features that help to distinguish them:

- two white bands on each antenna
- single light band on each leg (more obvious on nymphs)
- smooth, rounded pronotum (“shoulders”) that do not protrude forward
- inward pointing white triangles on the edge of the abdomen

Damage: Both the nymphs and the adults feed by inserting their piercing-sucking mouthparts into various parts of the plant. Small necrotic areas form at the feeding site. Symptoms of stink bug feeding include discoloured, deformed or corky fruit; death of buds; leaf stippling; punctured kernels and delayed maturity.

Biology: The adults are long-lived, with females laying multiple egg masses over an extended time period from late May to early August. All life stages, eggs, nymphs and adults may be present in the field at the same time. There is one generation per year in northern climates.

Scouting and Thresholds: BMSB is a new pest in Ontario. Pheromone traps are available and may be useful for early detection. Pest pressure is typically highest on the edges of fields. Thresholds are still under development for most vegetable crops. In sweet corn, insecticide sprays should be initiated at tasseling if bugs are present and repeated as needed until harvest. See *Trapping*, Chapter 4, for more information on monitoring.

Management Notes: Monitor from mid-June through harvest, particularly along field margins next to woodlots. Check plants for adults, nymphs and signs of damage. Border sprays may be sufficient in some crops. Multiple applications of insecticide may be necessary if re-infestation occurs.

Common Armyworm (True Armyworm)

Mythimna unipuncta

Crop Affected: Sweet corn, cereal cover crops, hay, grain crops, an occasional pest of other vegetable crops.

Identification: Larval stages are dull-green to brown with white-bordered stripes running laterally along the body. There is a dark, diagonal band at the top of each proleg. They are as large as 5 cm (2 in.) in length at maturity.

Damage: Armyworms attack young corn plants, often eating everything but the stalk and the leaf mid-vein. Plants outgrow moderate leaf-feeding as long as the growing point is not damaged. Damage often first occurs when neighbouring cereal crops begin to dry down and the larvae look for a new food source.

Biology: Armyworms do not overwinter in Canada or bordering northern states. Populations in Ontario originate from spring storm fronts that carry moths from the southern U.S. where they overwinter. Arrival in Ontario usually occurs early in the spring. Once here, females lay their eggs in cereal crops or grassy vegetation. There are two generations in Ontario.

Scouting and Thresholds: Scout carefully along the edges of fields bordering cereal crops. Larvae are active at night. If possible, scout in the early morning or late evening. During the day, larvae often hide in the leaf whorl, in crop debris or under soil clods. Look for feeding damage, frass and larvae on the young seedlings throughout June and early July.

In seedling corn, an insecticide may be warranted if more than 10% of the plants show feeding damage. Once the plants reach the mid-whorl stage, they are more tolerant of feeding injury and the threshold increases to 50% of the plants with damage. Larvae that have reached 3.5 cm (1¼ in.) in size are ready to pupate and have finished feeding on the crop.

Management Notes: Naturally occurring beneficial organisms and parasites often keep armyworm populations from building to damaging levels. Border sprays may provide sufficient control for infestations that are entering the field from neighbouring cereal crops. Maintain good grassy weed control both in and around the field.

Cutworms (Early-Season)

Agrotis ipsilon (black cutworm), *Euxoa messoria* (dark-sided cutworm), *Crymodes devastator* (glassy cutworm), *Euxoa detersa* (sandhill cutworm)

Crops Affected: Many vegetable crops, including asparagus, bean, carrot, cucurbits, eggplant, ginseng, lettuce, maize, parsnip, pea, pepper, potato, tomato and sweet corn.

Identification: Species commonly found in Ontario vegetable crops include black cutworm, dark-sided cutworm and the sandhill cutworm. Black cutworm is most often associated with damage to sweet corn, peppers, tomatoes, cucurbits and brassica seedlings. Cutworm larvae are soft and fat, and they roll up when disturbed. Mature larvae can be as large as 3–5 cm (1¼–2 in.) in length. Black cutworms are grey to black with no striping on the body, whereas most other cutworms have stripes along their back or sides. For information on cutworms attacking fruit and foliage later in the season, see *Variegated Cutworm*, *Tomatoes*, Chapter 7.

Damage: Cutworm damage occurs most often in late April and early May, coinciding with early-season planting and emergence of seedlings. Larvae cut the petioles or stems of seedling plants below or at the soil surface. Most of their damage is found at the field edge or in weedy fields. One cutworm can kill several plants before it reaches full size and pupates. Most species of cutworm feed at night, hiding during the day in the soil near the base of the plant. Black cutworms may cause serious damage in potatoes by feeding on the tubers late in the season.

Biology: Most species of cutworm do not overwinter in Ontario. In the early spring, adult moths are transported on the trade winds from more southerly areas. Females are attracted to dense, green cover to lay their eggs. Often, when they arrive in Ontario in early spring, the main source of habitat for the females are winter annual or perennial weeds. Cutworms are therefore more frequent in fields with green cover early in the spring before primary tillage. Egg hatching and larval feeding often coincide with planting and crop emergence.

Scouting and Thresholds: Most species of cutworm feed at night, hiding during the day under loose stones or in the soil near the base of the plant. Scouting is best done in the middle of the day, when the water demand of plants is high. Check for cutworm damage by walking through the field and looking for wilted and/or fallen plants. If any are found, dig around in the soil at the base of the plant. The cutworm, if present, will be found 2–3 cm (about 1 in.) deep and within 10 cm (4 in.) of the damaged plant(s). Make control decisions based on the number and size of larvae found. Look for cutworm larvae in the top 2.5 cm (1 in.) of soil surrounding the damaged plant.

For most vegetable crops, the control guideline is 5% damaged plants.

For potatoes, cutworm is a sporadic pest. Monitor populations with pheromone traps.

For sweet corn, the threshold is 10% damage, if plants are less than 4–6 leaves and larvae are less than 4 cm (1½ in.).

Management Notes: Cutworm control is most effective on larvae under 2.5 cm (1 in.). Larger larvae are difficult to control with insecticides. At more mature stages that are greater than 2.5 cm (1 in.) in length, they cease feeding as they prepare to pupate, and control becomes unnecessary. Apply insecticides in the early evening, as the cutworms come to the surface to feed at night. Insecticides are more effective on moist soils.

European Chafer

See *White Grubs/European Chafer*, in this chapter.

European Corn Borer

Ostrinia nubilalis

Crops Affected: Sweet corn, beans (snap and lima), peppers and potatoes

Identification: Full-grown corn borer larvae are 2.5 cm (1 in.) in length. They are greasy white in colour, with a dark head and spots on each segment. The eggs are shiny, white and laid in clusters of 30 that resemble fish scales. The adult is a light-brownish moth, with patterns of wavy lines on the wings.

Damage: In sweet corn, the newly hatched larvae produce pin-sized holes or window panes on the leaves. The larvae will often bore through the young whorl, creating a straight line of pinholes across the width of the leaf when it unfolds. As they mature, the larvae move into the mid-vein of the leaf and subsequently into the stalk. The borers feed on the internal stalk tissue, often causing the tassels to break and the stalks to lodge. As the crop matures, borers move from the stalk into the ear. An entry hole is often (but not always) present at the base of the cob. Damaged ears will attract birds and sap beetles.

Second-generation ECB frequently lay eggs on the ear leaf. The larvae immediately enter the ear through the silk channel, leaving little indication of feeding on the leaves or husk.

In peppers and snap beans, the larvae enter the fruit or pods under the calyx (stem cap). The larvae develop inside the fruit or pods, feeding on the seeds. There are frequently no external signs that the snap bean pods have been infected.

Pepper fruit are susceptible to damage by European corn borer once fruit reach about 1.5–3 cm (½–1¼ in.) in diameter. Infested peppers are more prone to fungal diseases and bacterial soft rot. Prior to fruit set, larvae may tunnel into pepper stems, but this is not usually economically significant.

In potatoes, larvae feed on the leaves for a few days and then bore into the stems, destroying the pith and the vascular tissue. Damaged stems wilt and break easily.

European corn borer larvae produce yellowish-brown sawdust-like droppings known as frass. Frass is often present at the entry hole on the mid-vein or leaf nodes of sweet corn plants. It may or may not be present near the stem-end of pepper fruit and snap bean pods.

Biology: Borers overwinter as mature larvae in corn stubble. Southwestern Ontario experiences two generations per year (bivoltine). Usually, the first-generation adults emerge in mid-June, and the population peaks in mid-July. Second-generation populations peak in August.

In the rest of the province, single-generation (univoltine) corn borers usually emerge in late June or early July. Populations peak in late July to early August.

Many areas within Southwestern Ontario (Lambton, Middlesex, Oxford, Brant, Norfolk and Niagara) have an overlap of the bivoltine and univoltine corn borer populations. These areas experience a sustained peak flight for much of July and August.

Growing degree days is another method of predicting corn borer development, using a base temperature of 10°C (50°F). See Table 5–2 for the predicted developmental stages.

Table 5–2. Growing Degree Day Thresholds for European Corn Borer

Event	Generational Types		
	Univoltine	Bivoltine First Generation	Bivoltine Second Generation
First catch	300	150	700
Peak catch	650–700	300–350	1,050–1,100

Scouting and Thresholds: In sweet corn, begin monitoring all fields at the mid-whorl stage. If monitoring indicates a need, apply the first spray at tassel emergence. The threshold is 5% feeding injury or the presence of egg masses.

It is very difficult to find signs of European corn borer in peppers and snap beans by scouting. The only reliable way to detect European corn borer activity in peppers is by using monitoring traps.

Monitor adult populations using black-light traps or pheromone traps. Set up traps in un-mowed grassy areas near the edge of the field. Use either heliothis or sticky traps (wing or milk carton models are often used). There are two strains of corn borer: the Iowa (E strain) and New York (Z strain). These strains respond to different pheromone lures. Due to changing population dynamics in Ontario, monitoring for both strains is advisable. Check traps twice a week and replace lures weekly according to the manufacturers recommendations.

Management Notes: In sweet corn, direct the sprays down into the whorl and maintain good spray coverage of the leaves, tassels and ears. Target the small larvae before they enter the protection of the stalk, ears, pods or fruit. For the second generation of moths, populations may be controlled by the corn earworm sprays.

There is no tolerance for this pest in peppers or snap beans. Monitor populations using pheromone traps and apply insecticides soon after flowering as the young fruit or pods begin to develop. Pepper crops must be protected from European corn borer whenever moths are flying and pepper fruit are present. The second generation and sometimes a partial third generation (in southern areas) attack pepper.

Leafminers

Liriomyza spp.

Crops Affected: Table beets, brassica crops, celery, leafy greens, sugarbeets

Identification: There are 4 main species of leafminers that may attack vegetables in North America. Generally, leafminers are small, 2–3 mm (~⅛ in.), shiny black-and-yellow flies that lay their eggs in leaves. The larvae of leafminers are small, pale yellow maggots.

Damage: Female leafminers lay their eggs on the leaves, leaving small "bronzed" puncture marks. Females pierce the leaves to feed on plant sap. Larvae feed between the upper and lower surface of the leaves. Depending on the species, mines can be straight (pea leafminer) or serpentine (other leafminers). Leafminer feeding reduces the plant's photosynthetic capacity. The mines also affect marketability and provide an entrance for disease organisms.

Damage to bunching beets or beet greens is of most concern as the damage reduces marketability. The pest is unlikely to affect root yield or quality.

Leafminers are most likely to attack head and leaf lettuce types. The pea leafminer adult causes severe stippling (bronzing) damage to spinach and Swiss chard leaves. Mining of the leaves by pea leafminer larvae is not as common. Other species of leafminer create twisted mines underneath the leaf surface.

For sugarbeets, leafminer damage occurs in Ontario but has not been known to cause economic losses. The leafminer adults that emerge in early spring are more damaging than later generations, as the beets are at a smaller, more susceptible stage of growth.

Biology: Optimal temperatures for leafminer development range from 21°C–32°C (70°F–90°F). Egg-laying is reduced at temperatures below 10°C (50°F). Leafminers can be a problem throughout the season. The pea leafminer is typically a late-season pest with populations peaking from the end of August through the middle of September.

Scouting and Thresholds: None have been established except for sugarbeets. In sugarbeets, if 50% of plants have eggs or larvae, treatment may be required. Leafminer control is usually required only for bunching beets, where damage-free tops are required.

Scout for mines and larvae or for eggs on the underside of leaves. Yellow sticky traps placed in the crop can be used to monitor adult flies.

Management Notes: Lamb's-quarters is an alternate host for leafminers. Good weed control can reduce infestations. Crop rotation is an effective pest management tool. Alternating leafminer-susceptible crops with leafminer-resistant crops reduces the population.

For pea leafminer, reduce severe damage by harvesting susceptible crops before the beginning of September when populations tend to rise. Apply insecticides as soon as pea leafminer adults first appear.

Millipedes

Cylindroiulus caeruleocinctus, *Blaniulus guttulatus*, *Pseudopolydesmus* spp.

Crops Affected: Many direct-seeded vegetables, carrots, radishes and sweet potatoes.

Identification: Millipedes belong to a class of arthropods distinct from insects. They are hard-shelled, cylindrical and approximately 2.5–10 cm (1–4 in.) long. They get their name (milli: thousands, pedes: legs) from having many legs: two short pairs of legs per body segment in the adult stage. Adult millipedes are dark reddish-brown to grey-black in colour and have hardened bodies, while the immature millipedes are white, have fewer legs and do not have hardened bodies. As they mature, they develop more legs and turn darker in colour. Another distinguishing characteristic is that they coil up tight when disturbed. Millipedes are frequently confused with wireworm. See *Wireworm*, in this chapter.

Only three species have been implicated as damaging Ontario root crops: *Cylindroiulus caeruleocinctus, Blaniulus guttulatus* and

Pseudopolydesmus spp. The first two species belong to a group called julids, sometimes referred to as snake millipedes. They have a typical millipede appearance — a cylindrical body and rounded head used for ramming through the soil. The third species, *Pseudopolydesmus*, has a flatter body shape with distinct body segments

Damage: Millipedes are normally considered beneficial in vegetable production due to their habit of feeding on decaying plant material, which helps to incorporate organic matter into the soil. However, under certain conditions, millipede populations can build to high levels and may damage the roots and seedlings of a variety of crops. During cool, wet springs, millipedes may feed on ungerminated seed and young seedlings. Millipedes are not usually an aggressive pest on direct-seeded crops. However, when combined with other stresses such as cold soils, fungal pathogens or other insect pests, millipedes have been known to affect plant populations and seedling vigour. Later in the season, millipedes may feed on root crops such as carrots, radishes and sweet potatoes. Damage ranges from superficial feeding on the skin, to fine tunnelling into the flesh or shallow cavities with ragged edges. This damage impacts the crop's marketability.

Biology: Both adult and immature millipedes overwinter in the soil under debris, rocks, etc. They can live for several years in the soil, taking up to 5 years to mature to the adult stage. They have become more prevalent with the adoption of reduced or no-till systems because of the increase in surface residues. Recent studies conducted in Ontario suggest that millipedes are most active in the early spring and late summer. Crop damage may be more severe under dry soil conditions when the millipedes feed on the root as a source of moisture.

Scouting and Thresholds: Inspect roots, germinating seed and soil around areas with gaps in the plant stand. If early-season injury is noticeable but no pest is present, set up bait stations. Research conducted in Ontario shows pitfall traps are effective for trapping millipedes early in the season; as the season progresses and plant canopies fill in, use corn bait traps. Place at 10–20 marked sites in a Z or W pattern across the middle of the field, with traps placed at least 10 m (33 ft) away from the field edge. Monitor populations for 2 consecutive weeks or more. Thresholds have not been established for millipedes in horticulture or field crops.

Management Notes: Where pre-season monitoring suggests millipede populations are high, early tillage prior to planting may help bring millipedes to the surface where they are susceptible to desiccation and predation. Harvest as early as possible, because millipedes will continue to feed on crops as long as they are in the soil. Remove crop residue to reduce food sources and possible overwintering sites. Generally, millipede populations are thought to do best under cool, moist conditions. Avoid practices that increase soil moisture above that required by the crop.

Slugs

Arion, *Deroceras*, *Helix*, *Limax* species

Crops Affected: Bean, celery, brassica crops, eggplant, leafy vegetables (lettuce, chicory, endive), pepper, potato, rhubarb, sweet corn and tomato.

Identification: Slugs are soft-bodied, legless, grey molluscs that have variations in colour from dark brown and black to light grey. They range in size from 0.5–10 cm (¼–4 in.) in length, depending on the species, and have a slimy covering to prevent them from drying out.

Damage: Slugs have rasping mouth-parts and will create ragged holes on the lower leaves, sometimes leaving a "window-pane" of waxy cuticle behind. Severely affected plants may become skeletonized. Under high populations, slugs also attack seeds and emerging seedlings. A slime trail is usually observed at the feeding location. Slug damage is most severe in years when there is prolonged cool, wet weather during May and June. They feed above or below ground, depending on the soil moisture level.

Biology: There is one generation per year, but two populations: one maturing as adults in the spring and one maturing in the fall. Both may cause crop injury. Under dry conditions, slug eggs can lay dormant for long periods of time. Slugs travel by gliding on a secreted stream of mucus.

Scouting and Thresholds: Scout for slugs at night or early morning, when they are active. Check under debris near damaged plants, and look for slime trails. Population levels in a field may be determined using monitoring boards. If slugs are commonly found under monitoring boards, the field should be considered at risk for slug injury. No thresholds have been established.

Management Notes: Most plants can successfully outgrow light feeding damage. Cultivating fields where slug pressure is high can help reduce the slug population. Tillage exposes the slugs to dehydration and predation by birds and mammals.

Removing weeds and crop residue from the zone immediately surrounding young seedlings may also help reduce damage. Zone tillage can remove slug habitat while maintaining the benefits of reduced tillage.

Spittlebug

Philaenus spumarius

Crops Affected: Garlic, herbs (especially members of the *Lamiaceae* (mint) family, e.g., basil, bee balm, catnip, lavender, marjoram, mint, oregano, perilla, rosemary, sage, savory, thyme).

Identification: Spittle bug nymphs are found in white spit-like froth on plants. They are soft-bodied, elongated, yellow to green, wingless and 0.3–0.6 cm (⅛–¼ in.) long. The adults, called froghoppers, are tan, black or grey, about 0.6 cm (¼ in.) long and have faces that resemble frogs.

Damage: Though spittlebugs feed on plant sap, damage is usually minimal. Very high populations can cause stunting, weakened plants, leaf distortion or reduced yields. The frothy "spit" can be a problem for pick-your-own operations.

Biology: Spittlebugs overwinter as eggs inserted into the leaf bases or crown of the plant. Eggs hatch, and nymphs appear in late April or early May. The nymphs take 5–8 weeks to mature. Adults migrate in June and return in September and October to lay their eggs.

Scouting and Thresholds: Scouting is usually not needed, as they will be evident when monitoring for other pests. Look for nymphs at the base of plants and leaves and on the underside of young leaves. There are no established thresholds for herbs, but in strawberries, the threshold is >10 spittle masses per 0.2 m^2 for yield reductions, and >2 spittle bugs per 1 m^2 for pick-your-own operations.

Management Notes: Good weed management will help control spittlebugs, because the adults are less likely to return in the fall to plantings that are free of weeds. Remove plant debris in the fall. Some pick-your-own operations have found that spraying plants with water each day can reduce populations, however this will also increase leaf wetness and may contribute to the development of foliar diseases.

Springtails

Collembola (Bourletiella hortensis)

Crops Affected: Springtail damage to sugarbeets has been seen in Ontario. They are generally considered beneficial insects, but may feed on crops. Damage to seedlings can be significant under the right conditions. Subterranean springtails are a rare pest of onions and their presence has been noted in conjunction with fungal pathogens.

Identification: At first glance, globular springtails may be confused with flea beetles. They are dark in colour and range in length from 0.8–3.0 mm (~⅛ in.). They can be found above-ground and tend to jump when disturbed. Subterranean springtail species are whitish and elongated, ranging from 0.8–2.4 mm (~1⁄16 in.) long. They live in the soil and do not have the ability to jump like other springtails.

Damage: They are generally not a concern except when extended cool, wet conditions occur during the seedling stage. Globular springtails feed on sugarbeet cotyledons, stems and roots. Subterranean springtails feed on roots. Damage may show up as small round holes in cotyledons or leaves or as pitting or scraping of plant tissue below- or above-ground. Stands can be reduced when springtail populations are high and sugarbeet seedlings are small and growing slowly.

Biology: Springtails usually feed on organic material in the soil, helping break down crop residue and improve soil structure. In extended moist conditions, populations can become very high and seedling damage may become noticeable.

Scouting and Thresholds: The crop is only vulnerable in the seedling stage. There is no established threshold or treatment, but where damage is seen, populations are probably in the thousands per square foot.

Management Notes: Crops generally outgrow the damage, and yield impacts have not been measured. Springtails are unlikely to cause significant damage in cases where a soil- or seed-applied insecticide has been used to target other seed or seedling insect pests.

Tarnished Plant Bug

Lygus lineolaris

Crops Affected: The tarnished plant bug (TPB) feeds on over 300 species of fruit, vegetable and field crops, as well as numerous weed species. Most crops discussed in this publication are susceptible to attack. Problems with TPBs may occur in bean, celery, brassica crops (including specialty brassicas), cucurbits, eggplant, lettuce, pepper, potato and tomato.

Identification: Nymphs are greenish in colour, with well-developed legs and moderately long antennae. Late instars have wing pads and four black spots on the thorax, behind the head, as well as one on the abdomen. Adults are pale green or yellow-to-dark brown, with dark markings and have a small triangle shape on their back.

Damage: TPBs have sucking mouthparts that they use to pierce into plant tissue and inject saliva that helps break down plant tissue. In many cases, damage from the TPBs is seen before the insect itself, thus, recognition of the damage symptoms is very important. Feeding on flowers may cause them to abort. TPBs cause a broad range of symptoms on vegetable crops including:

- stings and lesions on celery stalks
- reduced fruit set on beans, peppers and eggplants
- stings and blemishes on tomato and pepper fruit
- necrotic spots on the florets and curd of broccoli and cauliflower
- small holes with brown margins on lettuce leaves
- indentations or holes on fruit
- corkiness of fruit flesh
- misshapen fruit
- dead leaves on potato and vine crops

Celery and leafy vegetables are susceptible to attack throughout the growing season.

Biology: TPBs overwinter as adults in plant debris and leaf litter in protected areas such as woodlots, fencerows and ditches. Emerging adults feed and oviposit on broadleaf weeds in the spring, before moving into crops. TPB is a sporadic pest, present in Ontario throughout the growing season. Two generations occur per year, with a partial third in parts of Southern Ontario. First generation adults emerge in July and second in August and September.

Scouting and Thresholds: For celery and lettuce, inspect the heart leaves of 50–100 plants per field at least twice a week. Few crops have established thresholds, and in many cases, management decisions are based on presence or absence.

Celery:	0.1 (last 3 weeks before harvest) to 0.2 TPB (transplant to 3 weeks before harvest) per plant
Other leafy vegetables:	0.1 TPB per plant
Tomato:	1 nymph or adult per 30 plants (after fruit set)

Management Notes: TPBs breed on many common weed species, including pigweed, chickweed, dandelion, lamb's-quarters, ragweed and fleabane. Weed control in and around vegetable plantings will help reduce potential infestations. Alfalfa is also a very attractive host. After the alfalfa is cut, TPB adults may disperse and invade nearby vegetable crops.

Two-Spotted Spider Mite

Tetranychus urticae

Crops Affected: Beans (snap and lima), cucurbit crops (especially watermelons), eggplant, herbs, leafy greens, tomato.

Identification: The adult mite is approximately 0.5–1 mm (<1⁄16 in.) in length, barely visible to the naked eye. It is a translucent yellowish colour with two dark spots on the sides of its abdomen.

Damage: Spider mites feed through sucking mouth parts. Injury first appears as a bronzed, stippled effect. Severe feeding causes curling and drying of the leaves. Symptoms are often confused with drought stress.

Biology: Spider mites overwinter as female adults in crop residue or sheltered areas. In early spring, they lay eggs on grassy weeds, in fence rows and in wheat fields. Spider mites often move into vegetable crops as the wheat fields and other grasses begin to dry down. Under hot, dry conditions, spider mites may complete a generation in as little as 6 days, resulting in numerous generations each year.

Scouting and Thresholds: No thresholds have been established. Look for "bronzed" leaves and for signs of webbing, eggs or mites on the lower leaf surface. If spider mites are present, re-visit the field over a 3–5-day period to determine if the mite population is increasing.

Management Notes: Heavy rain or overhead irrigation often reduces mite populations to tolerable levels. Vegetables are most susceptible to mite damage in the period leading up to harvest as the crop is sizing.

Whiteflies

Bemisia tabaci (species complex) (sweetpotato whitefly), *Trialeurodes vaporariorum* (greenhouse whitefly)

Crops Affected: Greenhouse vegetables and transplants or slips, herbs, field lettuce, sweetpotato, many other vegetable and non-vegetable crops.

Identification: Adult whiteflies are small, white, winged insects about 1.5–2 mm (~1⁄16 in.) long. They lay microscopic eggs on the underside of the youngest leaves. Nymphs are flattened and oval in shape, with (greenhouse whitefly) or without (sweetpotato whitefly or *Bemesia* spp.) waxy filaments around their perimeter. There are three nymphal instars, only the first of which (crawler stage) is mobile. Once settled, crawlers moult and develop a hard, protective scale under which they eventually pupate. The major diagnostic differences between greenhouse whitefly (GWF) and sweetpotato whitefly (SPW) appear in the pupal stages. The GWF pupa is white or cream-coloured, is raised off the leaf surface and is surrounded by a fringe of hairs, while SPW pupae are more yellow in colour, sit flat on the leaf and do not have a fringe. These features are best seen with a microscope, although with practice they can be seen through a 10x hand lens.

Damage: Piercing/sucking mouthparts allow whiteflies to remove sap from the plant, reducing plant vigour. Whiteflies excrete large amounts of a sugary substance called honeydew, which promotes the growth of a black sooty mould fungus, reducing photosynthesis and growth. Whiteflies can also transmit plant viruses.

Biology: Whiteflies survive in colder climates, including Southern Ontario, only in protected areas including greenhouses. Contaminated vegetable transplants or other host plant material originating from whitefly-infested areas may serve as a route for introduction to the field.

Scouting and Thresholds: Nymphs and adults may be observed by examination of leaves. Sticky cards are typically used in greenhouse production to detect adults. There are no established thresholds.

Management Notes: Whiteflies are primarily a greenhouse pest in Ontario. Field populations result from the movement of whiteflies from nearby greenhouses or infested transplant material, but these rarely persist. Whitefly populations are not usually sufficiently damaging to make treatment necessary.

White Grubs/European Chafer

Amphimallon majale

Crops Affected: Beet (table), brassica crops, potato, sweetpotato, sugarbeet and sweet corn.

Identification: White grubs are the larvae of the June beetle, the European chafer and (in some areas) the Japanese beetle. The grubs have six well-developed legs with a C-shaped white body and darker head. The tail end of the grub often appears dark due to soil it ingests during feeding. Identification of species may be important from a management standpoint and is possible by examination of the raster pattern of grubs:

- European chafer: Y-shaped raster
- June beetle: oval-shaped raster, with two parallel rows
- Japanese beetle: V-shaped raster

Damage: Crop damage depends on the species and on which year of the life cycle the majority of grubs are in. Severe feeding damage early in the season may cause the plant to dwarf, become wilted and die. Feeding on root crops in the fall renders them unmarketable. Feeding also opens the root up to disease infection.

Biology: Adults feed above-ground on foliage, blossoms and fruit, while larvae feed underground on plant roots. June beetle adults can feed on tree species and ornamentals, but not crops. European chafer adults do little if no feeding. Japanese beetle adults are highly polyphagous and will feed on the foliage of many crops and ornamentals.

European chafers (an annual grub) overwinter as early instar larvae. Peak feeding occurs in April to mid-May. Larvae pupate in the late spring, after which time they are not usually a problem in vegetable crops.

Japanese beetles (an annual grub) overwinter as third-instar larvae, which resume feeding in late spring to complete their development. Although the roots of grasses are preferred, larvae will also feed on the roots of vegetables and other crops. Adults emerge in late June and are active through August, feeding on a wide variety of crop and ornamental foliage. Vegetable crops are not preferred for oviposition, so damage usually occurs because crops are planted at sites that previously hosted grass varieties, and larvae are still present in the soil.

June beetle larvae are present in the soil for 3 years. Feeding is most noticeable in the late spring. However, damage may occur throughout the growing season on root crops.

Scouting and Thresholds: None have been established. Look for grubs in the crop row, approximately 5 cm (2 in.) below the soil surface. Older larvae of the June beetle may feed on deeper roots, down to 25 cm (10 in.).

Management Notes: To avoid injury by white grubs, wait 2 or more years before planting vegetables on land that had been planted with grass sod. Where white grubs have been identified prior to planting (or in replant situations), consider planting to a non-host crop, such as beans. Where European chafer or Japanese beetle larvae are present, delaying planting to late spring may eliminate the problem.

Wireworm

Limonius spp.

Crops Affected: Beet (table), carrot, onion, sweet corn, potato, vine crops, eggplant, tomato, pepper, sweetpotato and sugarbeet.

Identification: Wireworms are the larvae of click beetles. They are copper-coloured, cylindrical and hard-bodied, with three pairs of tiny legs. Wireworms are commonly confused with multi-legged millipedes and symphylans. They can reach 2.5 cm (1 in.) in length.

Damage: Wireworms can be seen burrowing into the ungerminated seeds, as well as underground roots and stems of plants. Infested plants do not develop well, and seedlings lack vigour or fail to emerge. Damage is often scattered randomly across the field. In the fall, wireworm feeding may render sweet potatoes, carrots and potatoes unmarketable.

Wireworms are present all season. Young plants are most susceptible, therefore early-season control is critical. They are likely to be present in fields that have recently had sod crops, or following years of high grassy-weed pressure.

Biology: Wireworms take up to 5 years to complete development from egg to adult. Most of this time is spent as a larva in the soil. Adult beetles are active in the spring, laying eggs in the soil or near grass roots. Eggs hatch 2–4 weeks later, and larvae move in search of food. Movement within the soil profile is affected by temperature, moisture and the presence of a food source/carbon dioxide. After 3–5 years, wireworm larvae pupate near the soil surface. New adult wireworms overwinter in the soil and emerge the following spring to lay eggs and continue the cycle.

Scouting and Thresholds: Wireworms may be monitored in the fall (or in the early spring for later-planted crops) prior to planting using bait stations. Bury whole carrots, 7.5 cm (3 in.) deep, at 10 marked stations across the field. Check the stations in 2–3 days. An average count of 0.5–1 wireworm per station indicates a potential problem. Make your planting and seed treatment decisions accordingly. Areas of the field where seedlings have not emerged should be checked for damage to the seed.

Management Notes: Planting into well-prepared, warm soils and avoiding unnecessarily deep planting depths will help encourage early-season growth, reducing the incidence of this pest. There are several species of wireworms present in Ontario, with varying degrees of susceptibility to registered insecticide seed treatments. Research is under way to reduce wireworm populations through the use of crop rotations to discourage egg-laying, as well as bait traps to pull wireworms out of crop rows and into areas where they can be controlled by insecticides or other amendments.

Chapter 6

General Pathology

This chapter is an overview of common diseases across multiple vegetable crops. For diseases specific to each crop, see Chapter 7.

Introduction

Plant diseases occur when a pathogen interacts with a susceptible host and the environment is conducive to its development. This is referred to as the disease triangle (Figure 6–1). If one or more of these conditions is not met, disease will not occur. For each disease, it is important to know as much as possible about each of these three factors as they can help with developing a management strategy.

Plant pathogens include:

- fungi
- oomycetes
- bacteria
- nematodes
- phytoplasmas
- slime moulds
- parasitic plants
- viruses and viroids

When identifying plant diseases, it is important to be familiar with the symptoms and signs of each disease. Symptoms are the plants' expression of an infection, while signs are the actual living organism or byproduct of the living organism.

Typical disease symptoms include:

- leaf spots or lesions
- wilting
- yellowing or chlorosis
- galls
- cankers
- blighting or necrosis
- rotting

Other pests, such as insects, and abiotic stressors, such as nutrient deficiencies, may also cause similar symptoms.

Signs can be:

- spores
- fruiting bodies
- mycelium
- biproduct of a pathogen (e.g., bacterial ooze)

Signs are often, but not always, viable on diseased plant tissue. A hand lens or small microscope is handy when identifying signs.

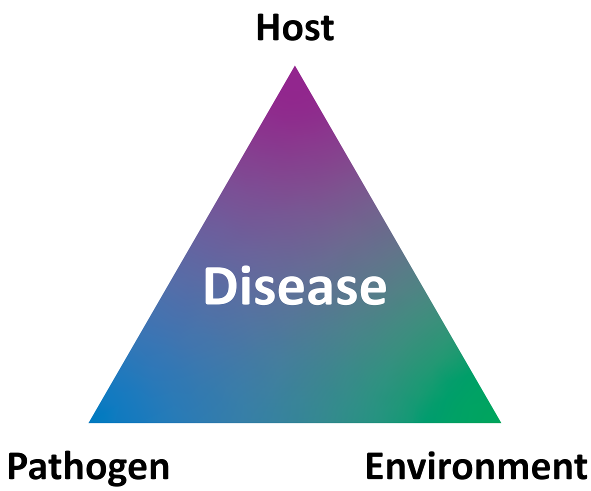


Figure 6–1. The three factors needed to cause disease are known as the disease triangle.

Properly diagnosing a disease is a crucial step in disease management. See *Appendix F. Diagnostic Services*.

There are three main ways to manage diseases:

- **Exclusion** (or avoidance) is the first method of defence and can include quarantines and inspections, use of pathogen-free seed or transplants, seed treatments (including hot water treatments) and use of virgin soil.
- **Eradication** refers to the removal of infected material, including ways to reduce the inoculum load. Methods can include crop rotation, sanitization, creating unfavourable environmental conditions, fumigation, use of resistant cultivars, soil solarization, etc.
- **Protection** refers to direct treatment of the pathogen on the plant. This can include biological controls, inducing plant defences and pesticides (including conventional and biopesticides).

Many plant pathogens are specific to each crop, but there can be commonalities in their symptoms and effect on a plant. Other plant pathogens, such as white mould, infest a wide range of crops.

Bacterial Diseases

including *Xanthomonas* spp., *Pseudomonas* spp., *Pectobacterium* spp., *Clavibacter* spp.

Identification: Bacterial pathogens can infect foliage, stems and fruit throughout the season. Some bacteria are systemic (e.g., *Clavibacter michiganensis* subsp. *michiganensis*) and move though the vascular system. Most bacterial infections start as water-soaked spots and can start on the edges of leaves, through the hydathodes. Spots commonly develop a chlorotic (yellow) halo with a necrotic (brown) centre. Under ideal conditions, ooze formation can occur.

Biology: There are over 100 known species pathogenic to plants and most are host specific (a bacteria that infects tomatoes will not infect brassica crops and vice versa). Many are seed-borne, but some can survive for short periods of time in crop residue. To infect, bacteria require a natural opening or a wound, such as hydathodes, stomata, flower cups, microtears, chemical or mechanical injury, etc. They are spread primarily though mechanical or human transmission, but some insects, such as the cucumber bettle, can vector bacterial pathogens. Bacteria multiply rapidly as temperatures increase; warm and wet conditions favour bacterial growth and spread. Some bacteria may survive epiphytically on plant tissues without causing symptoms.

Management: Exclusion and eradication are very important for bacterial diseases, as more protection methods offer little control against bacteria. Use disease-free, certified seed. Treating seeds with hot water can be very effective on seed-borne pathogens but must be used with caution and before a chemical seed treatment is applied. Inspect transplants for symptoms before planting. Follow a 3-year rotation away from host crops. Bacteria are easily spread by splashing rain or irrigation and by machinery, so avoid working in the field when the foliage is wet.

Damping-Off

Pythium spp., *Phytophthora* spp., *Fusarium* spp., *Rhizoctonia* spp.

Identification: Seeds infected prior to emergence rot and typically fail to produce a seedling. If the seedlings do emerge, they are usually weak and lack vigour. Post-emergence infections cause the seedlings to rot at soil line. This usually occurs within 2–4 weeks of emergence (or transplanting). Affected plants tend to curl downward or melt into the soil. Other symptoms include mouldy seeds and lesions or cankers on the roots, hypocotyl or lower stem (Figure 6–2).

Biology: *Pythium* and *Phytophthora* species are oomycetes known as water moulds. They are particularly destructive in wet soil conditions. Infections commonly occur on heavier soil types or in poorly drained fields. These pathogens can also cause disease later in the season, see Chapter 7.

Figure 6–2. Radish seedlings that have emerged are infected with soil-borne pathogens and damping-off.

Fusarium species are found in most agricultural soils, and many are not pathogenic to crops. The overwintering spores remain in the soil for long periods of time. Infections occur under a wide range of soil and temperature conditions, depending on the species and the crop. Many *Fusarium* species also cause foliar or fruit infections later in the season.

Rhizoctonia solani persists in soil as a hard, resting structure (sclerotia) and grows as microscopic threads (hyphae) through the soil. This damping-off pathogen tends to prefer slightly warmer and dryer soil than *Pythium* and *Phytophthora* species. Often, *R. solani* will girdle the stems of susceptible crops slightly above and below the soil line, referred to as wire stem. See *Diseases Caused by Rhizoctonia solani*, in this chapter.

Management: Ensure vegetable transplants are grown in sterilized flats and in sterile soil-less mixture in the greenhouse. Do not overwater seedlings and transplants. Before planting into the field, ensure all transplants are healthy, disease-free and vigorous.

When direct-seeding vegetables, plant seeds treated with a registered fungicide seed treatment that controls damping-off pathogens. Do not seed too deep. Plant only when soil and weather conditions are favourable for quick germination, emergence and vigorous crop development.

Scout fields early in the spring, soon after planting, to assess the plant stand and its establishment. Look for areas of patchy or poor emergence. Dig up non-emerged seedlings or plants and look for symptoms of rotting or stem girdling.

Diseases Caused by *Rhizoctonia solani*

A wide variety of vegetable crops is affected by the fungal pathogen *R. solani*. It is known by a variety of common names and causes a wide range of symptoms. See Table 6–1.

Biology: This species of *Rhizoctonia* is a ubiquitous soil-borne fungus. It can survive in the soil for many years. Infections can occur throughout the season under warm and wet or very humid conditions.

In potatoes, *Rhizoctonia solani* also survives on the surface of seed potatoes. This can lead to increased black scurf on daughter tubers and add more inoculum (sclerotia) to the soil.

In addition to the diseases listed above, *Rhizoctonia solani* is one of the fungal species that cause damping-off. See *Damping-Off*, in this chapter.

Table 6–1. Vegetable Crops Affected by *Rhizoctonia solani*

Crop	Disease Name	Symptoms
Beets, table	pocket rot	Infected roots show large openings where roots have decayed. The rotted tissue is dry and black.
Carrots	crown rot	Crown rot appears in patches across the field. Plants become stunted and yellow, followed by wilting and death of the foliage. Large, grey-brown lesions form near the top of the carrot root.
Cucumbers	belly rot	Sunken, reddish-brown, irregular-shaped lesions develop on the fruit where it rests on the soil surface.
Lettuce	rhizoctonia bottom rot	Rust-coloured sunken lesions appear on the midrib of lower lettuce leaves. Infected leaves decay under favourable environmental conditions.
Potatoes	rhizoctonia stem canker	Brown lesions pinch off the sprouts before plant emergence, resulting in severe crop damage. Secondary sprouts develop from the pinched-off sprouts. They are less vigorous and emerge much later, causing irregular, uneven stands. Cankers on young stems cause the emergence of weak, spindly-looking plants. Mid- and late-season infections result in long, deep, sunken cankers on the stems. A white-to-grey mat of fungal mycelium may develop at the base of the stems. Infected leaves roll upwards and may turn reddish. Aerial tubers form on the leaf axils and/or at ground level.
	black scurf	Sclerotia form on the skin of daughter tubers. Sclerotia are hard, black structures of irregular shapes and variable sizes that are tightly attached to the tuber skin, giving it an unsightly appearance.
Sugarbeets	rhizoctonia root and crown rot	Symptoms include wilting at the base of the plant and the eventual death of the foliage. Root infections occur on the crown, sides or tips. In some cases, tips infections begin before foliar symptoms. Roots may develop large cracks. Infection often spreads down the row.

Management: Avoid planting susceptible crops in previously infected areas. Rotate for several years with non-host crops such as corn or small grains and practise strict sanitation procedures to avoid spreading infected soil between fields.

Growing lettuce on raised beds will improve air circulation near the base of the plant, where infection is likely to begin. Avoid throwing soil onto beet crowns during cultivation. *Rhizoctonia*-resistant sugarbeet cultivars are available. Do not dump sugarbeet tare dirt or potato culls onto fields scheduled for sugarbeets or potatoes the following year.

Plant only certified, disease-free, seed. In potatoes, harvest as soon as the tuber skin is set. Delaying harvest in the fall increases the amount of sclerotia on the tubers.

Nematodes

Nematodes are abundant in most soils. Plant parasitic nematodes possess a stylet to feed on plants. Several nematode species affect a wide range of vegetable crops in Ontario. The symptoms and thresholds vary, depending on both the causal nematode and the host crop. Root vegetables, in general, have lower thresholds for nematode damage due to their marketable crop being below ground.

In some cases, several types of nematodes may be present and causing damage in the crop. The presence of nematodes may also exacerbate the impact of certain soil-borne fungal diseases, such as verticillium wilt.

Before deciding upon a management strategy for nematodes, complete a nematode soil test to determine the levels of nematodes present. In Ontario, nematode populations in soil and roots are usually at their highest in May to June and again in September to October. The fall months are a good time to soil sample for nematodes, as the populations are high and controls can be taken well in advance of planting the crop.

For sampling methods, see the OMAFRA Factsheet, *Sampling Soil and Roots for Plant Parasitic Nematodes*.

Cyst Nematodes
Heterodera spp.

Hosts: Many vegetable crops. Particularly susceptible crops include carrot, sugarbeet, table beet, brassica crops, legumes.

Identification: Oval or elongated patches of plants appear stunted, yellow or lighter green, unthrifty with delayed maturity or flowering. Small white-to-cream or yellow-coloured immature lemon-shaped cysts are attached to roots. Cysts turn brown at maturity.

Biology: Cysts will hold eggs that hatch in the spring with the first juvenile stage. At the second stage, the juveniles will move towards host roots. They enter the roots and set up feeding sites where they remain until they become an adult male or female. Females become lemon-shaped cysts, depositing over 100 eggs internally.

Management: Threshold for susceptible crops is 2,000 nematodes or eggs/kg soil, or over 250 cysts/kg soil.

Cyst nematodes can survive in the soil for over 10 years, so it is important to avoid cyst nematodes for as long as possible. Avoid contaminating soil that is not currently infected by removing soil from equipment if used in an infected field. Crop rotation with non-hosts can reduce population numbers.

Northern Root Knot Nematode
Meloidogyne hapla

Hosts: Most vegetable crops. Particularly susceptible crops include carrot, parsnip, potato, other tuberous crops and many weeds.

Identification: Plants may appear stunted, yellow or lighter green and unthrifty in patches. White (orange on carrot roots), irregularly shaped galls of various sizes form along the roots. An abundance of secondary and tertiary roots form slightly below the galls, giving the root a ‘hairy” appearance.

Biology: Nematodes overwinter in the soil, in roots and in crop debris. When soil conditions become favourable, young nematodes migrate to the roots of host plants. Most nematodes live in the top 60 cm, but they may travel over a metre in search of host roots. Once roots are found, nematodes begin feeding and disrupt the water and nutrient-conducting vascular tissue, resulting in reduced plant growth and yield. Root knot nematodes stimulate root cells to enlarge and become galls.

Management: Thresholds are as follows:

Carrot:	0/kg soil
Other root vegetables, e.g., parsnip, potato, onion and other tuberous crops:	500/kg soil

Where possible, purchase plants grown according to the guidelines of an accredited plant propagation program. Inspect transplants for root swellings and tiny knots, and never plant seedlings that appear to have symptoms of root knot damage on the roots.

To reduce nematode numbers, use biofumigants, fumigants or nematode-suppressing cover crops before planting. Long periods of fallow have proven to reduce population levels, but this is not always an economically viable solution.

Reduce soil populations by growing grasses, cereals or corn that are not hosts of root knot nematode.

Root Lesion Nematode
Pratylenchus penetrans

Hosts: Most vegetable crops

Identification: Plants severely attacked appear stunted with yellow leaves, declined in vigour and may be easily pulled from the soil. Root lesion nematodes cause narrow, scratch-like, reddish-brown to black lesions on roots. Severely affected roots appear to be severely rotted with brown, rotted lateral or secondary roots. Root lesion nematodes cause microscopic wounds in roots that allow for some soil-borne pathogens such as *Verticillium* spp. to infect, resulting in severe wilting of plants.

Biology: Root lesion nematodes overwinter in the soil. When soil conditions become favourable, young nematodes migrate to the roots of host plants. Most nematodes live in the top 60 cm (2 ft), but they may travel over a metre (3 ft) in search of host roots. Once roots are found, nematodes begin feeding and disrupt the water and nutrient-conducting vascular tissue, resulting in reduced plant growth and yield. Root lesion nematodes move in and out of plant roots, depending on soil conditions, while root knot nematodes remain in the root.

Management: The threshold for root lesion nematodes is 1,000/kg soil prior to planting or 50/g dry root for most vegetables, including fresh market tomato and older tomato cultivars.

Nematodes must be controlled before planting. Always purchase plants grown according to the guidelines of an accredited plant propagation program. Inspect any transplants for root swellings and tiny knots and never plant seedlings that appear to have damage on the roots.

Use biofumigants or nematode-suppressing cover crops before planting to reduce nematode numbers. Long periods of fallow have proven to reduce population levels, but this is not always an economically viable solution.

Viruses

Identification: Viral diseases show a range of different symptoms, including leaf distortion, yellow-to-green mottling, stunted growth, shortened internodes or petioles and malformed fruit. Field identification of viruses is often difficult as they are easily confused with other conditions such as herbicide injury, air pollution, insect feeding and other foliar diseases. Lab diagnosis is the main way to confirm a disease caused by a virus. Some in-field tests (e.g., immunoassays) are available for diagnosing viruses, but caution should be taken in interpreting results, as many tests are cross reactant to viruses in the same group.

Biology: Depending on the crop, viruses may be spread by aphids and/or other leaf-feeding insects. Virus particles are usually acquired from infected plants. Insects can carry and transmit a virus for their entire life (persistent transmission) or for only a short time (non-persistent transmission). Management options and control tactics vary considerably between persistent and non-persistent viruses.

In persistent transmission, an insect can become infected after feeding on an infected plant for an extended period (at least several minutes to 1 hour). After an incubation period (sometimes several days or weeks), the insect can spread the virus for the rest of its life. These viruses are often found where the insect pest has formed large colonies on a plant. A good insect management program including pesticide applications can help reduce the spread of persistent viruses.

Migratory aphids, including the soybean aphid, are common vectors of many non-persistent viruses. These aphids often feed for only short periods of time on vegetable crops before moving to new food sources. They do not necessarily form colonies within a specific field.

When an aphid lands on an infected plant, it can acquire a non-persistent virus on its stylet (mouthparts) within less than 1 minute of feeding. If the aphid then moves on to sample a new plant, the virus is spread from the infected plant to a healthy plant. As an aphid feeds, it clears the virus from its mouthparts and is no longer able to transmit the disease to additional plants. Once the problem is identified, the aphids have already moved on, making insecticide applications inefficient for the control of non-persistent virus diseases.

Non-insect vectored viruses can be spread through sap transmission and can move from plant to plant on humans or equipment. Crops that are frequently touched can result in injury and this can lead to transmission from infected plants to healthy plants. For example, in garlic, removal of the scape is beneficial, and careful removal is required to not contact the vascular tissue of each plant. Snapping the scapes off by hand is preferred to mechanical or tool removal, as the risk of coming into contact with the sap is much lower, reducing the risk of viral transmission.

For more information on the different types of viruses, hosts and transmission, see each crop section in Chapter 7.

Management: Viruses are very challenging to manage, once in a crop. Plant virus-free, certified seed. Ensure transplants are virus-free before moving them to the field. Control weeds within and around fields as many are known to harbour viruses. Scout fields and rogue symptomatic plants regularly. Plant resistant cultivars when available.

White Mould

Sclerotinia sclerotiorum, *S. minor*

Hosts: Wide range of hosts: vegetable crops including bean, brassica crops, carrot, celery, cucurbit crops, leafy greens, herbs, pea, sweetpotato, potato and fruiting vegetables. Non-vegetable crops include soybean, other legumes, sunflower, canola and tobacco.

Identification: In bean and pea, dark-green, water-soaked lesions develop on the pods, branches or stems. The lesions enlarge rapidly, encompassing the branches and stems, causing leaves to turn yellow and die. As the crop nears harvest, white, cottony fungal growths develop on pods and stems. Hard, black pea-sized sclerotia are usually embedded in the fungal growth.

In brassica crops, white rot appears as water-soaked spots on the lower leaves or on the head. The infected tissue often turns grey, giving rise to a fluffy white mould in wet weather. Hard, black sclerotia eventually form on the white fungal growth.

In potato, the first symptoms are often wilting stems. Water-soaked lesions and white, cottony mycelium can be seen on the stem.

White mould is less common in cucurbit crops, however white, cottony mycelium may form at the stem/fruit junction of certain pumpkin and gourd cultivars.

Biology: White mould overwinters in the soil as small (pea-sized), black sclerotia. The fruiting structure (apothecia) emerge in the spring from the sclerotia and release ascospores that are spread via the wind. When crops are in flower, they are the most susceptible to infection from these ascospores. Infected petals fall and land in the foliage, leading to lesions on stems and leaves. Temperatures ranging from 20°C–25°C (68°F–77°F) and continuous leaf wetness (high humidity and/or heavy dews) favour white mould development. Crops can also be infected where they sit on the soil, as the sclerotia can produce hyphae that can directly infect plants. Overwintering sclerotia may survive for several years in the soil (Figure 6–3).

Management: Where possible, practice a 3–4-year crop rotation away from susceptible crops to reduce inoculum load in the soil. Avoid applying high rates of nitrogen fertilizer. Excess nitrogen promotes an exceptionally dense crop canopy, resulting in restricted air movement and more favourable disease development conditions. Use irrigation strategies to reduce the duration of leaf wetness. Some potato cultivars have reduced susceptibility to white mould.

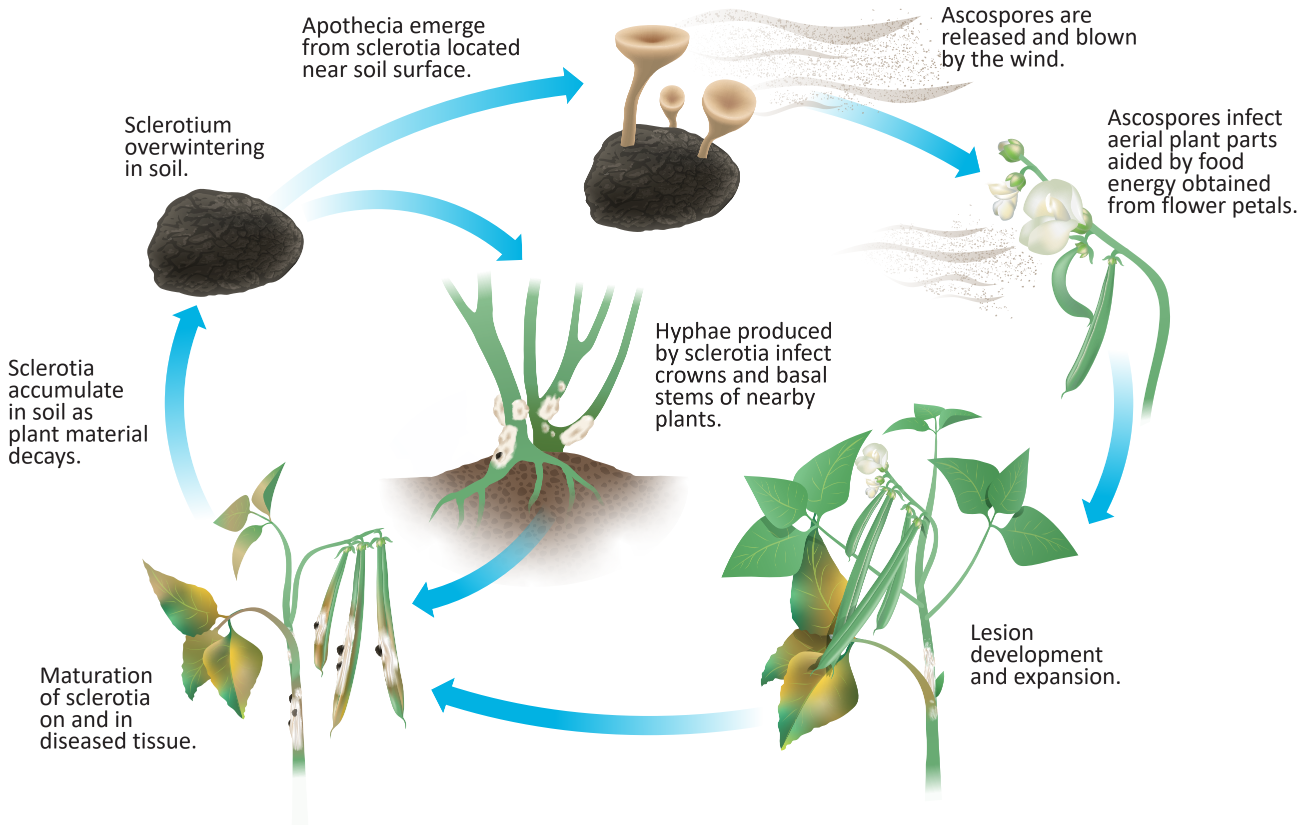


Figure 6–3. Disease cycle of white mould caused by *Sclerotinia* species. Adapted with permission, from Heffer Link, V., and K. B. Johnson. 2007. *White Mold.* The Plant Health Instructor. DOI: 10.1094/PHI-I-2007-0809-01. Updated 2012.

Chapter 7

Crops

Asparagus

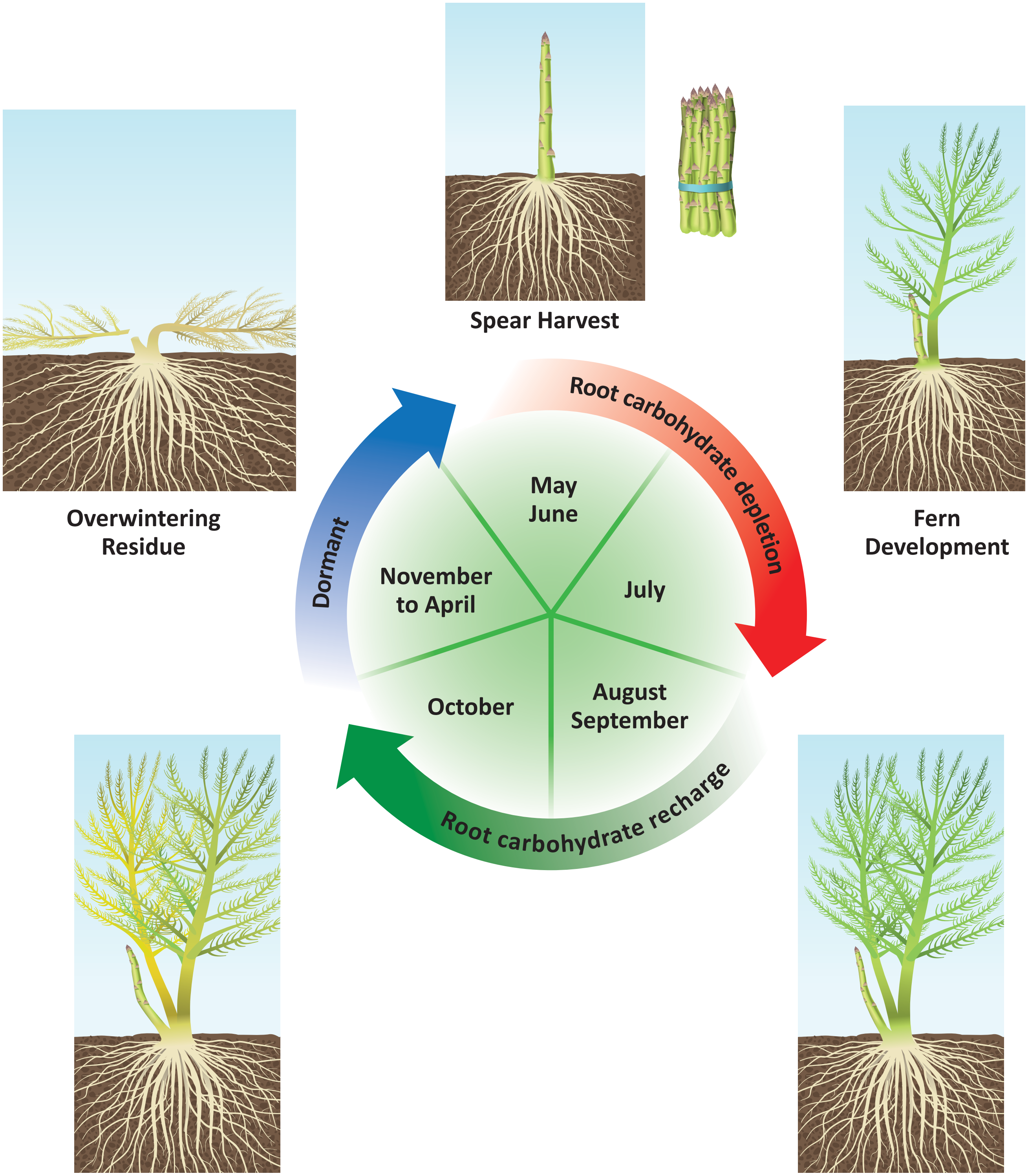


Figure 7–1. Asparagus growth cycle.

Crown Production
Plant crown production fields in mid-May for harvest the following spring.

Year 1
Field establishment.

Year 2
Promote fern health to ensure maximum crown root development.

Year 3
First harvest. Harvest for 2 weeks. Extend the harvest period by an additional 2 weeks each following year, to a maximum of 8 weeks.

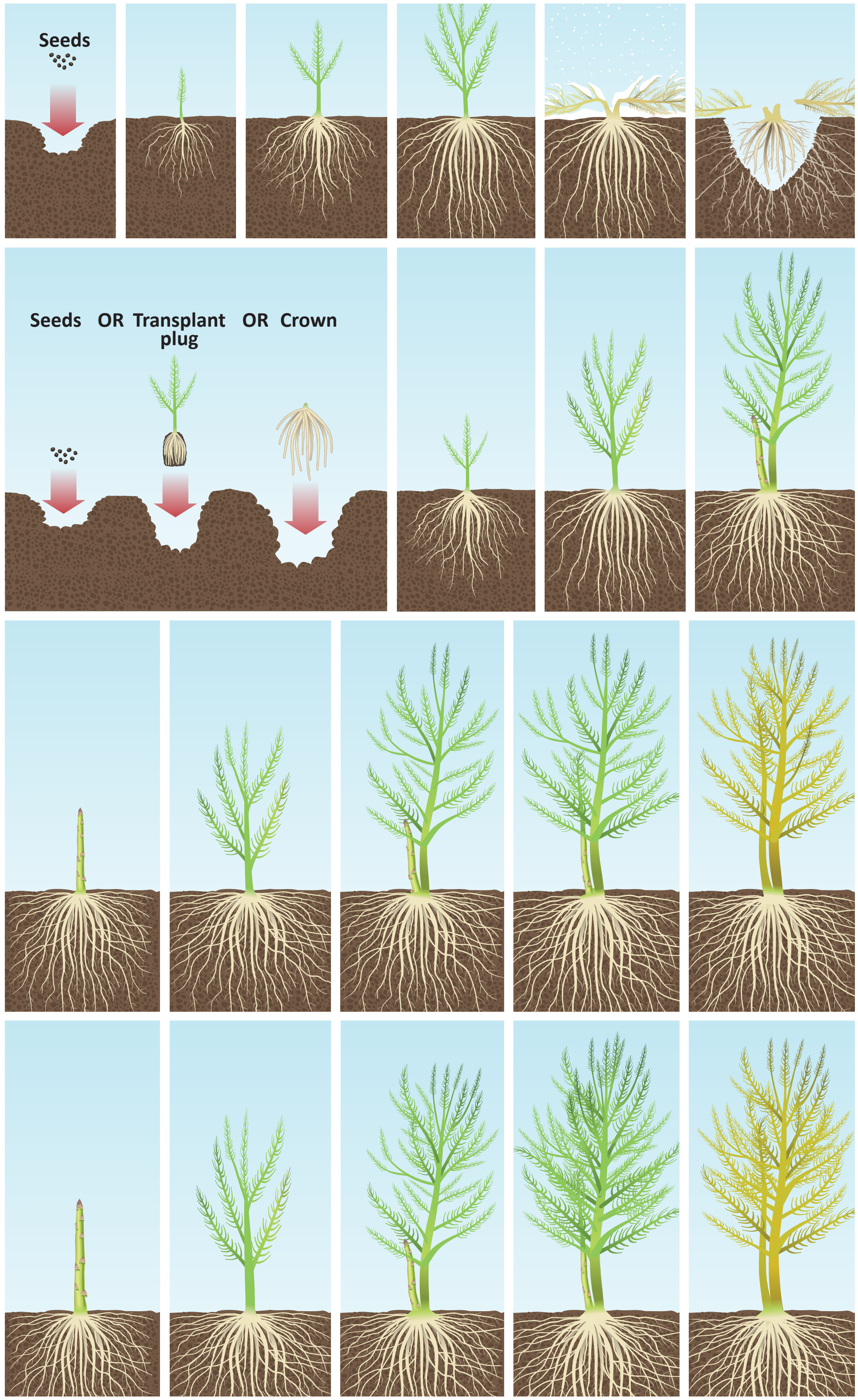
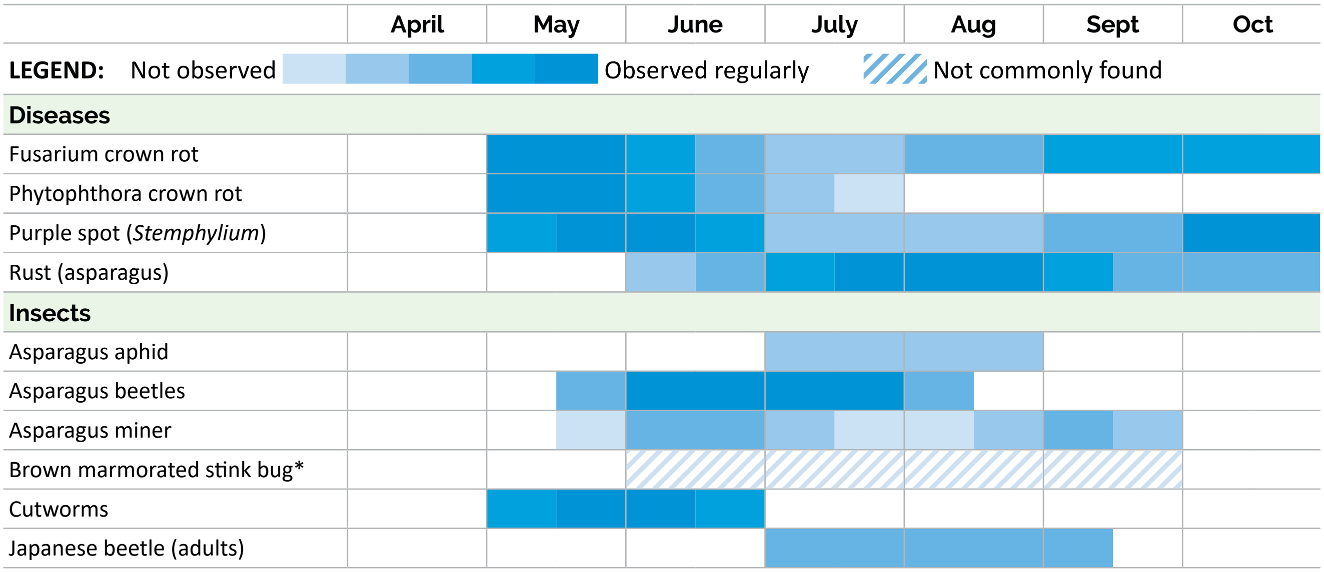


Figure 7–2. Asparagus crop establishment.



* Not commonly found as a pest in Ontario, however it may be problematic in other jurisdictions.

Figure 7–3. Asparagus pest activity calendar. The actual period of activity for any given pest will vary significantly from year to year, depending on environmental factors.

Production Requirements

Soil types:	sandy or sandy loam soils
Soil pH:	6.0–6.8
Suitable rotational crops:	green manure, alfalfa, soybeans
Do not rotate with:	corn or asparagus
Minimum soil temperature:	10°C (50°F)
Optimum air temperature:	18°C–25°C (64°F–77°F)
Earliest planting date:	early-to-late April

Asparagus Crop Growth

Asparagus is a deep-rooted perennial plant that is comprised of shoots (the harvested portion), fern, crown, storage roots and feeder roots. The growth cycle of asparagus is important when considering crop development, nutrient availability and pest management (Figure 7–1).

The crown is a massive bundle of rhizomes, fleshy storage roots and fine feeder roots. The rhizomes produce buds that will become spears the following spring. Buds are usually set in late summer. The storage roots provide the developing shoots with the energy (carbohydrates) they need to emerge in the early spring. The roots system on a mature asparagus plant can weigh as much as 20 kg (45 lb). Stress-free growing conditions during the establishment years help to ensure a large, vigorous crown.

In addition to the storage roots, asparagus plants produce many fine feeder roots. These feeder roots penetrate deep into the ground, making asparagus more resilient to drought stress than many other vegetable crops. They also allow the plant to effectively scavenge nutrients. Feeder roots can be very sensitive to disturbances such as tillage.

When left to grow, each spear (shoot) will produce a central stalk (fern) on which fronds of fine needle-like leaves, called cladophylls, develop. Each crown will produce multiple stalks from which the plant will produce the carbohydrates needed to fuel the crowns for future harvests. When the ferns turn yellow in the fall, the carbohydrates are moved into the crown. Over-harvesting, poor plant health or premature defoliation due to foliar disease or insects, can reduce the movement of carbohydrates into the crown. After the top growth has died back and the residue decomposes, any extra nutrients will be returned to the soil and become available for the plant to recycle.

The yield and duration of asparagus harvest will depend on the age and health of the plantation. It takes 2–3 years after seeding to harvest the first crop of spears (Figure 7–2).

In the first year of harvest, spears may be cut for 2 weeks (approximately 8 days of picking). In subsequent years, the duration of harvest can be increased by 2 weeks per year, up to a maximum of 8 weeks (approximately 20–24 days of picking). The actual duration of harvest will depend on the health of the crowns and the weather. Stop harvesting a field if there are any sudden drops in the number of spears cut per day or if the spear diameter decreases.

All-Male Hybrids

All-male hybrids are commonly used for commercial asparagus fields. These cultivars are more vigorous than the older, open-pollinated cultivars. They do not use valuable photosynthetic reserves to produce berries and seed. The lack of berries also eliminates volunteer asparagus seedlings between the rows, which also reduce the productivity of the field and slow down the harvesting process. Seed and crown supplies are often limited. Be prepared to order them at least 1 year in advance of planting.

Site Selection and Preparation

A well-managed commercial field will produce for 10–15 years or more. Perennial crops require substantial planning and site selection. Asparagus requires very well-drained soils. Excess moisture, even at the subsoil level, will make the roots prone to root diseases, which will reduce the productive life of the planting. Address soil fertility issues, such as pH and phosphorus levels, prior to planting. For pH, it may take 6 months to a year for the levels to adjust.

Seeding and Spacing

One-year-old crowns are a common way to establish commercial asparagus fields. However, the use of plug transplants or direct seeding is also becoming more common.

Plan to grow extra crowns or transplant plugs — 1 kg of good seed/ha (1 lb/acre) should provide enough crowns or transplants to allow for selection of healthy plants. See Table 7–1.

For crown production, soak the seed in 32°C (90°F) water for 3–4 days. Dry and sow immediately into fertile, well-prepared soil. See Table 7–2, for crown production planting densities. Plant seed in mid-May or once the ground is prepared and soil temperatures are above 15°C (59°F).

An advantage of using plug transplants is that it eliminates the year required to grow the crowns. It can also help prevent the spread of fusarium and other soil diseases between production fields.

See Table 7–2, for row spacing, in-row spacing and desired plant populations.

Place plugs or crowns into a 20–25 cm (8–10 in.) trench with any required phosphorous fertilizer. Fill in the trench with 7.5 cm (3 in.) of soil. Six weeks later, fill in an additional 7.5 cm (3 in.) of soil. Fill in the remainder of the trench and level the field once the plants go dormant in the fall. Irrigation and careful crop management, including weed control, are essential for the successful establishment of transplants in the field.

Table 7–1. Asparagus Transplant Requirements

Seed Required for 20,000 Transplants	Seeding Depth	Germination Temperature	Days to Germination	Optimum Growing Temperature		Time (weeks)
				Day	Night	
453 g (1 lb)	1.25 cm (0.5 in.)	24°C–29°C (75°F–84°F)	10–12 days	21°C–24°C (70°F–75°F)	16°C–18°C (61°F–64°F)	10–12

Table 7–2. Asparagus Crop Spacing

Crop	Row Spacing	In-Row Spacing	Depth	Seedling Rate
Nursery fields (for crown production)	45–60 cm (18–24 in.)	8–10 cm (3–4 in.)	2.5–4 cm (1–1.5 in.)	approximately 11 kg/ha (10 lb/acre)
Production fields (from crowns or transplants)	1.2–1.5 m (4–5 ft)	20–30 cm (8–12 in.)	15 cm (6 in.)	36,000–43,000 plants/ha (15,000–18,000 plants/acre)

Tillage and Cover Crops

Asparagus is commonly grown on coarse sandy or sandy loam soils. These soils are particularly vulnerable to soil erosion in the winter or early spring and sandblasting during harvest. Sandblasting results in poor quality spears at harvest. It also increases the susceptibility to diseases such as purple spot (stemphylium). Research has shown that even light tillage can cause significant damage to the fine feeder roots, impacting both the size and overall health of the crown. For these reasons, consider using a variety of soil management practices including planting cover crops, establishing windbreaks and using no-till or reduced tillage systems.

Fertility

Green manure crops planted in the year prior to asparagus establishment require 30–40 kg N/ha (27–36 lb N/acre) before planting or at seeding.

The low amounts of nutrients removed in the harvested portion of the asparagus crop, combined with the crop's ability to recycle nutrients from the previous year's fern, mean that asparagus does not require large amounts of supplemental fertilizer.

Adjust phosphorus (P) levels according to soil test results prior to planting.

Macronutrients

Nitrogen

See Table 7–3. For new plantings, broadcast all the required nitrogen and potash prior to planting. In crown nurseries, an additional 50 kg N/ha (45 lb N/acre) may be applied as a side-dress application in August or early September if rainfall was excessive in the summer.

Table 7–3. Asparagus Nitrogen Requirements

Timing	Actual N
Nursery	75 kg/ha (67 lb/acre)
New plantings	110 kg/ha (98 lb/acre)
Established plantings	
Pre-harvest	55 kg/ha (49 lb/acre)
Post-harvest	55 kg/ha (49 lb/acre)
Total	**110 kg/ha (98 lb/acre)**

Table 7–4. Asparagus Phosphorus Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Sodium Bicarbonate Phosphorus Soil Test (ppm)													
	0–3	4–5	6–7	8–9	10–12	13–15	16–20	21–25	26–30	31–40	41–50	51–60	61–80	81+
Established plantings														
Phosphate (P_2O_5) required kg/ha (lb/acre)	110 (98) (HR)	100 (89) (HR)	90 (80) (HR)	70 (62) (HR)	50 (45) (HR)	20 (18) (MR)	20 (18) (MR)	20 (18) (LR)	20 (18) (LR)	0 (RR)	0 (RR)	0 (RR)	0 (NR)	0 (NR)
Nurseries and new plantings														
Phosphate (P_2O_5) required kg/ha (lb/acre)	270 (241) (HR)	260 (232) (HR)	250 (223) (HR)	240 (214) (HR)	230 (205) (HR)	220 (196) (HR)	200 (178) (HR)	170 (152) (HR)	140 (125) (MR)	110 (98) (MR)	80 (71) (MR)	50 (45) (LR)	0 (RR)	0 (RR)

Table 7–5. Asparagus Potassium Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Ammonium Acetate Potassium Soil Test (ppm)											
	0–15	16–30	31–45	46–60	61–80	81–100	101–120	121–150	151–180	181–210	211–250	251+
Potash (K_2O) required kg/ha (lb/acre)	420 (375) (HR)	400 (357) (HR)	360 (321) (HR)	320 (286) (HR)	280 (250) (HR)	250 (223) (HR)	220 (196) (HR)	190 (170) (MR)	160 (143) (MR)	130 (116) (MR)	80 (71) (MR)	0 LR)

Phosphorus and Potassium

Test the soil prior to planting to determine phosphorus and potassium requirements. See Table 7–4 and Table 7–5.

Band the phosphate below the crowns at planting. It is very difficult to adjust the phosphorus levels at the rooting depth once the crowns are established.

Irrigation

Asparagus is a deep-rooted vegetable crop. Once established, it does not have a strong response to irrigation. However, crown nurseries and crops during the establishment stage have shallow root systems and are more likely to respond to irrigation. If the available soil moisture level in the root zone reaches less than 60% during the establishment phase, over-head irrigation could help maintain crop yield and quality. For drip irrigation systems, consider irrigating when the available soil water drops below 85%.

For more information on irrigation scheduling, see the *Irrigation Management* BMP (order number BMP08E) and the OMAFRA factsheet, *Monitoring Soil Moisture to Improve Irrigation Decisions*.

Harvest

Crowns: Dig crowns in the early spring, before the buds begin to grow. Avoid damaging the roots and select only the healthy crowns with plump buds and strong roots. Discard undersized and damaged crowns — 20%–40% of crowns may be discarded.

Spears: For information on the expected harvest duration of asparagus based on the age of the planting see Figure 7–2. If weeds, insects, disease or adverse weather conditions reduce plant vigour, decrease the harvest duration accordingly the following season.

Cut the spears slightly below the soil surface once they reach 20–30 cm (8–12 in.) in length, depending on the market specifications. Stop harvesting when 75% of the spears are smaller than 1 cm (½ in.) in diameter, or if there is a sudden decline in the number of spears harvested per day. Harvest may occur 2–7 times per week, depending on the temperature. Most mature plantings can handle 20–24 picks per season.

Average yields: 4.7 tonnes/ha (4,200 lb/acre)

Individual field yields will vary significantly from the provincial average depending on the age of the planting and crop management.

Storage

Freshly harvested asparagus is very perishable and rapidly loses quality. Collect harvested spears from the field, protect them from the sun and move them to cold storage as soon as possible. Cooling methods suitable for use with asparagus include room cooling, forced air cooling and hydrocooling.

Storage temperature:	1°C–2°C (34°F–36°F)
Relative humidity:	95%–100%
Duration:	2–3 weeks
Chilling injury symptoms:	darkened, water-soaked tips leading to bacterial soft rot

Pest Management and Disorders

See Figure 7–3. *Asparagus pest activity calendar.*

Diseases

Fusarium Crown Rot

Fusarium oxysporum **f. sp.** ***asparagi*****,**
F. redolens**,** ***F. verticillioides*****,**
F. proliferatum

Identification: Crown rots cause yield decline and can significantly limit the productive lifespan of an asparagus planting. Infected fields have poor stands with many gaps within the rows.

Initial signs of infection include stunted, yellow shoots that often wilt, turn yellow and die. Reddish-brown lesions may be present at the base of the stem, just below the soil surface.

Infected crowns and roots have a reddish-brown discolouration of the vascular tissue (Figure 7–4). Severely infected crown tissue may become completely hollow, leading to the death of the plant.

Symptoms on the fern include stunting and bright yellow foliage on one or more stalks per crown. Infected crowns typically produce fewer stalks per crown than their uninfected neighbours. Fusarium crown rot is the main cause of asparagus yield declines over time.

Figure 7–4. Fusarium crown rot.

Biology: Fusarium are soil-borne fungi. New infections enter a field from infected seed, infected crowns or even wind-borne soil particles. Concentrations increase in soils over time as more plants become infected.

Scouting and Thresholds: Take note of any yellowing or undersized plants while scouting. If fusarium is suspected, dig up a section of the crown and look for vascular discolouration. Document the location of the damage and the percentage of plants affected.

Management Notes: Avoid planting asparagus into fields that have previously grown asparagus. Even though it takes at least 5–10 years after an asparagus crop for soil fusarium and the associated toxins to decrease to baseline levels, spores can live for up to 30 years. Do not plant asparagus where corn has been grown in the previous 4 years.

Vigorously growing asparagus plants are less susceptible to crown rots. Take care to avoid stressful growing conditions caused by over-harvesting, insect or foliar disease pressure, weed competition, soil compaction, drought stress and low fertility.

Tillage is very harmful to asparagus roots. Even shallow tillage damages the fine surface roots, providing potential infection sites for fusarium spores. Minimize tillage or use zero-tillage practices where possible.

Fusarium may also be spread from plant to plant by insects such as the asparagus miner.

Phytophthora Crown Rot
Phytophthora asparagi

Identification: Phytophthora infections cause soft, water-soaked lesions to develop on emerging shoots at, or slightly below, the soil line. These lesions elongate and turn light brown, causing the infected shoot to collapse and shrivel. The infected side of the spear ceases to grow, causing bending and hooking.

Phytophthora infections on the crown are very similar to fusarium crown rot symptoms. Infections reduce crown vigour and carbohydrate reserves, affecting the long-term productivity of infected fields.

Biology: Phytophthora is a soil-borne pathogen. It survives as oospores in infected fields for long periods of time. Infections are more common during periods of excessive rainfall or in poorly drained fields. Once infected, phytophthora will live in the crown indefinitely.

Laboratory studies indicate that the pathogen requires a wound (sandblasting, rain splashing) for infection. It grows in a range of temperatures from 10°C–25°C (50°F–77°F), with maximum growth occurring at 25°C (77°F).

Management Notes: Avoid planting asparagus in low areas, poorly drained soils or fields with a clay sub-soil. Phytophthora can spread from these areas infecting previously healthy plants. On all soil types, compaction may reduce drainage and increase the likelihood of infection.

Manage the crop to reduce stress and promote vigorous crown growth. Avoid depleting the crown's carbohydrate reserves through premature harvest or over-harvesting young plantings.

Figure 7–5. Stemphylium pseudothecia.

Purple Spot (Stemphylium)
Stemphylium vesicarium

Identification: Tan-to-brown, sunken, elliptical lesions with purple edges appear on infected spears, stems and fronds. As the disease spreads, the lesions expand and merge together, killing the affected tissue and eventually causing widespread defoliation. Small black spores (pseudothecia) may be visible at the base of infected plants, particularly on the previous season's crop residue (Figure 7–5).

During harvest, infections reduce the marketability of the crop. Severe summer infections result in the premature defoliation of the fern, which can reduce the following year's yields by up to 52%. Initial infections commonly occur on the bottom 30 cm (12 in.) of the stem, moving upwards onto the fern as the season progresses.

Biology: Stemphylium overwinters on asparagus crop residue. During harvest, infections often occur after sandblasting or high winds have damaged the spears. These microscopic wounds act as a point of entry for the fungi. Once established, stemphylium lesions continue to release spores for the duration of the growing season, infecting new fern as it emerges. *Stemphylium vesicarium* is known to infect asparagus, onions and pears, although research suggests that infection between different crops is not common.

Purple spot is most prevalent during cool, wet conditions. It has a temperature range of 0°C–30°C (32°F–86°F), with peak activity occurring from 15°C–25°C (59°F–77°F). It is often active during the early spring and again in the late summer. Hot, dry conditions in July and August slow the progression of this disease. However, levels of infection often dramatically increase as the temperatures cool in early fall.

Even in fields that were kept clean of purple spot during the growing season, levels of overwintering inoculum may continue to develop after the fern has died back for the season, especially during above-freezing, wet, late-fall conditions.

Scouting and Thresholds: As the plants begin to develop fern, look for signs of lesions at the base of the plants. Continue monitoring throughout the growing season, especially if cooler night-time temperatures lead to heavy dew fall and prolonged periods of leaf wetness.

No thresholds have been established. The most successful fungicide programs rely on preventive protective applications before the disease has become established.

Management Notes: Use cover crops and reduced tillage or zero-tillage to minimize sandblasting and wind damage. No-till fields may host higher levels of overwintering stemphylium inoculum. However, tillage damages the crown, increasing the risk of fusarium and impacting the long-term productivity of the field. The benefits of zero-till systems outweigh the associated stemphylium risks.

Second- and third-year asparagus plantings often act as a source of secondary inoculum. Begin scouting these fields for signs of infection immediately after harvest and start a preventive fungicide program at the first sign of infection.

Rust (Asparagus)
Puccinia asparagi

Identification: The initial infection, caused by basidiospores, appears as slightly raised, light green lesions 10–20 mm (¼–½ in.) in length. As the lesions mature, they turn cream to light orange. These initial infections generally appear at the base of the stalks.

In the early summer, wind-or-rain dispersed aeciospores produce bright orange lesions with distinct pustules (Figure 7–6).

Figure 7–6. Rust aeciospores.

Mid-summer infections appear as raised, reddish-brown pustules. These pustules release uredospores that continue to infect the plants throughout the summer. New generations are produced every 10–14 days, allowing for rapid spread of the disease if the weather is conducive to its spread. These brick-red blisters occur on all plant parts (Figure 7–7).

Figure 7–7. Rust uredospores.

In late-summer to early-autumn, the overwintering spores begin to appear in the upper canopy. These lesions are almost black in colour. Severe rust infections cause the plants to die prematurely in the fall, impacting the vigour of the crown and the following year's harvest.

Biology: The rust fungi overwinter in the field, on crop debris. Infection of growing foliage can occur from April through to early September. Warm weather with heavy dew, fog or light rainfall enhances rust development. Infection can occur with as few as 3–9 hours of leaf wetness.

Scouting and Thresholds: Look for lesions at the base of the plants. Rust is often first identified in 2nd-year asparagus plantings or immature fields as they begin to develop ferns. These fields act as a source of initial innoculum for the mature fields later in the season.

Management Notes: Some asparagus cultivars have moderate levels of rust resistance. Avoid planting at high densities that may reduce airflow through the field, increasing the duration of leaf wetness and potentially prolonging the active infection period.

Protect plantings as soon as the fronds are about 30 cm (12 in.) high. This usually occurs in early June for new plantings or early July for established ones. Thorough spray coverage of the entire canopy is important.

Insects

Asparagus Aphid
Brachycorynella asparagi

Identification: Asparagus aphids are very small (less than 1 mm (1⁄16 in.) long), much smaller than other types of aphids commonly found in vegetable crops. The bodies are green and are covered with a mealy grey wax. The cornicles ("tailpipes" found at the base of the abdomen of all aphid species) are very short and cannot be seen by the naked eye.

Damage: Aphids suck sap from the plant, often under the bracts or at the base of the needles. As they pierce the plant tissue, they inject a toxin into the plant. This results in the abnormal growth of the fern at the site of the wound. This growth may resemble a bonsai tree or a ball of fern. Feeding also causes stunting of the cladophylls and shortened stem internodes. Asparagus aphids may also transmit several different viruses infecting asparagus plants. This is not usually a significant problem in the Ontario landscape.

Biology: The asparagus aphid feeds only on asparagus. It overwinters as an egg in crop residue and adjoining fence rows. Eggs hatch in early spring as the spears begin to develop. Female aphids give live birth during the growing season. A generation of males is produced in the early fall. The adults mate and lay the overwintering eggs. Adults found on ferns are commonly wingless, although a winged (alate) generation will occasionally develop.

Scouting and Thresholds: While scouting, look for distorted branches and fern tips. Aphids are often difficult to find on the plants. Where damage is suspected, shake the infested fern over a light-coloured surface to dislodge and identify the aphids. In Michigan, a spray threshold of 5% damaged plants is suggested.

Management Notes: Aphids are not commonly found in Ontario asparagus fields.

Asparagus Beetles (Common and Spotted)
Crioceris asparagi, *Crioceris duodecimpunctata*

Identification: Asparagus beetle larvae are soft-bodied and dark green-grey with a black head and black legs. The adult beetles are a metallic blue-black colour. They have red wing margins and three distinct cream rectangular markings on each wing cover. The eggs are yellow-to-reddish-brown, bullet-shaped and laid in clusters perpendicular to the spear. The less common spotted asparagus beetle is reddish-orange with six black spots on each wing. The larvae are non-descript, greyish and slug-like in shape. They have a black head and sturdy black legs.

Damage: Feeding injury or the presence of eggs on the spears at harvest impacts the marketable yield. After harvest, feeding on the fern reduces the vigour of the plant, resulting in lower carbohydrate levels in the storage roots. Stress caused by feeding damage may predispose the plant to disease infections.

The spotted asparagus beetle typically causes less damage than the common asparagus beetle.

Biology: Asparagus beetles overwinter as adults in crop residue and in sheltered areas such as evergreen windbreaks. Beetle emergence and egg-laying usually coincide with asparagus harvest. First generation larvae feed on the growing fern after harvest. Nursery plants and new plantings are often most susceptible to feeding damage from the first generation larvae. A second generation of adults (and larvae) emerges in late July.

Scouting and Thresholds: If possible, schedule field-monitoring activities for the afternoon when the asparagus beetles are more active. Pay careful attention to field edges, especially those close to fence rows and evergreen windbreaks.

Eggs:	1%–2% of spears with eggs
Larvae on fern:	50% of plants with larvae present or 10% defoliation
Adults on fern:	5%–10% of plants infested

Similar to foliar diseases, the impact of multiple years of damaged fern on the health of the crown is cumulative. If a field has sustained asparagus beetle damage in the past, consider using a lower threshold.

Management Notes: Consider using spot sprays to target overwintering beetles as they enter the field. When selecting a chemical control method during the harvest season, pay special attention to the pre-harvest interval. Two-year-old and immature fields are often at the highest risk of infestation, as they develop fern at the peak of feeding activity for the first-generation larvae.

Asparagus Miner
Ophiomyia simplex

Identification: Adult asparagus miner flies are shiny, black and about 3.5–5 mm (⅛–¼ in.) long. The larvae are creamy white, tube-like maggots. They have 3 instars, reaching up to 5 mm (¼ in.) long.

Damage: Asparagus miner larvae create winding tunnels (mines) on the stalks just below the epidermis. The mines are normally found near the base of the plant.

Biology: Miner adults emerge in late-May to early-June. There are two generations per year, with peak populations normally occurring in mid-June and again in mid-August.

Scouting and Thresholds: None have been established.

Management Notes: Miners are not usually associated with any significant plant injury or direct yield loss; however, they transmit *Fusarium* from infected plants to healthy ones. See *Fusarium Crown Rot*, also in *Asparagus*.

Foliar insecticides are not typically effective at controlling either the adult or larval stage of this pest. Degree day models are available to predict the two generational peaks for this pest. See *Growing Degree Days*, Chapter 4.

Brown Marmorated Stink Bug

See Chapter 5.

Cutworms

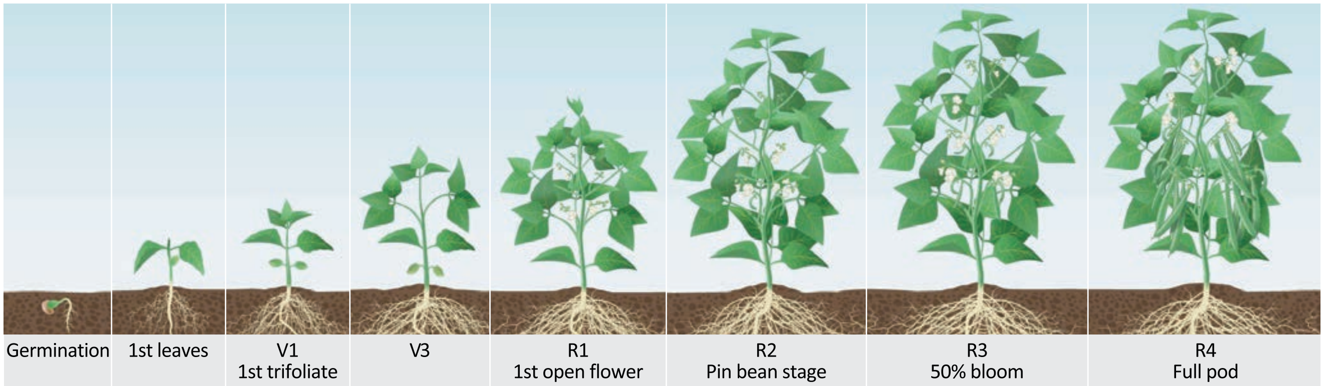
See Chapter 5.

Japanese Beetle

See *White Grubs/European Chafer*, Chapter 5.

Beans

(snap (green and wax), lima, edamame and yardlong)



Planting to harvest: snap (green and wax) 50–60 days; lima 70–90 days; yardlong 65 days; edamame 85–95 days

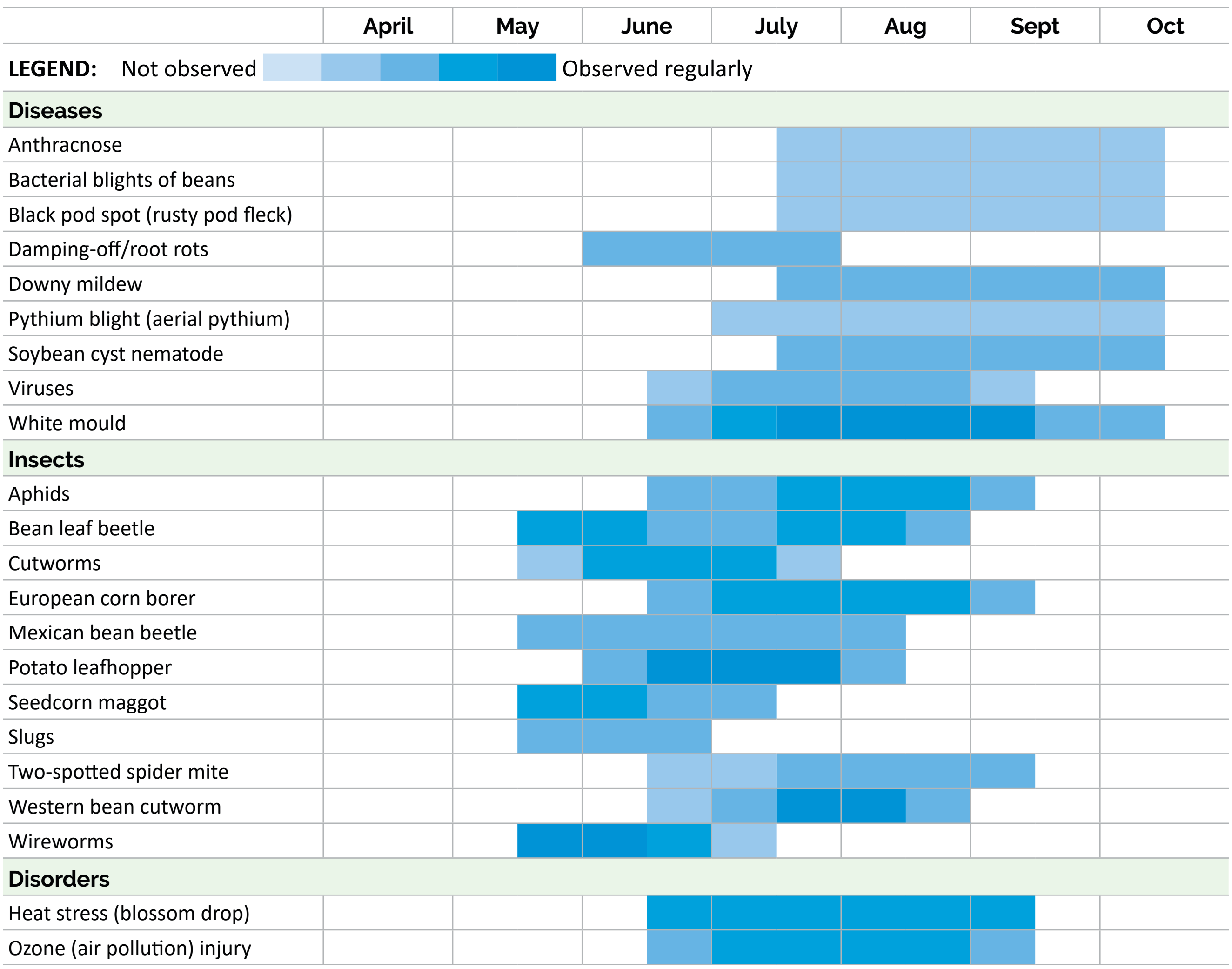


Figure 7–8. Bean stages of development and pest activity calendar. The actual period of activity for any given pest will vary significantly from year to year, depending on environmental factors.

Production Requirements

Soil types:	most soil types except very heavy clay loams
Soil pH:	6.1–6.5
Suitable rotational crops:	sweet corn, tomatoes, peppers, cereal crops
Do not rotate with:	soybeans, edible beans, peas, canola, brassica crops
Minimum soil temperature:	snap beans — 13°C (50°F) lima beans — above 15°C (59°F) edamame — above 10°C (50°F) yardlong beans — 16°C (61°F)
Optimum air temperatures:	16°C–21°C (61°F–70°F)
Earliest planting date:	snap and edamame beans — early to late May lima and yardlong beans — late May

Bean Development

Snap (green and wax) beans, lima beans, edamame and yardlong beans are all grown in Ontario. For snap and lima beans, the largest markets are for processing (frozen and canned). Edamame can be grown for processing or fresh market, whole pod or shelled. Yardlong beans have also been successfully grown in Ontario.

Snap bean planting usually begins in mid-May and continues sequentially until early July. Some processing fields may be planted into late July or even early August. Sequential plantings are usually determined by the emergence of the previous planting or by switching to longer-maturity cultivars. Market expectations and storage capacity or the processor schedule will also impact the crop plan.

Yardlong beans are more tolerant of high temperatures than the other classes of beans. Stakes or trellises are required to produce long straight beans and for ease of harvest.

For the stages of bean development, see Figure 7–8. *Bean stages of development and pest activity calendar.* From emergence to the third trifoliate and the bloom period are significant times for the management of various insect and disease pests. From emergence through the third trifoliate is also very important from a weed management standpoint. Later emergence of problem weeds such as nightshade or pigweed may still require management to avoid contamination issues in processing crops.

Seeding and Spacing

For processing crops, the cultivar is selected by the processor. Edamame varieties are not the same as standard soybean cultivars. Consult the vegetable seed supplier for cultivars recommended for the Ontario climate.

Machine-harvested snap and lima beans require a level soil surface to minimize harvest losses and prevent contamination with crop residue. Planting dates will be determined by soil moisture and temperature conditions, especially early in the season as soils warm up. Projected market demands and the processor's schedule will also impact the planting schedule. For processing crops, planting dates are determined by the processor.

Planting into cold soils will have a negative impact on germination rate and seedling vigour. It may also result in an increase in seed decay or soil insect pest pressure. Under good soil conditions, germination normally occurs within 6–10 days of planting. Beans are frost tender. Emerged plants are damaged at temperatures of 0°C (32°F) or colder.

Row spacing and seeding rates vary, depending on the bean type, harvest method, cultivar and seed size. For processing crops, the seeding rate is determined by the processor. Adjust the seeding rate according to seed count and the expected germination rate. The germination percentage is usually listed on the seed bag. See Table 7–6.

Table 7–6. Bean Crop Spacing

LEGEND: – = information not available

Crop	Row Spacing	In-Row Spacing	Depth	Seeding Rate	Population (seeds per acre)
Snap beans (hand harvest)	75–90 cm (30–36 in.)	5–10 cm (2–4 in.)	2.5–4 cm (1–1⅔ in.)	45–90 kg/ha (40–80 lb/acre)	50,000–100,000
Snap beans (machine harvest)	50–75 cm (20–30 in.)	5 cm (2 in.)	2.5–4 cm (1–1⅔ in.)	78–112 kg/ha (70–100 lb/acre)	100,000–120,000
Lima beans	75 cm (30 in.)	5 cm (2 in.)	2.5–5 cm (1–2 in.)	101–112 kg/ha (90–100 lb/acre)	85,000–100,000
Edamame	18–75 cm (7–30 in.)	10–20 cm (4–8 in.)	2.5–5 cm (1–2 in.)	–	–
Yardlong	60–150 cm (24–60 in.)	15–40 cm (6–16 in.)	–	–	–

Innoculation

Where soybeans have been grown in the past, further inoculation for snap beans is usually unnecessary. There is limited data to support specific snap bean rhizobium inoculants. Yardlong beans would require inoculation with *Bradyrhizobium* sp., if they have not been grown in the field in the past. In general, vegetable legumes do not form robust root systems, and nodulation can be limited. The short duration of growth and maturity for these cultivars also reduces the potential to fix large amounts of nitrogen from the atmosphere.

For snap bean nitrogen fertilizer recommendations, see *Fertility*, also in *Beans*.

Fertility

Macronutrients

Nitrogen

For snap beans, apply 30–40 kg N/ha (27–36 lb/acre) prior to planting as a preplant broadcast application or banded through the planter. Research from lima bean production areas, such as Delaware, suggests that higher rates of nitrogen may be required.

If banding, place the band 5 cm (2 in.) below and 5 cm (2 in.) to the side of the seed. Apply side-dress nitrogen only if the foliage symptoms or tissue analysis indicate nitrogen deficiency. Over-application of nitrogen will cause excess leaf growth, resulting in uneven maturity and increased disease pressure.

Pop-up or seed-placed fertilizer is not usually advised for snap beans.

If manure is applied or legume crops are plowed down, reduce the nitrogen (N) application. See Table 1–12 and Table 1–13, Chapter 1.

Phosphorus and Potassium

Test the soil to determine phosphorus and potassium requirements. See Table 7–7 and Table 7–8.

Table 7–7. Bean Phosphorus Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Sodium Bicarbonate Phosphorus Soil Test (ppm)													
	0–3	4–5	6–7	8–9	10–12	13–15	16–20	21–25	26–30	31–40	41–50	51–60	61–80	81+
Phosphate (P_2O_5) required kg/ha (lb/acre)	80 (71) (HR)	60 (54) (HR)	50 (45) (HR)	40 (36) (HR)	30 (27) (MR)	20 (18) (MR)	0 (LR)	0 (LR)	0 (RR)	0 (RR)	0 (RR)	0 (RR)	0 (NR)	0 (NR)

Table 7–8. Bean Potassium Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Ammonium Acetate Potassium Soil Test (ppm)											
	0–15	16–30	31–45	46–60	61–80	81–100	101–120	121–150	151–180	181–210	211–250	251+
Potash (K_2O) required kg/ha (lb/acre)	120 (107) (HR)	110 (98) (HR)	90 (80) (HR)	80 (71) (HR)	60 (54) (MR)	40 (36) (MR)	30 (27) (MR)	0 (LR)	0 (RR)	0 (RR)	0 (RR)	0 (NR)

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. See *Micronutrients*, Chapter 1.

Boron

Beans are very susceptible to boron toxicity. Do not grow them in the year after boron has been applied to previous crops in the field, such as brassica crops, celery or rutabaga.

Manganese

Manganese deficiency may be a problem on beans, especially on soils with pH values above 6.5. Symptoms include a yellowing of the leaf tissue while the veins remain dark green. Correct the deficiency as soon as it is detected with a foliar manganese spray. Soil application is not advised for manganese because of the large amounts of fertilizer required.

Zinc

Zinc deficiencies are uncommon on most soil types in Ontario. The exceptions are coarse sand-loams and eroded areas. Zinc is not mobile within the plant, so deficiencies appear on the newer growth first. Look for pale green tissue between the veins and yellowing of the tips and leaf margins. Correct a deficiency with a foliar application of zinc sulfate. Soil applications are not effective.

Plant Tissue Analysis

When used in conjunction with a soil analysis, plant tissue analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. Plant tissue analysis does not replace soil testing or a sound soil fertility program.

For sampling purposes, use the most recently mature trifoliate leaf. Provide the lab with at least 20 leaves (250 g fresh leaf material) for each sample. When sampling a problem area, it is often useful to take a separate sample from a good area for comparison. For more information, see Table 7–9.

Table 7–9. Snap Bean Nutrient Ranges

	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu	Mo
Time of Sampling	Per Cent (%)						Parts per Million					
Before bloom	3–4	0.3–0.5	2–3	0.8–1.5	0.25–0.45	0.2–0.4	25–200	20–100	20–40	15–40	5–10	0.4
Full bloom	2.5–4	0.2–0.4	1.6–2.5	0.8–1.5	0.26–0.45	0.2–0.4	25–200	20–100	20–40	15–40	5–10	0.4

Adapted from G Hochmuth, et al. 2018. *Plant Tissue Analysis and Interpretation for Vegetable Crops in Florida*. University of Florida IFAS Extension. HS964.

BEANS

BEANS

Irrigation

Beans are moderately responsive to irrigation. While irrigation of processing beans is unusual, fresh market crops may benefit from supplemental water.

Effects of moisture stress: blossom/pin-bean abortion, poor seed set and misshapen pods
Critical irrigation period: flowering and pod set
Rooting depth: 30–60 cm (12–24 in.)

If the available soil moisture (ASM) level in the root zone reaches 50% during the critical irrigation period, irrigation could help maintain crop yield and quality. Be cautious if using an overhead irrigation system during flowering, as excessive moisture may promote white mould.

For more information on irrigation scheduling, see the *Irrigation Management Best Management Practices* (order number BMP08E) and the OMAFRA factsheet, *Monitoring Soil Moisture to Improve Irrigation Decisions*.

Harvest

For processing crops, the processor will determine the harvest schedule. Snap bean harvest occurs approximately 14 days after full bloom, while the seeds are still immature (R-4 stage of development). Pods should be fairly uniform in size and maturity. There is very low tolerance in the marketplace for broken beans, defects and leaf and stem material. Both the processed and larger acreage fresh market crops are harvested with a mechanical, once-over harvester.

Lima bean harvest occurs 45–50 days after first bloom.

Harvest edamame when they reach the R-6 stage of development. The seeds within the pod should be fully developed, and the pods should be green and immature.

Yardlong beans can be harvested, by hand, every 1–3 days, depending on air temperatures and market preferences. Different market demographics will prefer different stages of maturity. Pods are usually sold in bundles tied at the stem end.

Average yields of snap beans (processing): 9.4 tonnes/ha (4.2 tons/acre)

Table 7–10. Bean Storage Conditions

Type	Storage Temperature	Relative Humidity	Duration
Snap beans	7°C–10°C (45°F–50°F)	95%	7–10 days
Lima beans	3°C–5°C (37°F–41°F)	95%	5–7 days
Edamame	0°C–2°C (32°F–36°F)	90%–95%	5–7 days
Yardlong	4°C–7°C (39°F–45°F)	90%–95%	7–14 days

Storage

Remove the field heat from harvested beans as soon as possible. Cooling methods suitable for use with snap and lima beans include forced air and hydrocooling. See Table 7–10. Be cautious of chilling injury, especially in snap and yardlong beans, which require a slightly warmer storage temperature. Chilling injury causes russetting, pitting and corky centres.

Pest Management and Disorders

See Figure 7–8. *Bean stages of development and pest activity calendar.*

Diseases

Anthracnose

Colletotrichum lindemuthianum

Identification: Anthracnose infections first occur as a reddish-brown to purple discolouration along the leaf veins on the leaf underside. Severe infections spread to the upper leaf surface, causing large, irregular-shaped brown lesions to develop. Stem and petiole lesions are circular-to-elliptical with a dark red-brown border.

Pod infections appear as small brown specks, enlarging into circular, sunken lesions. These lesions often have a pale brown centre and a darker brown margin. Small black spores (acervuli) may be visible in the centre of the lesion. Under very humid conditions, these spores may turn pinkish.

Biology: Anthracnose is spread through infected seed and in crop residue, although survival on crop residue is limited. Wet, windy weather with a relative humidity of at least 92% promotes disease development. Temperatures around 17°C (63°F) are most conducive to spread, although spores can be produced at any temperature from 13°C–26°C (55°F–79°F).

Management Notes: Use only certified, treated seed. Avoid rotating with other host crops, including dry edible beans and peas. Avoid working in wet fields. Low levels of infection can be quickly spread by field machinery and foot traffic. This disease is not usually a significant concern in snap and lima beans.

Bacterial Blights of Beans (Common Blight, Halo Blight, Brown Spot)

Xanthomonas axonopodis pv. *phaseoli*, *Pseudomonas syringae* pv. *phaseolicola*, *Pseudomonas syringae* pv. *syringae*

Identification: The three bacterial blight diseases are difficult to distinguish in the field. On leaf tissue, look for red-brown, necrotic lesions, often surrounded by a yellow border. Lesion shape ranges from angular to irregular. Infected spots often enlarge and coalesce to form large, brown dry areas between the leaf veins.

Infected pods develop round, water-soaked lesions, which later become sunken, dry and reddish brown (Figure 7–9). Under very wet conditions, pod lesions may begin to ooze bacteria spores. Infected pods often become twisted or bent where the lesions develop.

Biology: Brown spot (*P. syringae* pv. *syringae*) is more commonly found in lima beans. It overwinters on infected plant debris. Common blight (*X. axonopodis* pv. *phaseoli*) is spread by infested seed. It usually occurs during warm, humid conditions of 25°C–30°C (77°F–86°F). Halo blight (*P. syringae* pv. *phaseolicola*) is also seed-borne. It thrives under cooler temperatures in the 16°C–20°C (61°F–68°F) range.

Figure 7–9. Bacterial disease on bean leaves and pods.

For all three pathogens, wet, windy field conditions are conducive to the spread of these diseases.

Management Notes: Use only certified, treated seed. Follow a 2–3-year rotation away from all bean crops. Plants damaged by high winds or sandblasting are more susceptible to infection. Bacteria can also be mechanically spread through the field by cultivators or spray equipment. While there are several products registered, copper treatments are unlikely to provide effective control, especially if applied after the onset of foliar symptoms.

Black Pod Spot/Rusty Pod Fleck

Alternaria alternata

Identification: Inconspicuous water-soaked flecks develop on the leaves. These lesions frequently go unnoticed. Symptoms are most obvious on the pods, which develop orange, rusty or brown-coloured flecks. Pod symptoms typically appear just before harvest, usually in late-August and September.

Biology: The fungus survives on plant debris in the soil and on weeds. Spores produced by the fungus can be wind-blown or rain-splashed. Infection requires about 4 hours of leaf wetness. Isolated rain showers or dew periods experienced during cool August mornings are often enough to initiate significant infections.

Severe disease is often associated with plants under stress either during cool and wet, or hot and dry growing conditions. Although symptoms appear on mature pods at the end of the growing season, there is evidence the initial infections develop on blooms, immature pods and leaves. The fungus remains inactive after early infection until the plant begins to mature.

Management Notes: Harvest early to avoid the appearance of symptoms and loss of quality. There are considerable differences in susceptibility of snap bean cultivars to black pod spot. Most yellow snap bean cultivars appear to be very susceptible.

Damping-Off and Root Rots

Various species

See *Damping-Off*, Chapter 6.

BEANS

Downy Mildew (Lima Beans)
Phytophthora phaseoli

Not commonly identified in Ontario, downy mildew can infect lima beans through the flowers and shoot tips. The pathogen produces white, cottony mycelium. The abundant spores can be seen with a hand lens. Infections may be surrounded by a reddish band. The infected tissue turns necrotic and dies.

Pythium Blight/Aerial Pythium
Pythium sp.

Identification: Infections typically appear at one of the lower leaf nodes. The leaves above this node quickly wilt, turn brown and die. The leaves below the node remain healthy and green. Under very humid conditions, a dense white fungal growth may develop on the infected plant material.

Biology: Pythium species are commonly found in most agricultural soils. They are normally associated with root rots and early-season die-back. Aerial infections occur when infested soil is deposited on the leaves by splashing rain or driving winds, followed by an extended period of leaf wetness. The disease is most active at temperatures from 16°C–28°C (61°F–82°F).

Soybean Cyst Nematode
Heterodera glycine

Identification: Soybean cyst nematode (SCN) is a common pest of soybeans in Southwestern Ontario and has become more prevalent in Eastern Ontario too. Edamame are very susceptible to this nematode. Snap beans have recently been identified as a potential host, however, the yield impact and prevalence on snap beans is still under investigation.

These microscopic, worm-like nematodes feed on the roots and damage the root system. They can prevent the uptake of water and nutrients. The wounds also act as an entry-point for various root rot pathogens.

SCN can be identified by the presence of very small cysts on the roots. Above ground, infected plants become stunted, the leaves turn yellow and the plant dries down prematurely. Infections often become obvious during stressful growing conditions or on eroded knolls. Symptoms usually occur in circular patches.

Biology: SCN eggs in the soil hatch into a worm-shaped juvenile. The juveniles penetrate the bean root and migrate towards the vascular tissue where they will establish a feeding site. As the female grows, she will break through the surface of the root, remaining attached to feed. Upon maturity, she will fill a yellow-brown cyst with 100–300 eggs. Depending on the level of infection, plants may host hundreds of cysts. These cysts can remain viable in the root zone for 10 or more years. The SCN lifecycle peaks about 45 days after planting a susceptible crop.

Management Notes: Follow a 4–6-year rotation with non-host crops, including sweet corn, cereal grains and non-legume vegetable crops. Properly clean and disinfect field equipment when moving between fields, especially if an infection has been identified.

When growing very susceptible crops, such as edamame, do a soil test for SCN eggs and cysts in the field every 3–6 years. Fields with levels of 1,000 eggs/100 g or higher of soil are at high risk of yield loss due to SCN.

Viruses

See Chapter 6.

White Mould
Sclerotinia sclerotiorum

Identification: Dark-green, water-soaked lesions develop on the pods, branches or stems. The lesions enlarge rapidly, encompassing the branches and stems, causing leaves to turn yellow and die. As the crop nears harvest, white, cottony fungal growths develop on pods and stems. The area surrounding the fungus is usually rotten and mushy. Hard, black pea-sized sclerotia are found embedded in the fungal growth (Figure 7–10).

Biology: White mould overwinters in the soil as small, black (pea-sized) sclerotia. The initial infection occurs during flowering and early pod development. Temperatures ranging from 20°C–25°C (68°F–77°F) and continuous leaf wetness (high humidity and/or heavy dews) favour sclerotinia white mould development. Overwintering sclerotia may survive for several years in the soil.

Figure 7–10. White mould sclerotia on a desiccated bean pod.

Management Notes: Practice a 3–4-year crop rotation away from susceptible crops (cucurbits, edible beans, soybeans, canola, carrots and lettuce). Avoid applying high rates of nitrogen fertilizer. Excess nitrogen promotes an exceptionally dense crop canopy, resulting in restricted air movement and more favourable disease development conditions. For more information, see *White Mould*, Chapter 6.

Insects

Aphids

Various species

See Chapter 5.

Bean Leaf Beetle

Cerotoma trifurcata

Identification: Bean leaf beetle adults are 5 mm (¼ in.) in length with four black spots on the wing covers. A small, black triangle is visible at the base of the head. The colour varies from yellow to tan or red (Figure 7–11).

Damage: Beetles feed on the leaves, creating large, roundish holes. Feeding on the pods renders them unmarketable. The presence of beetles in the harvested product can cause problems during processing. Excessive defoliation from these beetles may also result in early maturity and yield losses.

Figure 7–11. Bean leaf beetle adult.

Biology: Bean leaf beetles complete only one generation per year. The adults emerge in late April. Egg-laying occurs until late June, with the larvae feeding on the roots for up to 30 days, at which time the adults emerge and become active in the crop from late July through August.

Scouting and Thresholds: Chemical controls may be required if leaf defoliation exceeds 20% prior to bloom and 10% during pod-fill.

Management Notes: Be aware of neighbouring alfalfa crops from which adults may migrate into snap bean fields. Row covers may help to exclude the beetles from the crop.

Cutworms

Various species

See Chapter 5.

European Corn Borer

Ostrinia nubilalis

See Chapter 5.

Mexican Bean Beetle

Epilachna varivestis

Identification: Mexican bean beetle adults are coppery-red, oval and approximately 6 mm (¼ in.) in length with 16 black spots on the wing casings. They resemble ladybugs. The larvae are yellow with rows of long, black-tipped spines along their backs.

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Damage: Both the adult beetles and the larvae feed on the leaves and pods of bean plants. Yield loss may occur if the leaf damage occurs on new-formed vegetative growth. Feeding on the pods renders them unmarketable and the presence of beetles in the harvested product can cause problems during processing. Excessive defoliation from these beetles may also result in early maturity and yield losses.

Biology: Mexican bean beetle adults emerge from overwintering sites (grassy fence rows and wooded areas) in early May. Eggs are laid and feeding continues for approximately 1 month. Mexican bean beetles complete one to two generations per year.

Scouting and Thresholds: Chemical controls may be required if leaf defoliation exceeds 20% prior to bloom and 10% during pod-fill.

Management Notes: Consider using border sprays to control the beetles as they move out of the fence row.

Potato Leafhopper
Empoasca fabae

Identification: Adults are small, pale green, about 3 mm (⅛ in.) long and wedge-shaped, with a broad head and thorax. The body tapers along the wings. Leafhoppers are very active and quick to fly. Nymphs are similar to adults but lack fully developed wings. When disturbed, nymphs run sideways like crabs over the edge of the leaflet to the underside. Do not confuse leafhopper nymphs with aphids. Leafhopper nymphs move fast and walk sideways. Aphids move very slowly.

Damage: Adults and nymphs feed by sucking sap from the leaves and stems. Initially, the feeding damage causes yellowing and browning of the tips and margins of the leaves. Later, the leaf margins pucker and roll inward, resulting in the typical hopperburn damage. Hopperburn is usually noticeable 4–5 days after leafhopper feeding. To avoid yield losses, leafhoppers must be controlled before hopperburn is visible.

Biology: The potato leafhopper does not overwinter in Ontario. It is carried by upper-level winds from the U.S. and can arrive in Ontario as early as May. Females lay eggs on alfalfa. The nymphs hatch in about 10 days. There are 5 nymphal instars, which reach maturity in 10–25 days. Depending on weather conditions, two to four generations can develop during the season. Potatoes and snap beans adjacent to alfalfa fields are at high risk of leafhopper infestation when hay is cut.

Scouting and Thresholds: Snap beans are most susceptible to leafhopper feeding from emergence to the third trifoliate stage. Inspect all the plants in 10 feet of row at 10 different locations in the field. Divide the number of insects found by 100 to determine the population per foot of row. Scout all fields for leafhopper activity, even if a systemic insecticide was used at planting. See Table 7–11.

Table 7–11. Potato Leafhopper Thresholds for Snap Beans

Insect Stage	Crop Stage	Threshold
Adults	seedling	2 per 30-cm (1-ft) row
	3rd trifoliate	5 per 30-cm (1-ft) row
Nymphs	any stage	10 per 100 leaves

Management Notes: Seed treatment systemic insecticides usually keep leafhopper populations under control, and further management is not required. Leafhopper populations can increase rapidly in warm weather. Regular field scouting can help identify any burgeoning populations. Where snap beans are planted in the vicinity of an alfalfa field, scout twice weekly. Apply an effective foliar insecticide if the threshold is reached.

Seed Corn Maggot
Delia platura

See *Seedcorn Maggot*, *Peas*.

Slugs
Various species

See Chapter 5.

Two-Spotted Spider Mite
Tetranychus urticae

See Chapter 5.

Western Bean Cutworm
Striacosta albicosta

Identification: Adult moths have a white band running along the edge or margin of the wing, a spot or "moon" and boomerang-like mark. The larvae are tan-to-pink in colour with two distinct brown stripes on the pronotum (the shield-like structure just behind the head). The spherical eggs are laid in clusters. They are initially white, turning purple as they mature. The eggs are very difficult to detect in beans.

Damage: Feeding and damage in succulent bean fields is less common. If the eggs are laid in bean crops, the larvae will tunnel directly into the side of the pod and feed upon the seed within it. Unlike the European corn borer, feeding injury is usually obvious.

Biology: Western bean cutworm overwinter as mature larvae. They pupate in late May and the adults emerge in July. Adult populations typically peak in late July to early August. Eggs hatch in the 5–7 days following the peak flight. Adult moths are most attracted to corn during the pre-tassel stages. After corn has tasseled, female moths may move to bean crops to complete their generation. The potential for pod feeding occurs 10–21 days after peak flight.

Scouting and Thresholds: Monitor for western bean cutworm populations using green bucket pheromone traps. Because they are difficult to detect in beans, begin scouting nearby corn fields as soon as the first adult moths are caught in an area. The eggs are commonly laid on the upper surface of the top 3–4 corn leaves. The risk of damage to bean crops may be determined by the local trap counts, the level of activity in corn fields and the physiological stage of the neighbouring corn crops.

Management Notes: Products used to control European corn borer are typically effective on the western bean cutworm.

Wireworms
Various species

See Chapter 5.

Disorders

Heat Stress (Blossom Drop)

Snap and lima beans are both sensitive to high temperatures during bloom. Symptoms most commonly occur in plantings that flower during mid-July through early August. High temperatures during blossom initiation and development can impact the quality of the pollen. During bloom, high temperatures impact pollen release and fertilization.

Heat stress results in aborted pods (most common in lima beans) or short, misshapen pods. It often causes a split set on the plants, with mature lower pods, a gap in the mid-portion of the plant and a new flush of pods developing in the upper canopy. This can make harvest scheduling for maximum yield a challenge.

Heat stress occurs at temperatures above 26°C (79°F). Cooler night-time temperatures may help to mitigate the impact of heat stress.

Ozone (Air Pollution) Injury

Ozone injury is also known as bronzing. It is caused by air pollution and lightning produced during storms. Conditions of intense sunlight or high temperature favour ozone damage. Under dry conditions, plants are more tolerant to ozone, therefore symptoms may be more severe under moist conditions. The amount of damage found on the plant, or in an area, often corresponds to air pollution alerts or heavy thunderstorms. Damage appears as reddish-brown fecking or "bronzing" on the upper surface of leaves (Figure 7–12).

Figure 7–12. Ozone injury.

BEANS

Beets, Table

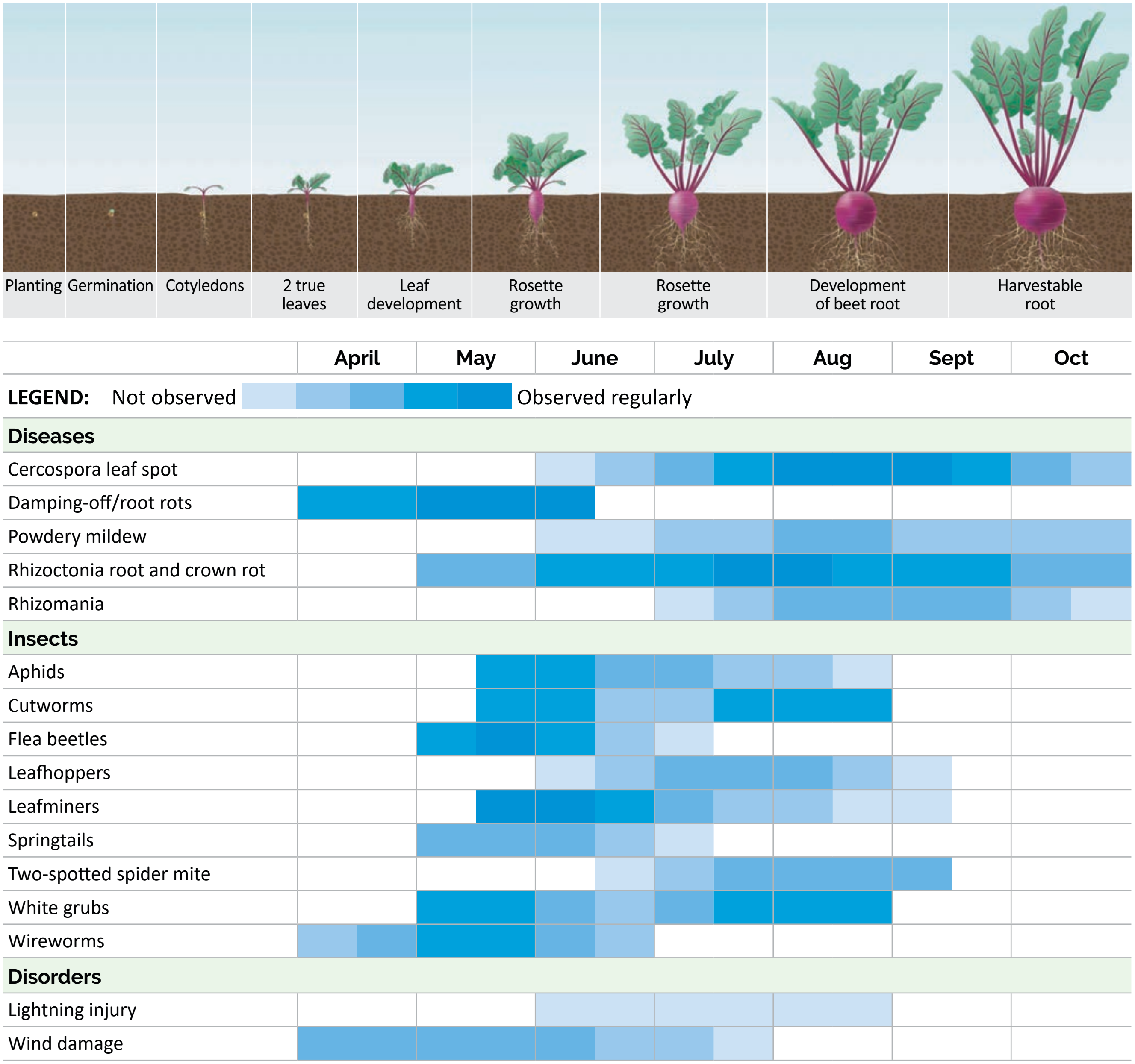


Figure 7–13. Table beet stages of development and pest activity calendar. The actual period of activity for any given pest will vary significantly from year to year, depending on environmental factors.

Table Beet Crop Growth

Beets are a biennial plant, which means they have a 2-year growth cycle. As an agricultural crop, we are mainly concerned with the first year of this cycle. There are two main beet types: globe-shaped and long-rooted. Beetroots can be a variety of colours including red, orange, gold, yellow, white and even concentrically ringed. A rosette of large edible leaves sprouts from the root and is generally green with red, yellow or white veins.

Beets are direct-seeded usually beginning in April. Seedlings emerge approximately 8–10 days after planting with a pair of cotyledons. Successive leaves develop in pairs throughout the growing season. Leaf development continues until the leaf canopy completely covers the soil around the root. The plant will then start to develop the tap root system, which can utilize water and soil nutrients to depths of up to 2 m (6½ ft). Beets are usually ready for harvest 50–70 days after planting.

Production Requirements

Soil types: well-drained, loamy soils and muck soils
Soil pH: 6.5–7.8
Suitable rotational crops: beans, cereal crops, corn, cucurbits, eggplant, peas, peppers, potatoes, soybeans, tomatoes
Do not rotate with: sugarbeets, brassica crops, swiss chard
Minimum soil temperature: 5°C (41°F)
Optimum air temperature: 10°C–18°C (50°F–64°F)
Earliest planting date: mid-April to mid-May

Table 7–12. Table Beet Crop Spacing

Crop	Row Spacing	In-Row Spacing	Depth	Seeding Rate
Beets, baby[1]	25–38 cm (10–15 in.)	100–115 plants/m of row (30–35 plants/ft of row)	1.0–2.5 cm (½–1 in.)	54–72 kg/ha (49–65 lb/acre)
Beets, fresh market	40–70 cm (16–28 in.)	16–39 seeds/m (5–12 seeds/ft)	1.0–2.5 cm (½–1 in.)	7–11 kg/ha (6–10 lb/acre)
Beets, slicing	40–70 cm (16–28 in.)	49–98 seeds/m (15–30 seeds/ft)	1.0–2.5 cm (½–1 in.)	17–28 kg/ha (15–25 lb/acre)

[1] Baby beets may also be a byproduct of producing larger roots (from thinning or sorted out at harvest).

Seeding and Spacing

For a continuous supply of beets for bunching, sow seed at 1–2-week intervals, from mid-April to the end of July. Early processing crops can also be seeded in early spring. For storage and late processing crops, sow about 10 weeks before the expected harvest date.

Closer in-row spacing tends to increase the proportion of small beets. Use closer row spacing for early harvest beets. Plant mid- and late-season crops at wider row spacings. If necessary, thin plants to the desired final stand, as beet seed is multigerm and is able to produce more than one plant per seed. For early fresh market beets, transplants are an option, but the taproot must not be damaged during transplanting. See Table 7–12.

Fertility

Macronutrients

Nitrogen

Broadcast and incorporate all the required preplant nitrogen along with the required potash and phosphate. On mineral soils, apply the remainder of the nitrogen as a side-dress application. See Table 7–13.

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. See Table 1–12 and Table 1–13, Chapter 1.

Table 7–13. Table Beet Nitrogen Requirements

Soil Type	Actual N
Mineral Soils	
Preplant	65 kg/ha (58 lb/acre)
Side-dress	45 kg/ha (40 lb/acre)
Total	**110 kg/ha (98 lb/acre)**
Muck Soils	
Preplant	40 kg/ha (36 lb/acre)

Phosphorus and Potassium

Test the soil to determine phosphorus and potassium requirements. See Table 7–14 and Table 7–15.

Table 7–14. Table Beet Phosphorus Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Sodium Bicarbonate Phosphorus Soil Test (ppm)													
	0–3	4–5	6–7	8–9	10–12	13–15	16–20	21–25	26–30	31–40	41–50	51–60	61–80	81+
Mineral soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	180 (161) (HR)	170 (152) (HR)	170 (152) (HR)	160 (143) (HR)	160 (143) (HR)	150 (134) (HR)	140 (125) (HR)	120 (107) (MR)	100 (89) (MR)	80 (71) (MR)	50 (45) (LR)	30 (27) (RR)	0 (RR)	0 (NR)
Muck soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	100 (89) (HR)	100 (89) (HR)	100 (89) (HR)	100 (89) (HR)	90 (80) (MR)	90 (80) (MR)	80 (71) (MR)	70 (62) (MR)	60 (54) (MR)	50 (45) (LR)	30 (27) (LR)	20 (18) (LR)	0 (RR)	0 (NR)

Table 7–15. Table Beet Potassium Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Ammonium Acetate Potassium Soil Test (ppm)											
	0–15	16–30	31–45	46–60	61–80	81–100	101–120	121–150	151–180	181–210	211–250	251+
Mineral soils												
Potash (K_2O) required kg/ha (lb/acre)	230 (205) (HR)	220 (196) (HR)	210 (187) (HR)	190 (169) (HR)	160 (143) (HR)	130 (116) (HR)	100 (89) (MR)	80 (71) (MR)	50 (45) (MR)	0 (LR)	0 (RR)	0 (NR)
Muck soils												
Potash (K_2O) required kg/ha (lb/acre)	100 (89) (HR)	100 (89) (HR)	90 (80) (HR)	80 (71) (HR)	60 (54) (MR)	40 (36) (MR)	30 (27) (MR)	20 (18) (MR)	20 (18) (MR)	0 (LR)	0 (RR)	0 (NR)

Table 7–16. Table Beet Nutrient Ranges

LEGEND: — = No data available

Plant Part	Time of Sampling	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu	Mo
		Per Cent (%)						Parts Per Million (ppm)					
Leaf blades	5 weeks after seeding	3–5	0.3–0.4	2–6	1.5–2	0.25–1	0.6–0.8	40–200	30–200	15–30	30–80	5–10	0.2–0.6
	9 weeks after seeding	2.6–4	0.2–0.3	1.7–4	1.5–3	0.3–1	0.6–0.8	–	70–200	15–30	60–80	5–10	0.6

Adapted from G Hochmuth, et al. 2018. *Plant Tissue Analysis and Interpretation for Vegetable Crops in Florida*. University of Florida IFAS Extension. HS964.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. See *Micronutrients*, Chapter 1, for more information. Although beets are rated as highly responsive to copper and molybdenum, there is no data to indicate if application of these micronutrients would provide an economic response in Ontario soils.

Boron

Boron deficiency shows up as a corky, dark discolouration of internal tissues. It is most likely to occur on high pH (alkaline) soils after prolonged hot, dry periods.

Manganese

Manganese deficiency may occur on high pH (alkaline) soils. Deficient plants show marked yellowing between the leaf veins, while the veins remain green. To correct a deficiency, spray with manganese sulfate.

Plant Tissue Analysis

When used in conjunction with a soil analysis, plant tissue analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. Plant tissue analysis does not replace soil testing or a sound soil fertility program.

For more information, see Table 7–16.

Irrigation

Note: You must have a Permit to Take Water issued by the Ministry of the Environment, Conservation and Parks to use more than 50,000 L (13,209 gal) of water in a day from either surface or groundwater sources.

Beets are usually responsive to irrigation.

Table beets require a uniform supply of moisture throughout the growing season. The average rainfall in Ontario is 70 mm/month (2¾ in./month) during the growing season. This provides approximately 65% of the water needed for optimum yield. Historically, moisture levels are often at their lowest in July and August when the crop water demand is at its highest.

Common issues caused by moisture stress in beet crops include poor germination and misshapen or undersized roots. The most critical period for irrigation is during stand establishment and root enlargement. If the available soil moisture level in the root zone (30–60 cm (12–24 in.) rooting depth) reaches 50% during the critical irrigation period, irrigation could help maintain crop yield and quality.

There are a number of types of irrigation systems that have been adapted for use in beets. They include hand-moved sprinklers, travelling gun systems, center-pivot and lateral systems, and, less commonly used, drip (trickle) irrigation. Whichever type of irrigation system is used, it is important to schedule irrigation to avoid drought stress and provide water when it is most needed. Timely application of water will reduce the potential for nutrient loss or disease pressure due to excess water. There are two basic methods of scheduling irrigation: the water budget method and measuring soil moisture.

For more detailed information on irrigation, see:

- *Best Management Practices — Water Management*
- *Best Management Practices — Irrigation Management*
- OMAFRA Factsheet, *Monitoring Soil Moisture to Improve Irrigation Decisions*
- OMAFRA Factsheet, *How to Prepare for Irrigation During Water Shortages*

Harvest

Table beet crops are ready to harvest within 50–70 days after planting, depending on the cultivar and market requirements. Fewer days are required for baby beets. Beets are ready to harvest when the tops are large enough to be used for greens or the root has reached the desired size for the target market. For most cultivars, beets become woody when larger than 7.5 cm (3 in.) in diameter.

Harvest of early plantings begins in mid-summer and can continue through fall frosts for late crops. Harvest must be completed before a hard freeze. Average yields for table beets can be found in Table 7–17.

Table 7–17. Average Yields of Ontario Table Beets

Crop	Yield	Standard Container
Fresh-market beets	1,000–1,500 bags/ha (400–600 bags/acre)	23 kg bag
Processing beets	34–45 tonnes/ha (15–20 tons/acre)	N/A

Storage

Rapid and efficient cooling is the most effective management practice for maintaining the quality and shelf-life of fresh beets. It is essential that only good-quality produce is placed in cold storage. Suitable cooling methods for table beets include forced air and hydrocooling.

Forced-Air Cooling

Beets are placed in a refrigerated room, and cold air is pulled through the containers using high-capacity fans. An effectively designed system allows good contact between the cold air and the produce. Forced-air cooling is not as rapid as hydro-cooling. However, it is adaptable to more types of produce and more flexible for smaller-scale operations. Forced-air cooling should be done quickly so the beets do not lose too much moisture.

Hydro-Cooling

Cold water is an effective method for quickly cooling table beets in containers or bulk bins. Hydro-coolers use either an immersion or a shower system to bring beets in contact with the chilled water. Hydro-cooling avoids product water loss and may even add water to a slightly dry batch.

Beets are best stored close to 0°C (32°F) and a relative humidity of 98%–100%, however, be careful not to allow the beets to freeze. When properly stored, beets can remain marketable for 4–6 months.

Pest Management and Disorders

See Figure 7–13. *Table beet stages of development and pest activity calendar.*

Diseases

Cercospora Leaf Spot
Cercospora beticola

Identification: Numerous small, circular lesions develop on the leaves. Small black dots (fungal structures) in the centre of the lesions can be seen with a hand lens. Cercospora leaf spot leads to defoliation and reduction in yield. Symptoms do not appear until 5–21 days after infection (Figure 7–14).

Biology: Cercospora leaf spot is most active from mid-July through September. Daytime air temperatures between 24°C (75°F) and 32°C (90°F) with night temperatures of at least 15°C (59°F) and extended periods of leaf wetness due to rain, dew or fog are favourable for disease development.

Management Notes: Use BEETcast to determine optimum fungicide timing. If BEETcast is unavailable, begin the fungicide program as soon as leaf symptoms appear. See *Disease Prediction Models*, Chapter 4.

Figure 7–14. Cercospora lesions on a sugarbeet leaf.

The currently registered cercospora fungicides must be managed responsibly to maintain their efficacy and to avoid the development of resistance to multiple fungicides. Scout fields regularly to ensure the fungicide program is controlling the disease.

The systemic fungicide families must be rotated; never apply systemic products from the same family in sequential applications. Tank-mix the systemic fungicides with contact fungicides that have multiple sites of action. Follow a shorter disease severity value (DSV) spray interval when using contact fungicides alone. Use water rates of at least 187–281 L/ha (20–30 gal/acre).

BEETcast

The BEETcast program uses temperature and leaf wetness measurements to schedule preventive fungicide applications, before the damaging disease symptoms are visible. BEETcast calculates a daily disease severity value (DSV) for each location. A zero means conditions were not favourable for disease development, due to cool temperatures or dry leaves. Favourable conditions, due to warm temperatures and periods of leaf wetness, are given a rating of 1 to 4. Spray applications are made when the accumulated daily DSVs reach a target number. BEETcast DSVs are available from Weather Innovations Incorporated. For more information, contact Weather Innovations Incorporated at 519-352-5334 or visit their website at www.weatherinnovations.com.

Damping-Off/Root Rots

Pythium sp., *Phytophthora* sp., *Rhizoctonia* sp., *Fusarium* sp.

Identification: Plants infected prior to emergence rot and typically fail to produce a seedling. If the seedlings do emerge, they are usually weak and lack vigour. Post-emergence infections cause the seedlings to rot at soil line. This usually occurs within 2–4 weeks of emergence. Affected plants tend to curl downward or melt into the soil. See *Damping-Off*, Chapter 6, for more information.

Powdery Mildew

Erysiphe polygoni (syn. *E. betae*)

Identification: Initial symptoms usually appear on the older, shaded leaves. A dense, white fungal (powdery) growth develops primarily on the upper leaf surface, though it can also occur on the lower leaf surface. A pale green-to-yellow discolouration may also appear on the corresponding leaf surface. Infected leaves and stems turn yellow, wither and die prematurely.

In beets, infected leaves are more susceptible to frost than healthy leaves.

Biology: The pathogen causing powdery mildew do not overwinter in the field in Ontario. Wind-borne spores usually arrive from the southern U.S. and Mexico in mid-summer. Peak infection periods occur when temperatures are in the range of 20°C–26°C (68°F–79°F). Disease development slows when temperatures climb above 26°C (79°F).

Infections can develop at relatively low humidity (<20%) levels, although humid weather conditions and heavy dews lead to more rapid disease development. Under these conditions, visual symptoms may appear 3–7 days after the initial infection.

Management Notes: There are varying levels of tolerance among table beet cultivars. Fungicides are available that may offer suppression of the disease, but good coverage on both the upper and lower leaf surfaces is essential. In this region, the fungicides used for cercospora leaf spot management generally offer acceptable control of powdery mildew.

Powdery mildew is difficult to detect in its early stages. Both the upper and lower leaf surfaces must be checked to detect spore growth. Once mildew and yellowing are present on the leaf surfaces, the disease is quite advanced and unlikely to respond to fungicide applications.

Due to its wide host range, it can be difficult to control powdery mildew with cultural practices.

Rhizoctonia Root and Crown Rot
Rhizoctonia solani

Identification: Symptoms include wilting of the leaves and the eventual death of the foliage. Infections occur on the crown, sides or tips. In some cases, tip infections begin before foliar symptoms. Roots may develop large cracks. Infection often spreads down the row (Figure 7–15).

Figure 7–15. Rhizoctonia crown and root rot damage in sugarbeet field.

Biology: This species of *Rhizoctonia* is a ubiquitous soil-borne fungi. It can survive in the soil for many years. Infections can occur throughout the season under warm and wet or very humid conditions.

Rhizoctonia root and crown rot is a warm weather disease. It becomes active at temperatures of 12°C–35°C (54°F–95°F) but is most active at 25°C–33°C (77°F–91°F). Fields considered at high risk for *Rhizoctonia* infections include those with a history of the disease or fields in which a host crop was grown the previous year. Stressful growing conditions such as soil compaction or poor soil drainage will also make plants more susceptible to infections.

Rhizoctonia solani is one of the fungal species that causes damping-off. See *Damping-Off*, Chapter 6, for more information.

Management Notes:

- Azoxystrobin fungicides should be applied in furrow, at the 6–8-leaf stage, or both, to effectively aid in managing the disease.
- *Rhizoctonia*-resistant beet cultivars should be used in fields with a history of the disease.
- Make sure fields are well drained.
- Take measures to reduce soil compaction.
- Avoid planting susceptible crops in previously infected areas.
- Rotate for several years with corn or small grains and practice strict sanitation procedures to avoid spreading infected soil between fields.
- Avoid throwing soil onto beet crowns during cultivation.
- Do not dump beet tare dirt onto fields scheduled for beets the following year.

Rhizomania
Beet Necrotic Yellow Vein Virus (BNYVV) vectored by the soil fungus *Polymyxa betae keskin*

Identification: Symptoms include stunted roots with a proliferation of lateral roots. The taproot is often constricted, giving the root a wineglass shape. Root vascular tissue becomes discoloured. Leaves become a bright, highlighter yellow colour and develop an erect growth habit. Symptoms may be patchy within a field (Figure 7–16).

Figure 7–16. Prolific growth of lateral beet roots caused by rhizomania.

BEETS, TABLE

Biology: Rhizomania is regarded as one of the most destructive of beet diseases. It can severely reduce tonnage in affected fields. A very small amount of contaminated soil can start an infection that will eventually spread throughout a field.

Management Notes: Once present, the disease cannot be eradicated, however, management practices can be used to slow its spread and reduce the impact. Any activity that moves soil has the potential to spread the disease (e.g., field work, tare dirt). Resistant beet cultivars are available and should be used when planting in fields known to be infected.

Sugarbeet Cyst Nematode
Heterodera schachtii

Sugarbeet cyst nematode (SBCN) is an expanding problem in Michigan but has not yet been identified in Ontario.

Identification: Oval or elongated patches of plants appear stunted, yellow or lighter green, and unthrifty. Small white to cream or yellow-coloured immature lemon-shaped cysts attached to roots. Cysts turn brown at maturity.

If ever identified in Ontario, planting resistant cultivars, extending the crop rotation and planting trap crops prior to beets are effective strategies to manage SBCN. Prior to deciding upon a management strategy, confirm the identification by contacting an OMAFRA Vegetable Crop Specialist via the Agricultural Information Contact Centre at 1-877-424-1300 or ag.info.omafra@ontario.ca.

See Chapter 6, for more information.

Insects

Aphids
Aphididae family

Identification: There are several aphid species affecting beet crops in Ontario. Aphids are small, soft-bodied, pear-shaped insects, with cornicles or “tail-pipes” near the tip of their abdomen.

Scouting and Thresholds: To scout for sugarbeet root aphids, dig up and inspect the roots of wilted beet plants. The aphids may also be found on the roots of weed hosts such as lamb’s-quarters and pigweed.

Beet cultivars with resistance to root aphids are available. The level of resistance varies between cultivars.

No threshold is established for beet (roots), but less than 10% infestation may result in reduced yield.

See Chapter 5, for more information.

Cutworms
Agrotis ipsilon (black cutworm),
Euxoa messoria (dark-sided cutworm),
Crymodes devastator (glassy cutworm),
Euxoa detersa (sandhill cutworm)

Cutworms are primarily an early-season pest that can severely affect seedlings. Seedlings appear as if they were cut off at the soil surface with scissors. See Chapter 5, for more information.

Flea Beetles
Phyllotreta sp.

Identification: Flea beetles are small (2–3 mm (⅛ in.) long), shiny black beetles. Adults are active and jump when disturbed.

Damage: Feeding damage consists of numerous very small “shot-holes,” 1–5 mm (1⁄16–¼ in.) in diameter. Older damage may be ringed with brown, dried leaf tissue, while fresh feeding holes have green edges. At the seedling stage, flea beetle feeding can kill the plant. Larval feeding on the root may reduce marketability.

Flea beetles and their larvae may feed on cotyledons, leaves and underground parts of beets. They are unlikely to cause significant damage unless populations are very high during the seedling stage, especially if the plants are growing slowly in cool conditions.

Other flea beetle species including potato flea beetle (*Epitrix cucumeris*) and possibly pale-striped flea beetle (*Systena blanda*) and spinach flea beetle (*Disonycha xanthomelas*) occasionally damage table beets. Small plants in less-than-ideal growing conditions are more likely to be affected by flea beetle feeding. Most plants are able to outgrow the damage.

Biology: Flea beetles in Ontario generally have one generation per year. The lifecycle from egg to adult may take as little as 7 weeks, making a second generation possible in some years. Adult flea beetles overwinter in leaf litter. They emerge and begin feeding on young plants in mid-May. Adults lay eggs near the roots of host plants throughout the spring and early summer. Larvae develop on the roots. In late July, adults emerge from the soil, feed and then seek hibernation sites in the fall.

Scouting and Thresholds: Begin monitoring for flea beetles as soon as the seedlings are through the soil surface. For table beets, treatment may be necessary if 25% of seedlings show damage or if damage is contributing to stand loss.

Leafhoppers

Empoasca spp.

Identification: Adults are small, pale green, about 3 mm (⅛ in.) long and wedge-shaped, with a broad head and thorax. The body tapers along the wings. Leafhoppers are very active and quick to fly. Nymphs are similar to adults but lack fully developed wings. When disturbed, nymphs run sideways like crabs over the edge of the leaflet to the underside. Do not confuse leafhopper nymphs with aphids. Leafhopper nymphs move fast and walk sideways. Aphids walk very slowly.

Damage: Adults and nymphs feed by sucking sap from the leaves and stems. Initially, the feeding damage causes yellowing and browning of the tips and margins of the leaves. Later, the leaf margins pucker and roll inward, resulting in the typical hopperburn damage. Hopperburn is usually noticeable 4–5 days after leafhopper feeding. To avoid yield losses, leafhoppers must be controlled before hopperburn is visible.

Leafhoppers are often present in a variety of vegetable crops including table beets. Consider treatment only if populations build to high levels and leaf curling becomes evident.

Biology: The potato leafhopper does not overwinter in Ontario. It is carried by upper-level winds from the U.S. and can arrive in Ontario as early as May. Females lay eggs on alfalfa. The nymphs hatch in about 10 days. There are 5 nymphal instars, which reach maturity in 10–25 days. Depending on weather conditions, 2–4 generations can develop during the season.

Management Notes: Leafhopper populations can increase rapidly in warm weather. Thus, field scouting is the first line of defence against this insect. For beet greens, control measures may be needed. However, for beet roots, leafhoppers are not often a concern.

Leafminers

Pegomya betae, *P. hyoscyami*

Identification: The primary species of leafminers that attack beets include the beet leafminer (*Pegomya betae*) and the spinach leafminer (*Pegomya hyoscyami*). Other species from the genera *Liriomyza* and *Psilopa* have also been observed on occasion. Generally, leafminers are small (7 mm (¼ in.)) greyish-green to greyish-brown flies that lay their eggs in leaves. The larvae of leafminers are small, translucent, whitish to pale green maggots that create serpentine mines in the leaf tissue.

Damage: Female leafminers lay their white, cigar-shaped eggs in clusters of 2–10 on the underside of leaves. Females pierce the leaves to feed on plant sap. Larvae feed between the upper and lower surface of the leaves. Leafminer feeding reduces the plant's photosynthetic capacity. The mines also provide an entrance for disease organisms (Figure 7–17).

Figure 7–17. Mines created by serpentine leafminers in beet leaves.

Biology: Optimal temperatures for leafminer development range from 21°C–32°C (70°F–90°F). Egg-laying is reduced at temperatures below 10°C (50°F). Leafminers are a problem primarily in the spring.

Scouting and Thresholds: For beet roots, if 50% of plants have eggs or larvae, treatment may be required. Scout for mines and larvae or for eggs on the underside of leaves. Yellow sticky traps placed in the crop can be used to monitor adult flies.

Management Notes: Lamb's-quarters is an alternate host for leafminers. Good weed control can reduce infestations. Crop rotation is an effective pest management tool. Alternating crops susceptible to leafminer with leafminer-resistant crops reduces the population.

Springtails

Collembola spp., *Bourletiella hortensis*

Springtail damage in beets has been seen in Ontario. They are generally considered beneficial insects but may feed on crops. Damage to seedlings can be significant under the right conditions.

Identification: At first glance, globular springtails may be confused with flea beetles. They are dark in colour and range in length from 0.8–3.0 mm (up to ⅛ in.). They can be found above ground and tend to jump when disturbed. Subterranean springtail species are whitish and elongated, ranging from 0.8–2.4 mm (up to ⅛ in.) long. They live in the soil and do not have the ability to jump like other springtails. Subterranean springtail species are rare in this region.

Damage: They are generally not a concern except when extended cool, wet conditions occur during the seedling stage. Globular springtails feed on table beet cotyledons, stems and roots. Subterranean springtails feed on roots. Damage may show up as small round holes in cotyledons or leaves or as pitting or scraping of plant tissue below or above ground. Stands can be reduced when springtail populations are high and beet seedlings are small and growing slowly.

Biology: Springtails usually feed on organic material in the soil, helping to break down crop residue and improve soil structure. In extended moist conditions, populations can become very high, and seedling damage may become noticeable.

Scouting and Thresholds: The crop is only vulnerable in the seedling stage. There is no established threshold or treatment, but where damage is seen, populations are probably in the thousands per square foot.

Management Notes: Beets generally outgrow the damage and yield impacts have not been measured. Springtails are unlikely to cause significant damage in cases where a soil- or seed-applied insecticide has been used to target other seed or seedling insect pests.

Two-Spotted Spider Mite

Tetranychus urticae

Identification: The adult mite is approximately 0.5–1 mm (<1⁄16 in.) in length, barely visible to the naked eye. It is a translucent yellowish colour with two dark spots on the sides of its abdomen.

Damage: Spider mites feed through sucking mouth parts. Injury first appears as a bronzed, stippled effect. Severe feeding causes curling and drying of the leaves. Symptoms are often confused with drought stress.

Biology: Spider mites overwinter as female adults in crop residue or sheltered areas. In early spring, they lay eggs on grassy weeds, in fence rows and in wheat fields. Spider mites often move into beet crops as the wheat fields and other grasses begin to dry down. Under hot, dry conditions, spider mites may complete a generation in as little as 6 days, resulting in numerous generations each year.

Scouting and Thresholds: No thresholds have been established. Look for "bronzed" leaves and for signs of webbing, eggs or mites on the lower leaf surface. If spider mites are present, re-visit the field over a 3–5-day period to determine if the mite population is increasing.

Management Notes: Heavy rain often reduces mite populations to tolerable levels. Beets are most susceptible to mite damage in the period leading up to harvest as the crop is sizing.

White Grubs

See Chapter 5.

Wireworms

Limonius spp.

See Chapter 5.

Disorders

Lightning Injury

A circular patch of affected plants (generally 3–20 m (10–66 ft) in diameter) suddenly appears in the field. Plants toward the outer edge may show less damage.

Leaves will begin to droop, followed by wilting, and in severe cases, death of the plant.

Wind Damage/Sandblasting, Wind Whipping, Dessication

Wind damage occurs in several different forms, including sandblasting, wind whipping and dessication.

Sandblasting (sand abrasion) occurs when light, sandy or exposed soils are eroded by high winds. Stems and leaves on the windward side of the plant develop light, tan-coloured, roughened areas. If severe, sandblasting can stunt or kill plants and significantly reduce yield.

Wind whipping occurs on any type of soil. The whipping and twisting of young plants by strong winds can severely damage or kill the plants. Beet seedlings are very susceptible to wind whipping.

Dessication is most common on tender, young seedlings during strong wind conditions and extreme temperatures.

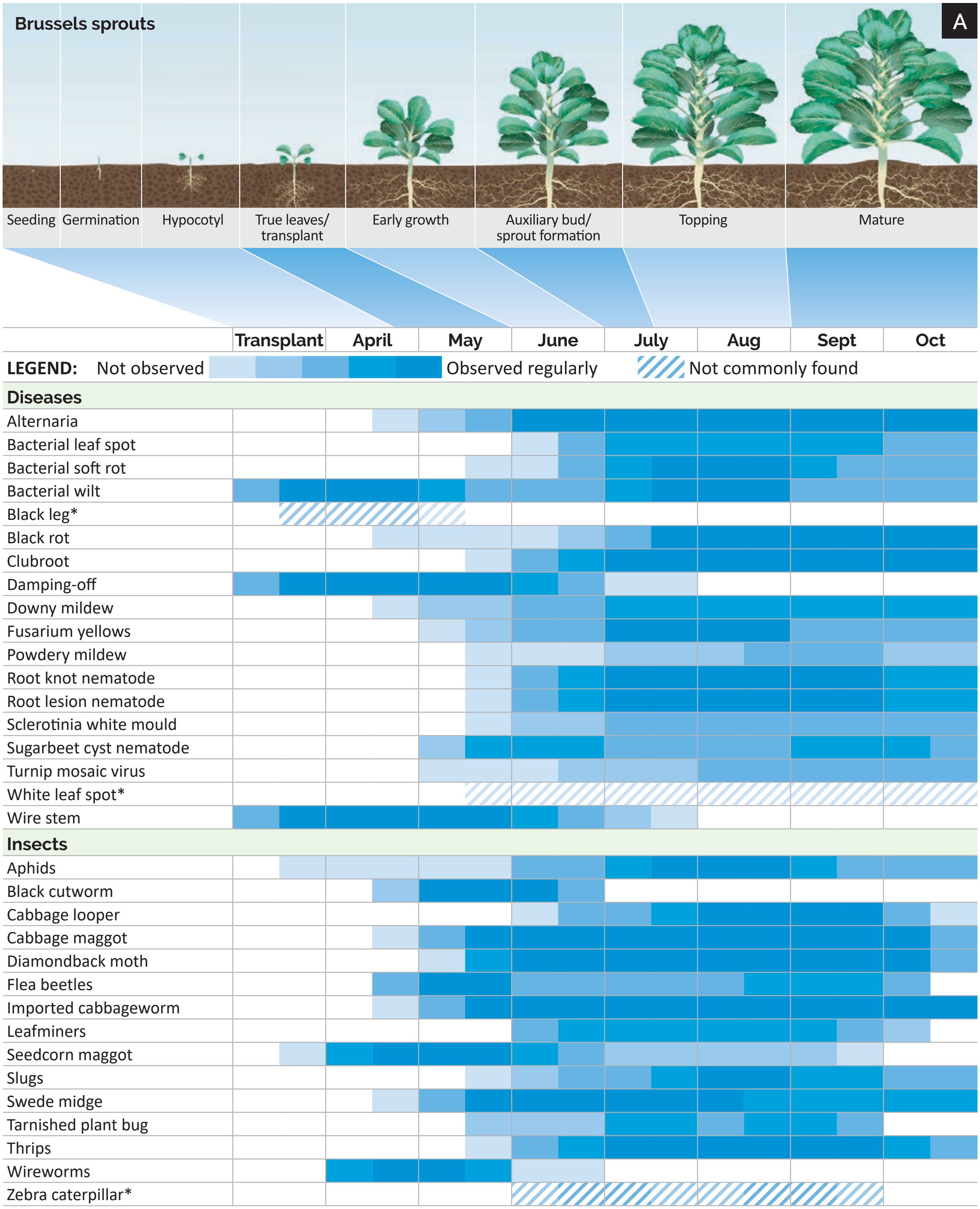
All types of wind damage can predispose plants to foliar diseases. Wind-strips, cover crops and windbreaks will minimize problems due to wind and sand movement.

Vertebrate Pests

Pests such as birds, deer, raccoons, etc., are common in horticulture crops. For more information, see *Vertebrate Pests*, *Sweet Corn*.

Brassica Crops

(broccoli, Brussels sprouts, cabbage, cauliflower and specialty brassicas, including horseradish, kale, kohlrabi, mustard greens and Napa cabbage)



* Not commonly found as a pest in Ontario, however it may be problematic in other jurisdictions.

BRASSICA CROPS

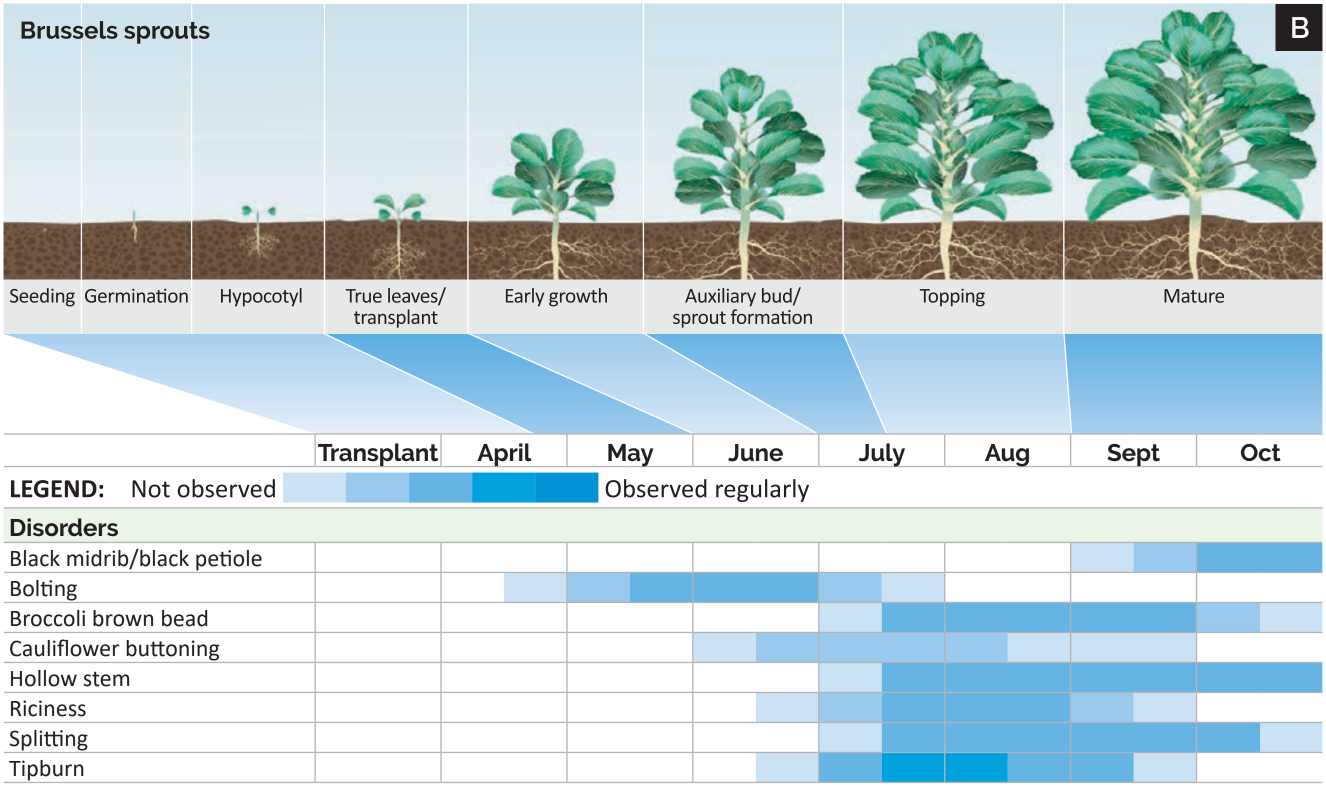


Figure 7–18. (A) (B) Brassica stages of development and pest activity calendar. The actual period of activity for any given pest will vary significantly from year to year, depending on environmental factors.

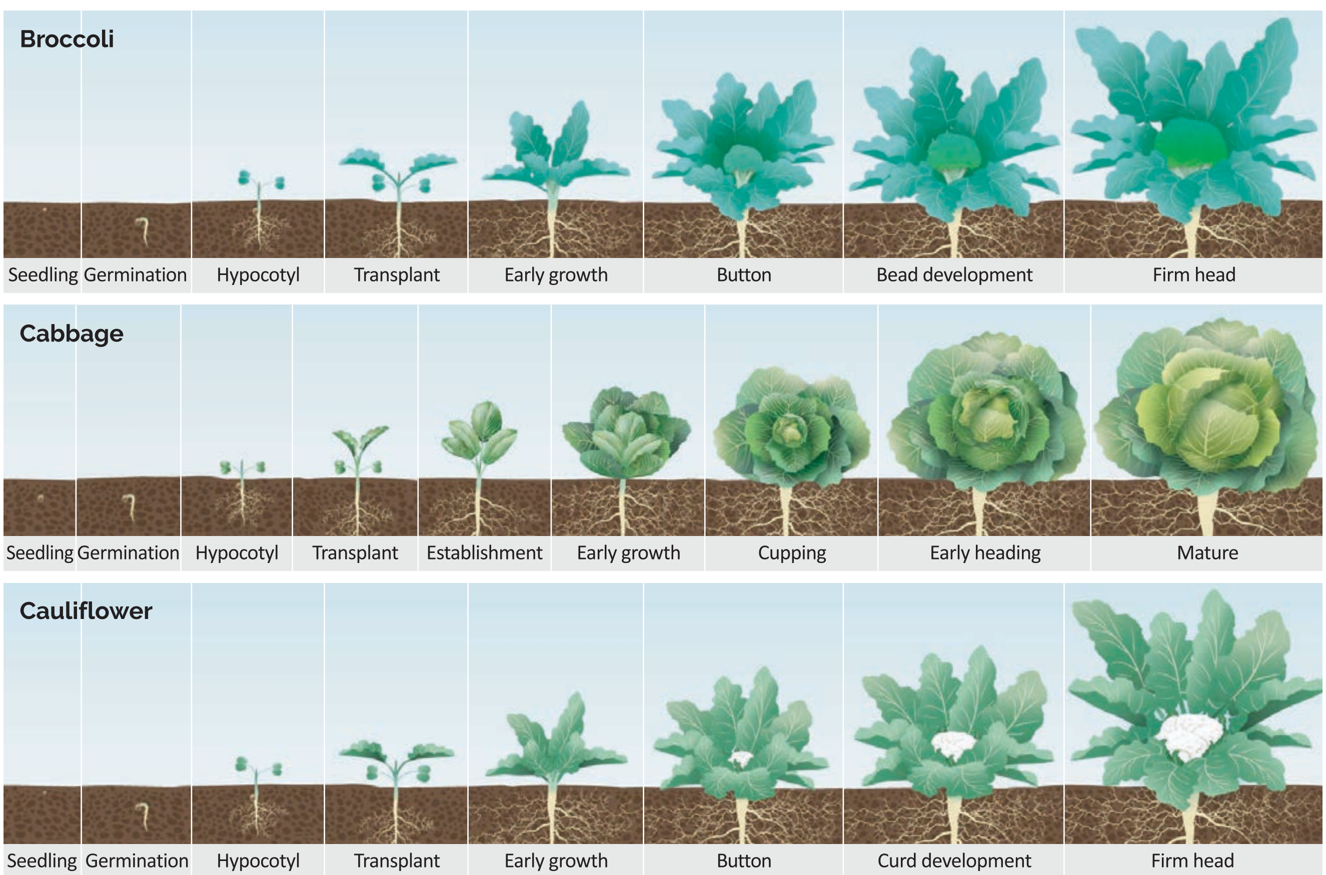


Figure 7–19. Stages of development for broccoli, cabbage and cauliflower.

Production Requirements

Soil types: sand or silt loam
Soil pH: 6.0–6.5 (ideal)
Suitable rotational crops: beans, celery, cereal crops, corn, garlic, onions, peas, peppers and tomatoes
Do not rotate with: other brassica crops, including canola
Minimum soil temperature: 5°C (41°F)
Minimum air temperature: -3°C (37°F) (if transplants are hardened off)
Earliest planting date: early to late April

Table 7–18. Brassica Crops Transplant Requirements

Brassica Crop	Seed Required for 10,000 Transplants	Seeding Depth	Germination Temperature [1]	Days to Germination[2]	Optimum Growing Temperature		pH Tolerance	Time (weeks)
					Day	Night		
Broccoli	57 g	0.6 cm (¼ in.)	29°C (84°F)	4	16°C–21°C (61°F–70°F)	10°C–16°C (50°F–61°F)	6.0–6.8	4–7
Brussels sprouts	57 g	0.6 cm (¼ in.)	27°C (81°F)	5	16°C–21°C (61°F–70°F)	10°C–16°C (50°F–61°F)	5.5–6.8	4–7
Cabbage	57 g	0.6 cm (¼ in.)	29°C (84°F)	4	16°C–21°C (61°F–70°F)	10°C–16°C (50°F–61°F)	6.0–6.8	4–7
Cauliflower	57 g	0.6 cm (¼ in.)	27°C (81°F)	5	16°C–21°C (61°F–70°F)	10°C–16°C (50°F–61°F)	6.0–6.8	4–7

[1] Germination may be possible for many vegetables at lower or higher temperatures, but percentage, speed and uniformity of germination may suffer.
[2] Under optimum germination temperatures.

Seeding and Spacing

The use of transplants from plug trays promotes uniform size and maturity. See Table 7–18. Direct seeding in the field is possible for late summer and fall-heading brassica crops, although this practice is not widely used in Ontario.

Despite the higher initial cost of plug plants, the benefits include better seed use efficiency and reduced transplanting and thinning costs. Plug-raised plants also establish quickly and provide a more uniform and vigorous stand compared to bare-root transplants.

See Table 7–19.

Table 7–19. Brassica Crops Spacing

Crop	Row Spacing	In-Row Spacing	Seeding Rate
Broccoli[1]	60–75 cm (24–30 in.)	30–45 cm (12–18 in.)	300–350 g/ha (124–145 g/acre)
Early cabbage	60–75 cm (24–30 in.)	30–45 cm (12–18 in.)	300–350 g/ha (124–145 g/acre)
Late cabbage	75–90 cm (30–36 in.)	45–60 cm (18–24 in.)	300–350 g/ha (124–145 g/acre)
Cauliflower	75–90 cm (30–36 in.)	45–60 cm (18–24 in.)	300–350 g/ha (124–145 g/acre)
Brussels sprouts[2]	75–90 cm (30–36 in.)	45–60 cm (18–24 in.)	300–350 g/ha (124–145 g/acre)
Horseradish	75–90 cm (30–36 in.)	40–60 cm (16–24 in.)	300–350 g/ha (124–145 g/acre)
Kale[3]	70–80 cm (28–32 in.)	Thinned to 30 cm (12 in.)	300–350 g/ha (124–145 g/acre)
Kohlrabi[3]	70–80 cm (28–32 in.)	Thinned to 10 cm (4 in.)	300–350 g/ha (124–145 g/acre)
Napa cabbage[3]	45–60 cm (18–24 in.)	25–30 cm (10–12 in.)	100–220 g/ha (41–91 g/acre)
Bok choy[3]	45 cm (18 in.)	15–20 cm (6–8 in.)	336 g/ha (139 g/acre)
Chinese broccoli[3]	30–45 cm (12–18 in.)	Thinned to 5–10 cm (2–4 in.)	900 g/ha (372 g/acre)

1 Increase plant spacing for broccoli crops that will be harvested during the hot, humid weather of late August to early September.
2 Square spacing of 60 x 60 cm or even 53 x 53 cm is required to improve the uniformity of Brussels sprouts that are grown for once-over harvesting and/or where smaller sprouts are required for freezing.
3 Direct seeded.

Fertility

Starter Solution

If no insecticide is being added to the planting water, use a starter solution high in nitrogen such as 20-20-20 at 1 kg/200 L and apply 0.2–0.3 L per plant.

Under high temperatures or in dry sandy soils, use a half rate of starter solution, in the same volume of water, to reduce the risk of crop injury.

Macronutrients

Nitrogen

Broadcast and incorporate the required preplant nitrogen with all the required potash and potassium. Side-dress the remaining nitrogen approximately 3 weeks after transplant. See Table 7–20.

Table 7–20. Brassica Crops Nitrogen Requirements

Soil Type	Actual N: Broccoli, Cauliflower, Brussels Sprouts	Actual N: Cabbage	Actual N: Horseradish, Kale, Kohlrabi
Mineral Soils[1]			
Preplant	100 kg/ha (89 lb/acre)	130 kg/ha (116 lb/acre)	80 kg/ha (71 lb/acre)
Side-dress[2]	30 kg/ha (27 lb/acre)	40 kg/ha (36 lb/acre)	30 kg/ha (37 lb/acre)
Total	**130 kg/ha (116 lb/acre)**	**170 kg/ha (152 lb/acre)**	**110 kg/ha (98 lb/acre)**
Muck Soils			
Preplant	70 kg/ha (62 lb/acre)	100 kg/ha (89 lb/acre)	70 kg/ha (62 lb/acre)
1st side-dress	30 kg/ha (27 lb/acre)	30 kg/ha (27 lb/acre)	30 kg/ha (27 lb/acre)
2nd side-dress	30 kg/ha (27 lb/acre)	30 kg/ha (27 lb/acre)	30 kg/ha (27 lb/acre)
Total	**130 kg/ha (116 lb/acre)**	**160 kg/ha (143 lb/acre)**	**130 kg/ha (116 lb/acre)**

1 If rainfall is excessive, an additional 40 kg N/ha may be side-dressed on sandy soils.
2 3 weeks after field setting.

If manure is applied or legume sod is plowed down, reduce the nitrogen application. See Table 1–12 and Table 1–13, Chapter 1, for more information.

Phosphorus and Potassium

Test the soil to determine phosphorus and potassium requirements. See Table 7–21 and Table 7–22.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. See *Micronutrients*, Chapter 1, for more information.

Table 7–21. Brassica Crops Phosphorus Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Sodium Bicarbonate Phosphorus Soil Test (ppm)													
	0–3	**4–5**	**6–7**	**8–9**	**10–12**	**13–15**	**16–20**	**21–25**	**26–30**	**31–40**	**41–50**	**51–60**	**61–80**	**81+**
Broccoli, Brussels Sprouts, Cabbage, Cauliflower														
Mineral Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	270 (241) (HR)	260 (232) (HR)	250 (223) (HR)	240 (214) (HR)	230 (205) (HR)	220 (196) (HR)	200 (178) (HR)	170 (152) (HR)	140 (125) (MR)	110 (98) (MR)	80 (71) (MR)	50 (45) (LR)	0 (RR)	0 (NR)
Muck Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	100 (89) (HR)	100 (89) (HR)	100 (89) (HR)	100 (89) (HR)	90 (80) (MR)	90 (80) (MR)	80 (71) (MR)	70 (62) (MR)	60 (54) (MR)	50 (45) (LR)	30 (27) (LR)	20 (18) (LR)	0 (RR)	0 (NR)
Horseradish														
Mineral Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	180 (161) (HR)	170 (152) (HR)	170 (152) (HR)	160 (143) (HR)	160 (143) (HR)	150 (134) (HR)	140 (125) (HR)	120 (107) (MR)	100 (89) (MR)	80 (71) MR)	50 (45) (LR)	30 (27) (RR)	0 (RR)	0 (NR)

Table 7–22. Brassica Crops Potassium Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Ammonium Acetate Potassium Soil Test (ppm)											
	0–15	**16–30**	**31–45**	**46–60**	**61–80**	**81–100**	**101–120**	**121–150**	**151–180**	**181–210**	**211–250**	**251++**
Broccoli, Brussels Sprouts, Cabbage, Cauliflower												
Mineral Soils												
Potash (K_2O) required kg/ha (lb/acre)	270 (241) (HR)	250 (223) (HR)	230 (205) (HR)	200 (178) (HR)	170 (152) (HR)	130 (116) (HR)	100 (89) (MR)	80 (71) (MR)	50 (45) (MR)	0 (LR)	0 (RR)	0 (NR)
Muck Soils												
Potash (K_2O) required kg/ha (lb/acre)	200 (178) (HR)	190 (170) (HR)	170 (152) (HR)	150 (134) (HR)	120 (107) (MR)	90 (80) (MR)	70 (62) (MR)	50 (45) (MR)	40 (MR)	0 (LR)	0 (RR)	0 (NR)
Horseradish												
Mineral Soils												
Potash (K_2O) required kg/ha (lb/acre)	230 (205) (HR)	220 (196) (HR)	210 (187) (HR)	190 (170) (HR)	160 (143) (HR)	130 (116) (HR)	100 (89) (MR)	80 (71) (MR)	50 (45) (MR)	0 (LR)	0 (RR)	0 (NR)

Boron Deficiency

Boron deficiency has been shown to cause hollow stem in broccoli, but not all hollow stem is caused by boron deficiency. Use caution when applying boron. Many rotational crops are sensitive to high levels of boron in the soil. See Table 1–7, Table 1–8 and Table 1–9, Chapter 1, for more information.

Molybdenum Deficiency (Whiptail)

Molybdenum deficiency rarely occurs in field conditions, however, it results in whiptail-like symptoms in cauliflower, broccoli and Brussels sprouts. The deficiency is usually associated with low soil pH. Molybdenum can be applied in the transplanting water at the rate of 30–40 g of sodium molybdate per 100 L of water, each plant receiving 0.3 L of this solution. See *Micronutrients*, Chapter 1, for more information.

Table 7–23. Brassica Crops Nutrient Ranges

LEGEND: – = no data available

Plant Part	Time of Sampling	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu	Mo
		Per Cent (%)						Parts Per Million (ppm)					
Broccoli													
Most recently mature leaf	heading	3–4.5	0.3–0.5	1.5–4	1.2–2.5	0.23–0.4	0.2	40–300	25–150	45–95	30–50	5–10	0–0.2
Brussels Sprouts													
Most recently mature leaf	at early sprouts	2.2–5	0.2–0.6	2.4–3.5	0.4–2	0.2–0.4	0.2–0.8	50–150	20–200	20–80	30–70	5–10	0.2
Cabbage													
Most recently mature leaf	5 weeks after transplanting	3.2–6	0.3–0.6	2.8–5	1.1–2	0.25–0.6	0.3	30–60	20–40	30–50	20–40	3–7	0.3–0.6
	8 weeks after transplanting	3–6	0.3–0.6	2–4	1.5–2	0.25–0.6	0.3	30–60	20–40	30–50	20–40	3–7	0.3–0.6
Wrapper leaf	heads half grown	3–4	0.3–0.5	2.3–4	1.5–2	0.25–0.45	0.3	20–40	20–40	20–30	30–50	4–8	0.3–0.6
	at harvest	1.8–3	0.3–0.4	1.5	1.5	0.25	0.3	20–40	20–40	20–30	30–50	4–8	0.3–0.6
Cauliflower													
Most recently mature leaf	buttoning	3–5	0.4–0.7	2–4	0.8–2	0.25–0.6	0.6–1	30–60	30–80	30–50	30–50	5–10	–
	heading	2.2–4	0.3–0.7	1.5–3	1–2	0.25–0.6	–	30–60	50–80	30–50	30–50	5–10	–
Chinese Cabbage (heading)													
Oldest undamaged leaf	8-leaf stage	4.5–5	0.5–0.6	7.5–8.5	4.5–5	0.35–0.45	–	–	14–20	30–50	15–25	5–10	–
	at maturity	3.5–4	0.3–0.6	3–6.5	3.7–6	0.4–0.5	–	–	13–19	20–40	30–50	4–6	–
Collards													
Tops	young plants	4–5	0.3–0.6	3–5	1–2	0.4–1	–	40–100	40–100	25–50	25–50	5–10	–
Most recently mature leaf	harvest	3–5	0.3–0.5	2.5–4	1–2	0.35–1	–	40–100	40–100	20–40	25–50	5–10	–

Adapted from G. Hochmuth, et al. 2018. *Plant Tissue Analysis and Interpretation for Vegetable Crops in Florida*. University of Florida IFAS Extension. HS964.

Plant Tissue Analysis

When used in conjunction with a soil analysis, plant tissue analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. For more information, see Table 7–23, and *Plant Tissue Analysis*, Chapter 1.

Irrigation

Brassica crops are usually responsive to irrigation.

Effects of moisture stress: tipburn in cabbage, premature heading in cauliflower, reduced size and quality in all brassica crops

Critical irrigation period: in head brassicas, during head formation and enlargement

Rooting depth: 30–60 cm (12–24 in.)

If the available soil moisture level in the root zone drops to 50% during the critical irrigation period, overhead irrigation could help maintain crop yield and quality. For drip irrigation systems, consider irrigating when the available soil water drops below 85%.

For more information on irrigation scheduling, see the *Irrigation Management* BMP (order number BMP08E) and the OMAFRA factsheet, *Monitoring Soil Moisture to Improve Irrigation Decisions.*

Harvest

See Table 7–24 and Table 7–25.

Table 7–24. Brassica Crops Harvest and Storage

Crop	Harvest Indicators	Expected Maturity	Approximate Storage Life
Broccoli	Cut heads when the clusters are green and compact. This should be before the flowers open and while the floret is still in a tight head.	50–75 days after transplanting	10–14 days
Brussels sprouts (multi-pick harvest)	Crop is mature when the sprouts are firm and well formed. The upper sprouts continue to form and enlarge as the lower ones are harvested.	90–110 days after transplanting with continuous harvest until sprouts are no longer forming	3–5 weeks
Brussels sprouts (single harvest)	Topping will encourage the maturity of the small sprouts at the top of the stem. Topping is done when the sprouts at the bottom of the stem are about 12–20 mm (½–1 in.) in diameter. A full stem of uniform, marketable-sized sprouts will develop about 4 weeks later. Do not de-leaf plants more than 1 day before harvest.	90–110 days after transplanting	3–5 weeks
Cabbage	**Napa:** Harvest when heads are firm and have reached the desired size.	50–70 days after transplanting	2–3 months
	Early: Heads are harvested slightly before the top leaves lose their bright green colour, and the head weighs ~1 kg.	70 days after transplanting	3–6 weeks
	Late: Harvested when they reach the desired size. Outer leaves are trimmed at harvest leaving 3–6 wrapper leaves. Care handling during harvest and processing is crucial to prevent problems in storage.	120 days after transplanting	5–11 months
Cauliflower	To blanch the curds, tie the outer leaves over the heads when the heads are 8–10 cm (3–4 in.) in diameter. In hot weather, blanching may take only 3–4 days. In cool weather, when growth is slow, 8–12 days or more may be required for blanching. Harvest when the curds are compact and fully developed and before they grow loose or separate.	50–125 days after transplanting	3–4 weeks
Collards	Harvest leaves as needed or wait until plant has reached a height of 25 cm (10 in.) and cut at base to create bunch.	70–85 days after planting with continuous harvest every week from June until frost	10–14 days
Horseradish	Dig the crop starting in October. Harvest can continue until the ground is frozen or it can be harvested in the early spring before the roots get woody.	120 days after planting or until average root is over 2 cm (¾ in.) in diameter and over 20 cm (8 in.) long	10–12 months
Kale	Harvest when the leaves are firm, crisp and bright green. Continue harvest of leaves from plant or cut at base and sell as a bunch once plants are 30 cm (12 in.) high.	55 days after planting	2–3 weeks
Kohlrabi	Harvest when stems about 5–8 cm (2–3 in.) in diameter.	50–60 days after planting	2–3 months

Table 7–25. Average Yields of Brassica Crops

Crop	Yield	Standard Container
Broccoli	650–800 cases/ha (260–320 cases/acre)	12, 14 or 18 bunches/ case
Brussels sprouts	11,000–13,500 kg/ha (10,000–12,000 lb/acre)	25-lb case
Cabbage	1,500–2,500 cases/ha (650–1,000 cases/acre)	12 or 16 heads/ case
Cauliflower	1,000–2,000 cases/ha (450–700 cases/acre)	6, 9, 12 or 16 heads/ case
Horseradish	7,500–12,000 kg/ha (6,750–10,800 lb/acre)	pallet box
Kale	45,000 kg/ha (40,000 lb/acre)	bushel or pallet box
Kohlrabi	13,500–18,000 kg/ha (12,000–16,000 lb/acre)	bushel or pallet box

Storage

Prevent the development of rots and disease in storage by removing field heat from the crop as soon as possible. Suitable cooling methods vary depending on the type of brassica crop. Forced air is commonly used with all brassicas. Hydrocooling and package icing are both suitable for Brussels sprouts and broccoli.

Avoid storing brassicas with any other crop that emits ethylene, such as apples. Ethylene can cause premature yellowing or abscission of the leaves in cabbage.

Storage Temperature: 0°C (32°F)
Relative Humidity: 95%–100%
Duration: See Table 7–24.

Pest Management and Disorders

See Figure 7–18, *Brassica stages of development and pest activity calendar.*

Diseases

Alternaria

Alternaria brassicae, A. brassicicola, A. raphani

Identification: Small, yellowish lesions develop on older leaves. As the spots expand, they resemble a "target" with tan concentric light and dark areas. On cauliflower and broccoli, black, sunken spots develop on individual florets and expand to include large areas of the head. Infections on cabbage heads range in size from pinpoints to several centimetres in diameter (Figure 7–20).

Figure 7–20. Alternaria leaf spot on cauliflower leaf.

Biology: Alternaria is seed-borne and spread by wind throughout the summer season. Cool, humid conditions favour black spot development. Spores require at least 9 hours at 15°C–25°C (59°F–77°F) of moisture to germinate and infect. Infected leaves fall, and the fungus grows, infecting marketable portions of the crop.

Scouting: Inspect 10 leaves at each of 20 random locations in the field. Observe both the older and newer leaf growth. Record the percentage of leaves infected and the average number of lesions per leaf. Also note any black spotting on florets or heads when inspecting mature plants.

Management Notes: Adequate air circulation will reduce humid conditions in the canopy. Avoid overhead irrigation once the disease has been diagnosed in a field. If this disease is present in the field, protect the plants with a fungicide prior to harvest. After harvest, incorporate crop debris immediately. Ensure that cabbage heads are free of alternaria before going into storage. In storage, temperatures below 4°C (39°F) inhibit the development of new infections.

Hot-water seed treatment will eliminate both internal infection and external infestation of seed, while fungicide seed treatment will only control spores on the seed.

Rotate with less-susceptible crops such as cereals or corn, and control chewing insects.

BRASSICA CROPS

Figure 7–21. Bacterial leaf spot.

Bacterial Leaf Spot
Pseudomonas maculicola

Identification: Small, yellow circular spots appear on the leaves. As the lesions enlarge, they turn to a rusty brown colour with a yellow halo. Small circular hole-like lesions often appear on the underside of leaves. Under heavy bacterial leaf spot pressure, lesions will merge and kill infected leaves. Bacterial leaf spot rarely infects the petioles (Figure 7–21).

Biology: Bacterial leaf spot overwinters in crop residue and on seed. Development is favoured by cool, wet conditions. Optimal temperatures between 20°C–25°C (68°F–77°F) and at least 10 hours of leaf wetness promote infection and growth. Following the initial infection, splashing water, tools and people can spread the disease, especially when foliage is wet.

Management Notes: Practice a 3-year crop rotation. Use hot-water-treated seed. Obtain seed that is tested to be free of *Pseudomonas*. Grow seedlings in a commercial soilless mix or heat-pasteurized soil. Rotate outdoor seedbeds. Do not transplant diseased seedlings into the field. Avoid overhead irrigation. Manage insect pests that may be vectors for bacteria such as swede midge.

Bacterial Soft Rot
Pectobacterium carotovorum subsp. *carotovorum*

Identification: In brassicas, infected leaf or head tissue often takes on a tan colour, becoming moist and mushy and developing a foul odour. Soft rot may attack the plant below the soil surface, especially when cabbage maggots are present. Rot below ground will cause plants to appear wilted and stunted. Cabbage tipburn and cabbage maggot larvae can provide entry points for the bacteria.

Biology: Bacterial soft rot causes serious losses in the field, in transit and in storage. Insect damage, mechanical damage or hail predispose plants to soft rot infection. Soft rot spreads rapidly in warm, humid conditions. It is spread by direct contact, hands, tools, soil water, insects and splashing rain or irrigation.

The soft rot bacteria overwinter in infected tissues, in the soil and on contaminated equipment and containers. They also overwinter in insects such as the cabbage maggot.

Warm, moist weather is favourable for infection by the bacterial soft rot pathogens.

Management Notes: Plant into well-drained soils and maximize air flow through the plant canopy. Obtain seed that is tested to be free of *Pseudomonas*. Once the disease is identified in a field, avoid overhead irrigation. Rotate with less-susceptible crops (cereals or corn) and control chewing insects. Excess nitrogen may promote soft rot infections. Manage insect pests that may be vectors for bacteria such as cabbage maggot or swede midge.

Storage temperatures below 4°C (39°F) to inhibit the development of new infections in brassica crops and radishes. When infections appear in storage, remove and destroy infected plants. Practice good storage sanitation.

Bacterial Wilt
Pseudomonas syringae pv. *maculicola*

Identification: Water-soaked, wedge-shaped spots form along the leaf margins. Spots may become olive-coloured.

Biology: Bacterial wilt is a seed-borne pathogen. It requires a wound, such as frost injury, sandblasting or mechanical damage, to infect healthy plants.

Management Notes: Excessive nitrogen or overhead irrigation may increase disease levels. Follow good sanitation practices in all greenhouse areas used for transplant production. Manage insect pests that may be vectors for bacteria.

Black Leg

Leptosphaeria maculans

Identification: Seedlings infected with black leg may die or may simply lose their cotyledons. Surviving plants will have stunted growth. On leaves, circular, light brown-to-grey spots develop. The stems of infected plants develop light brown lesions with purplish or black edges. Spores produce sunken, black cankers at the stem base. Tiny black pycnidia can be seen in spots and cankers.

Biology: Black leg overwinters on weeds, seeds and residue from previous year's crop. Pycnidia contain spores that ooze out and spread during wet weather. The optimum temperature for the development of black leg is 5°C–10°C (41°F–50°F). However, plants may be infected at any time in the field. Cut a cross-section in the stalk of the plant and look for discolouration of the xylem tissue.

Management Notes: Follow a 4–5-year rotation away from all brassica crops, including canola. Control brassica weeds. Before planting, treat seeds with hot water or fungicide. Use well-drained fields during months that are typically wet and cool. Avoid working in wet fields. Rogue out diseased plants. Incorporate crop debris immediately after harvest. The black leg pathogen can move with wind and water from adjacent fields. Never store diseased produce. Clean out and disinfect the storage area each spring.

Black Rot

Xanthomonas campestris pv. *campestris*

Identification: Affected crops develop blackened veins and vascular bundles. This is most noticeable when the stems or roots are cut lengthwise or crosswise. In leaves, V–shaped, yellow lesions develop along the leaf margins. As the lesions expand, the tissue turns brown, and the veins become blackened. Infected brassica seedlings grown in the greenhouse under cool conditions may not show symptoms. Upon transplanting into the field where the conditions are warm and humid, they may become symptomatic. Cauliflower and cabbage are the most readily infected among brassica crops (Figure 7–22).

Biology: As little as one infected plant in 10,000 can result in a field epidemic. Black rot is spread rapidly during warm, humid weather with an optimal temperature range of 27°C–30°C (81°F–86°F) at 80%–100% humidity. It can survive in the soil on undecomposed plant debris for up to 3 years. Once in the soil, the bacteria spread by splashing rain and wind. Bacteria enter plants through wounds or natural openings at the leaf margins called hydathodes.

Scouting and Thresholds: Inspect 10 older and newer leaves at each scouting stop. Record the percentage of leaves infected and the average number of lesions per leaf. Hold leaves up to the light to observe black veins.

Management Notes: Use certified disease-free seed and/or hot-water-treated seed. Discard all diseased or unhealthy transplants before planting. Greenhouse sanitation is essential to produce seedlings that are free of black rot. Thoroughly disinfect all surfaces. Where black rot has been present in the greenhouse, discard or disinfect used trays. Follow at least a 2–3-year crop rotation to non-brassica crops and control all brassica weeds. Work all crop debris deeply into soil immediately after harvest.

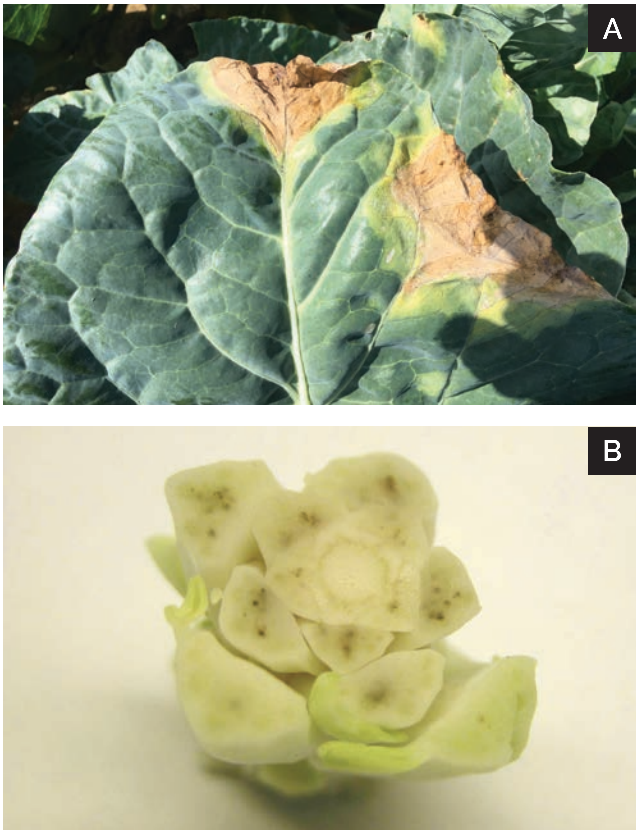


Figure 7–22. Bacterial black rot with characteristic "V" shaped lesion in a leaf (A) and black veins in Brussels sprouts (B) caused by *Xanthomonas campestris*.

BRASSICA CROPS

Clubroot
Plasmodiophora brassicae

Identification: Clubroot will cause wilting, stunting and yellowing of plants in patches in the field. When these plants are pulled, a characteristic thickening or "clubbing" of the infected root tissue is evident. Severely distorted roots have difficulty absorbing water and minerals from the soil (Figure 7–23).

Biology: Clubroot is a soil-borne disease. It affects all members of the brassica family. Spores infect root hairs and multiply, and the next generation of spores infects the main roots and causes clubbing. Clubbed roots will cause yield drag and may kill the plants. Conditions for clubroot infection are most favourable in conditions of 19°C–23°C (66°F–73°F) and high soil moisture levels. Once in a field, the resting spores can persist for over 23 years, and become active when close to brassica roots.

Management Notes: Implement a 3-year crop rotation with non-brassica crops to avoid infection and control brassica weeds. Maintain a soil pH of 7.2 or higher using lime. Practise good biosecurity, clean equipment from other fields, and ensure no soil is left on tires, shoes or any equipment when visiting other farms. Use clubroot-resistant cultivars in fields that historically have shown symptoms of clubroot.

Figure 7–23. Clubroot causing galls on cauliflower roots.

Damping-Off
***Pythium* sp., *Phytophthora* sp., *Rhizoctonia* sp., *Fusarium* sp.**

Identification: Seeds infected prior to emergence rot and typically fail to produce a seedling. If the seedlings do emerge, they are usually weak and lack vigour. Post-emergence infections cause the seedlings to rot at the soil line or develop lesions along the stem.

Biology: *Pythium, Fusarium* and *Rhizoctonia* overwinter in soils and will develop on the seedling in wet and cool soil conditions. Infections commonly occur on heavier soil types, or in poorly drained fields. *Rhizoctonia solani* tends to prefer slightly warmer and dryer soil than the water moulds. Often, *Rhizoctonia* will girdle the stems of susceptible crops slightly above and below the soil line resulting in wire stem. See *Wire Stem,* also in *Brassica Crops*.

Management Notes: Ensure vegetable transplants are grown in sterilized flats and in pathogen-free soil-less mixture in the greenhouse. Do not over-water seedlings and transplants. Before planting into the field, ensure all transplants are healthy, disease-free and vigorous.

When direct-seeding vegetables, plant seeds treated with a registered fungicide seed treatment that controls damping-off pathogens. Do not seed too deep. Plant only when soil and weather conditions are favourable for quick germination, emergence and vigorous crop development.

Scout fields early in the spring soon after planting to assess the plant stand and its establishment. Look for areas of patchy or poor emergence. Dig up non-emerged seedlings or plants and look for symptoms of rotting or stem girdling. Consider applying a biological production that suppresses *Pythium, Fusarium* or *Rhizoctonia* at seeding.

Downy Mildew
Hyaloperonospora parasitica

Identification: Symptoms appear as 1–2 cm (½–¾ in.) yellow spots on the upper leaf surface with corresponding greyish-white growths on the underside. In seedlings, symptoms can appear as the yellowing of cotyledons and white cottony growth on the underside of leaves. Leaves turn dry and papery but rarely drop. Infected cauliflower curds develop dark-grey spots. When the curds are cut open, grey streaks are evident beneath the florets. In broccoli, no lesions are found on the beads but grey streaks occur beneath the beads. This discolouration leads back to the main stem. Cabbage heads develop numerous black spots (Figure 7–24).

Biology: This fungus overwinters in seed and on crop debris and brassica weeds. Downy mildew spores are carried by wind and will float in cool, moist air. Infection occurs at any growth stage. Cool temperatures of 10°C–15°C (50°F–59°F) and prolonged periods of leaf wetness, dew or fog favour disease development. Downy mildew fungi survive for at least 1 year in the soil and 2 years in infected seed. Crops planted in infested soil will become infected.

Scouting and Thresholds: Inspect 10 older and newer leaves at each scouting location. Record percentage of leaves infected and the average number of lesions per leaf. Also note any black spotting on florets or heads when inspecting mature plants.

Figure 7–24. Downy mildew on a brassica leaf.

Management Notes: Plant disease-resistant cultivars into well-drained soil. Avoid overhead irrigation or irrigate only in morning when plants are already moist due to the morning dew. Apply downy mildew–specific fungicides when downy mildew is present in the region or first seen in the field. Follow a minimum 2-year rotation with non-host crops.

Fusarium Yellows

Fusarium oxysporum f. sp. *conglutinans*

Identification: Generally, the lower leaves are the first affected. As the disease progresses, the infected older leaves drop off the plant. Infected seedlings turn yellow and die within 2–4 weeks. The yellowing is often more intense on one side of the plant. Infections occurring later in the season cause severely weakened plants with spongy or hollow roots. The vascular tissue of infected roots becomes yellowish-brown. Affected plants are often stunted, lopsided and have black veins. Plants may be affected at any time during growth.

Biology: There are a number of races of this fungus that attack different members of the crucifer family. For instance, the race that attacks cabbage may not attack radish. Fusarium wilt is both soil- and seed-borne. Spores enter roots through wounds on older roots. Inside the plant they move to xylem and multiply when temperatures are between 16°C (61°F) or below 32°C (90°F).

Fusarium wilt grows best at soil temperatures of 27°C–29°C (81°F–84°F). Spores are produced on dead plant tissue and spread on soil particles, wind-blown soil, farm implements and surface water.

Scouting and Thresholds: Cut open the stem and inspect suspect plants for discoloured xylem. Record the number and location of any infected plants. Take note of any wilted leaves.

Management Notes: Resistant cultivars are available. Use certified, treated seed. Follow a 2–3-year crop rotation to reduce inoculum; however, be aware that this disease can survive in the soil in the absence of a host plant for several years. This disease is less common on high pH soils. Maintain a balanced soil pH. Potassium deficiency may further aggravate this disease.

Powdery Mildew

Erysiphe cruciferarum

Identification: In most vegetable crops, initial symptoms usually appear on the older, shaded leaves. A dense, white fungal (powdery) growth develops on the lower leaf surface. A pale green-to-yellow discolouration may also appear on the corresponding upper leaf surface. The white, powdery growth spreads to the upper leaf surface and down the petiole. Infected leaves and stems turn yellow, wither and die prematurely.

Biology: The pathogens causing powdery mildew do not overwinter in the field in Ontario. Wind-borne spores usually arrive from the southern U.S. and Mexico in mid-summer. Peak infection periods occur when temperatures are in the range of 20°C–26°C (68°F–79°F). Disease development slows when temperatures climb above 26°C (79°F).

Infections can develop at relatively low humidity (<20%) levels, although humid weather conditions and heavy dews lead to more rapid disease development. Under these conditions, visual symptoms may appear 3–7 days after the initial infection.

Management Notes: There are varying levels of tolerance among brassica cultivars. Fungicides are available that may offer suppression of the disease, but good coverage on both the upper and lower leaf surfaces is essential.

Powdery mildew is difficult to detect in its early stages. The underside of leaves must be checked to detect spore growth. Once mildew and yellowing are present on the upper leaf surfaces, the disease is quite advanced and unlikely to respond to fungicide applications.

Root Knot Nematode
Meloidogyne hapla

Identification: Plant can have stunting, yellowing of leaves, uneven growth and wilting in the hottest part of day. This issue begins as small patches in the field. Root knot nematodes increase severity of root pathogens (e.g., *Fusarium*). Root knot nematode is similar to clubroot, but root galls are smaller.

Biology: Eggs hatch when soil temperatures reach 18°C (64°F). Juvenile nematodes enter the root, where they establish a feeding site until it moults into the adult stage. Feeding induces formation of root galls.

Scouting and Thresholds: When scouting, use a shovel to carefully dig roots and look for galls on roots. If found, dig in multiple areas and record the percentage of field infested.

Management Notes: Maintain a minimum 3-year crop rotation and avoid crops such as onions and barley. Early-season crops such as peas, spinach or radish grow in cooler weather before nematode activity reaches its peak in season. Destroy infested plants at harvest.

Root Lesion Nematode
Pratylenchus penetrans, P. crenatus

Identification: Plants can have chlorotic, yellow leaves and stunted growth. Under high stress conditions, plants may wilt. Often found in patches or along rows. Secondary roots appear dry with dead brown regions/lesions. Secondary rots on roots may occur.

Biology: Eggs hatch and move toward susceptible host. Nematodes use their stylet to penetrate cell and gain access root. They feed and reproduce in the root usually on the cortex of the root. Females lay eggs inside of root. Reproduces optimally between 15°C–25°C (59°F–77°F).

Management Notes: Select tolerant cultivars. Plant early to avoid favourable conditions for nematode. Avoid rotations with soybean, wheat, canola, oats, rye, chickpea and mustard. Short rotations with very susceptible crops will select for high populations. Growing forage millet or pearl millet in rotation can decrease numbers.

Sclerotinia White Mould
Sclerotinia sclerotiorum

Identification: In brassica crops, white mould appears as water-soaked spots on the lower leaves or on the head. The infected tissue often turns grey, giving rise to a fluffy white mould in wet weather. Hard, black sclerotia eventually form on the white fungal growth.

Biology: White mould overwinters in the soil as small, black (pea-sized) sclerotia for up to 8 years. Spores are produced from sclerotia when soil moisture in the top inch of soil remains near saturation for 10 days and over 10°C (50°F). Spores are blown from sclerotia near the soil surface. The initial infection occurs during flowering and early pod development. Temperatures ranging from 20°C–25°C (68°F–77°F) and continuous leaf wetness (high humidity and/or heavy dews) favour disease development.

Scouting and Thresholds: Record the incidence of plants infected with *Sclerotinia* at each location.

Management Notes: Practise a 3–4-year crop rotation away from susceptible crops (cucurbits, edible beans, soybeans, canola, carrots and lettuce). Choose fields with well-drained soil. Avoid applying high rates of nitrogen fertilizer. Excess nitrogen promotes an exceptionally dense crop canopy, resulting in restricted air movement and more favourable disease development conditions.

Sugarbeet Cyst Nematode
Heterodera schachtii

Identification: Oval or elongated patches of plants appear stunted, yellow or lighter green, unthrifty, with delayed maturity or flowering. Small white-to-cream or yellow-coloured immature lemon-shaped cysts attached to roots. Cysts turn brown at maturity and show no visible foliar symptoms in fields with relatively low population levels. High levels in the field may produce patches of areas of stunted plants that will wilt during hot and dry weather.

Biology: Nematodes feed on roots after hatching from egg. Males leave the root after feeding for a few days. Females attach to the root, lose the ability to move and swell into small, lemon-shaped white cysts.

Scouting and Thresholds: Established threshold is 2,000 nematodes or eggs/kg soil, or 251+ cysts/kg soil. When scouting, use a shovel to carefully dig roots and look for cysts on root hairs. If found, dig in multiple areas and record the percentage of field infested.

Management Notes: Before deciding upon a management strategy for nematodes, complete a nematode soil test to determine the levels of nematodes present. In Ontario, nematode populations in soil and roots are usually at their highest in May to June and again in September to October. The fall months are a good time to soil sample for nematodes, as the populations are high and controls can be taken well in advance of planting the next crop. Plant tolerant cultivars, and rotate with non-host crops including grains, corn, soybeans or alfalfa. Plant cover crops to prevent wind blowing infested soil to non-infested fields. Plant early in season in infested fields to avoid favourable environments for nematodes.

Turnip Mosiac Virus (TuMV)

Identification: Infected leaves exhibit mottling (yellow or light green areas surrounded by normal green colour), and wrinkling or puckering of the leaf tissue between the veins. It can also cause necrotic ring spots. TuMV is often confused with herbicide injury.

Biology: This virus requires a living host. TuMV overwinters in volunteer rutabagas and winter canola. It is vectored by green peach and cabbage aphids. It can also be transmitted mechanically.

Scouting and Thresholds: When scouting, document the location of infected plant within the field, and rogue infected plants if possible.

Management Notes: Avoid planting near fields (5 km) that were planted in rutabaga or winter canola in the previous year. Volunteer rutabagas growing in fields of wheat, barley or other crops can allow for severe outbreaks. Ensure infected plants are removed. Manage aphid populations to reduce rate of virus.

White Leaf Spot
Pseudocercosporella capsellae

Identification: Infected leaves exhibit scattered, circular, white-to-tan spots. These spots become white and papery, enlarging as the disease develops. Heavily infected plants show severe spotting, with some defoliation. On waxy-leafed brassica crops, the lesions take on a branching shape.

Biology: White spot persists on cruciferous weeds and crop debris. Cool temperatures from 12°C–18°C (54°F–64°F), rainfall and long periods of humidity support disease development. Spores are spread by wind, splashing rain and irrigation. The disease does not spread in warm weather.

Management Notes: Control brassica weeds. Crop rotation and planting on well-drained soil can help.

Wire Stem
Rhizoctonia solani

Identification: Wire stem symptoms include pre-emergence damping-off where seedlings fail to emerge. Post-emergence damping-off (similar to *Pythium* spp.), in which lesions on lower leaves develop, can also be observed. Purpling on the lower leaves and lower stem becomes constricted. Seed decay, rotting roots and cankers on lower petioles can also be observed. Often confused with wireworm (Figure 7–25).

Biology: Seeds with spores inoculate seedbeds or trays. Infection occurs when cool, wet weather allows mycelium to penetrate roots and other plant tissues. The mycelium grow and infect between cells, and sclerotia may be found between leaves. This fungus survives in the soil and crop debris in the form of a sclerotia, a hardened mass of fungal threads. Soft rot bacteria may invade tissue colonized by *Rhizoctonia*. This fungus can be spread by wind, water and machinery.

Management Notes: Ensure propagation trays and equipment are sterilized. Use fungicide-treated seeds. Avoid overcrowding of seedlings and improve ventilation. In greenhouses and cold frames, avoid using cold water. Pre-warm water before irrigation. Ensure there is adequate drainage in flats/trays.

Figure 7–25. *Rhizoctonia solani* causing wire stem on recently transplanted Brussels sprouts.

Insects

Aphids
Aphididae family

Identification: There are several aphid species affecting brassica crops in Ontario, including the green peach aphid, cabbage aphid, turnip aphid and turnip root aphid. Aphids are small, soft-bodied, pear-shaped insects, with cornicles or “tail-pipes” near the tip of their abdomen. They have relatively long legs and prominent antennae. Colour may vary depending on the species and the host plant. A few species found in vegetable crops have a waxy or woolly appearance.

Wingless aphids establish colonies in the field, on the underside of the leaves or along the stems or petioles. Winged aphids form under crowded conditions, allowing them to migrate to new food sources.

Damage: Aphids often congregate on new growth. They pierce the leaves and suck the sap from the plant, causing leaf distortion, stunting, delayed maturity and wilting. Feeding damage interferes with the uptake of water and nutrients. It also opens the plant up to other insect and disease problems. Aphids also secrete toxins that can lead to leaf curling. Aphids are often a major concern on Brussels sprouts as each of the sprouts is a growing point that aphids often target.

While feeding they exude a sticky substance called “honeydew.” Honeydew, and the moulds associated with it, may affect the marketability of the harvested product.

Aphids also act as a primary vector of several economically significant virus diseases in either a persistent or non-persistent manner. The control of aphid populations with conventional insecticides does little to prevent the spread of non-persistent viruses.

Biology: Most aphids overwinter as eggs on primary hosts, such as weeds, and migrate to vegetable crops in the summer. Populations increase rapidly under favourable conditions, including hot, dry weather.

Scouting and Thresholds: Aphid distribution may be patchy within a field. Populations are often higher along field margins and hedgerows. Inspect the underside of leaves from the top, middle and bottom of plants. Note the presence of aphid honeydew on the foliage and fruit. Natural predators (lady beetles, lacewings, minute pirate bugs, etc.) or parasitoids (*Aphelinus* and *Aphidius* spp.) often help keep aphid populations below threshold levels. Look closely to distinguish live aphids from dead aphids and moulted skins. Aphids may also be found on the roots of weed hosts such as lamb's-quarters and pigweed.

Management Notes: When controlling other insect pests, select pest control products that are safer for beneficial insects. Broad-spectrum insecticides may also control natural enemies, resulting in higher aphid populations. Note that the sunflower aphid and the green peach aphid may have developed resistance to insecticides in some areas. Lamb's-quarters and pigweed are alternative hosts of some root aphids; crop rotation and weed management may help reduce their numbers. Destruction of infested crops following harvest may prevent excessive dispersal.

Black Cutworm
Agrotis ipsilon

Identification: Cutworm larvae are soft and fat, and they roll up when disturbed. Mature larvae can be as large as 3–4 cm (1–2 in.) in length. Black cutworms are grey to black with no striping on the body, whereas most other cutworms have stripes along their back or sides.

Damage: Cutworm damage occurs most often in late April and early May, coinciding with early-season planting and emergence of seedlings. Larvae cut the petioles or stems of seedling plants below or at the soil surface. Most of their damage is found at the field edge or in weedy fields. One cutworm can kill several plants before it reaches full size and pupates. Most species of cutworms feed at night, hiding during the day in the soil near the base of the plant (Figure 7–26).

Biology: Most species of cutworm do not overwinter in Ontario. In the early spring, adult moths are transported on the trade winds from more southerly areas. Females are attracted to dense, green cover to lay their eggs. Often, when they arrive in Ontario in early spring, the main source of habitat for the females are winter annual or perennial weeds. Cutworms are therefore more frequent in fields with green cover early in the spring before primary tillage. Egg-hatching and larval feeding often coincide with planting and crop emergence.

Figure 7–26. Recently transplanted Brussels sprouts showing cutworm damage.

Scouting and Thresholds: Most species of cutworms feed at night, hiding during the day under loose stones or in the soil near the base of the plant. Scouting is best done in the middle of the day, when the water demand of plants is high. Check for cutworm damage by walking through the field and looking for wilted and/or fallen plants. If any are found, dig around in the soil at the base of the plant to find the cutworm. Make control decisions based on the number and size of larvae found. Scouting should be completed 3x per week, targeting crop borders and weedy areas. For brassica crops, the control guideline is 5% damaged plants.

Management Notes: Cutworm control is most effective on small larvae that are less than 2.5 cm (1 in.) in length. Larger larvae are difficult to control with insecticides. At more mature stages where the cutworms are greater than 2.5 cm (1 in.) in length, they cease feeding as they prepare to pupate, and management becomes unnecessary. Apply insecticides in the early evening, as the cutworms come to the surface to feed at night. Insecticides are more effective on moist soils.

BRASSICA CROPS

Cabbage Looper

Trichoplusia ni

Identification: The cabbage looper larvae is smooth and pale green, with a thin white line along each side and two faint lines down the middle of the back. The larvae are up to 4 cm (1½ in.) long. They move in a very distinctive "looping" manner similar to an inch worm. The larvae leave behind dark green frass in piles. The pupa is initially light green in a loose cocoon, darkening in colour as it matures. Adult moths are mottled greyish-brown with a wingspan of 4 cm (1½ in.). They have a distinctive silvery figure-eight pattern on their forewings and a slight tuft of hair behind the head. Eggs are small, rounded and greenish-white. They appear in small groups on the underside margins of leaves (Figure 7–27, Figure 7–28 and Figure 7–29).

Damage: Small larvae feed on the underside of leaves, while more mature larvae chew large, irregular holes throughout the plant. Large amounts of dark, brown-green frass can also stain cauliflower heads and make cabbage and broccoli unmarketable. Cabbage looper's presence is virtually unpredictable, and it may show up in one field and not in the adjacent field.

Biology: Cabbage looper do not overwinter in Ontario. The adults travel on weather patterns from the south in mid-summer to early fall. They are often found earlier in the Southwestern Ontario municipalities of Chatham-Kent and Essex. There may be 1–2 generations in Southern Ontario, depending upon the time of arrival and temperatures during August and September.

Scouting and Thresholds: Count the number of cabbage looper, diamondback moth and imported cabbageworm larvae on 25 randomly selected plants in the field. See *Diamondback Moth* and *Imported Cabbageworm*, also in *Brassica Crops*. There are two ways to quantify caterpillar infestations, using cabbage looper equivalents (CLE) or the per cent infestation method. See Table 7–26.

Management Notes: Insecticides are most effective against small larvae. Begin application of insecticides when young larvae are found. Continue on a 5–10-day schedule, or as determined by scouting.

Table 7–26. Thresholds for Brassica Lepidopteran Pests

	Cabbage Looper Equivalent Method	Per Cent Infestation Method	
Cabbage	0.3	before head fill	20%–30%
		after	10%–15%
Cauliflower and broccoli	0.2–0.3	before head fill	20%–30%
		after	5%–10%

Cabbage Maggot

Delia radicum

Identification: The cabbage maggot adult is a grey fly, approximately half the size of the common housefly. The female lays eggs in the soil at the base of seedlings. The small, white eggs look like tiny (1 mm) grains of rice. The larvae are small (7 mm (¼ in.)), legless and white.

Damage: Cabbage maggots tunnel and feed along the roots of brassica crops. Brassica crop seedlings are very susceptible to damage by the cabbage maggot. Plants are most susceptible to damage from the seedling stage to 1-month after transplanting. These wounds also act as points of entry for soft rot bacteria.

Biology: Cabbage maggots overwinter as pupae in the soil. There are three periods of egg-laying throughout the season. The first generation is the most active and most damaging. It occurs from mid-May through June (flowering of yellow rocket). A second occurs in mid-July (flowering of day lilies) and a third in late August (flowering of goldenrod).

Hot, dry conditions reduce maggot survival, especially for the later generations. Damage from all three generations may be expected in cooler regions of the province. Crops receiving irrigation, root crops and most specialty brassicas are more susceptible to this pest.

Scouting and Thresholds: Growing degree days (base of 6°C) may be used to predict cabbage maggot activity. First-generation adults emerge between 314 and 398 GDDs. Second-generation adults emerge between 847 and 960 GDDs. Third-generation adults emerge between 1,446 and 1,604 GDDs. See *Growing Degree Days*, Chapter 4, for more information. Time control of root maggots to coincide with the egg-laying activity of each generation.

Management Notes: Cabbage root maggot management is primarily preventive. Later plantings of brassica crops are less likely to require protection. Follow a 3–4-year crop rotation. Do not grow early and late rutabagas in the same field and avoid growing rutabagas near winter canola, early broccoli, cabbage or cauliflower.

Figure 7–27. Eggs (top left) and larvae of diamondback moth (bottom left), imported cabbageworm (middle) and cabbage looper (right). *Source:* (imported cabbageworm larvae) Dr. Mary Ruth McDonald.

Figure 7–28. Pupae of diamondback moth (left), chrysalid of imported cabbageworm (middle) and pupae of cabbage looper (right). *Source:* (cabbage looper pupae) Dr. Whitney Cranshaw.

Figure 7–29. Adult diamondback moth (left), imported cabbageworm butterfly (middle) and cabbage looper moth (right). *Sources:* (diamondback moth) Russ Ottens; (imported cabbageworm butterfly) Dr. Mary Ruth McDonald; (cabbage looper) Dr. Whitney Cranshaw.

Diamondback Moth
Plutella xylostella

Identification: Diamondback moth (DBM) eggs are scale-like, laid in small groups. The larvae are small, hairless, pale green caterpillars with tapered ends; the rear legs extend in a "V" from the body. When disturbed, they wiggle frantically, attach a silken thread to the leaf and dangle over the edge. Pupae create small, gauze-like cocoons. The adult DBM has diamond-shaped spots along the centre of its back. See Figure 7–27, Figure 7–28 and Figure 7–29 for visuals of eggs and larvae compared to cabbage looper and imported cabbageworm.

Damage: On brassica crops, DBM larvae chew through the inner-leaf layers, leaving the waxy epidermis, creating a "window-pane." See Figure 7–29 for a comparison of diamondback moth damage compared to cabbage looper and imported cabbageworm.

Biology: Infestations of DBM begin very early in the season. The DBM has traditionally not overwintered in Southern Ontario. The majority of adult moths arrive from the south during May and June. However, there is evidence that in some cases, and during mild winters, some may survive in Ontario. Depending upon temperatures, there may be 2–4 generations per year in Ontario.

Scouting and Thresholds: Scouting is an excellent way to assess the population of brassica crop caterpillars. For brassica crops, count the number of cabbage looper, imported cabbageworm and diamondback moth larvae on 25 randomly selected plants in the field. There are two ways to quantify caterpillar infestations, using cabbage looper equivalents (CLE) or per cent infestation method. See Table 7–26.

Management Notes: Insecticides are most effective against small larvae. Begin application of insecticides when young larvae are found and continue on a 5–10-day schedule, or as necessary for adequate protection of the crop.

Diamondback moth develops resistance very quickly. To limit the development of resistance, alternate between chemical groups. Use pyrethroid insecticides during the fall, as they are more effective under cool conditions.

Flea Beetles
Phyllotreta sp.

Identification: Two main species are crucifer flea beetle and striped flea beetle. Flea beetles are small (2–3 mm (~⅛ in.) long), shiny black beetles. Adults are active and jump when disturbed.

Damage: While these beetles attack all brassicas, they prefer the non-waxy, leafy brassicas. Feeding damage consists of numerous very small "shot-holes," 1–5 mm in diameter. Older damage may be ringed with brown, dried leaf tissue, while fresh feeding holes have green edges. At the seedling stage, flea beetle feeding can kill the plant.

Flea beetles and their larvae may feed on cotyledons and leaves. They are unlikely to cause significant damage unless populations are very high during the seedling stage, especially if the plants are growing slowly in cool conditions. Foliar feeding could be a concern for bunching beets or beet greens.

Biology: Flea beetles in Ontario generally have one generation per year. The lifecycle from egg to adult may take as little as 7 weeks, making a second generation possible in some years. Adult flea beetles overwinter in leaf litter. They emerge and begin feeding on young plants in mid-May. Adults lay eggs near the roots of host plants throughout the spring and early summer. Larvae develop on the roots. In late July, adults emerge from the soil, feed and then seek hibernation sites in the fall. Feeding damage can allow for the entry of xanthomonas black rot.

Scouting and Thresholds: Begin monitoring for flea beetles as soon as the transplants are set in the field. Try to make counts as you approach the plant — flea beetles are very active and will jump. Flea beetles prefer sunny areas and isolated plants. Inspect 25 randomly selected plants throughout the field for flea beetles and damage. Up to the 6-leaf stage, plants can tolerate no more than 1 flea beetle per plant. After this stage, feeding will not interfere with plant growth. Feeding damage at later stages may impact marketability and crop quality.

Management Notes: Early brassica crop plantings may be protected with row covers. Transplants are less susceptible to damage than direct-seeded crops.

Beetles tend to prefer specialty crops (e.g., Chinese cabbage, bok choy, daikon) over head brassica crops. Trap crops, such as Indian mustard, have worked well in traditional brassicas. If black rot is present in the field, flea beetle management is important, as the beetle can spread black rot as it feeds.

Imported Cabbageworm

Pieris rapae

Identification: Imported cabbageworm (ICW) eggs are yellow and ridged like a bullet. The larvae are leafy green and velvety in appearance, with a pale-yellow stripe down the centre of the back. They are mobile, but sluggish and leave behind dark green frass near feeding holes. The adult ICW is a white butterfly that is a day flier. See Figure 7–27, Figure 7–28 and Figure 7–29 for visuals of eggs and larvae compared to cabbage looper and diamondback moth.

Damage: ICW chew large, ragged holes in the leaves. See Figure 7–29 for a comparison of imported cabbageworm damage compared to cabbage looper and diamondback moth.

Biology: The ICW overwinters in Ontario. Adults emerge mid-to-late May and can often be seen flying during the day around brassica crop fields. Each female ICW is capable of laying between 200–300 eggs. Depending on temperatures, eggs hatch in 3–7 days, and the larvae begin feeding. The larvae grow quickly to maturity in about 2 weeks. Once mature, larvae enter the pupal stage, which lasts about 2 weeks, and the new adults emerge. There are 3 generations of cabbageworm in Ontario. Infestations of ICW can last until the first hard frost in the fall.

Scouting and Thresholds: Scouting is an excellent way to assess the population of brassica crop caterpillars. For brassica crops, count the number of cabbage looper, imported cabbageworm and diamondback moth larvae on 25 randomly selected plants in the field. There are two ways to quantify caterpillar infestations, using cabbage looper equivalents (CLE) or per cent infestation method. See Table 7–26.

Management Notes: Insecticides are most effective against small larvae. Begin application of insecticides when young larvae are found, and continue on a 5–10-day schedule, or as necessary for adequate protection of the crop. Use pyrethroid insecticides during the fall, as they are more effective under cool conditions. To limit the development of resistance, alternate between chemical groups.

Leafminers

See Chapter 5.

Seedcorn Maggot

Delia platura

Identification: Small, translucent white maggots less than 6 mm (¼ in.) in length, that are legless and have an oblong-shape with a pointed anterior. Pupae are small — 4–5 mm long — brown and oblong. The adult is a small 6 mm (¼ in.), slender, grey-black fly.

Damage: Maggots burrow into germinating seeds and the below-ground parts of emerging seedlings. Poor stand establishment is often a symptom of infestation. Damage is worse when cold, wet conditions slow germination. Later in the season, seedcorn maggot flies may lay eggs inside the heads of nappa cabbage during hot, dry conditions. Larvae then feed on inner leaves, creating a ragged appearance, rendering the heads unmarketable. Pupae may also be observed within the head.

Biology: The seedcorn maggot overwinters as a pupa in the soil. Adults emerge in early spring. Females are attracted to moist soils that give off an odour of decaying organic matter, such as crop residues, areas where manure has been freshly applied or freshly tilled soil. There are 3–6 generations per year in Ontario, however, the first generation is generally the most damaging. First-generation females lay their eggs from April until the middle of June. Larvae hatch in 7–10 days and remain in the field for 1–3 weeks feeding on residue, seeds and young seedlings.

Scouting and Thresholds: Yellow sticky cards may be used to monitor adult activity. Look for signs of poor stand emergence and feeding damage at the base of emerging plants. No thresholds have been established.

Management Notes: Seedcorn maggot management is primarily preventive. Rescue treatments are not available. Use an insecticide seed treatment if available. Egg-laying females are attracted to moist soils and the odour of decaying organic matter. Discourage egg-laying by applying manure or incorporating winter cover crops well in advance of planting.

Slugs

Arion sp., *Deroceras* sp., *Helix* sp., *Limax* sp.

Identification: Slugs are soft-bodied, legless, grey molluscs that have variations in colour from dark brown and black to light grey. In Ontario, slugs range in size from 0.5–10 cm (¼–4 in.) in length, depending on the species.

Damage: Slugs have rasping mouth-parts and will create ragged holes on the lower leaves, sometimes leaving a "window-pane" of waxy cuticle behind.

Biology: There is one generation per year, but two populations: one maturing as adults in the spring and one maturing in the fall. Both populations can cause crop injury. Under dry conditions, slug eggs can lay dormant for long periods of time. Slugs travel by gliding on a secreted stream of mucus.

Scouting and Thresholds: Scout for slugs at night or early morning, when they are active. Check under debris near damaged plants, and look for slime trails on the underside of lower leaves

Management Notes: Most plants can successfully outgrow light feeding damage. Cultivating fields where slug pressure is high can help reduce the slug population. Tillage exposes the slugs to dehydration and predation by birds and mammals.

Removing weeds and crop residue from the zone immediately surrounding young seedlings may also help reduce damage. Zone tillage can remove slug habitat while maintaining the benefits of reduced tillage.

Swede Midge

Contarinia nasturtii

Identification: Clusters of eggs are laid on the youngest plant tissue. The translucent-to-creamy-yellow-white larvae are 3 mm (⅛ in.) in length when mature. When disturbed, larvae jump off plants. Adults are small — 1.5–2 mm (<⅛ in.) — light brown flies that are difficult to distinguish from other closely related midge species present in Ontario.

Damage: Swede midge larvae, the destructive life stage, feed on all brassica crops. Severity of damage is directly related to crop development at the time of attack. Damaged seedlings often appear twisted and may have a noticeable brown scar or a gall at the growing point. Also look for brown, corky scarring along the leaf petiole. Heart leaves become crinkled and crumpled. If damage occurs before the plant reaches the button stage, the plant may be barren or blind. Later feeding injury results in twisted and distorted heads.

Figure 7–30. Swede midge damage in broccoli (A) and swede midge larvae on cabbage leaf (B).

BRASSICA CROPS

Biology: First-generation swede midge adults emerge from overwintering from mid-May to the beginning of June. Swede midge adults may be present until early October, and larvae may be found on plants until mid-October. There are four to five overlapping generations of swede midge in Ontario. Female lays eggs in clusters or strings of 15–20 eggs in the growing point/meristem. These eggs hatch in 3 days, and after 2–3 weeks, the larvae jump off plant, spin a cocoon and pupate for 2 weeks. Pupae can remain dormant for up to 2 years.

Scouting and Thresholds: Use a pheromone trap to monitor swede midge populations throughout the growing season. Check traps two or three times a week and apply insecticides as soon as possible once the threshold is reached. See Table 7–27.

Table 7–27. Swede Midge Thresholds for Brassica Crops

Crop	Number of Swide Midges
Cabbage	5–10 males/trap/day
Broccoli (in regions of low swede midge populations)	1 male/trap/day

Management Notes: Chop and bury infested residue immediately after harvest. Most pupae are found within the top 5 cm (2 in.) of the soil and may remain dormant for 2 years. A 2–3-year rotation away from brassica crops is essential. Swede midge are weak fliers, and moving next year's crop over 200 m from the previous year's crop will help lower incidence. Plant the following year's crop upwind of the prevailing winds. Brassica weeds may act as reservoirs for swede midge populations even in the absence of a brassica crop.

Foliar insecticides targeting adult swede midge are used with some success. Systemic insecticides are required to kill the larvae. Rotate insecticides to prevent the development of resistance.

Tarnished Plant Bug

See Chapter 5.

Thrips

Thrips tabaci, *Frankliniella occidentalis*

Identification: Thrips are small (<3-mm (<⅛ in.) long), soft-bodied insects. Adult thrips have straw-brown bodies and four wings fringed with hairs. Nymphs are smaller, wingless and pale white in colour.

Damage: Thrips have sucking-rasping mouth parts and cause tissue damage when they feed on the leaves. Thrips feed on all brassica crops, however cabbage appears to be the most susceptible. Brassica plants respond by forming scar tissue at the feeding site, giving the leaf a rough, rusty, warty appearance. On cauliflower, brown/tan streaks can be observed. Severe injury may cause reduced yields and increase susceptibility to diseases. Thrips are especially damaging to late-season cabbage and cauliflower.

Biology: In Ontario, both adults and nymphs overwinter on winter grains, clover and alfalfa. They migrate into vegetable fields as roadsides dry down or are cut and the winter wheat and alfalfa are harvested. Females insert white, bean-shaped eggs into the leaf tissue. Development from egg to adult requires 10–30 days, depending on temperature. Once mature, females begin to lay eggs and can do so without mating. Consequently, increases in the population of thrips can occur very rapidly, especially during periods of hot, dry weather. There are several overlapping generations per year.

Scouting and Thresholds: Thrips move into outer leaves first, often on the upper surface, and will hide between cabbage leaf layers. Sample 25 plants and record their presence or absence without an actual count of their numbers. Their presence on cabbage is a threat, whether that cabbage is for processing or long-term storage. Sticky cards will indicate when migration starts. If field monitoring indicates a need, start spraying for thrips once cabbage reaches the cupping stage. There is no established threshold for brassica crops. It may also be beneficial to look for minute pirate bugs, a natural predator of thrips.

Management Notes: Cabbage cultivars vary in their susceptibility to thrips. Late plantings often suffer less damage than earlier ones. Harvest cabbage at the proper maturity. Over-mature cabbage is a prime target for thrips. Control of thrips during head development is very challenging. Heavy rainfall is effective in knocking thrips off the plant for a short time but management tools may still be required under high pest populations.

White Grubs

See Chapter 5.

Wireworm

See Chapter 5.

Zebra Caterpillars/Armyworms

Ceramica picta

Identification: Minor caterpillar of brassica crops. Zebra caterpillars have bright yellow stripes with black bodies.

Biology: Zebra caterpillars have two generations per year with the first occurring in June to July and the second in August to October.

Scouting and Thresholds: Zebra caterpillars are often present as many larvae on a single plant. Infestations are sporadic and random. Zebra caterpillars prefer cauliflower over cabbage and broccoli.

Management Notes: Do not include in the counts of zebra caterpillars for the main caterpillar pests of brassica crops that include cabbage looper, diamondback moth and imported cabbageworm. Remove the infested plant material and destroy larvae. These caterpillars do not warrant control measures.

Disorders

Black Midrib/Black Petiole

Blackish discoloration on the dorsal side of the internal leaf petioles where the midrib attaches to the core. An imbalanced phosphorus:potassium ratio can cause this discolouration. To prevent future damage, some fields have responded well to increasing potassium levels in the soil without increasing levels of phosphorous. Black midrib may also be linked to high rates of nitrogen, genetic susceptibility, maturity at harvest as well as storage conditions (Figure 7–31).

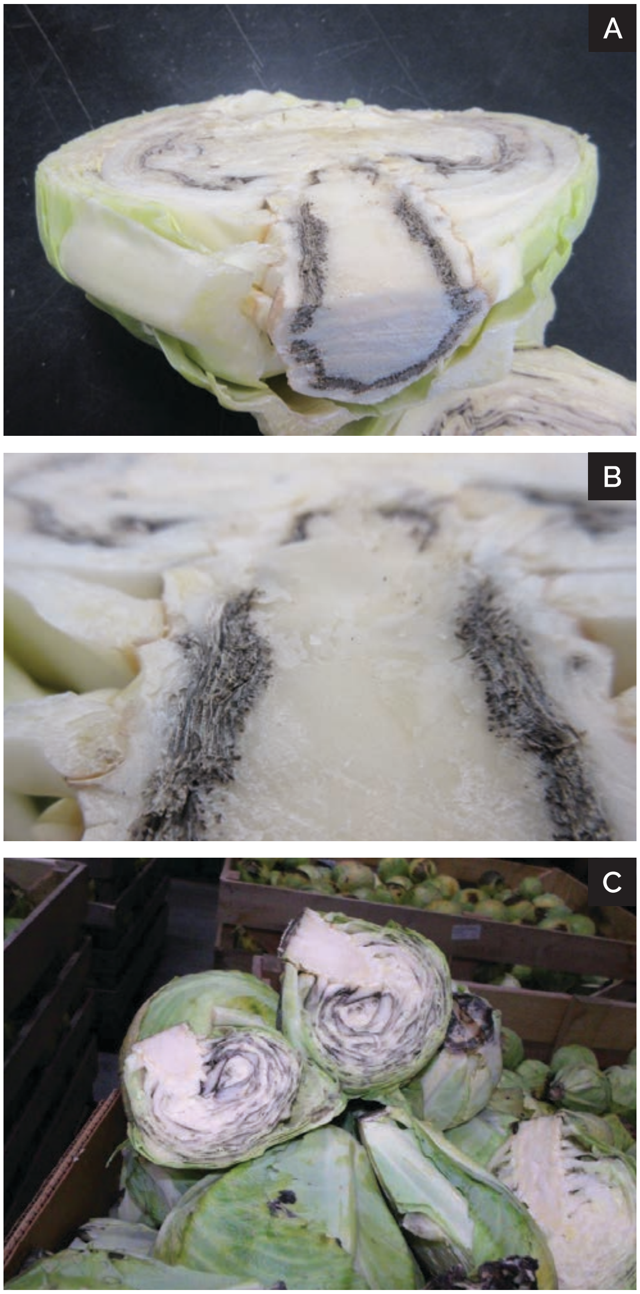


Figure 7–31. Cross section of storage cabbage displaying black midrib (A–C).

Bolting

Bolting occurs when young plants are stressed. Low temperatures early in the growing season may cause premature seedstalk development or loose, pointed heads in cabbage. The earlier the seed is sown, the greater the probability of bolting. Extreme changes in temperature, poor soil conditions or low nutrient levels also induce bolting. Some cultivars are more susceptible to bolting than others. To minimize bolting, ensure transplants are properly hardened off before planting.

Broccoli Brown Bead

Broccoli buds/florets turn tan and brown. Often follows periods of rapid growth, high temperature and abundant moisture. Managing moisture levels may help reduce incidence. Tarnished plant bugs can cause similar symptom development. See Chapter 5, for more information.

Cauliflower Buttoning

Buttoning is the premature formation of a cauliflower curd. Buttoning usually occurs shortly after planting in the field. The curd forms very early in the plant's life, and the leaves are not large enough to nourish the curd to a marketable size.

Losses are usually most severe in early plantings during cold, wet seasons. Conditions that reduce the vigour of the plant and slow vegetative growth appear to encourage buttoning. Some cultivars are more susceptible than others. Conditions that may cause buttoning include:

- too-rapid hardening-off treatment of young plants raised under protection
- insufficient hardening-off treatment of young plants before being planted in the field
- unbalanced soil fertility in the field (particularly low nitrogen)
- low soil moisture
- cold weather, 4°C–10°C (39°F–50°F) for 10 days or more, especially in combination with excess moisture
- certain diseases, insects and trace-element deficiencies, such as clubroot, nematodes, root maggots and molybdenum deficiency (whiptail)

Hollow Stem

The symptoms are internal and are usually not visible from the outside. Small cracks develop in the stem of broccoli and cauliflower and enlarge as the crop matures. These cavities may become discoloured, especially if associated with boron deficiency. In some rare instances, breakdown does occur, but in most cases this disorder does not affect marketability. This disorder is often associated with nutrient imbalances (i.e., boron deficiency, high nitrogen or potassium fertilizer rates) and/or fluctuations in growth due to heat or moisture stress. See Table 1–7, Table 1–8 and Table 1–9, Chapter 1, for more information.

Riciness

Heads are fuzzy in appearance as a result of cool or hot weather at various stages of floral initiation in broccolli and cauliflower. Excessive moisture and large increases in nitrogen may increase the susceptibility in different cultivars.

Splitting

Well-developed cabbage heads may split or burst if rain or a heavy irrigation follows dry conditions. Splitting results from rapid new growth due to increased moisture. Maintain steady plant growth with timely irrigation. Choose cabbage cultivars that are split resistant.

Tipburn

Tipburn can occasionally cause severe economic losses in cabbage, cauliflower and Brussels sprouts. Tipburn is a breakdown of plant tissue near the centre of the head in cabbage and Brussels sprouts and on the inner wrapper leaves of cauliflower. It is a physiological disorder associated with an inadequate supply of calcium to leaf margins, causing a collapse of the tissue and cell death. Secondary rot organisms such as *Erwinia* spp. can follow tipburn.

High temperatures and fluctuating soil moisture conditions hinder the movement of calcium into the leaves, leading to tipburn. Cultivation in the root zone that causes root injury has also been associated with tipburn. Foliar applications of calcium will not necessarily prevent the occurrence of tipburn.

Many cultivars of cabbage and cauliflower have been noted to be tolerant to tipburn. Maintain steady plant growth with timely irrigation. See Table 1–7, Table 1–8 and Table 1–9, Chapter 1, for more information.

Carrots

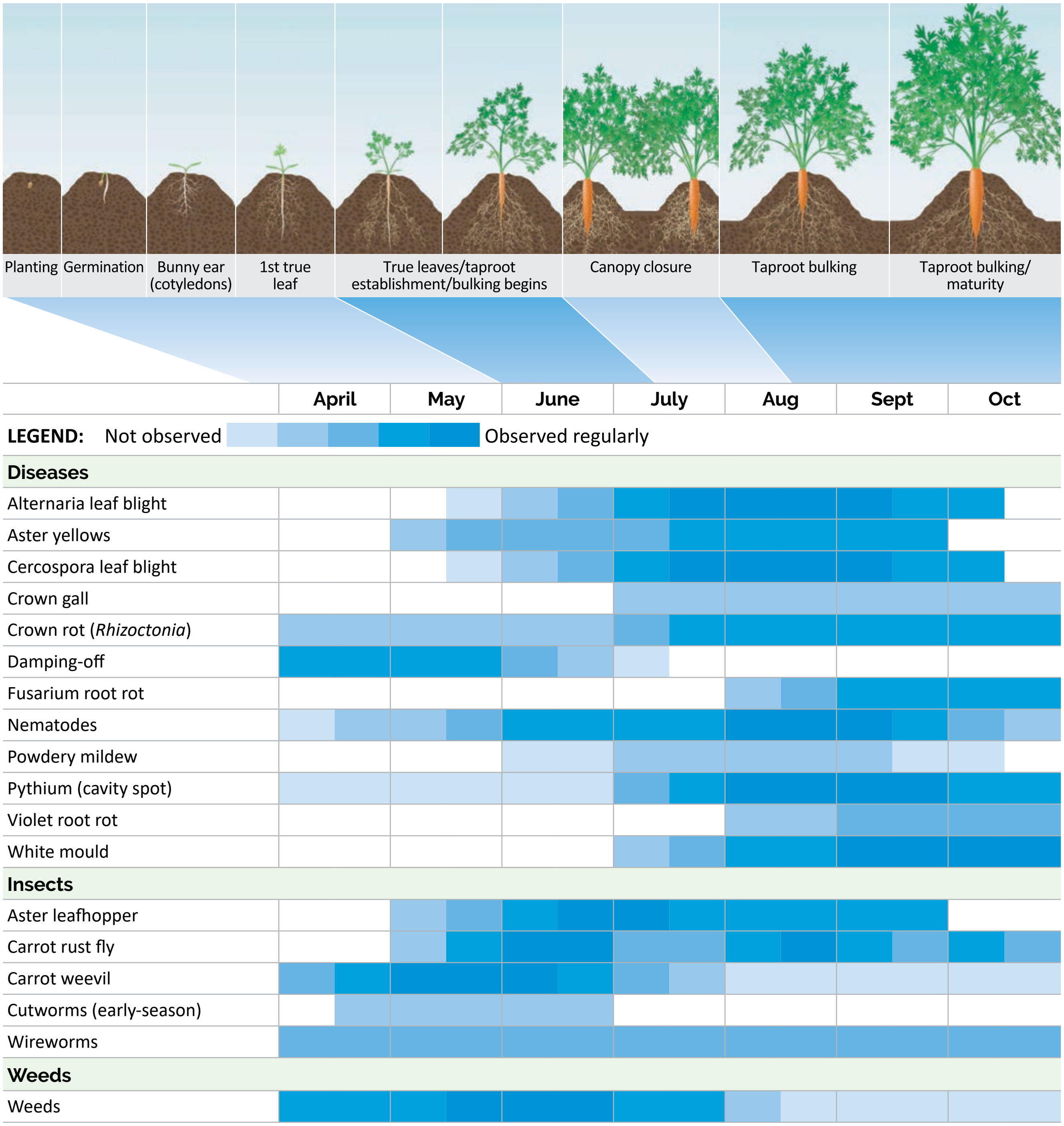


Figure 7–32. Carrot stages of development and pest activity calendar. The actual period of activity for any given pest will vary significantly from year to year, depending on environmental factors.

Production Requirements

Soil types:	deep, well-drained muck and sandy loam soils
Soil pH:	muck soil – 5.5
	sandy loam – 6.5
Suitable rotational crops:	onions, beets, spinach, cereal crops
Do not rotate with:	other *Apiaceae*/umbellliferous crops (e.g., celery, parsley, parsnip)
Minimum soil temperature:	4°C (40°F)
Optimum air temperature:	15°C–18°C (59°F–64°F)
Optimal planting date:	mid-April to mid-June

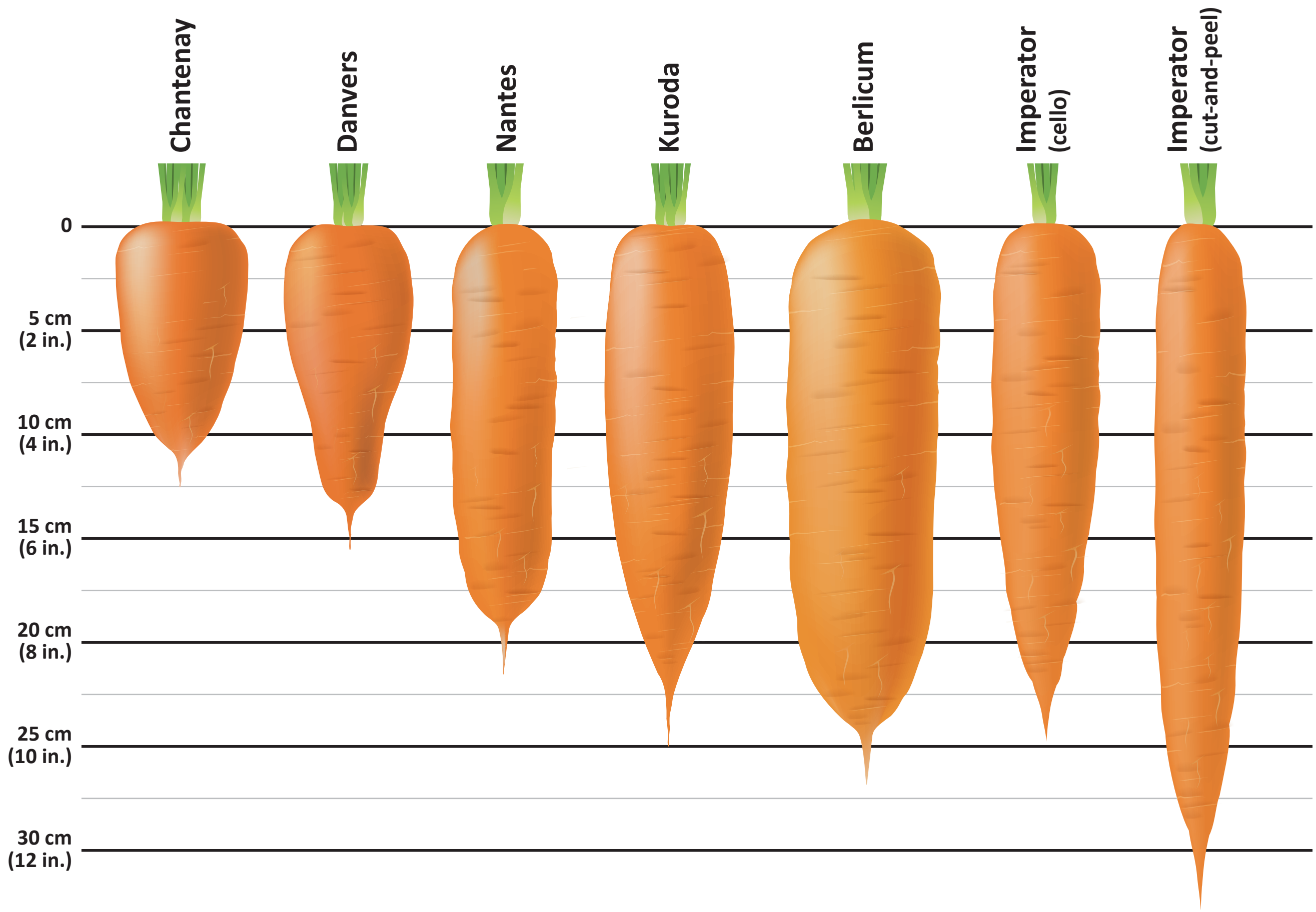


Figure 7–33. Carrot types with their relative shapes and sizes. Carrot size and shape can also be influenced by seeding rate.

Cultivars and Uses

In Ontario, carrots are grown for fresh market (cellopack (cello), jumbo, bunching, cut-and-peel (baby carrots)) and processing (dicers, slicers, cut-and-peel (baby carrots)). Carrot cultivars can be categorized based on the size and shape of the taproot. Imperator type carrots have long, tapered roots. Imperator carrots are typically grown for cello, slicers and cut-and-peel uses. Berliculum-type carrots have large cylindrical roots. Not as long as Imperator types, Berliculum carrots are much wider, generally have a longer growing season and are high yielders. These are typically used for fresh-market jumbo or dicing uses. Danvers are wider and shorter than Imperator carrots but have a tapered root. They are typically used for fresh-market jumbo or dicing uses. Nantes types are cylindrical with a blunt tip and have a very sweet flavour. Nantes carrots are usually used for fresh-market and bunched carrots.

Seeding and Spacing

Carrots are a cool-season vegetable crop, and seeds are notoriously slow to germinate. They can germinate in soil temperatures as low as 4°C (40°F), but it is best to wait until soil temperatures are above 10°C (50°F). The warmer the soil temperature, the quicker the germination, but carrots usually germinate in 7–14 days after seeding. The use of "primed" seeds can help decrease the time from seeding to emergence to 3–7 days in some conditions. Carrots can germinate up until 27°C (81°F), after which emergence will be poor.

Seed as early as soil and weather conditions permit in the spring, based on end use. In Southwestern Ontario (Essex, Chatham-Kent counties), planting dates can be as early as mid-March with the majority of seeding completed in April to early May. In Central Ontario, early crops are usually seeded in April with the majority of seeding completed May to early June. Do not plant after July 1 — later-seeded carrots may "burn off" and die if they emerge during hot, dry weather.

Carrots should be grown using raised beds at least 15–20 cm (6–8 in.) high to improve drainage and quality. Configurations of raised beds can vary considerably (71–91 cm (28–36 in.) spacing) and depend on the grower's available equipment and desired spacing. Beds that are 85 cm (33 in.) wide at the bottom and 50 cm (20 in.) wide at the top have yielded good results. Beds are seeded with one row per hill. In some cases (usually processing carrots), wider beds are used with 2–3 rows on one bed. One carrot row is usually made up of 3 seeded lines spaced 4–5 cm (1½–2 in.) apart. The middle line of the seeded row is planted with fewer seeds to mitigate the edge effect of the outer two rows and keep taproot size consistent. Seeding rates are usually 10%–15% higher on muck soil vs. mineral soil, so use the higher rates of the range for muck soils and the lower rates for mineral soils. See Table 7–28.

Good seed bed preparation is required to encourage quick germination and consistent emergence. Often multiple tillage passes are needed to obtain an optimal seed bed consistency. Seeds should be planted at a fairly shallow depth of 0.6–1.2 cm (¼–½ in.). Irrigation shortly after seeding may also be required to ensure adequate germination, especially with later planting dates.

Table 7–28. Carrot Seeding Rates
(Assuming a 76-cm (30-in.) row spacing)

Crop	Plant Density	Population
Fresh Market		
Jumbo	49–59 plants/m (15–18 plants/ft)	741,000–865,000/ha (300,000–350,000/acre)
Cello	66–82 plants/m (20–25 plants/ft)	1.1–1.2 million/ha (450,000–500,000/acre)
Processing		
Cut-and-peel (baby carrots)	**Early:** 131–164 plants/m (40–50 plants/ft) **Main Crop:** 197–262 plants/m (60–80 plants/ft)	**Early:** 2.0–2.2 million/ha (825,000–900,000/acre) **Main Crop:** 2.7–3.2 million/ha (1.1–1.3 million/acre)
Dicers	33–39 plants/m (10–12 plants/ft)	445,000–494,000/ha (180,000–200,000/acre)
Slicers	82–105 plants/m (25–32 plants/ft)	1.2–1.5 million/ha (500,000–600,000/acre)

Early Season

Small seeded carrots are susceptible to wind damage early in the season. Nurse or windbreak crops of barley or oats can be used to protect emerging seedlings. They can be broadcast just prior to seeding or applied on the bed by the seeder using separate planter boxes. Nurse crops should be terminated when they are 10–15 cm (4–6 in.) tall.

Carrots are very susceptible to weed competition. The critical weed-free period is from seeding to the 12th leaf stage and up to the 4th leaf stage in later-seeded carrots. Uncontrolled weeds also affect the harvestability of carrots if using a pull-type harvester, therefore, some growers find it worthwhile to continue weed control after the critical weed-free period.

Table 7–29. Carrot Nitrogen Requirements

Soil	Actual N
Mineral Soils	
Preplant	70 kg/ha (63 lb/acre)
Side-dress	40 kg/ha (36 lb/acre)
Total	**110 kg/ha (98 lb/acre)**

Fertility

Macronutrients

Nitrogen

Broadcast and incorporate the required preplant nitrogen with all the required phosphate and potash. Apply side-dress nitrogen when the plants are 10 cm (4 in.) tall. See Table 7–29.

Ontario research has shown that carrots grown on established muck soils in rotation with onions receive adequate nitrogen from the soil, and there is no yield response to added fertilizer nitrogen.

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. See Table 1–12 and Table 1–13, Chapter 1, for more information.

Phosphorus and Potassium

Test the soil to determine phosphorus and potassium requirements. See Table 7–30 and Table 7–31.

Table 7–30. Carrot Phosphorus Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Sodium Bicarbonate Phosphorus Soil Test (ppm)													
	0–3	**4–5**	**6–7**	**8–9**	**10–12**	**13–15**	**16–20**	**21–25**	**26–30**	**31–40**	**41–50**	**51–60**	**61–80**	**81+**
Mineral Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	180 (161) (HR)	170 (152) (HR)	170 (152) (HR)	160 (143) (HR)	160 (143) (HR)	150 (134) (HR)	140 (125) (HR)	120 (107) (HR)	100 (89) (MR)	80 (71) (MR)	50 (45) (LR)	30 (27) (RR)	0 (RR)	0 (NR)
Muck Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	100 (89) (HR)	100 (89) (HR)	100 (89) (HR)	100 (89) (HR)	90 (80) (MR)	90 (80) (MR)	80 (71) (MR)	70 (62) (MR)	60 (54) (MR)	50 (45) (LR)	30 (27) (LR)	20 (18) (LR)	0 (RR)	0 (NR)

Table 7–31. Carrot Potassium Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Ammonium Acetate Potassium Soil Test (ppm)											
	0–15	16–30	31–45	46–60	61–80	81–100	101–120	121–150	151–180	181–210	211–250	251+
Mineral Soils												
Potash (K_2O) required kg/ha (lb/acre)	230 (205) (HR)	220 (196) (HR)	210 (187) (HR)	190 (170) (HR)	160 (143) (HR)	130 (116) (HR)	100 (89) (MR)	80 (71) (MR)	50 (45) (MR)	0 (LR)	0 (RR)	0 (NR)
Muck Soils												
Potash (K_2O) required kg/ha (lb/acre)	230 (205) (HR)	220 (196) (HR)	210 (187) (HR)	200 (178) (HR)	170 (152) (MR)	150 (134) (MR)	120 (107) (MR)	80 (71) (MR)	40 (36) (MR)	0 (LR)	0 (RR)	0 (NR)

Magnesium

Magnesium deficiency may occur on carrots. The usual symptoms are yellowing of older leaves while the veins remain dark green. See *Macronutrients*, Chapter 1.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. For complete information, see *Micronutrients*, Chapter 1.

Boron

Boron deficiency in carrots can cause the growing point to die off or cause internal breakdown of the roots. Apply boron on newly cultivated muck soils. Use caution when applying boron. This nutrient can build to toxic levels quite quickly, harming rotational crops.

Copper

Copper (Cu) deficiency may occur on acid peat and muck soils resulting in carrot roots with poor orange colour. Apply 14–29 kg Cu/ha (12–26 lb Cu/acre) on newly cultivated muck soils. Reapply 4.5–9.5 kg Cu/ha (4–8.5 lb Cu/acre) every 2–3 years.

Plant Tissue Tests

When used in conjunction with soil tests, plant tissue tests can be useful for diagnosing crop problems or for evaluating a fertilizer program. Plant tissue tests do not replace soil testing or a sound soil fertility program.

For more information, see Table 7–32 and *Plant Tissue Analysis*, Chapter 1.

Table 7–32. Carrot Nutrient Ranges

LEGEND: – = no data available

		N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu
Plant Part	**Time of Sampling**	**Per Cent (%)**						**Parts Per Million (ppm)**				
Most recently mature leaf	60 days after seeding	1.8–2.5	0.2–0.4	2–4	2–3.5	0.2–0.5	–	30–60	30–60	20–60	20–40	4–10
	harvest	1.5–2.5	0.2–0.4	1.4–4	1–1.5	0.4–0.5	–	20–30	30–60	20–60	20–40	4–10

Adapted from G Hochmuth, et al. 2018. *Plant Tissue Analysis and Interpretation for Vegetable Crops in Florida*. University of Florida IFAS Extension. HS964.

Irrigation and High Temperature

Carrots are responsive to irrigation.

Effects of moisture stress: poor germination, lower yields and undersized roots.

Critical irrigation period: crop establishment and root enlargement.

Rooting depth: 30–60 cm (1–2 ft)

If the available soil moisture level in the root zone reaches 50% during the critical irrigation period, irrigation could help maintain crop yield and quality. For more information on irrigation scheduling, see the *Irrigation Management* BMP (order number BMP08E) and the OMAFRA factsheet, *Monitoring Soil Moisture to Improve Irrigation Decisions.*

High temperatures >30°C (86°F) later in the season also cause:

- reduced yield
- slow growth
- strong flavour
- coarse root

Harvest

Carrots can be harvested using a pull-type or self-propelled harvester that pulls the carrots out of the ground by their tops, using belts. When using this type of harvester, it is important to maintain good top health to maximize harvest recovery. It is also possible to top the carrots and dig them using a potato digger. "De-dirter" attachments for the harvester are useful to reduce the amount of soil and foliage that go into storage. This reduces disease development in storage, as dead or dying leaves may harbour plant pathogens.

Carrot crops typically mature in 60 days for Nantes and bunching cultivars, 60–120 days for cello, slicing and cut-and-peel cultivars, and 120–180 days for jumbo and dicing cultivars. Fresh market carrot harvest extends from July to November. Processing carrots are usually harvested in October and November. Cold weather or frosts late in the season can increase the sugar content of the roots and result in sweeter-tasting carrots. Carrots can survive temperatures as low as –5°C (23°F) for short periods of time, as long as the crowns of the carrots do not freeze. Harvest carrots before the ground freezes. In some milder regions of Ontario, it is possible to overwinter carrots in the field using a thick layer of mulch as insulation, similar to practices in Europe.

Storage

Rapid cooling of carrots after harvest is very important for reducing storage rots. Carrots can be stored in pallet boxes or in bulk. For long-term storage, it is important to wait until the soil is cool or cold before harvesting. Suitable cooling methods for carrots include forced air, hydrocooling and package icing. For long-term storage, unwashed carrots maintain quality better than washed carrots. See Table 7–33.

Table 7–33. Carrot Storage Requirements

Type	Storage Temperature	Relative Humidity	Duration
Bunched	0°C (32°F)	95%–100%	2 weeks
Immature	0°C (32°F)	98%–100%	4–6 weeks
Mature	0°C (32°F)	95%–98%	7–9 months

Pest Management and Disorders

See Figure 7–32. *Carrot stages of development and pest activity calendar.*

Diseases

Aster Yellows

Candidatus phytoplama asteris

Identification: The symptoms of aster yellows on carrots first appear as a reddening of several leaves. Multiple shoots begin to form out of the crown. Crown growth becomes yellow, twisted and brittle, followed by hairy root development (Figure 7–34).

Biology: The aster leafhopper transmits aster yellows. See *Aster Leafhopper*, Chapter 5, for more information on that insect.

Management Notes: Control measures are targeted at aster leafhopper, the vector of aster yellows.

Figure 7–34. Red leaves typical of aster yellows (A) and excessive shoot growth (B).

Cavity Spot

See *Pythium (Cavity Spot, Rusty Root, Root Dieback)*, also in *Carrots*.

Crown Gall

Agrobacterium tumefaciens

Identification: Yellow-to-tan galls form near the crown or on the roots. Gall development usually occurs where lateral roots join the taproot and in locations where the root or crown has been damaged.

Biology: Crown gall is caused by *Agrobacterium tumefaciens*, a bacterium that can live in the soil for several years and can overwinter in galls. Galls generally start to appear in mid-summer and continue to develop until harvest.

Scouting and Thresholds: During regular scouting and at harvest, note the presence of crown gall. No thresholds have been established and no products are available to control this disease on carrots.

Management Notes: Reduce soil populations of the bacteria using long crop rotations with non-host plants (i.e., onions, oats, corn). A high incidence of crown gall is associated with high levels of nitrogen, so avoid over-application of nitrogen.

Crown Rot

See *Damping-Off*, also in *Carrots*.

Damping-Off

Pythium sp., *Rhizoctonia* sp., *Fusarium* sp.

Identification: Seeds infected prior to emergence rot and typically fail to produce a seedling. If the seedlings do emerge, they are usually weak and lack vigour. Post-emergence infections cause the seedlings to rot at soil line within 2–4 weeks of emergence. *Rhizoctonia solani* can also cause crown rot of carrots. Crown rot appears in patches across the field. Plants become stunted and yellow, followed by wilting and death of the foliage. Large, grey-brown lesions form near the top of the carrot root.

Biology: *Pythium* is a water mould. It is particularly destructive in wet and cool soil conditions. Infections commonly occur on heavier soil types or in poorly drained fields. *Rhizoctonia solani* persists in soil as hard resting structures (sclerotia) and grows as microscopic threads through the soil. This damping-off pathogen tends to prefer slightly warmer and dryer soil than the water moulds. Often, *Rhizoctonia* will girdle the stems of susceptible crops slightly above and below the soil line.

Management Notes: Plant seeds treated with a registered fungicide seed treatment that controls damping-off pathogens. Planting "primed" seeds can result in quicker germination and reduce the amount of time a seed is exposed to damping-off pathogens. Do not seed too deep. Plant only when soil and weather conditions are favourable for quick germination, emergence and vigorous crop development. Scout fields early in the spring soon after planting to assess the plant stand and its establishment. Look for areas of patchy or poor emergence. Dig up non-emerged seedlings or plants and look for symptoms of rotting or stem girdling.

Fusarium Root Rot

See *Damping-Off*, also in *Carrots*.

Leaf Blights

***Alternaria dauci*, *Cercospora carotae*,**
Xanthomonas campestris* pv. *carotae

Identification: Alternaria leaf blight (*Alternaria dauci*) produces irregular brown spots (often surrounded by yellowish halos), mainly along the edges of carrot leaves, giving the appearance of a burn. Cercospora leaf blight (*Cercospora carotae*) causes circular grey or brown lesions on leaves and elliptical brown lesions on the petioles. Alternaria leaf blight usually develops on the older leaves first, where cercospora leaf blight often starts on younger or middle leaves in the canopy. Bacterial leaf blight (*Xanthomonas campestris*) causes irregular dark brown lesions with necrotic centres and yellow halo on leaf margins inducing lateral curl. Lesions dry and become brittle (Figure 7–35).

Biology: Both *Alternaria* and *Cercospora* fungi overwinter in crop residue of infected carrots. Their spores are dispersed by wind. All three diseases are favoured by warm, humid conditions in the 20°C–30°C (68°F–86°F) range. Symptoms usually appear 10 days after infection.

Scouting and Thresholds: Sample 50–100 mid-age leaves across the whole field area. If alternaria or cercospora leaf blight is present on 25% of sample leaves, apply a fungicide.

Management Notes: After the initial fungicide application, apply a recommended fungicide at 7–10-day intervals. Extend the intervals between sprays when the weather is unfavourable for blight. For alternaria leaf blight, once the average daily temperature is less than 9°C (48°F), disease development slows considerably, and fungicides are not necessary. Alternaria-tolerant cultivars are available. The risk of cercospora leaf blight is lower if there is no rainfall or irrigation. Follow a 3–4-year crop rotation to reduce inoculum in the field. Crop rotation is most effective if there are no other carrot fields planted nearby.

Figure 7–35. Lesions beginning at the leaf margins caused by alternaria leaf blight (A), spotty lesions caused by cercospora leaf blight (B, C) and warped leaves caused by bacterial leaf blight (D).

Nematodes

Heterodera carotae, *Meloidogyne hapla*, *Pratylenchus penetrans*

Identification: The best time to identify nematode damage is at harvest when malformed taproots can be easily seen. Nematodes can cause forking, hairy roots and reduced root mass. Root-knot nematode (*Meloidogyne hapla*) can be identified by the characteristic tiny galls (swelling) found on the roots. Carrot cyst nematode (*Heterodera carotae*) is currently only found in muck soils in Ontario and can be identified by the tiny female cysts found on the roots. Root lesion nematode (*Pratylenchus penetrans*) tunnels into roots and causes brown necrotic lesions. Occasionally, above-ground symptoms will be visible, usually in a patch of stunted, sometimes yellowing and wilted plants (Figure 7–36).

Biology: Nematodes overwinter in the soil, in roots and crop debris. When a host is present, juvenile nematodes will migrate and enter the roots. In the case of root-knot nematode, they stimulate the root cell to enlarge and become a gall to establish a feeding site. The female will swell and release hundreds of eggs back into the soil. Carrot cyst nematode also establishes a feeding site in the root. The female cyst will harden and be released back into the soil while protecting hundreds of eggs inside. Root lesion nematodes are migratory and will feed on plant roots, laying eggs as they tunnel.

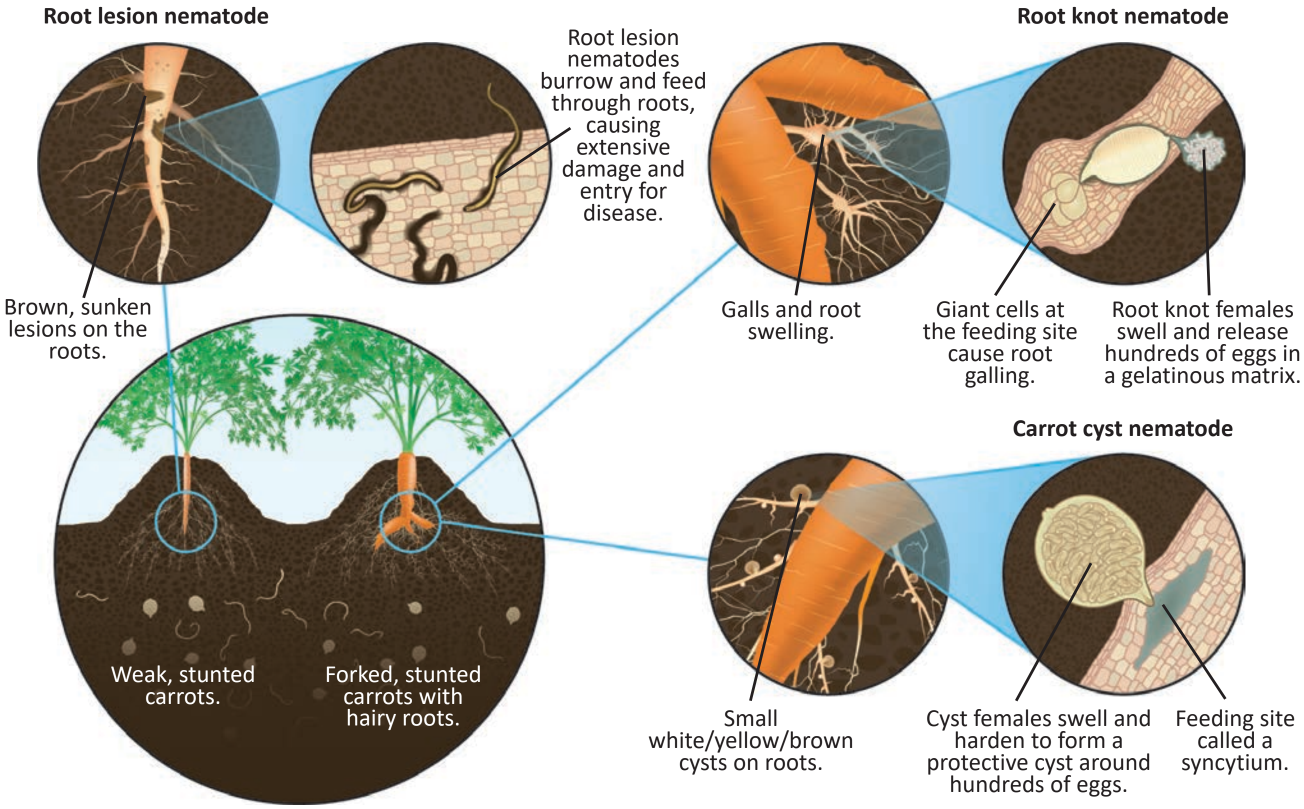


Figure 7–36. Common nematodes infecting carrots including root knot, carrot cyst and root lesion nematodes with common symptoms and life cycle.

Figure 7–37. Hairy roots, galling and stunting caused by root knot nematode (A) and cyst nematodes on hairy side roots of a forked carrot (B).

Scouting and Thresholds:

Root knot nematode:	0/kg of soil
Carrot cyst nematode:	no threshold established
Root lesion nematode:	1,000/kg of soil

Management Notes: Before deciding upon a management strategy for nematodes, complete a nematode soil test to determine the levels of nematodes present. In Ontario, nematode populations in soil and roots are usually at their highest in May to June and again in September to October. The fall months are a good time to soil sample for nematodes, as the populations are high and control measures can be taken well in advance of planting the next crop.

Powdery Mildew

Erysiphe heraclei

Identification: White, powdery growth usually on the leaves but can cover all above-ground parts of the carrot. Powdery mildew is mostly found in the southern regions of Ontario. Powdery mildew infections do not typically result in significant yield loss unless infection occurs very early in the season (Figure 7–38).

Figure 7–38. White powdery growth on the upper side of carrots leaves caused by powdery mildew.

Biology: Powdery mildew can survive on previous carrot residue and weed hosts. Windblown spores can also be blown long distances. Powdery mildew grows best under high humidity conditions.

Management Notes: Growing tolerant cultivars, good plant health and nutrition can mitigate most powdery mildew infections.

Pythium (Cavity Spot, Rusty Root, Root Dieback)

Pythium sp.

Identification: Pythium infections cause a variety of symptoms, including deformed roots (short, stubby, forked), rusty red roots, the formation of fibrous roots, leaf wilting and discolouration. In the case of cavity spot, dark, oval lesions on the surface of the carrot root are formed as a result of infection (Figure 7–39).

Biology: *Pythium* is a persistent, soil-borne water mould that is often found in wet soils. Cavity spot lesions usually start to appear in August and September and slowly enlarge while carrots are in storage.

Management Notes: Grow tolerant cultivars, avoid problem fields and grow carrots on raised beds. There are reports that too much nitrogen and not enough calcium can promote cavity spot.

Figure 7–39. Elliptical cavity spot lesions along the carrot root caused by *Pythium* spp.

Figure 7–40. White fuzzy growth with purple hue typical of violet root rot.

Violet Root Rot

Rhizoctonia crocorum

Identification: Plants become stunted and yellow, followed by wilting and death of the foliage. It is found in patches in the field. Violet root rot covers the root with a thick, purplish fungal layer. When infected carrots are pulled, a considerable amount of soil adheres to them (Figure 7–40).

Biology: Appears mid-summer. Violet root rot is caused by a soil-borne fungus that has a wide host range including other vegetable crops and numerous weed species.

Management Notes: The only practical control is to avoid previously infected areas and rotate for several years with cereal crops. Practise strict sanitation procedures to avoid spreading infected soil between fields.

White Mould

Sclerotinia sclerotiorum

Identification: White, cottony fungal growths develop on older and dying leaves at the bottom of the carrot canopy. Hard, black pea-sized sclerotia are usually embedded in the fungal growth. The growth can continue up the petiole until it infects the crown of the carrot. In storage, white mould and black sclerotia are present along with a soft, watery rot.

Biology: White mould overwinters in the soil as small, black (pea-sized) sclerotia. The initial infection occurs when the carrot canopy closes and the older leaves start to die off. Temperatures ranging from 20°C–25°C (68°F–77°F) and continuous leaf wetness (high humidity and/or heavy dews) favour sclerotinia white mould development. Overwintering sclerotia may survive for several years in the soil.

Management Notes: A fungicide application just prior to canopy closure can help reduce the disease and is helpful if the carrots will be stored for a long period of time. Carrot trimming is also a practice shown to be effective in Ontario and Eastern Canada. The carrot canopy is trimmed back about 30% using cutting wheels. This promotes air movement and makes conditions unfavourable for disease development with no negative impact on yield. Practice a 3–4-year crop rotation away from susceptible crops (cucurbits, edible beans, soybeans, canola and lettuce) if there are no carrot fields or other susceptible crops nearby. Avoid applying high rates of nitrogen fertilizer. Excess nitrogen promotes an exceptionally dense crop canopy, resulting in restricted air movement and more favourable disease development conditions.

Insects

Aster Leafhopper

Macrosteles quadrilineatus

Identification: Aster leafhoppers are small, greenish-blue insects with six spots arranged in pairs on top of the head. Its wings are transparent and heavily veined (Figure 7–41).

Figure 7–41. Green/blue aster leafhopper on a sticky trap with distinctive spots on its head.

Damage: Aster leafhoppers transmit aster yellows to carrots, celery and leafy greens by feeding on these crops. See *Aster Yellows*, also in *Carrots*.

Biology: The aster leafhopper overwinters as an egg in the leaf tissue of winter grains such as wheat and rye. Approximately 130 degree days, base 9°C, are required for egg maturation. An additional 270 degree days are required for development to adulthood. See *Growing Degree Days*, Chapter 4.

As the winter grains mature in late May and early June, local first-generation leafhoppers disperse into vegetable crops. Leafhopper populations from the U.S. are also carried into Ontario on weather systems. Both local dispersal and long-distance movement influence the incidence and severity of the aster leafhopper and aster yellows.

Scouting and Thresholds: The Aster Yellows Index (AYI) determines the need to treat a crop. To use the AYI, monitor aster leafhoppers with a sweep net. Multiply the number of aster leafhoppers captured in 100 sweeps by the percentage of leafhoppers carrying aster yellows in your area (4%–5% is the currently recommended per cent infectivity in Ontario). Use this formula:

AYI =
Infectivity rate (4%–5%) x # of leafhoppers/100 sweeps)

Use these AYI thresholds for carrots:

Resistant	100
Intermediate	70
Susceptible	50

In carrots, the threshold varies depending on varietal tolerance. If a carrot cultivar has not been evaluated for aster yellows tolerance, use an AYI threshold of 70.

Management Notes: Grow resistant cultivars and remove perennial weeds from fields that may act as reservoirs.

Carrot Rust Fly

Psila rosae

Identification: The adult rust fly is shiny and black, measuring approximately 6 mm (¼ in.) in length. It has an orange head, brown eyes and pale, yellow legs. The larva is cream-white and legless with dark mouthhooks 6–7 mm (about ¼ in.) long (Figure 7–42).

Figure 7–42. Shiny black body, orange head and yellow legs of carrot rust fly caught on a sticky card (A) and tunneling feeding damage caused by carrot rust fly larvae (B).

Damage: Larvae feed on the root hairs for up to a month before tunnelling into the carrot, where they continue feeding. Feeding damage from rust fly larvae is usually limited to the lower two-thirds of the root.

Biology: The carrot rust fly overwinters as a pupa in the soil and usually has two generations per year. The first generation often coincides with lilac bloom, the second begins in late July to mid-August. Occasionally, sufficient heat units are accumulated so that a third generation emerges in late September or October. This third generation usually occurs too late in the season to have any serious effect on the crop.

Scouting and Thresholds: In carrots, control adults if populations reach a level of 0.1 flies/trap/day (fresh market) or 0.2 flies/trap/day (processing) as determined through monitoring. For more information on carrot rust fly trapping, see *Trapping*, Chapter 4. Rust flies are no longer a concern once the crop is within 21 days of harvest.

Growing degree days (GDDs) (base of 3°C) are used to predict the emergence of carrot rust flies. First-generation adults emerge between 329 and 395 GDDs. Second-generation adults emerge between 1,399 and 1,711 GDDs. For more information, see *Growing Degree Days*, Chapter 4.

Management Notes: Crop rotation will reduce background populations of the carrot rust fly. Avoid growing carrots in sheltered areas where rust flies are more prevalent.

Carrot Weevil
Listronotus oregonensis

Identification: The carrot weevil adult is a dark-brown snout beetle about 6 mm (¼ in.) long. Larvae are legless and creamy white with an ambercoloured head about 5–8 mm (¼–⅓ in.) long (Figure 7–43).

Monitor adult carrot weevil activity using either wooden traps baited with carrots or pieces of mature carrot roots buried in the field. Set traps in the field by the beginning of May in Central Ontario, earlier in southern regions.

For wooden traps, keep a record of the accumulated total of the number of weevils found in each trap:

- greater than 1.5 weevils/trap = apply a treatment at the second leaf stage
- greater than 5 weevils/trap = apply a treatment at the second leaf stage and an additional treatment at the fourth leaf stage

For buried carrot root sections, consider treatments when 25% of the carrots have oviposition damage, which presents as small pits in the carrot.

Figure 7–43. Brown carrot weevil adults caught in a Boivin weevil trap (A) and open tunnel feeding damage caused by carrot weevil larvae (B).

Management Notes: Time treatments to target adults prior to egg-laying. Adult females are not attracted to carrots prior to the first true leaf stage. Late seeding in mid-June can avoid most carrot weevil damage. Early-seeded carrots are most at risk from carrot weevil damage, and careful trapping and scouting is needed. Crop rotation and weed control around field edges may reduce overwintering populations. The egg parasite *Anaphes sordidatus* (a small braconid wasp) provides some biological control.

Cutworms (Early-Season)

Agrotis ipsilon (black cutworm),
Euxoa messoria (dark-sided cutworm),
Crymodes devastator (glassy cutworm),
Euxoa detersa (sandhill cutworm)

See Chapter 5.

Millipedes

Cylindroiulus caeruleocinctus, *Blaniulus guttulatus*, *Pseudopolydesmus* spp.

Identification: Millipedes are not insects but arthropods. They are hard-shelled, cylindrical and approximately 2.5–10 cm (1–4 in.) long. Millipedes are frequently confused with wireworm.

Damage: Millipedes are normally considered beneficial in vegetable production due to their habit of feeding on decaying plant material, which helps to incorporate organic matter into the soil. However, under certain conditions, millipede populations can build to high levels and may damage the roots and seedlings of carrots. The damage appears as open feeding cavities on the outer carrot root.

Biology: Both adult and immature millipedes overwinter in the soil under debris, rocks, etc. They can live for several years in the soil, taking up to 5 years to mature to the adult stage. Recent studies conducted in Ontario suggest that millipedes are most active in the early spring and late summer. Crop damage may be more severe under dry soil conditions when the millipedes feed on the root as a source of moisture.

Scouting and Thresholds: Inspect roots, germinating seed and soil around areas with gaps in the plant stand. If early-season injury is noticeable but no pest is present, set up bait stations. For more baiting instructions see *Millipedes*, Chapter 5. No thresholds have been established.

Management Notes: Millipede damage is not common in Ontario. Where pre-season monitoring suggests millipede populations are high, early tillage prior to planting may help bring millipedes to the surface where they are susceptible to desiccation and predation. Harvest as early as possible, because millipedes will continue to feed on crops as long as they are in the soil.

Wireworm

Limonius spp.

Identification: Wireworms are the larvae of click beetles. They are copper-coloured, cylindrical and hard-bodied, with three pairs of tiny legs. They can reach 2–3 cm (¾–1¼ in.) in length.

Damage: Wireworms can be seen burrowing into carrot roots. Infested plants do not develop well, and seedlings lack vigour or fail to emerge. When feeding occurs on more mature carrots, there are no above-ground symptoms. Damage is often scattered randomly across the field. In the fall, wireworm feeding may render carrots unmarketable. Wireworms are rare in muck soils but can be a problem in mineral soils, especially fields with potatoes and grains in the rotation.

Biology: Wireworms take up to 5 years to complete development from egg to adult. Most of this time is spent as a larva in the soil. Wireworms are present all season. See *Wireworm*, Chapter 5, for more information on the biology of wireworms.

Scouting and Thresholds: Wireworms may be monitored in the fall (or in the early spring for later-planted crops) prior to planting using bait stations. See *Wireworm*, Chapter 5, for more information about baiting.

Management Notes: Plant into well-prepared, warm soils and avoid unnecessarily deep planting depths. There are several species of wireworms present in Ontario, with varying degrees of susceptibility to registered insecticides. Research is under way to reduce wireworm populations through the use of crop rotations to discourage egg-laying, as well as bait traps to pull wireworms out of crop rows and into areas where they can be controlled by insecticides or other amendments.

Disorders

Bolting Carrots

Identification: Seed stalks and flowers develop, making the carrot root woody and unmarketable. Bolting in carrots is controlled by a number of factors including temperature/day length and varies by cultivar. Cold temperatures, <10°C (<50°F), in the first two months after seeding increases the likelihood of bolting carrots. Generally, non-orange or coloured carrot varieties are more susceptible to bolting in addition to orange cultivars not adapted to Ontario's climate and daylength.

Forked Carrots

Identification: Determining the cause of forked carrots can be difficult since the cause can be a number of biotic and abiotic stressors including:

- pythium
- nematodes
- soil compaction
- too much water
- not enough water
- pounding rain
- heat stress
- wind damage
- herbicide injury

Celery

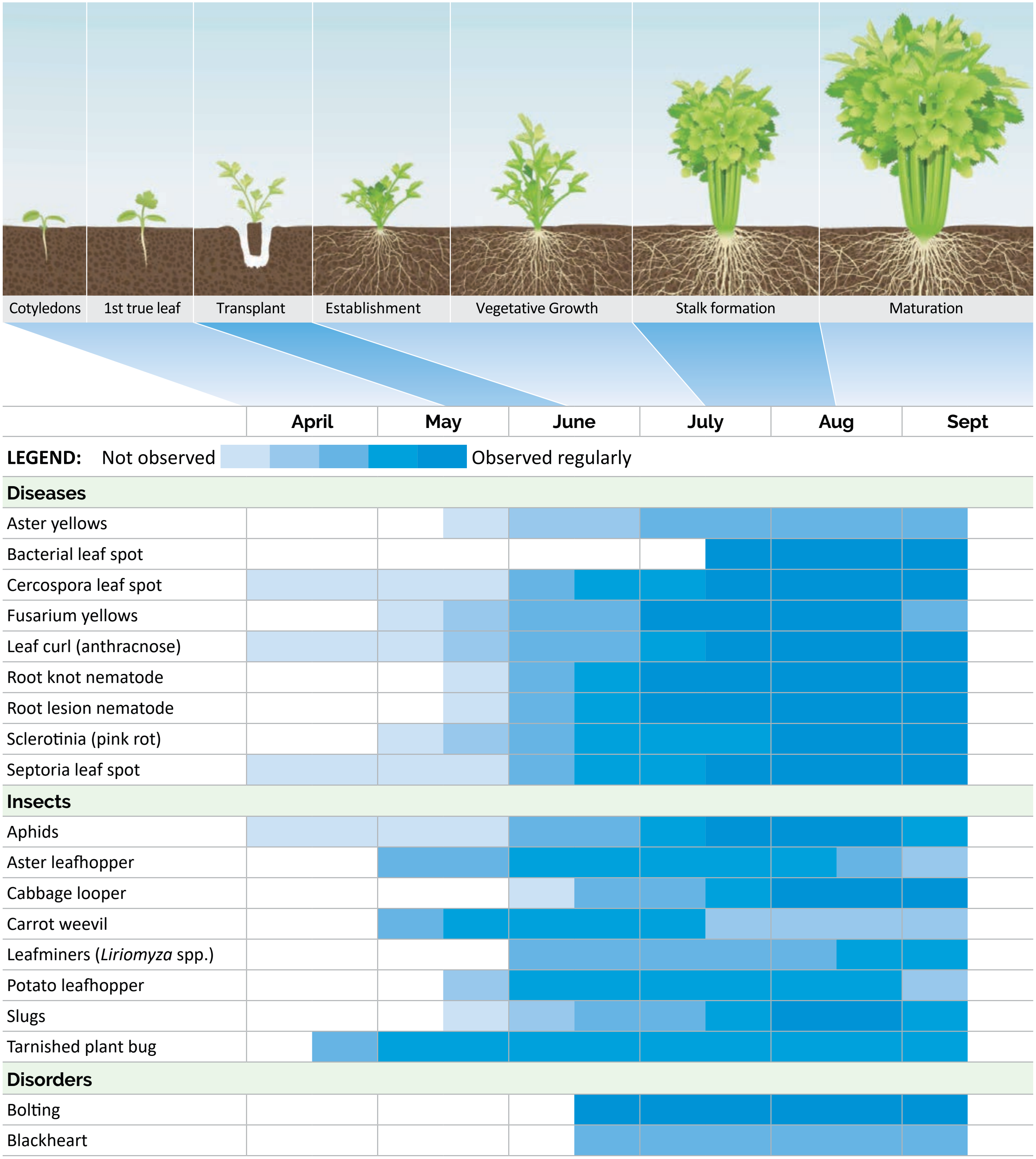


Figure 7–44. Celery stages of development and pest activity calendar. The actual period of activity for any given pest will vary significantly from year to year, depending on environmental factors.

Production Requirements

Soil types: muck soils or well-drained mineral soils
Soil pH: mineral soil – 6.0
muck soil – 5.5
Suitable rotational crops: onions, potato, radishes, lettuce
Do not rotate with: other *Apiaceae*/umbellliferous crops (e.g., carrots, celeriac, parsley, parsnip)
Minimum soil temperature: 4°C (39°F)*
Optimum air temperature: 16°C–24°C (61°F–75°F)
Earliest planting date: mid-April to mid-May

* Premature seed stalk development or "bolting" may occur if young plants are exposed to temperatures below 13°C (55°F) for 10 days or more.

Table 7–34. Celery Transplant Requirements

Seed Required for 10,000 Transplants	Seeding Depth	Germination Temperature			Days to Germination	Optimum Growing Temperature		pH Tolerance	Time (weeks)
		Min.	Opt.	Max.		Day	Night		
28 g	0.3–0.6 cm (⅛–¼ in.)	16 °C (61°F)	21°C (70°F)	24°C (75°F)	7	18°C–24°C (64°F–75°F)	16°C–18°C (61°F–64°F)	6.0–6.8	10–12

Seeding and Spacing

Early celery is started from seed in the greenhouse at the beginning of February. Seeding in the greenhouse continues through June 1 for July transplanting. See Table 7–34.

If row covers are used, transplanting in the field can occur as early as April 1.

Plants for the late crop may be started in irrigated, outdoor seedbeds. Seed may also be broadcast onto a finely prepared seedbed. The first method provides sturdier plants. See Table 7–35, for typical planting and seeding rates.

Table 7–35. Celery Crop Spacing

Row Spacing	In-Row Spacing	Seeding Rate
50–55 cm (20–22 in.)	15 cm (6 in.)	Approx. 140 g seed/ha (Approx. 56 g seed/acre)

Fertility

Macronutrients

Nitrogen

Broadcast and incorporate preplant nitrogen with all the required potash and potassium. See Table 7–36.

Table 7–36. Celery Nitrogen Requirements

Soil Type	Actual N
Mineral Soils	
Preplant	135 kg/ha (120 lb/acre)
Side-dress [1]	30 kg/ha (27 lb/acre)
Total	**195 kg/ha (175 lb/acre)**
Muck Soils	
Preplant	80 kg/ha (71 lb/acre)
Side-dress [1]	40 kg/ha (36 lb/acre)
Total	**160 kg/ha (143 lb/acre)**

[1] Up to 2 applications.

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. See Table 1–12 and Table 1–13, Chapter 1.

Phosphorus and Potassium

Test the soil to determine phosphorus and potassium requirements. See Table 7–37 and Table 7–38.

Calcium

Calcium deficiency in the youngest leaves results in a physiological disorder known as "blackheart." The celery heart turns black, while the outer leaves are unaffected. Blackheart may occur even when there is adequate calcium in the soil. If celery is under heat and moisture stress, weekly foliar calcium sprays directed into the heart of the plant may reduce blackheart symptoms. Irrigation scheduling to provide consistent soil moisture can help prevent blackheart.

Magnesium

Magnesium deficiency appears as yellowing of the tips of older leaves, progressing around leaf margins and between veins. Some celery cultivars are inefficient at taking up magnesium from the soil. Where soil magnesium levels are low, apply foliar sprays, starting when the plants are about one-third grown. Magnesium deficiency is sometimes seen during transplant production in the greenhouse. See Table 1–7, Chapter 1.

Table 7–37. Celery Phosphorus Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Sodium Bicarbonate Phosphorus Soil Test (ppm)													
	0–3	4–5	6–7	8–9	10–12	13–15	16–20	21–25	26–30	31–40	41–50	51–60	61–80	81+
Mineral Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	230 (205) (HR)	230 (205) (HR)	220 (196) (HR)	220 (196) (HR)	220 (196) (HR)	210 (187) (HR)	190 (170) (HR)	160 (143) (HR)	140 (125) (MR)	110 (98) (MR)	80 (71) (MR)	50 (45) (LR)	0 (RR)	0 (NR)
Muck Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	120 (107) (HR)	120 (107) (HR)	120 (107) (HR)	120 (107) (HR)	120 (107) (HR)	110 (98) (MR)	100 (89) (MR)	90 (80) (MR)	80 (71) (MR)	70 (62) (LR)	50 (45) (LR)	40 (36) (LR)	0 (RR)	0 (NR)

Table 7–38. Celery Potassium Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Ammonium Acetate Potassium Soil Test (ppm)											
	0–15	16–30	31–45	46–60	61–80	81–100	101–120	121–150	151–180	181–210	211–250	251+
Mineral Soils												
Potash (K_2O) required kg/ha (lb/acre)	340 (303) (HR)	330 (294) (HR)	310 (277) (HR)	280 (250) (HR)	250 (223) (HR)	200 (178) (HR)	150 (134) (MR)	90 (80) (MR)	50 (45) (MR)	0 (LR)	0 (RR)	0 (NR)
Muck Soils												
Potash (K_2O) required kg/ha (lb/acre)	230 (205) (HR)	220 (196) (HR)	210 (187) (HR)	200 (178) (HR)	170 (152) (MR)	150 (134) (MR)	120 (107) (MR)	80 (71) (MR)	40 (36) (MR)	0 (LR)	0 (RR)	0 (NR)

Table 7–39. Celery Nutrient Ranges

LEGEND: – = no data available

Plant Part	Time of Sampling	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu
		Per Cent (%)						Parts Per Million (ppm)				
Outer petiole	6 weeks after transplanting	1.5–1.7	0.3–0.6	6–8	1.3–2.0	0.3–0.6	–	20–30	5–10	20–40	15–25	4–6
	at maturity	1.5–1.7	0.3–0.6	5–7	1.3–2.0	0.3–0.6	–	20–30	5–10	20–40	20–40	1–3

Adapted from G. Hochmuth, et al. 2018. *Plant Tissue Analysis and Interpretation for Vegetable Crops in Florida*. University of Florida IFAS Extension. HS964.

Micronutrients

Celery is more susceptible to nutrient deficiencies than some crops, and foliar micronutrients are often needed. For complete information, see *Micronutrients*, Chapter 1.

Boron

Boron deficiency results in a physiological disease known as "cracked stem" or "cat scratches." Foliar applications of boron can be applied. Use caution when applying boron. This nutrient builds to toxic levels quite quickly, potentially harming rotational crops.

Plant Tissue Analysis

When used in conjunction with soil analysis, plant tissue analysis can be useful for planning foliar micronutrient applications, diagnosing crop problems or for evaluating a fertilizer program. Plant tissue analysis does not replace soil testing or a sound soil fertility program.

For more information, see Table 7–39, and *Plant Tissue Analysis*, Chapter 1.

Irrigation

Celery is very responsive to irrigation. If the available soil moisture level in the root zone drops below 60% during the critical irrigation period, irrigation is important to maintain crop yield and quality. For drip irrigation systems, consider irrigating when the available soil water drops below 85%. Blackheart and buttoning occur when there are extreme fluctuations in moisture and the critical irrigation period is transplanting to harvest. Plants have a rooting depth of 30–60 cm (1–2 ft).

For more information on irrigation scheduling, see the *Irrigation Management* BMP (order number BMP08E) and the OMAFRA factsheet, *Monitoring Soil Moisture to Improve Irrigation Decisions*.

Harvest

Celery crops mature within 90–125 days after transplanting. Harvest begins late July and continues until several frosts have occurred. A field is ready to begin harvest once the majority of the plants have reached a desirable size. Celery stalks should be entirely green when cut crosswise. Pithiness will result if the crop is harvested late. Pithiness occurs when celery stalk cross-sections turn from green to white. Fresh market celery is cut just below the soil line, while processing celery may be cut slightly above. Fresh market celery is cut by hand or machine and packed in the field, while processing celery is generally cut by machine and transported in bulk hoppers or trailers to the processing facility. See Table 7–40.

Table 7–40. Average Yields of Celery

Crop	Yield
Fresh market (24 plants/carton)	1,850–2,450 27-kg cartons/ha (750–1,000 60-lb cartons/acre)
Processing	45–68 tonnes per ha (20–30 tons per acre)

Storage

Do not store celery damaged by frost, insects, disease or handling. The stalks readily absorb foreign flavours. It is important to store celery in a room that is free from odours. To maintain quality, remove the field heat before placing in large storage rooms.

Cooling methods suitable for use with celery include vacuum cooling, forced air cooling and hydrocooling.

Storage Temperature:	0°C (32°F)
Relative Humidity:	98%–100%
Duration:	2–3 months

See Table 3–1, Chapter 3.

Caution

Some individuals may be sensitive to furocoumarins, the natural chemicals found in celery. These substances increase in diseased celery. Rashes or blisters can develop when skin is exposed to celery in the sunlight. Using rubber gloves and wearing long-sleeve shirts when handling celery, and leg protection when walking in the field, will prevent the development of skin rashes.

Pest Management and Disorders

See Figure 7–44, *Celery stages of development and pest activity calendar.*

Diseases

Aster Yellows

Candidatus phytoplasma asteris

Identification: Symptoms on celery first appear as a bright yellowing of leaves. Excessive, brittle, yellow crown growth follows, accompanied by severe twisting (Figure 7–45).

Biology: The aster leafhopper vectors and transmits aster yellows.

Management Notes: Removing infected plants within the crop, as well as perennial weeds, may reduce disease incidence in future years. Control measures are targeted at aster leafhopper, the vector of aster yellows. See *Aster Leafhopper*, also in *Celery*.

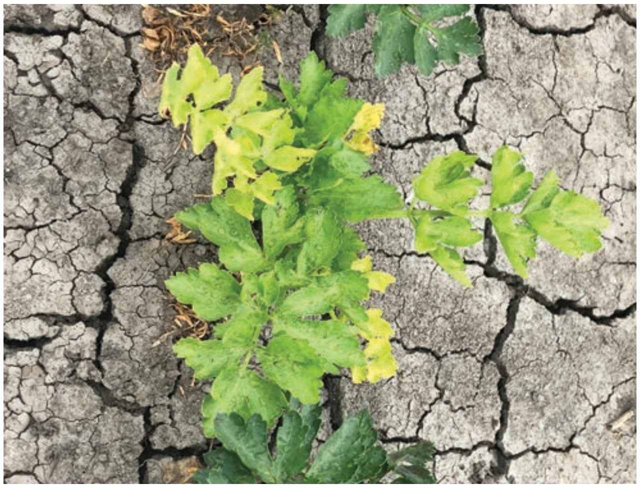


Figure 7–45. Symptoms of aster yellows on celery.

Bacterial Leaf Spot

Pseudomonas syringae pv. *apii*

Identification: Small, yellow, circular spots appear on the leaves. As the lesions enlarge, they turn a rusty brown colour with a yellow halo. Under heavy bacterial leaf spot pressure, lesions will merge and kill infected leaves. Bacterial leaf spot rarely infects the petioles.

Biology: Bacterial leaf spot overwinters in crop residue. Development is favoured by cool, wet conditions. Optimal temperatures between 20°C–25°C (68°F–77°F) and at least 10 hours of leaf wetness promote infection and growth. Following the initial infection, splashing water, tools and people can spread the disease, especially when foliage is wet.

Management Notes: If the field has a history of foliar pathogens, rotate out of celery for at least 2 years. Use hot-water-treated seed. Grow seedlings in a commercial soilless mix or heat-pasteurized soil. Avoid evening irrigation and prolonged periods of leaf wetness. Do not transplant diseased seedlings into the field.

Cercospora Leaf Spot (Early Blight)

Cercospora apii

Identification: Circular yellow or tan spots that may enlarge to 1 cm (½ in.) or more in diameter develop on the leaves. During periods of high humidity, greyish spores appear on the leaf lesions. In severe cases, lesions also develop on the petioles (Figure 7–46).

Figure 7–46. Cercospora leaf spot of celery.

Biology: Cercospora leaf spot occurs during mid-summer when heavy evening dews follow sunny, warm, daytime weather. This disease overwinters in crop residue. Following the initial infection, splashing water and the wind disperse disease spores.

Management Notes: If the field has a history of foliar pathogens, rotate out of celery for at least 2 years. Use hot-water-treated seed and select resistant cultivars. Grow seedlings in a commercial soilless mix or heat-pasteurized soil. Do not transplant diseased seedlings into the field. Incorporate crop residue once early seedings have been harvested.

After transplanting, begin fungicide applications when plants are one-third grown or when the first signs of disease are detected.

Cucumber Mosiac Virus

See *Northern Root Knot Nematode*, Chapter 6.

Fusarium Yellows

Fusarium oxysporum f. sp. *apii*

Identification: Yellowing of outer celery leaves follows the fungal infection of the roots and basal plate. Stunting and stiffening of outer stalks or petioles occurs in some cultivars. Infection results in darkening of the vascular tissues, followed by basal rot. The leaves may become more brittle, with a rougher texture, and curl upwards. In the later stages of pathogen development, the foliage turns brown, and the plant dies.

Biology: Early-season infections often lead to more severe yield and quality losses than infections occurring later in the season. Spore populations in the soil and the weather during the growing season are also important. Severe symptoms are associated with high spore levels in the soil, heavy wet soils and warm growing seasons. This fungus persists in soil for many years. Fusarium yellows may be introduced on infected transplants, on workers, equipment and soil carried by wind or water erosion.

Figure 7–47. Discolouration of the celery heart (A) and veins (B) due to fusarium yellows.

Management Notes: Sanitation is important in preventing the spread of this disease. Avoid cultivation practices that spread infected soil from one area to another. Do not return infected celery trimmings to fields after harvest, if fusarium yellows is present in the field. Practice a 3-year rotation with onions or lettuce to reduce spore populations in infected fields. Avoid the use of carrots in the rotation.

Planting tolerant cultivars is the most effective management method; they will withstand moderate levels of the fungus. High fungal populations, excessive heat and drought stress may diminish this tolerance.

Leaf Curl (Anthracnose)

Colletotrichum fiorniae

Identification: Downward cupping of leaves that are small and stunted. Tan-to-brown cracks and streaks develop along stalks. Some stalks become twisted and brittle, and brown lesions may develop on leaf margins. Adventitious roots can develop along the stalk, and crown rot (similar to blackheart) can develop (Figure 7–48).

Figure 7–48. Row of infected celery plants (A) showing downward cupping of leaves (B) caused by celery leaf curl, *Colletotrichum acutatum*.

Biology: Overwinters on celery and carrot leaf residue and seed. Pathogen survives on celery and non-hosts, including several common weeds, without producing symptoms allowing inoculum to build up throughout the season. Spores are spread by splashing during rain or irrigation as well as equipment and people moving through the crop while leaves are wet.

Management Notes: Practice a 3–4-year crop rotation with non-host crops. Some cultivars are more susceptible than others. Grow tolerant cultivars when possible. Inspect and rogue out infected seedlings at transplant and rogue out infected plants throughout the season. Avoid prolonged periods of leaf wetness and allow the canopy to dry out between irrigation events. Incorporate crop residue immediately after harvest.

Root Knot Nematode

See Chapter 6.

Root Lesion Nematode

See Chapter 6.

Sclerotinia (Pink Rot)

Sclerotinia sclerotiorum

Identification: White mycelium forms on water-soaked lesions starting on the outer leaves and progresses into the heart. Black, hard, pea-sized sclerotia will be produced on white mycelium as the disease progresses. The tissue under the mycelium develops a pinkish soft rot. The fungi can also cause damping-off of seedlings (Figure 7–49).

Figure 7–49. Sclerotinia producing water-soaked lesions and white mycelial growth, characteristic of pink rot.

Biology: Sclerotinia overwinters as small black structures (sclerotia) in the soil. Cool, wet conditions with excessive moisture cause the sclerotia to germinate. These produce spores that spread in the air and land on the plant tissue to cause infection. Temperatures ranging from 20°C–25°C (68°F–77°F) and continuous leaf wetness (high humidity and/ or heavy dews) favour sclerotinia development. Overwintering sclerotia may survive for several years in the soil.

Management Notes: Practice a greater than 4-year crop rotation away from susceptible crops (cucurbits, edible beans, soybeans, canola, carrots and lettuce). Increase row spacing to maintain better air movement. Avoid prolonged periods of leaf wetness and allow canopy to dry out between irrigation events.

Septoria Leaf Spot (Celery Late Blight)
Septoria apiicola

Identification: Small yellow specks develop in the foliage and move upwards. Older lesions frequently turn tan-to-brown coloured and enlarge up to 1.5 cm (⅔ in.) in diameter. Small black specks (pycnidia) typically appear on the lesions (Figure 7–50).

Figure 7–50. Black lesions of septoria leaf spot (*Septoria apicola*) of celery.

Biology: Septoria development is favoured by moderate temperatures between 10°C–27°C (50°F–81°F) and wet conditions. This disease overwinters in crop residue. Following the initial infection, spore dispersal occurs through splashing water, people, machinery and the wind.

Management Notes: If the field has a history of foliar pathogens, rotate out of celery for at least 2 years. Use hot-water-treated seed and select resistant cultivars. Grow seedlings in a commercial soilless mix or heat-pasteurized soil. Do not transplant diseased seedlings into the field. Incorporate crop residue once early seedings have been harvested.

After transplanting, begin fungicide applications when plants are one-third grown or when the first signs of disease are detected.

Insects

Aphids
Aphididae family

Identification: Small, 1–3-mm (<⅛ in.) sap-sucking insects with two cornicles (outward projections) on their hind ends and a pear-shaped body. The most common aphid species on celery is the green peach aphid, however, sunflower, potato, foxglove and buckthorn aphids also periodically infest celery.

Damage: When populations become high, the presence of aphids renders the crop unmarketable. Aphids also transmit viruses between plants as they feed on these crops. See *Northern Root Knot Nematode*, Chapter 6.

Biology: Most aphids have a wide range of host plants and some aphid species, such as the green peach aphid, overwinter as eggs on a perennial host. Eggs hatch into nymphs, which appear as smaller versions of the adults. Over 10 generations can occur in a growing season. Populations can build rapidly since females give birth to large numbers of live young without mating.

Scouting and Thresholds: Examine at least 50 plants per field, checking the undersides of the leaves and tender new growth. A threshold of 5% of plants with aphids is high; 1% is high if plants are less than 2 weeks from harvest. Fewer than 10 aphids on a given plant is considered a light infestation and over 20 aphids per plant is considered severe.

Management Notes: Whenever possible, use products that are selective for aphids. Many beneficial insects can significantly reduce aphid infestations below economically damaging levels.

See the OMAFRA factsheet *Aphids Infesting Lettuce and Celery in Ontario*.

Aster Leafhopper
Macrosteles quadrilineatus

Identification: Aster leafhoppers are small, greenish-grey insects with six spots arranged in pairs on top of the head. Their wings are transparent and heavily veined (Figure 7–51).

Figure 7–51. Aster leafhopper.

Damage: Aster leafhoppers transmit aster yellows to celery, carrots and leafy greens by feeding on these crops. See *Aster Yellows*, also in *Celery*.

Biology: The aster leafhopper overwinters as an egg in the leaf tissue of winter grains such as wheat and rye. Approximately 130 degree days, base 9°C, are required for egg maturation. An additional 270 degree days are required for development to adulthood. See *Growing Degree Days*, Chapter 4.

As the winter grains mature in late May and early June, local first-generation leafhoppers disperse into vegetable crops. Leafhopper populations from the U.S. are also carried into Ontario on weather systems. Both local dispersal and long-distance movement influence the incidence and severity of the aster leafhopper and aster yellows.

Scouting and Thresholds: The Aster Yellows Index (AYI) determines the need to treat a crop. To use the AYI, monitor aster leafhoppers with a sweep net. Multiply the number of aster leafhoppers captured in 100 sweeps by the percentage of leafhoppers carrying aster yellows in your area (4%–5% is the currently recommended per cent infectivity in Ontario). Use this formula:

Infectivity rate (4%–5%) x # of leafhoppers/100 sweeps) = AYI

Use an AYI threshold of 30–35 for celery.

Management Notes: Grow resistant cultivars and remove perennial weeds from fields that may act as reservoirs. Manage populations of leafhopper with insecticides. See the OMAFRA factsheet *The Aster Leafhopper and Aster Yellows*.

Cabbage Looper

See *Brassica Crops*, in this chapter.

Carrot Weevil

See *Carrot*, in this chapter.

Leafminers
Liriomyza spp.

Identification: Leafminers are small (2–3 mm (~⅛ in.)), shiny, black-and-yellow flies that lay their eggs in leaves. The larvae of leafminers are small, pale yellow maggots.

Damage: Female leafminers lay their eggs on the leaves, leaving small “bronzed” puncture marks. Females also pierce the leaves to feed on plant sap. Larvae feed between the upper and lower surface of the leaves. Depending on the species mines can be straight (pea leafminer) or serpentine (other leafminers). Leafminer feeding reduces the plant’s photosynthetic capacity. The mines also affect marketability and provide an entrance for disease organisms.

Biology: Optimal temperatures for leafminer development range from 21°C–32°C (70°F–90°F). Egg-laying is reduced at temperatures below 10°C (50°F). Leafminers can be a problem throughout the season. The pea leafminer is typically a late-season pest with populations peaking from the end of August through the middle of September.

Management Notes: Lamb’s-quarters is an alternate host for leafminers. Good weed control can reduce infestations. Crop rotation is an effective pest management tool. Alternating leafminer-susceptible crops with leafminer-resistant crops reduces the population. Apply insecticides as soon as pea leafminer adults first appear.

Potato Leafhopper

See *Potato*, in this chapter.

Slugs

See *Slugs*, Chapter 5.

Tarnished Plant Bug
Lygus lineolaris

Identification: The immature tarnished plant bug (TPB) nymphs are greenish in colour, with well-developed legs and moderately long antennae. Late instars have wing pads and four black spots on the thorax, behind the head, as well as one on the abdomen. Adults are pale green or yellow-to-dark brown, with dark markings and have a small triangle shape on their back. Nymphs of tarnished plant bugs look similar to the green peach aphid but lack the cornicles and are much faster moving than aphids.

Damage: The insects have sucking mouthparts that they use to pierce into plant tissue and inject saliva that helps break down plant tissue. The damage of stings and lesions on celery stalks is often seen before the insect itself. Yellowing often moves up the leaf or stalk from the original "sting" as the toxic saliva moves up in the transpiration stream of the leaf (Figure 7–52).

Biology: TPBs overwinter as adults in plant debris and leaf litter in protected areas such as woodlots, fence rows and ditches. Emerging adults feed and oviposit on broadleaf weeds in the spring, before moving into crops. TPB is a sporadic pest, present in Ontario throughout the growing season. Two generations occur per year, with a partial third in parts of Southern Ontario. First-generation adults emerge in July and the second in August and September.

Scouting and Thresholds: Inspect the heart leaves of 50–100 plants per field at least twice a week. A threshold of 0.1 (last 3 weeks before harvest) to 0.2 TPB (transplant to 3 weeks before harvest) per plant has been identified for celery.

Figure 7–52. Tarnished plant bug feeding marks on celery stalk (A) and tarnished plant bug nymph (B) at the base of the celery plant.

Management Notes: Manage alternate hosts such as pigweed, chickweed, dandelion, lamb's-quarters, ragweed and fleabane. Avoid planting celery near alfalfa, as tarnished plant bugs migrate as soon as the alfalfa is cut.

Disorders

Blackheart

Identification: Breakdown of young tissues in the growing points and leaf tips of the plant resulting in brown to black rot on the inner leaves. As the plant grows, these leaf tips continue to die back and are colonized by secondary pathogens. Adventitious roots can develop along the stalk, and crown rot (similar to leaf curl) can develop (Figure 7–53).

Figure 7–53. Blackheart causing stunting and dead tissue in the growing point of the celery plant.

Management: Blackheart is the result of calcium deficiency in the tissue when there is a wide fluctuation in soil moisture and excessive soil fertility, especially nitrogen, which stimulates rapid growth. Some cultivars show tolerance to this physiological disorder. Avoid wide fluctuations in soil moisture and over-fertilization. A foliar spray of soluble calcium directed at the heart of the plant may help prevent the disorder if there are not adequate levels of calcium already in the soil.

Bolting

See *Brassica Crops*, in this chapter.

Cucurbit Crops

(bitter melon, cucumber, gourds, muskmelon (including cantaloupe), pumpkins, winter squash, watermelon and zucchini)

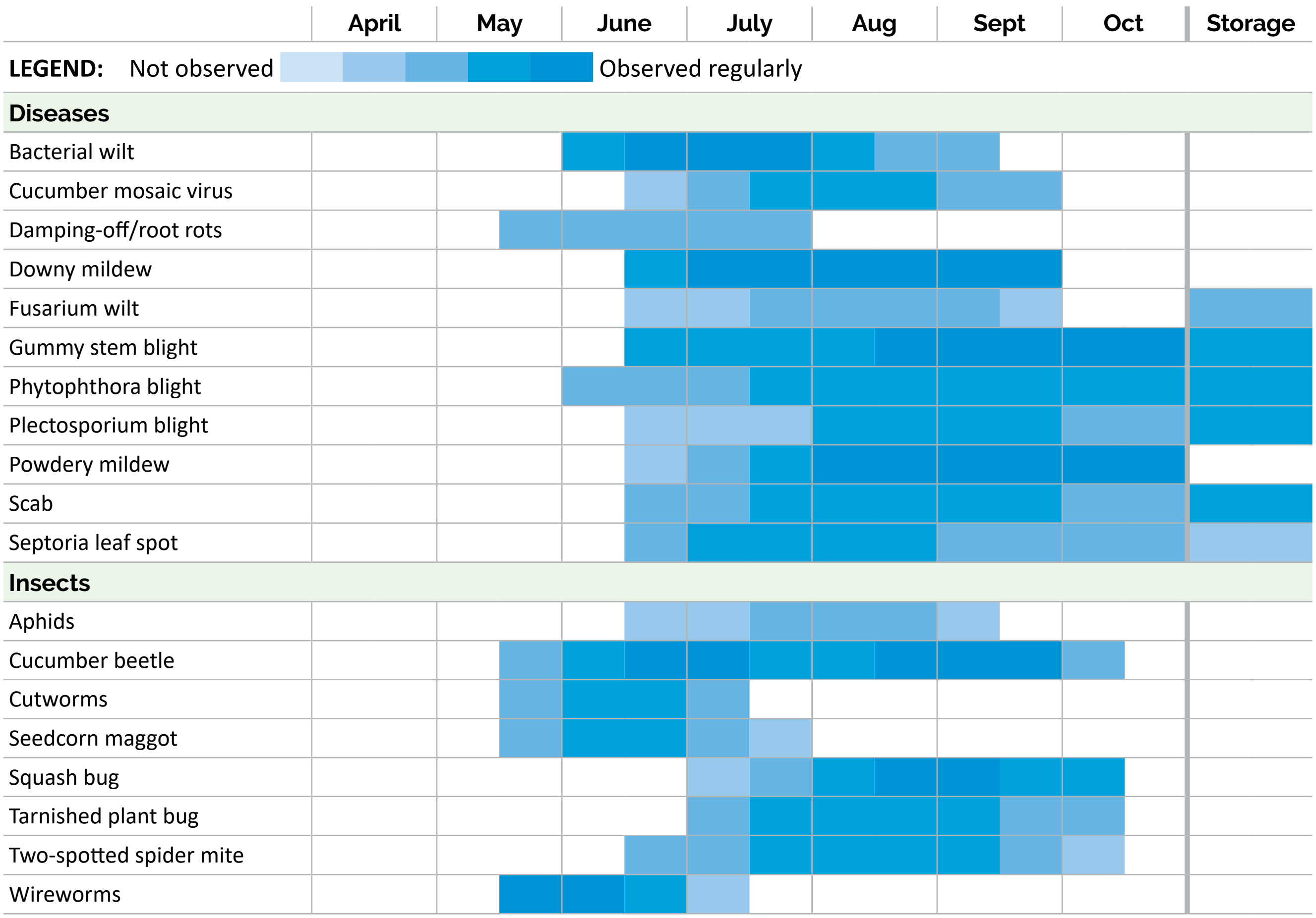


Figure 7–54. Cucurbit pest activity calendar. The actual period of activity for any given pest will vary significantly from year to year, depending on environmental factors.

CUCURBIT CROPS

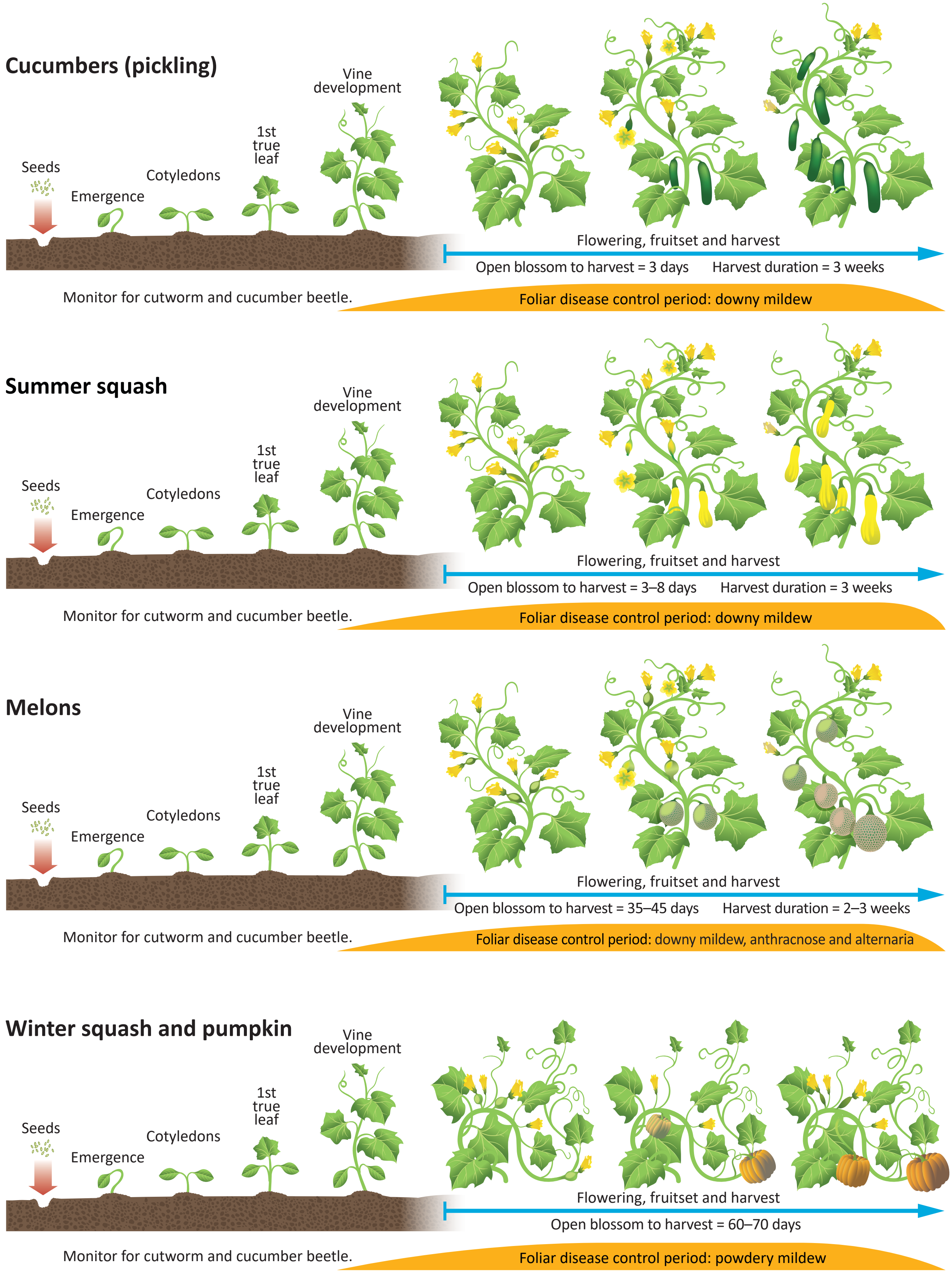


Figure 7–55. Cucurbit development stages and key pest management periods.

Production Requirements

Soil types:	well-drained sandy-loam
Soil pH:	6.1–6.5
Suitable rotational crops:	corn, cereal crops, brassica crops, onions, leafy greens
Do not rotate with:	beans, peppers, cucurbits
Minimum soil temperature:	15°C (59°F)
Optimum air temperature:	18°C–24°C (64°F–75°F) (watermelon: 22°C–30°C/72°F–86°F)
Earliest planting date:	after risk of frost has passed, unless protected by row covers or tunnels

Cucurbit Development

Cucurbit plants produce imperfect flowers. The male (anthers) and female (pistil) are formed on separate blooms. Male flowers are typically formed higher in the canopy and outnumber the female ones significantly. Cucumbers are the exception. Cucumber cultivars are gynoecious, predominantly female. The female blossoms of all cucurbits are easily recognized by the small fruit at the base of the blossom. Once pollination has occurred, the resulting seeds will develop, causing the fruit to expand.

Cucurbit plants are indeterminate in growth. They will continue to produce flowers until the plants are killed, usually by frost or disease. However, once the plant has made its fruit load, it will usually abort newly developing fruit. In cucumbers and summer squash, removing the mature fruit will promote the development of further fruit sets. In the other cucurbit crops, late-setting fruit generally do not reach maturity in time for commercial harvest (Figure 7–55).

Seeding and Spacing

Total cucurbit yields tend to increase with plant density. Processing cucumbers for machine harvest benefit the most from close spacings. In other cucurbits, high plant populations may result in harvest problems due to excessive vine growth. An overly dense canopy is also more conducive to disease pressure.

In pumpkins and squash, fruit size decreases as plant populations increase. Larger-sized pumpkin and winter squash varieties will benefit from wider spacing. Extremely wide rows are slow to close canopy, resulting in higher levels of weed pressure.

Gourds and mini-pumpkins respond to significantly higher populations (up to 14,800 plants/ha).

Depending on the type, cucurbits may be either direct-seeded or transplanted. See Table 7–41 and Table 7–42.

Table 7–41. Cucurbit Type and Planting Method

LEGEND: Y = yes
N = not suggested
O = used only occasionally in commercial fields

Crop Type	Direct Seeded	Transplants
Cucumbers, pickling	Y	O
Cucumbers, slicing	O	Y
Muskmelons	N	Y
Pumpkins and gourds	Y	Y
Summer squash	N	Y
Watermelons	N	Y
Winter squash	Y	Y

CUCURBIT CROPS

Table 7–42. Cucurbit Crop Spacing

Crop	Row Spacing	In-Row Spacing	Depth	Seeding Rate
Cucumbers				
Fresh	0.9–1.8 m (3–6 ft)	20–30 cm (8–12 in.)	1.25–4 cm (½–1½ in.)	3.3–5.6 kg/ha (3–5 lb/acre)
Cucumbers (processing)				
Hand-pick	0.76–1.2 m (2½–4 ft)	10–15 cm (4–6 in.)	1.25–4 cm (½–1½ in.)	37,000–49,400 seeds/ha (15,000–20,000 seeds/acre)
Machine harvest	50–76 cm (20–30 in.)	10 cm (4 in.)	1.25–4 cm (½–1½ in.)	185,250–197,600 seeds/ha (75,000–80,000 seeds/acre)
Pumpkins and squash				
Standard types	1.5–3 m (5–10 ft)	60–150 cm (2–5 ft)	2.5–4 cm (1–1½ in.)	2.2–4.5 kg/ha (2–4 lb/acre)
Semi-bush types	1.2–1.8 m (4–6 ft)	45–91 cm (1.5–3 ft)	2.5–4 cm (1–1½ in.)	2.2–4.5 kg/ha (2–4 lb/acre)
Small bush types	0.9–1.5 m (3–5 ft)	45–91 cm (1.5–3 ft)	2.5–4 cm (1–1½ in.)	2.2–4.5 kg/ha (2–4 lb/acre)
Melons[1]				
Muskmelons	1.5–1.8 m (5–6 ft)	60–90 cm (2–3 ft)	1.25–1.9 cm (½–¾ in.)	2.2 kg/ha (2 lb/acre)
Watermelons[2]	1.8–2.4 m (6–8 ft)	90–120 cm (3–4 ft)	1.25–1.9 cm (½–¾ in.)	2.2 kg/ha (2 lb/acre)

[1] Approximately 2.2 kg of seed are required to produce enough melon seedlings for 1 ha.
[2] Wider in-row spacing (120 cm (4 ft)) may help increase fruit size, depending on the cultivar.

CUCURBIT CROPS

Seedless Watermelon Production

Seedless watermelon are not entirely seedless: they produce small white, sterile seed traces. These seed traces are triploid, containing three sets of chromosomes. Seedless watermelon is produced when the female flowers on a special tetraploid (four sets of chromosomes) watermelon cultivar are fertilized with the pollen from a normal diploid (two sets of chromozomes) cultivar.

Seeded cultivars are commonly used as the diploid pollinators. Use one pollinator plant for every three seedless ones. For the best results, mix the pollinator cultivars in the same row as the seedless watermelon plants. Plant a pollinator with a different fruit type to distinguish it from the seedless cultivar at time of harvest.

Many seed companies have developed specific pollenizer cultivars. These cultivars produce undersized, unmarketable fruit that do not use the space or resources required by standard diploid varieties. The pollenizer cultivar is typically interplanted between the seedless plants, one pollenizer between every 3–4 plants. The suitable ratio may change, depending on the pollenizer cultivar.

Consider using two different pollinizers in each field to optimize early and late production. Also consider the disease tolerance levels of the pollinizer cultivars. Hollow heart, a common production issue in watermelon, is often caused by insufficient pollination. Having an ample source of pollen for the duration of the fruit set period will help reduce the incidence of hollow heart.

Under cool or stressful growing conditions, some seed development may occur in seedless watermelons.

Pollination

All cucurbit crops depend on insects to transfer pollen from the male to the female blossoms. Each female blossom must be visited 15–20 times for adequate pollination to occur. Poorly pollinated fruit exhibit awkward shape and poor size.

Figure 7–56. Female hoary squash bee.

Native Pollinators

Native pollinators often play an important role in pumpkin and squash production. The hoary squash bee is commonly found in many pumpkin and squash fields in Southern Ontario (Figure 7–56). Adult squash bees visit pumpkin and squash flowers for nectar and pollen, which is used to feed developing larvae. Unlike honey bees, which will forage from a wide variety of flowering plants, squash bees are specialist feeders and live exclusively in pumpkin and squash fields. Females build underground nests for the larvae that can often be found in the field, or along the field edges. Compared to honey bees, squash bees are more effective at pollinating pumpkin and squash blossoms.

Native bees are less common in cucumbers, muskmelons and watermelons. Bumblebee and honey bee populations may not provide sufficient pollination for a high yielding crop, especially in larger acreage settings. Assess all cucurbit fields for bee activity at early bloom. If there is adequate pollination occurring, a clear buzz of activity can be heard in the field in the early morning hours.

Honey Bees

In melons and cucumbers, consider introducing one colony of honey bees for every hectare. Aim to have the hives in the field at first bloom. When renting hives, ensure that the bees have available water and sufficient food from other sources when the cucurbit crop flowering begins to decline. Bee colonies fed solely on cucurbit pollen may be undernourished heading into the winter months.

Insecticides may poison bees. Follow label requirements regarding spraying insecticides during bloom. If necessary, spray only in the evening or at night, after bees have finished foraging for the day. If possible, remove hives from the field prior to spraying.

Fertility

Macronutrients

Nitrogen

Apply up to 110 kg N/ha. Broadcast 65 kg N/ha and all the phosphate and potash required, prior to planting. Side-dress the remainder of the nitrogen before the vines start to run. On sandy soils, a second application may be necessary after the vines begin to run.

Alternatively, up to 100 kg of N + K_20/ha can be applied in a band, 5 cm (2 in.) to the side and 5 cm (2 in.) below the seed at planting. Broadcast the remainder of the fertilizer requirements before planting, or side-dress before the vines start to run.

In no-till fields, planted into a dense cereal cover crop, ensure that the plants have sufficient available nitrogen at planting to compensate for the residual nitrogen that is tied up by the cover crop. While it can be significant in the early growing season, especially under cool growing conditions, the nitrogen tie-up in this growing system is temporary and will not usually impact the total amount of nitrogen required to grow the crop.

Over-application of nitrogen may result in excessive vine growth, reduced fruit yields and an increased potential for fruit rots.

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. See Table 1–12 and Table 1–13, Chapter 1.

CUCURBIT CROPS

Table 7–43. Cucurbit Phosphorus Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Sodium Bicarbonate Phosphorus Soil Test (ppm)													
	0–3	4–5	6–7	8–9	10–12	13–15	16–20	21–25	26–30	31–40	41–50	51–60	61–80	81+
Mineral Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	230 (205) (HR)	230 (205) (HR)	220 (196) (HR)	220 (196) (HR)	210 (187) (HR)	190 (170) (HR)	170 (152) (HR)	140 (125) (MR)	110 (98) (MR)	80 (71) (MR)	50 (45) (MR)	30 (27) (LR)	0 (RR)	0 (NR)

Table 7–44. Cucurbit Potassium Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Ammonium Acetate Potassium Soil Test (ppm)											
	0–15	16–30	31–45	46–60	61–80	81–100	101–120	121–150	151–180	181–210	211–250	251+
Mineral Soils												
Potash (K_2O) required kg/ha (lb/acre)	230 (205) (HR)	220 (196) (HR)	200 (178) (HR)	180 (161) (HR)	140 (125) (HR)	100 (89) (HR)	70 (62) (MR)	50 (45) (MR)	40 (36) (MR)	0 (LR)	0 (RR)	0 (NR)

Phosphorus and Potassium

Test the soil to determine phosphorus and potassium requirements. See Table 7–43 and Table 7–44.

Fertigation

For fertigated cucurbit crops, broadcast all the phosphate requirement and approximately 30%–50% of the nitrogen and potash requirements prior to planting. Inject the remainder through the drip irrigation system at the rates shown in Table 7–45.

Table 7–45. Cucurbit Nitrogen and Potash Injection Schedules

Stage	Rate per week
Transplanting to fruit set	5 kg/ha (4.5 lb/acre)
Fruit sizing to harvest	10 kg/ha (9 lb/acre)
During harvest	5 kg/ha (4.5 lb/acre)

Plant Tissue Analysis

When used in conjunction with a soil analysis, plant tissue analysis is a useful tool for diagnosing crop problems or for evaluating a fertilizer program. Plant tissue analysis does not replace soil testing or a sound soil fertility program.

For sampling purposes, use the most recently mature leaf. Provide the lab with at least 20 leaves (250 g fresh leaf material) for each sample. When sampling a problem area, it is often useful to take a separate sample from a good area for comparison. For more information, see *Plant Tissue Analysis*, Chapter 1, and Table 7–46.

Table 7–46. Cucurbit Nutrient Ranges

LEGEND: – = No data available

Plant Part	Time of Sampling	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu	Mo
		Per Cent (%)						Parts per Million (ppm)					
Cucumber													
Most recently mature leaf	before bloom	3.5–6	0.3–0.6	1.6–3	2–4	0.58–0.7	0.3–0.8	40–100	30–100	20–50	20–60	5–20	0.3–1.0
	early bloom	2.5–5	0.3–0.6	1.6–3	1.3–3.5	0.3–0.6	0.3–0.8						
Muskmelon													
Most recently mature leaf	12-in. vines	4.0–5.0	0.4–0.7	5–7	3–5	0.35–0.45	0.2	40–100	20–100	20–60	20–80	5–10	0.6–1.0
	early fruit set	3.5–4.5	0.3–0.4	1.8–4	1.8–5	0.3–0.4	0.2						
Pumpkin													
Most recently mature leaf	5 weeks after seeding	3–6	0.3–0.5	2.3–4	0.9–1.5	0.35–0.6	0.2–0.4	40–100	40–100	20–50	25–40	5–10	0.3–0.5
	8 weeks from seeding	3–4	0.3–0.4	2–3	0.9–1.5	0.3–0.5	0.2–0.4	40–100	40–100	20–50	20–40	5–10	0.3–0.5
Squash (summer)													
Most recently mature leaf	early fruit	3–5	0.3–0.5	2–3	1–2	0.3–0.5	0.2–0.5	40–100	40–100	20–50	25–40	5–20	0.3–0.5
Watermelon													
Most recently mature leaf	last cultivation	3–4	0.3–0.5	3–4	1–2	0.25–0.5	0.2–0.4	30–100	20–100	20–40	20–40	5–10	–
	first flower	2.5–3.5	0.3–0.5	2.7–3.5	1–2	0.25–0.5	0.2–0.4						
	first fruit	2–3	0.3–0.5	2.3–3.5	1–2	0.25–0.5	0.2–0.4						
	harvest period	2–3	0.3–0.5	2–3	1–2	0.25–0.5	0.2–0.4	30–100	20–100	20–40	20–40	3–10	–

Adapted from G. Hochmuth, et al. 2018. *Plant Tissue Analysis and Interpretation for Vegetable Crops in Florida*. University of Florida IFAS Extension. HS964.

Irrigation

Cucumbers, cantaloupe and summer squash are responsive to irrigation. Pumpkins, watermelon and winter squash are deeper rooted and only moderately responsive to irrigation.

Effects of moisture stress: smaller fruit size, hollow heart (watermelon), blossom end rot

Critical irrigation period: flowering, fruit set and sizing

Rooting depth: 30–60 cm/12–24 in. (cucumbers, cantaloupe and summer squash); 60–110 cm/24–44 in. (pumpkins, watermelon and winter squash)

For overhead irrigated cucurbits, grown on bare soil, irrigate when the available soil moisture (ASM) level reaches 50%. Crops grown with trickle irrigation, under plastic mulch, will require more frequent (smaller) applications of water to maintain >80% ASM.

For more information on irrigation scheduling, see the *Irrigation Management Best Management Practices* (order number BMP08E) and the OMAFRA factsheet *Monitoring Soil Moisture to Improve Irrigation Decisions*.

Table 7–47. Cucurbit Maturity and Harvest Parameters

Crop	Harvest Indicators	Harvest Frequency	Harvest Duration
Cucumbers, pickling[1]	◦ Average time from flower set to harvest is 4–5 days. ◦ Pick according to size standards set by the processor/buyer.	daily	4–6 weeks
Cucumbers, slicing[1]	◦ 15–18 days from flower to harvest. Fruit length of 15–20 cm (6–8 in.)	every 2–3 days	4–6 weeks
Muskmelon	◦ Average time from flower set to harvest is 40 days. ◦ For local shipping and sales, harvest at "½ slip" when the fruit detaches from the stem with moderate pressure. For longer-term storage and shipping, harvest at "¼ slip." Soluble solid content of mature fruit should range from 9°–12° Brix. Standard sizes 9, 12 or 15 fruit/box.	every 3–5 days	2–4 weeks
Pumpkin & gourds	◦ Average time from flower set to harvest is 60–70 days. ◦ Mature fruit have a thick, hard rind. They are not easily scratched or nicked. Fruit that have at least 60% colour development will continue to turn orange after picking. Exposure to severe frosts damages the skin.	usually once or twice per field depending on the season and marketing strategy	September to October
Summer squash[1]	◦ Average time from flower set to harvest is 3–8 days. ◦ Pick according to size standards set by the buyer.	daily	2–4 weeks
Winter squash	◦ Average time from flower set to harvest is 60–70 days. ◦ Mature fruit have a thick, hard rind. They are not easily scratched or nicked. Exposure to severe frosts damages the skin.	usually once or twice per field depending on the season and marketing strategy	September to October
Watermelon	◦ Average time from flower set to harvest is 40 days. ◦ Harvest based on sweetness and internal colour development. Soluble solid content of mature fruit should be greater than 8°–10° Brix. Ripeness indicators include yellowing of the underbelly and drying of the first tendril attached to the fruit stem.	every 3–5 days	2–4 weeks

[1] Do not leave oversized, mature fruit on the vine as they will inhibit the growth of new fruit.

Harvest

Harvest fruit according to the timelines and parameters listed in Table 7–47.

Mature pumpkins, gourds and winter squash will "hold" in the field for several weeks under dry, sunny weather conditions. As the vines begin to die back, cut the stems from the main plant to prevent disease development and decay on the "handles."

Overall yields of cucurbit crops will vary greatly depending on planting rates, growing conditions, varietal selection, and insect, disease and weed management. See Table 7–48.

Table 7–48. Average Yields of Cucurbit Crops

Crop	Yield
Cucumbers (pickling, hand harvest)	25 tonnes/ha (11 tons/acre)
Cantaloupe	22 tonnes/ha (10 tons/acre)
Pumpkin	27 tonnes /ha (12 tons/acre)
Squash	20 tonnes/ha (9 tons/acre)
Watermelon	50 tonnes/ha (22 tons/acre)

Curing Pumpkin and Squash

Windrowing squash and pumpkins in the field prior to storage often acts as a natural curing process. Room curing is not always necessary. Butternut and hubbard cultivars respond to this treatment, but storage life may be shortened. Curing acorn-type squashes decreases the storage life and eating quality. If deemed necessary, fruit may be cured for 10–20 days at 24°C–27°C (74°F–80°F).

Storage

Cucurbits vary significantly in their storage life expectancy. They are very susceptible to chilling injury, which appears after the fruit has been brought back to room temperature. For information on storing cucumbers, melons and summer squash, see Table 3–1, Chapter 3.

Pest Management and Disorders

See Figure 7–54. *Cucurbit pest activity calendar*.

Diseases

Alternaria

Alternaria alternata

Identification: Alternaria lesions develop on the older leaves first. The initial infection causes small, yellow-to-brown flecks with a light-yellow halo. As they enlarge, the flecks turn brown and necrotic. The lesions also develop concentric rings, although the rings may not always be present.

In muskmelons, alternaria lesions may grow as large as 2 cm (¾ in.) in diameter. Watermelon lesions are a darker brown and somewhat smaller (5 mm or ¼ in.). If left untreated, the lesions often grow together, causing the entire leaf to turn brown, wither and die. The resulting reduction in the leaf canopy often causes decreased fruit size, reduced levels of sugar and an increase in sunscald. Fruit infections are uncommon but may occur under high disease pressure.

Biology: Alternaria mycelium can survive for 1–2 years in cucurbit residue. Under humid weather conditions, dormant mycelium become active and produce conidia, which then infect the current year's crop. Secondary spores are spread to neighbouring plants by splashing water. They may also become airborne, resulting in further spread across the field.

Alternaria infections require periods of high humidity (2–24 hours) and can occur at almost any temperature from 12°C– 30°C (54°F– 86°F). The rate of infection increases at warmer temperatures. Heavy dews or intermittent rainfall followed by warm windy conditions favour the spread of this disease by promoting sporulation.

Scouting and Thresholds: Watermelons and cantaloupe are particularly susceptible to this disease. There are no thresholds established for alternaria.

Management Notes: Follow a 3–4-year rotation away from all cucurbits. Avoid heavy fertilizer applications. An unnecessarily dense, heavy canopy will prolong humidity on the leaf surface. For watermelons and cantaloupe, follow a preventive fungicide program starting no later than row closure.

Angular Leaf Spot

Pseudomonas syringae pv. *lachrymans*

Identification: Small, "water-soaked" lesions develop on infected leaves. These lesions expand in size until they are confined by the veins, resulting in an angular appearance. Affected areas turn brown, and the centres fall out, leaving small holes in the leaf. In cucumbers, the lesions are usually very small. In pumpkins and squash they may become up to 0.5 cm (¼ in.) long.

Biology: This bacterial disease is seed-borne, although bacteria also survive in infected crop residue. In wet conditions, it spreads rapidly across the field through splashing rainwater or machinery. While infections may appear at a certain stage, based on the weather conditions, under good growing conditions it does not usually spread to the new growth.

Thresholds: None have been established.

Management Notes: Angular leaf spot is more prevalent in pumpkins and squash. There is good varietal resistance available in cucumbers. Purchase pathogen-free seed; do not save seed from infected fields. A 2-year rotation away from cucurbit crops will reduce overwintering inoculum.

Anthracnose

Colletotrichum magnum (on fruit), *C. orbiculare*

Identification: Dry, reddish-brown, circular lesions appear on the leaves. These lesions often have a lighter yellow border. Black fruiting bodies (called acervuli) may be visible on the under-surface of older lesions. The new growth on infected plants may become twisted and distorted. As the disease progresses, the dead tissue may fall out of the centre of the lesion, giving the leaf a ragged appearance.

Infected fruit develop sunken lesions, 2–5 mm (⅛–¼ in.) in diameter (or larger). Salmon pink spores may develop on the lesions under moist conditions. Anthracnose lesions may appear on infected muskmelons after harvest, as well as during storage and shipping.

Biology: Crop residue is the primary source of inoculum. Rainfall from heavy storms often results in the deposition of spore-laden soil on the leaf surface.

Symptoms develop 4–5 days after infection. Anthracnose infections often spread faster on the older leaves. Anthracnose is a late-season disease. It prefers warm temperatures of 22°C–27°C (72°F–81°F) and high relative humidity (100% for 24 hours).

Scouting and Thresholds: None established. Apply preventive fungicides at row closure, at the first sign of disease or when nighttime temperatures exceed 15°C (59°F), whichever comes first.

Management Notes: Muskmelon and watermelon are most susceptible to anthracnose. Infections in pumpkins and squash are less common. A 3–4-year rotation away from all cucurbit crops will effectively reduce soil-borne infections. Avoid heavy fertilizer applications, which promote unnecessarily dense canopy and reduce airflow. Overhead irrigation may also increase the spread of this disease from plant to plant. Avoid working in the field when the foliage is wet, and workers and equipment may transfer spores from infected plants to clean ones.

Bacterial Leaf Spot

Xanthomonas campestris pv. *cucurbitae*

Identification: Leaf lesions begin as an elongated yellow area along a leaf vein. As the disease progresses, the lesions become dark brown with yellow margins. Eventually they may coalesce to form large necrotic areas. They are easily confused with several other foliar diseases, including angular leaf spot. This disease infects only pumpkins, gourds and squash (Figure 7–57).

Fruit lesions are circular in shape, small and slightly sunken. They often have a dark brown border. As the lesions enlarge in size (up to 12 mm (½ in.) in diameter) they crack and become scab-like. They often penetrate deeper than the rind, causing a small hole. In the larger pumpkin cultivars, infected fruit will develop an internal rot, often collapsing in the field prior to harvest. In squash and smaller pumpkin fruit, the infection usually remains more localized, however infected fruit may continue to rot in storage.

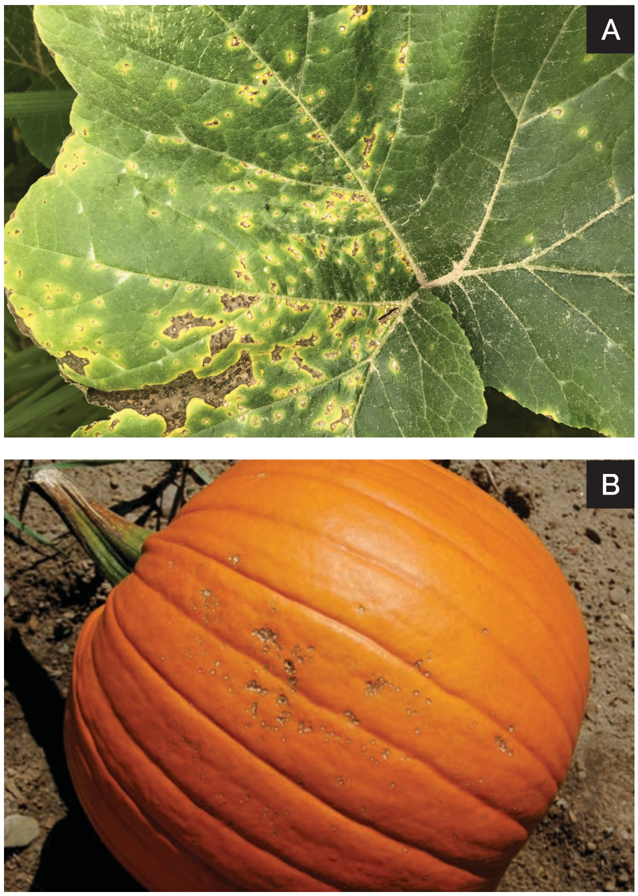


Figure 7–57. Bacterial leaf spot lesions on pumpkin leaf (A) and fruit (B).

CUCURBIT CROPS

Biology: Bacterial spot survives in crop residue. It is also seed-borne. It tolerates high mid-summer temperatures and can spread very quickly within the field.

Management Notes: Use disease-free, certified seed. Follow a 2–3-year rotation away from all cucurbit crops. The bacteria are easily spread by splashing rain or irrigation and by machinery. Avoid working in the field when the foliage is wet.

Bacterial Wilt

Erwinia tracheiphila

Identification: Infected leaves develop dull green patches followed by wilting and yellowing. Bacterial wilt often starts on one leaf, spreading leaf-by-leaf back towards the main crown. Eventually the whole plant will turn olive-to-brown and die. The distribution of the disease within the field is often very random, with infected plants appearing next to healthy ones (Figure 7–58).

Figure 7–58. Bacterial wilt in cucumbers.

If the cut ends of an infected runner are placed together and slowly drawn apart, sticky strands of bacteria are sometimes visible (especially during humid conditions or early in the day).

Biology: This disease survives in the stomachs of adult cucumber beetles. Bacteria in the beetle excrement fall on the chewed surfaces and enter the plant through the wound. Once inside the plant, the bacteria multiply and colonize the vascular tissue, preventing the transport of water and nutrients to the growing tips of the infected runners.

Cucurbit crop species and cultivars differ in their susceptibility to bacterial wilt. Cucumber and melon cultivars are often very susceptible.

Management Notes: There are no control methods for bacterial wilt. The effective management of cucumber beetle populations is the only way to prevent the spread of this disease. For more information, see *Cucumber Beetles*, also in *Cucurbit Crops*.

Cucumber Mosaic Virus (CuMV)

Various causal agents

See Chapter 6.

Damping-Off and Root Rots

Pythium sp., *Phytophthora* sp., *Rhizoctonia* sp., *Fusarium* sp.

Use sterile soil or soil-less mix for growing seedlings. For identification and management information on these common vegetable diseases, see Chapter 6. See also *Fusarium Wilt*, also in *Cucurbit Crops*.

Downy Mildew

Pseudoperonospora Cubensis

Identification: Downy mildew–infected leaves initially develop darker green (water-soaked) areas on the upper leaf surface. As the infection progresses, the lesions become yellow-to-tan, then brown and necrotic (Figure 7–59). The corresponding lower leaf surface may be covered with a downy, grey-to-purple mould with black spores (sporangia).

In cucumbers, the lesions are often confined by the leaf veins and take on an angular appearance. During favourable environmental conditions, downy mildew can completely defoliate an unprotected crop within a week of the initial infection. Fruit from infected plants are usually undersized, deformed, susceptible to sunburn and otherwise unmarketable.

Biology: Downy mildew is favoured by cool, wet or humid weather conditions. The heavy dewfalls common to the Great Lakes region support downy mildew infections. Infection can occur in less than 2 hours of leaf wetness. Spore production is highest at temperatures of 15°C–20°C (59°F–68°F). Under favourable weather conditions, the pathogen will produce new innoculum in as little as 4 days. Downy mildew is an obligate parasite. It requires living host tissue to survive. As a result, it does not overwinter in the field in Ontario.

Thresholds: Downy mildew must be managed proactively and preventively. There are no thresholds.

Management Notes: Follow a basic 7–14-day fungicide program. Apply all downy mildew fungicides preventively. Always rotate between different fungicide groups.

Ensure good spray coverage. Select nozzles and set the air pressure to deliver a medium-to-fine droplet size. All fungicides should be applied in a minimum 340 L water/ha (30 gallons/acre).

As downy mildew does not overwinter in the field in Ontario, outbreak reports from the southern U.S. can act as an early warning system for activity in Ontario. Once it has been identified somewhere in the Great Lakes region (Ohio, Michigan or Ontario), further reports usually occur within 1–2 weeks, or less.

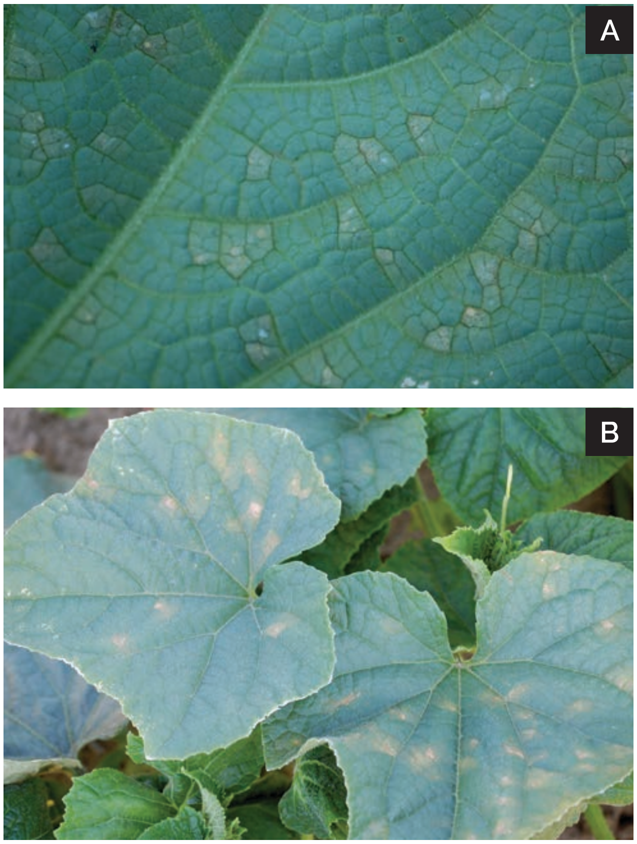


Figure 7–59. Cucurbit downy mildew — newly infected “watersoaked” lesions (A) and chlorotic-to-necrotic older lesions (B).

Once downy mildew has been identified in the Great Lakes regions, cucumber and cantaloupe growers should switch to the targeted downy mildew fungicides. Also consider using these products during prolonged periods of cool, humid weather **OR** when there are cool night-time temperatures followed by heavy dewfall. If downy mildew has been identified in an area, maintain a strict 5–7-day fungicide schedule.

Cucumbers: Cucumbers are particularly susceptible to this disease. Downy mildew–tolerant cultivars provide a level of protection but will not offer complete resistance. Initiate broad-spectrum fungicides no later than vine development. If suitable environmental conditions exist during the early stages of crop development, use a banded application to protect the young plants.

Cantaloupe (muskmelon): The predominant clade of downy mildew will also infect cantaloupe. Early melons grown under plastic row covers should be treated with a preventive fungicide before the covers are installed and as soon as they are removed. Keep in mind that most downy mildew–targeted fungicides will not control fungal diseases such as anthracnose and alternaria. Include broad-spectrum products in the fungicide rotation to manage these diseases.

Pumpkins and Squash: Downy mildew is less common in pumpkin and squash crops. Zucchini is more susceptible than winter squashes, however, with these crops, powdery mildew is the primary pathogen of concern. Downy mildew fungicides will not provide protection against diseases such as powdery mildew, scab or gummy stem blight. Use downy mildew–targeted fungicides if the disease has specifically been identified in pumpkins and squash in the Great Lakes region.

Fusarium Wilt

Fusarium oxysporum f. sp. *cucumerinum* (cucumber), *F. oxysporum* f. sp. *melonis* (muskmelon), *F. oxysporum* f. sp. *niveum* (watermelon)

Identification: Fusarium wilt is a serious problem in muskmelons and an occasional problem in other cucurbits. Early-season fusarium wilt infections result in the damping-off of seedlings and transplants. Later infections often appear as the fruit reaches maturity. The foliage turns a dull grey-green and wilts, followed by a general yellowing and defoliation. These symptoms are often mistaken for water stress and the disease remains unidentified until large portions of the field collapse and die.

Fusarium oxysporum infection causes the vascular tissue to turn reddish-brown. A gummy exudate may form on the underside of infected vines.

Muskmelons (cantaloupe) from infected fields may develop raspberry-pink fungal growths on the underside of the fruit or in the internal tissue at the blossom-end.

Biology: Fusarium wilt attacks the plant at any stage. Outbreaks often follow periods of crop stress, including hot, dry weather conditions. Soil temperatures of 18°C–25°C (64°F–77°F) support rapid disease progression. Cucurbit crops grown in slightly acidic soils (pH 5.0–5.5) may be more prone to fusarium infections. Fusarium spores may survive in infested soil for several years.

Management Notes: Foliar fungicides will not control this disease. Fusarium-resistant cultivars are available. Look for cultivars with multiple resistance genes.

Follow a 3–4-year rotation away from all cucurbits and use only sterile, soil-less mix for transplant production. Lime soil to a target pH of 6.0–6.5 and avoid over-fertilization, especially with fertilizers containing ammonium. Maintain adequate soil moisture levels, especially during fruit-set and sizing. Fungicides registered for application at planting or through drip irrigation may help to slow the progression of this disease, but under favourable weather conditions they will not provide complete control.

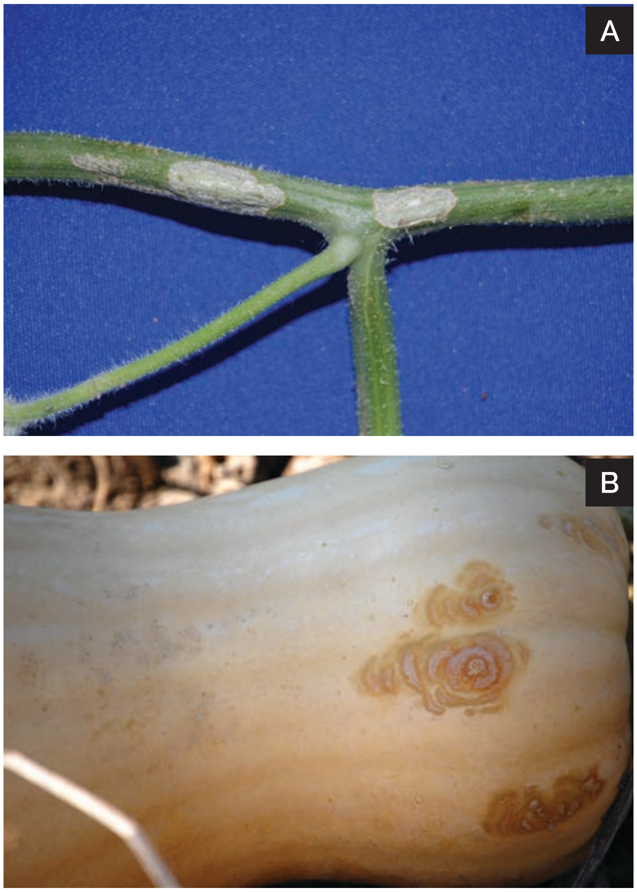


Figure 7–60. Gummy stem blight lesions on the stem (A) and fruit (B).

Gummy Stem Blight (also known as Black Rot or Alligator Skin)

Didymella bryoniae

Identification: Circular tan-to-dark brown lesions develop between healthy green leaf veins. Infected leaves often curl inwards and become necrotic. Stem cankers often produce a gummy brown exudate, although other cucurbit diseases such as fusarium also produce stem exudates. Under humid conditions, black pycnidia may develop on the stem lesions. Later in the season, gummy stem blight infections cause fruit decay, often accompanied by copious amounts of black spores (known as black rot). On butternut squash, distinct circular bronze patterns (alligator skin) develop on the surface of infected fruit (Figure 7–60).

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Biology: Gummy stem blight survives on crop residue and in infected seed. Infections often occur in "hot spots," spreading out from a single infected seed. All cucurbit crops are susceptible to this disease. It can be spread long distances by ascospores, as well as shorter distances when the conidia formed in the gummy exudate are spread by machinery or human activities. Gummy stem blight thrives between 16°C–24°C (61°F–75°F) and a moisture level of 85% RH in the canopy.

Thresholds: None have been established. Apply fungicides at the first sign of foliar symptoms.

Management Notes: Follow a 2–3-year crop rotation and use certified, treated seed. Do not save seed from infected fields. Avoid working in fields with wet foliage.

Phytophthora Blight
Phytophthora capsici

Identification: Phytophthora symptoms include foliar blight, fruit rot and stunting. The foliar blight/ crown rot phase often starts at the growing point. Dark-green lesions form on the crown, eventually girdling it and causing the entire plant to turn brown, collapse and die. Infections often start in low-lying areas, however the disease can spread quickly across the field, including higher ground. Often, infected plants will be located next to otherwise healthy-looking plants.

Figure 7–61. Characteristic "powdered sugar" lesions caused by phytophthora on pumpkin.

Fruit infections begin as a large water-soaked lesion. White spores resembling powdered sugar develop on the surface of the lesion (Figure 7–61).

Biology: Phytophthora spreads rapidly during warm, wet weather. Ideal conditions for infection are moist soils above 18°C (64°F) and air temperatures between 24°C (75°F) and 29°C (84°F). Phytophthora oospores live in the soil for up to 10 years.

Thresholds: None have been established.

Management Notes: Rotate fields for a minimum of 3 years away from all host crops (cucurbits, peppers, beans). **Do not plant cucurbit crops in a field that has a history of phytophthora infections.** Select well-drained fields. Minimize soil compaction and avoid excessive irrigation, especially in overhead systems. Disinfect farm equipment if travelling between infected and non-infected fields. Products registered for at-planting or application through trickle irrigation will help delay the spread of this disease. If the weather conditions are conducive to the spread of this disease, fungicides will provide suppression only.

Plectosporium Blight (also known as Microdochium Blight)
Plectosphaerella cucumerina

Identification: Light-tan to white, spindle-shaped lesions form on the stems, vines and peduncles. Infections on the lower leaf surface may sporulate, infecting the upper surface of the fruit below. Heavy foliar infections will lead to defoliation, decreased fruit size and soluble solids, and sunburn. Infected fruit develop superficial white specks, or a silvery russeting.

Biology: Plectosporium is soil borne. It survives on decaying crop residue and as a saprophyte on organic matter. This disease is more common under warm wet conditions.

Scouting and Thresholds: There are no thresholds established for plectosporium.

Management Notes: Pumpkins, squash and zucchini are more susceptible to this disease than the other cucurbits. A broad-spectrum preventive fungicide program aimed at controlling powdery mildew will also help prevent plectosporium. Follow a minimum 3–5-year crop rotation and avoid unnecessarily dense crop canopies caused by high plant populations or over-fertilization.

Powdery Mildew

Golovinomyces cichoracearum (syn. *Erysiphe cichoracearum*),
Podosphaera xanthii (syns. *Sphaerotheca fuliginea; Podosphaera fusca*)

Identification: Initial symptoms develop on the undersides of older, shaded leaves. A pale yellow spot may be visible on the upper leaf surface. The corresponding area on the under surface of the leaf will produce fine, white mycelium (Figure 7–62). This white, powdery growth spreads to the upper leaf surface as the disease progresses. Infected leaves and stems wither and die prematurely, impacting both yield and fruit quality.

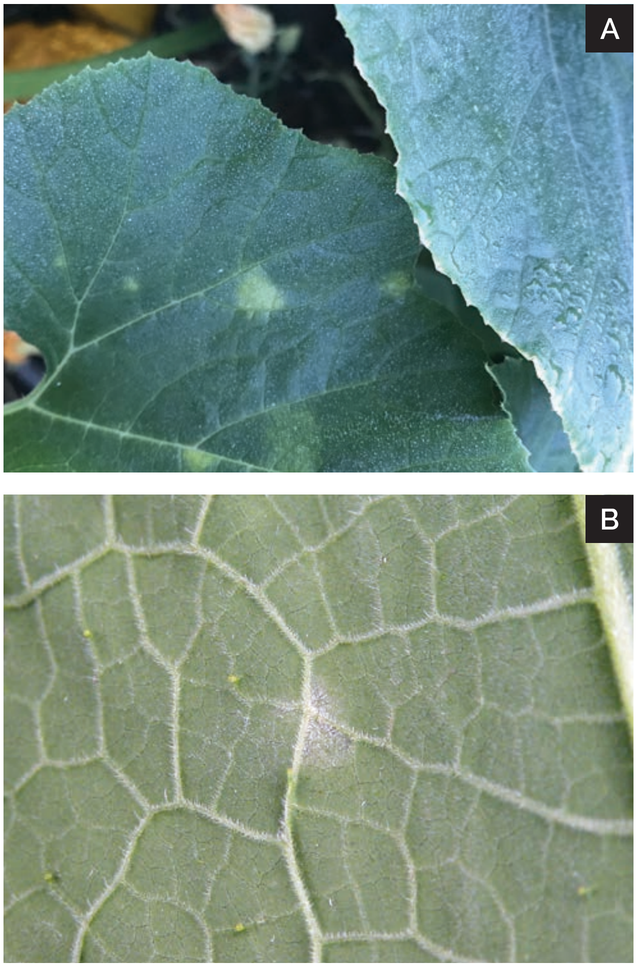

Figure 7–62. Yellow powdery mildew lesions on the upper leaf surface (A) and white fungal growth (hyphae) on the lower leaf surface (B).

Biology: This disease does not overwinter in Ontario. Wind-borne spores usually arrive from the southern U.S. and Mexico in mid-summer. Peak infection periods occur when temperatures are in the range of 20°C–26°C (68°F–79°F). Disease development slows when temperatures climb above 26°C (79°F).

Infections can develop at relatively low humidity levels, although humid weather conditions and heavy dews lead to more rapid disease development.

Scouting and Thresholds: Begin applying protectant fungicides at the first sign of disease. Lesions often appear on the petioles before they become noticeable on the leaves. Late July through August is usually the most critical powdery mildew control period.

Management Notes: There is a wide selection of powdery mildew–resistant cultivars available for all types of cucurbit crops. Good spray coverage on both the upper and lower leaf surfaces is important. Apply all fungicides in a minimum of 340 L water/ha (30 gallons/acre). Begin a broad-spectrum preventive program when the rows begin to close over, and continue on a 7–14-day schedule during fruit sizing.

Scab

Cladosporium cucumerinum

Identification: Scab lesions occur on the leaves, stems, petioles and fruit. Foliar infections appear as numerous, small, pale yellow-to-white spots. These lesions are somewhat angular in shape. The centre of each lesion may deteriorate, leaving a shot-hole appearance to the leaf. Severely infected plants may also develop shortened internodes and deformed new growth. Symptoms do not always develop on the leaves. Occasionally, fruit infections will occur without any apparent leaf lesions.

Infected fruit develop small, irregular-shaped cavities. The margins of these sunken lesions are often coated with a dried, corky layer. Fruit are most prone to infection while they are green and rapidly expanding, before the rind begins to harden. When pumpkin and winter squash fruit are infected at an early stage of development, the fruit will continue to expand around the lesions, causing bumpy, misshapen fruit.

Biology: Scab survives in the soil on infected cucurbit residue. It may also be seed-borne. The conidia can travel for long distances on moist air currents. Widespread infections can occasionally be traced to a specific storm front. Cool temperatures of 17°C– 20°C (62°F–68°F) and heavy dews or intermittent showers are conducive to scab development. Dry days following moist nights allow for significant wind-borne spore distribution. Scab symptoms on melons may progress in storage at temperatures as low as 8°C (46°F). Symptoms first appear 3–4 days after the initial infection. In Ontario, fruit infections often occur in late-summer or early fall.

Scouting and Thresholds: Apply a broad-spectrum fungicide at the first sign of foliar infection.

Management Notes: Follow a 3–4-year crop rotation, and use certified, treated seed.

Septoria Leaf Spot
Septoria cucurbitacearum

Identification: Septoria leaf lesions are small and circular. They are very small — approximately 1–2 mm (~1⁄16 in.) in diameter. They are white-to-light-brown in colour with a darker brown border. As the symptoms progress, the lesion may crack and produce small black pycnidia. Later-season infections may cause small, straw-coloured pimple-like lesions to develop on the fruit. These lesions are usually superficial and will not develop into fruit rots in storage.

Biology: Septoria overwinters as dormant mycelium on cucurbit residue. In the spring, the mycelia form pycnidia and conidia, which serve as the primary inoculum. Driving rains and splashing soil spread the conidia from plant to plant. Disease spread may be stalled by hot mid-summer conditions, only to return again once temperatures become more moderate in the fall. Cool, humid conditions of 16°C–19°C (61°F–66°F) support septoria infections.

Scouting and Thresholds: Scout cucurbit fields at least once a week to identify foliar disease before it begins to infect the fruit.

Management Notes: Follow a 3–4-year crop rotation and use certified, treated seed. Broad-spectrum fungicides used for other foliar diseases will usually help eliminate septoria infections.

Insects

Aphids
Various species

See Chapter 5.

Cucumber Beetles
Acalymma vittata

Identification: Striped cucumber beetles are 6–7 mm (¼–⅓ in.) long. They are yellow with three black stripes. The stripes of the cucumber beetle extend the entire length of the wing pad. The lower portions of the legs are black (Figure 7–63). It is commonly confused with the Western corn rootworm. Rootworm beetles are slightly flattened, and the stripes to do not extend the full length of the back. The spotted cucumber beetle, also known as the southern corn rootworm, can also be found in Ontario, especially in the later summer months. It is slightly larger and yellow with black spots.

Figure 7–63. Adult striped cucumber beetles, frass and feeding damage.

Damage: While feeding damage can seriously harm seedlings, the main threat to cucurbit crop yield is the transmission of bacterial wilt. See *Bacterial Wilt*, also in *Cucurbit Crops*. High levels of feeding on the blossoms is common but does not usually impact yield. Late-season feeding on the fruit may damage the rind of pumpkins, reducing marketable yields.

Biology: Cucumber beetles over-winter as adults in grassy fence rows and sheltered areas. They begin to emerge as the soil temperatures reach 10°C (50°F). Overwintering beetles feed on weeds and grasses until the cucurbit crops emerge. There is one generation of cucumber beetles per year, however; beetle development is often very staggered. As a result there may be several "flushes" of beetle activity throughout the season.

Scouting and Thresholds: Treat when beetles exceed 0.5–1 per plant. Use the lower threshold on bacterial wilt–susceptible cultivars. A follow-up spray may be necessary, as beetle emergence is often staggered.

Management Notes: Cucumber beetles tend to congregate in certain areas of the field, making them an excellent candidate for spot spraying. Cucurbit crops vary in their attractiveness to beetles. Zucchini and pumpkins are highly attractive, cucumbers and melons less so. The more attractive species offer opportunities for trap cropping.

The percentage of cucumber beetles harbouring bacterial wilt tends to increase dramatically over the course of the summer. The best way to stop the occurrence and spread of this disease is to control overwintering adult beetles early in the season.

Cutworms
Various species

See Chapter 5.

Seedcorn Maggot
Delia platura

See Seedcorn Maggot, *Peas*.

Squash Bug
Anasa tristis

Identification: Squash bug eggs are laid in clusters of 7–20 on the underside of the leaf. The bullet-shaped eggs are yellow when first laid, turning reddish-brown as they mature (Figure 7–64).

Figure 7–64. Squash bug eggs.

Squash bug nymphs have pear-shaped, pearly grey bodies with darker legs and antennae. Squash bug adults have flattened, tear-shaped bodies. They are brownish-grey with yellow-to-orange markings.

Damage: Squash bugs prefer pumpkins and winter squash over other types of cucurbits. They suck the sap from the leaves, resulting in a yellow speckling. Heavy feeding may cause the leaf to wilt, turn brown and die. Late summer populations may feed on the peduncle, leaving it more susceptible to fungal rots. Feeding on the rind of the fruit can render it unmarketable.

Biology: Adults emerge from overwintering sites in the spring and begin laying eggs in early June. Due to a prolonged egg-laying period, several different stages of development are often present in the field at the same time. Populations often peak in late summer to early fall.

Scouting and Thresholds: Starting in early July, inspect the lower leaf surface for egg masses. Squash bugs like to hide in well-sheltered locations. Pay special attention to weedy areas and to the lower surface of the developing fruit. The threshold is one egg mass per plant.

Management Notes: Insecticides are most effective when targeted at small young nymphs. Good weed control will help reduce the potential squash bug habitat in the field.

Tarnished Plant Bug
Lygus lineolaris

Tarnished plant bugs are not a common pest of cucurbit crops, however, populations in melons have been identified from time to time. See Chapter 5, for more information.

Two-Spotted Spider Mite
Tetranychus urticae

The two-spotted spider mite will feed on all cucurbits, although it is more commonly found in watermelon. See Chapter 5, for more information.

Wireworm
Various species

See Chapter 5.

Eggplant

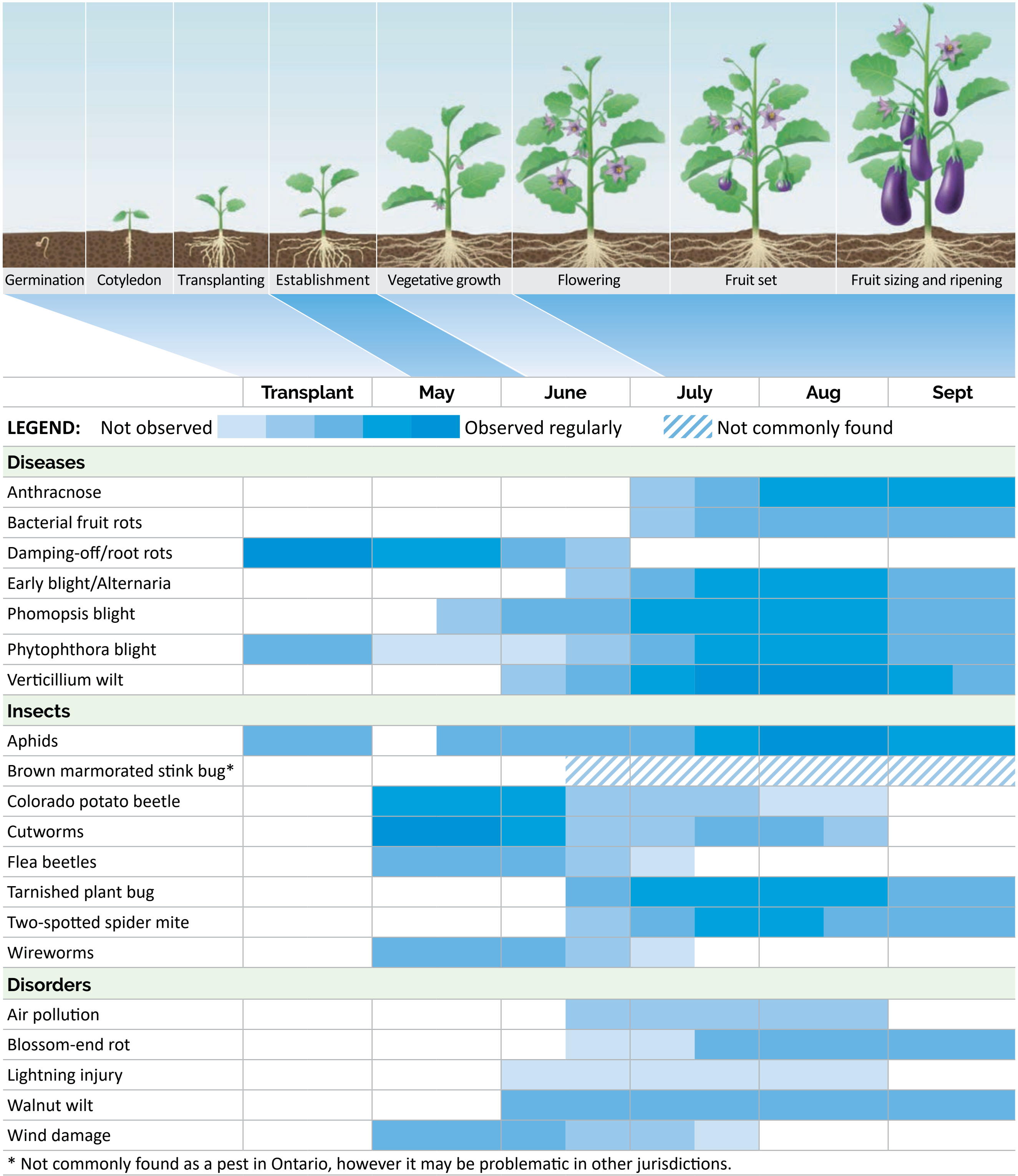

Figure 7–65. Eggplant stages of development and pest activity calendar. The actual period of activity for any given pest will vary significantly from year to year, depending on environmental factors.

EGGPLANT

Eggplant Crop Growth

Eggplant in Ontario is planted in the field as transplants. Transplants are grown in greenhouses for approximately 7–9 weeks. Seeds germinate 7–10 days after seeding and sprout two initial leaves called cotyledons, which have an elongated oval shape. The next two leaves to grow are called the first true leaves and will have the shape of a traditional eggplant leaf. Fresh market transplants are usually around 10–20 cm (4–8 in.) tall and usually have 6 or more true leaves.

Once transplanted, the plants continue to establish a root system and focus on vegetative growth, or growth of leaf tissue. Once the first flowers are visible, the plants have entered the flowering stage. Flowers are pollinated primarily by insects, and small fruit begin to form. This is the flowering and fruit set stage. The next stage is sizing, where the fruit are growing in size. Eggplants are ready to harvest when they are a marketable size, but before the seeds turn colour or the fruit become soft. Fruit are picked one to two times per week until the temperature drops and the crop is no longer productive.

Production Requirements

Soil types: well-drained sandy loams
Soil pH: 5.5–6.5
Suitable rotational crops: beans, brassica crops, cereal crops, corn, peas, soybeans
Do not rotate with: peppers, potatoes, tomatoes, tobacco
Minimum soil temperature: 16°C (61°F)
Optimum air temperature: 22°C–30°C (71°F–86°F)
Earliest planting date: late-May after risk of frost has passed

Table 7–49. Eggplant Transplant Requirements

Seed Required for 10,000 Transplants	Seeding Depth	Germination Temperature			Days to Germination	Optimum Growing Temperature		pH Tolerance	Time (weeks)
		Min.	Opt.	Max.		Day	Night		
113 g (4 oz)	0.6 cm (¼ in.)	24°C (75°F)	29°C (84°F)	32°C (90°F)	7–10	21°C–27°C (70°F–81°F)	18°C–21°C (64°F–70°F)	6.0–6.8	7–9

Seeding and Spacing

See Table 7–49.

Eggplant transplants are very responsive to fertilizer. If feeding at every watering, use approximately 100 ppm nitrogen. Increase the concentration if feeding less often. See Table 1–14, Chapter 1.

Water quality is an important component of transplant production. See Table 1–16, Chapter 1.

See Table 7–50.

Table 7–50. Eggplant Crop Spacing

Row Spacing	In-Row Spacing	Seeding Rate
90–120 cm (36–48 in.)	45–60 cm (18–24 in.)	Approx. 200–300 g of seed will produce enough transplants for 1 ha (2½ acres).

Table 7–51. Eggplant Phosphorus Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Sodium Bicarbonate Phosphorus Soil Test (ppm)													
	0–3	4–5	6–7	8–9	10–12	13–15	16–20	21–25	26–30	31–40	41–50	51–60	61–80	81+
Mineral Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	270 (241) (HR)	260 (232) (HR)	250 (223) (HR)	240 (214) (HR)	230 (205) (HR)	220 (196) (HR)	200 (178) (HR)	170 (152) (HR)	140 (125) (MR)	110 (98) (MR)	80 (71) (MR)	50 (45) (LR)	0 (RR)	0 (RR)

Table 7–52. Eggplant Potassium Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Ammonium Acetate Potassium Soil Test (ppm)											
	0–15	16–30	31–45	46–60	61–80	81–100	101–120	121–150	151–180	181–210	211–250	251+
Mineral Soils												
Potash (K_2O) required kg/ha (lb/acre)	270 (241) (HR)	250 (223) (HR)	230 (205) (HR)	200 (178) (HR)	170 (152) (HR)	130 (116) (HR)	100 (89) (MR)	80 (71) (MR)	50 (45) (MR)	0 (LR)	0 (RR)	0 (NR)

Plasticulture and Season Extension

Eggplant responds well to plastic mulches and row covers. However, it is very susceptible to low temperatures. Row covers may not provide significant frost protection. Monitor the temperature under the row cover regularly and ventilate when it reaches 35°C (95°F) or higher. Remove the cover once conditions are favourable for good growth and prior to pollination. To control weed growth under the mulch, choose one that blocks most light transmission, such as black, white on black, or infrared-transmitting mulch.

Fertility

Macronutrients

Nitrogen

Apply up to 70 kg/ha (62 lb/acre). Broadcast 35 kg/ha (31 lb/acre) and all the required phosphate and potash before planting. The remainder of the nitrogen should be side-dressed 3–4 weeks after transplanting.

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. See Table 1–12 and Table 1–13, Chapter 1.

Phosphorus and Potassium

Test the soil to determine phosphorus and potassium requirements. See Table 7–51 and Table 7–52.

Starter Solution

At transplanting, apply a high-phosphorus starter solution. Starter fertilizer is especially important when planting in cool soils. See *Starter Fertilizers for Vegetable Crops*, Chapter 1. Adjust application rates according to the temperatures listed in Table 7–53.

Table 7–53. Eggplant Transplant Starter Solution Adjustments

Soil Temperature	Starter Concentration[1]
Below 18°C (64°F)	Full rate specified on the label.
18°C–27°C (64°F–81°F)	Half the rate specified on the label.
Above 27°C (81°F)	Starter not normally required.

[1] Under dry conditions or in sandy soils with less than 2% organic matter, use half the rate specified on the label.

Table 7–54. Eggplant Nutrient Ranges

Plant Part	Time of Sampling	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu	Mo
		Per Cent (%)						Parts Per Million (ppm)					
Most recently mature leaf	early fruit set	4.2–5	0.3–0.6	3.5–5	0.8–1.5	0.25–0.6	0.4–0.6	50–100	50–100	20–40	20–40	5–10	0.5–0.8

Adapted from G. Hochmuth, et al. 2018. *Plant Tissue Analysis and Interpretation for Vegetable Crops in Florida*. University of Florida IFAS Extension. HS964.

Plant Tissue Analysis

When used in conjunction with a soil analysis, plant tissue analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. Plant tissue analysis does not replace soil testing or a sound soil fertility program.

For more information, see Table 7–54 and *Plant Tissue Analysis*, Chapter 1.

Irrigation

Note: You must have a Permit to Take Water issued by the Ministry of the Environment, Conservation and Parks to use more than 50,000 L (13,209 gal) of water in a day from either surface or groundwater sources.

Most vegetable crops require a uniform supply of moisture throughout the growing season. The average rainfall in Ontario is 70 mm/month (2¾ in./month) during the growing season. For most vegetable crops, this provides only 65% of the water needed for optimum yield. Historically, moisture levels are often at their lowest in July and August when the crop water demand is at its highest.

Eggplant is usually responsive to irrigation. Common defects caused by moisture stress include blossom drop and reduced fruit size, yield and quality. The critical irrigation period for eggplant is during flowering, fruit set and sizing. If the available soil moisture level in the root zone (30–60 cm (12–24 in.) rooting depth) reaches 50% during the critical irrigation period, irrigation could help maintain crop yield and quality. For drip irrigation systems, consider irrigating when the available soil water drops below 85%.

Several types of irrigation system have been adapted for use in vegetable crops. They include hand-moved sprinklers, travelling gun systems, centre-pivot and lateral systems, and drip (trickle) irrigation. Whichever type of irrigation system is used, it is important to schedule irrigation to avoid drought stress and provide water when it is most needed. Timely application of water will reduce the potential for nutrient loss or disease pressure due to excess water. There are two basic methods of scheduling irrigation: the water budget method and measuring soil moisture.

For more detailed information on irrigation see:

- *Best Management Practices — Water Management*
- *Best Management Practices — Irrigation Management*
- OMAFRA Factsheet, *Monitoring Soil Moisture to Improve Irrigation Decisions*
- OMAFRA Factsheet, *How to Prepare for Irrigation During Water Shortages*

Fertigation

Fertigation is a method of applying water and nutrients through a drip-irrigation system. It can be used to increase the yield and quality of many vegetable crops.

Dissolve a stock solution of soluble fertilizer in a tank and introduce it through a valve into the irrigation system either by suction or pressure. Feed the fertilizer solution through the system slowly. After the fertilizer has passed through the system, continue to irrigate to flush the lines. **Do not apply phosphorus through the drip tape.** Certain forms of phosphorus will clog the drip emitters. Phosphorous fertilizers encourage the growth of algae in the drip lines. Algae may also cause emitters to plug.

Table 7–55. Eggplant Nitrogen and Potash Injection Schedules

Stage	Rate per week
Transplanting to fruit set	3–5 kg/ha (2.7–4.5 lb/acre)
Fruit sizing to harvest	7–10 kg/ha (6.2–9 lb/acre)
During harvest	3–5 kg/ha (2.7–4.5 lb/acre)

Adapted from cucurbit and pepper recommendations.

Fertigation applications are usually made weekly. However, depending on the design of the irrigation system, the soil type and time constraints, applications may be made more or less frequently. It is important that the irrigation cycle is run for ample time to adequately flush the system after each fertigation. Avoid over-watering after fertigation. Excess water has the potential to leach the fertilizer below the crop rooting zone.

For fertigated eggplant crops, broadcast all the phosphate requirement and approximately 50% of the nitrogen and potash requirements prior to planting. Inject the remainder through the drip irrigation system at the rates shown in Table 7–55.

There are no established recommendations for eggplant fertigation In Ontario.

Harvest

Eggplant crops usually reach maturity within 50–80 days of transplant. Harvest begins by early August and can continue up until the first frost. Growers using season extension techniques may be able to advance harvest and extend harvest beyond these dates. Ripe eggplants are usually harvested once or twice per week until temperatures drop and the crop becomes unproductive.

Harvest eggplant when they have reached marketable size but before the seeds begin to change colour. Fruits should be glossy and firm, not soft and spongy. Harvest by cutting the fruit from the plant. Handle carefully, as eggplant fruit bruise easily. Average yields are outlined below.

Average Yields*: 1,250 boxes/ha graded product (50 boxes/acre graded product)
Standard Container: 1⅑ bu cartons (18 or 24 fruit per box)

*standard large purple types

Storage

After harvest, wash fresh-market eggplant in chlorinated water (100–150 ppm chlorine) to eliminate fruit rotting organisms. Rapid and efficient cooling is the most effective management practice for maintaining the quality and shelf-life of fresh eggplant. It is essential that only good quality produce is placed in cold storage. Room cooling and forced-air cooling are the most common methods used for eggplant fruit.

Room Cooling

Containers of produce are placed into a refrigerated room and cold air from the evaporator coils slowly cools the product. It takes considerable time to cool produce to acceptable storage temperatures. The cold air does not always penetrate deep within the container. Highly perishable produce may suffer significant quality loss and hence shelf life.

Forced-Air Cooling

Vegetables are placed in a refrigerated room, and cold air is pulled through the containers using high-capacity fans. An effectively designed system allows good contact between the cold air and the produce. Forced-air cooling is not as rapid as hydro-cooling. However, it is adaptable to more types of produce and is more flexible for smaller-scale operations. Forced-air cooling should be done quickly so produce does not lose too much moisture.

Eggplant Storage Conditions

Storage Temperature: 7°C–13°C (45°F–55°F)
Relative Humidity: 90%–95%
Duration: 1 week (fully ripe)
Chilling Injury Symptoms: browning of the flesh, pitting, decay of cap, fruit rot

Pest Management and Disorders

See Figure 7–65. *Eggplant stages of development and pest activity calendar*.

Diseases

Anthracnose
Colletotrichum melongenae

Identification: Leaf lesions are inconspicuous. Fruit symptoms appear as small, sunken, water-soaked, circular spots. Lesions gradually expand to 20 mm (¾ in.) diameter, developing a pattern of concentric rings. The lesions darken, and small black fungal structures appear in the centre.

Biology: Anthracnose overwinters in infected plant debris. It can also survive in the soil for a short time. Many common weeds and some crops are symptomless hosts. Anthracnose is also seed-borne. Once leaf or fruit lesions are present, they act as inoculum for more infections.

Infections take place under a wide range of temperatures from 10°C–30°C (50°F–86°F). Rapid development occurs during periods of prolonged leaf wetness.

Management Notes: Follow a minimum 3-year rotation with non-solanaceous crops. Control weeds that act as hosts. Use disease-free or treated seed.

Fungicide programs must begin before fruit infection occurs — well before the onset of symptoms. Where available, use the TOMcast program for scheduling fungicide applications. See *Disease Prediction Models*, Chapter 4. Properly timed fungicide sprays are effective at reducing losses to this disease.

If TOMcast is unavailable, begin a preventive spray program when the first fruits are about walnut size. Repeat at 5–7-day intervals during continuous moist weather. Extend the schedule to 12–14 days in warm, dry weather if diseases are under control. Applications should continue until close to harvest as anthracnose lesions can appear on unprotected fruit within 5–6 days in favourable conditions.

Bacterial Fruit Rots

See *Peppers*, in this chapter.

Blossom End-Rot

See *Tomatoes*, in this chapter.

Damping-Off – Root Rots

See Chapter 6.

Early Blight/Alternaria
Alternaria solani

Identification: The first signs of disease often appear on older foliage, deep in the canopy where the leaves stay wet. Foliar lesions first appear as dark spots, 8–13 mm (¼–½ in.) in size. The lesions are circular to angular with dark concentric rings (target spot) and enlarge over time. They are usually limited by large veins and surrounded by a narrow light green-to-yellow halo. In severe infections, the foliage is completely covered by lesions and dries up. Lesions may also appear on stems and blossoms.

Fruit symptoms are most common late in the season, especially when extended wet periods occur at harvest.

Eggplant fruit lesions appear as dark, sunken spots with dark concentric rings. Lesions can enlarge to cover large areas of the fruit. The concentric rings typical of tomato and potato foliar lesions may not be noticeable on eggplant foliage.

Biology: The early blight fungal spores overwinter in the field in crop residue, on infected tubers (potatoes), infected seed (tomatoes and eggplant) and on weed hosts such as hairy nightshade.

Infections occur under warm temperature conditions (20°C–30°C (68°F–86°F)) and periods of prolonged leaf wetness due to wet weather or heavy dewfall. Spores are spread primarily by wind and splashing water. As a result, the disease progresses rapidly during periods of alternating wet and dry weather.

Late Blight
Phytophthora infestans

Mild infections of eggplant have been reported, though they are very uncommon.

Identification: Initial leaf symptoms are pale green-to-brown water-soaked spots, which enlarge rapidly and become brown to purplish-black. A pale yellow or green halo may surround the leaf lesions. Under conditions of high humidity, a grey-to-white mouldy growth develops on the underside of the leaf lesion.

Brown lesions may appear on leaf petioles and stems. The stem lesions may quickly girdle the stem and kill it. Under favourable conditions, the pathogen can blight the foliage so quickly, that it appears the plants were hit by frost. Fruit lesions appear as firm greyish-green-to-brown, rough, irregular shaped blotches, which rapidly enlarge.

Biology: Late blight is caused by the oomycete, *Phytophthora infestans*. Spores are produced from 10°C–27°C (50°F–81°F). It grows most actively from 18°C–21°C (64°F–70°F) and a relative humidity of 90%. A minimum of 8 hours of leaf wetness is required for the spores to germinate and penetrate the plant tissue. After infection takes place, late blight symptoms develop in 3–5 days.

The pathogen produces spores on the lesions of infected plants at any time during the growing season. The spores are splashed by rain to neighbouring healthy plants or by wind to other areas of the field. Spores can travel great distances by wind.

Scouting: There is no tolerance for this disease as it is easily spread by wind and can rapidly destroy the crop. Begin scouting for late blight as soon as green tissue emerges. Monitor fields closely, at least twice a week, to detect late blight at its early stages. Pay special attention to centre pivot tracks, low pockets, near tree lines and other areas that may experience prolonged periods of high humidity. Be sure to look for late blight in the lower portions of the plant, where the foliage stays wet longer and the disease is most likely to begin.

One infected plant in the entire field is enough to start an epidemic. Pull, bag and remove the first infected plants found. Mark these areas with a flag and revisit regularly. Always scout infected fields at the end of the day to prevent carrying the infection into clean fields.

Management Notes: Most preventive fungicide sprays for early blight and anthracnose also offer some protection against late blight in eggplant. If the disease is present in the field, follow a 5–7-day fungicide schedule, using fungicides recommended specifically for late blight control. For in-season updates on late blight in solanaceous crops in Ontario and neighbouring regions, visit ONvegetables.com and usablight.org.

Hose down all farm equipment after leaving an infected field. Farm equipment carrying contaminated plant material can spread the pathogen to healthy fields. Continue intensive scouting and remove any plants that develop symptoms.

Nematodes

See Chapter 6.

Phomopsis Blight

Phomopsis vexans

Identification: This fungal pathogen causes lesions on leaves, stems and fruit. It also affects seedlings. Leaf lesions are grey to brown with a dark margin, up to 2.5 cm (1 in.) in diameter. Older lesions are light-coloured in the centre, with black specks (pycnidia) that may show a pattern of concentric rings. Fruit symptoms begin as pale, sunken lesions that darken and expand up to 5–8 cm (2–3 in.) in diameter. Lesions may coalesce to cover much of the fruit surface (Figure 7–66).

Figure 7–66. Lesions caused by phomopsis on eggplant leaf.

EGGPLANT

Biology: The fungus can survive on plant debris (for over a year) or seed. Warm temperatures and moist conditions favour the disease. It is spread by splashing water.

Management Notes: Reduce carryover of the disease on crop residue by following a crop rotation of at least 3 years. Inspect transplants for any disease symptoms before transplanting.

Phytophthora Blight
Phytophthora capsici

Phytophthora blight occurs on fruit that are in contact with the soil or splashed with soil. It produces grey-to-dark brown concentric rings.

Identification: The surface of the fruit remains smooth initially, but wrinkles as the fruit underneath rots. Under wet conditions, sporulation may occur on the fruit as well. Foliar symptoms are also mainly caused by movement of soil onto leaves by splashing or mechanical transfer. Foliar lesions are dark brown to blackish green, often with a lighter brown area where the infection began, and can coalesce into larger lesions (Figure 7–67).

Biology: Phytophthora survives between crops as a thick-walled oospore in the soil or as mycelium on crop residue. The oospores can survive in the soil for 5–10 years. Under intensive solanaceous and cucurbit production systems with short crop rotations, the levels of inoculum build up over time, potentially becoming a significant production problem.

Spores are spread long distances by air, on equipment and vehicles, and splashing water.

Phytophthora spreads rapidly during warm, wet weather. Ideal conditions for infection are moist soils above 18°C (64°F) and air temperatures of 24°C–29°C (75°F–84°F).

Management Notes: Phytophthora issues are becoming more common in certain areas of Ontario. Once established in a field, phytophthora is extremely difficult to control. Prevention is critically important.

Rotate fields for a minimum of 3 years away from all host crops. Select well-drained fields.

Raised beds, the use of plastic mulch, improved drainage and remediation of sub-surface compaction significantly reduces *Phytophthora capsici* infections. Beds must be dome-shaped, to prevent water collecting at the base of the plant. Ensure that the planter does not leave a depression at the base of the plants.

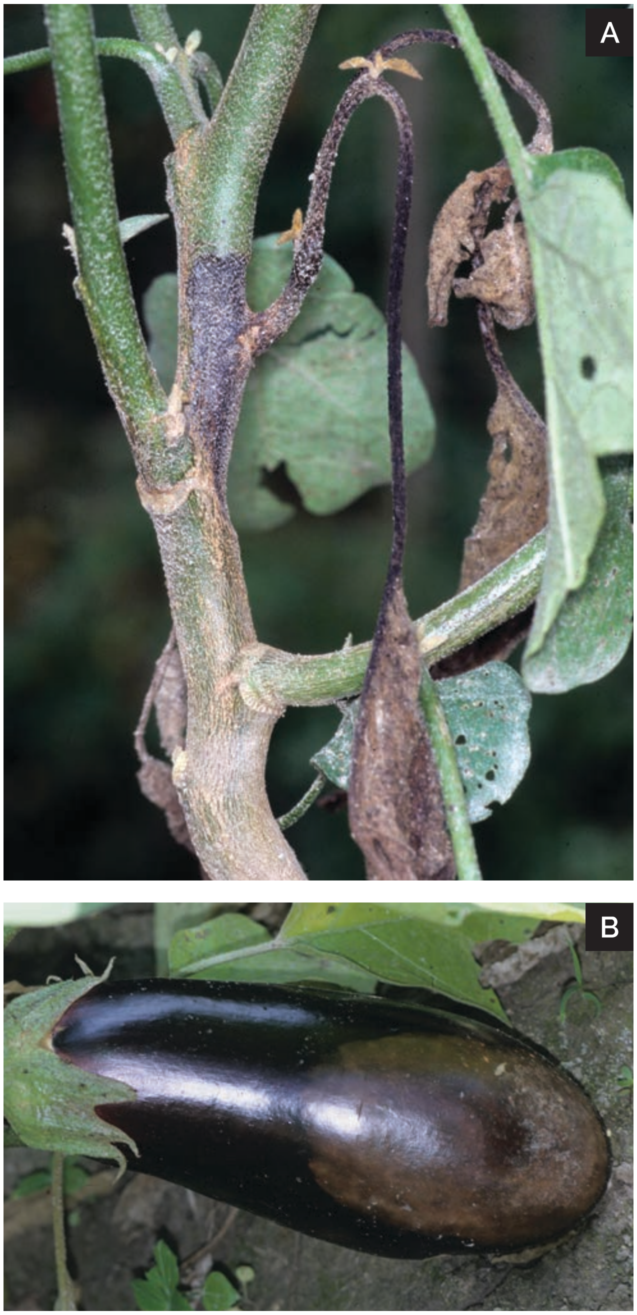

Figure 7–67. Symptoms of *Phytophthora capsici* infection on eggplant leaves and stem (A) and fruit (B).
Source: Gerald Holmes, Strawberry Centre, Cal Poly San Luis Obispo, Bugwood.org.

EGGPLANT

Verticillium Wilt

Verticillium albo-atrum, V. dahliae

Identification: The first symptom of verticillium wilt in eggplant is yellowing of the leaves, possibly followed by wilting (especially during the heat of the day, with recovery at night). Yellow leaf lesions, extending between veins out to the leaf edge, develop initially on the lower leaves. The lesions often have a characteristic V-shape. Tissue within the lesions may die, but this is typically surrounded by an irregular yellow area. Surrounding leaves may show yellowing, initially without the browning. This helps distinguish the disease from early blight. Symptoms often appear on one side of the plant or one side of the leaf. When sliced lengthwise, the vascular tissue of the main stem will be brown, especially at the soil line (Figure 7–68).

Biology: The fungal inoculum survives in the soil and on debris from host plants. Weed species such as ragweed, lamb's-quarters, pigweed, velvetleaf and solanaceous weeds are also hosts.

Symptoms are often more severe after fruit set or during dry periods. The presence of plant parasitic nematodes may increase the severity of the disease.

Management Notes: Follow a 4–6-year crop rotation. Do not rotate with other host crops. Cereals and grasses are non-hosts. Keep fields clean of host weeds, such as nightshades.

Plant tolerant cultivars where available. Graft onto resistant tomato rootstocks if you must.

Figure 7–68. Typical "V" shaped lesion caused by verticillium wilt on eggplant.

Take soil samples to test for verticillium and nematodes. Soil fumigation may be required if verticillium and nematode counts are high. The best times to sample are in May to June and September to October. Try to sample at the same time of year each time, using the same laboratory, so that you can compare the counts from year to year. Counts will be lower in the spring than in the fall. The established thresholds are based on spring sampling.

Insects

Aphids

Aphididae family

Aphids are a common pest in many crops and are often found feeding on young leaves. Feeding damage can cause leaf distortion and the production of sticky honeydew promotes the growth of sooty mould on leaves. There is no established threshold for eggplant. For more information, see Chapter 5.

Brown Marmorated Stink Bug

Halyomorpha halys

Brown marmorated stink bug (BMSB) is a new pest to Ontario. It has the potential to damage a wide variety of agricultural crops but has not yet caused economic damage to eggplant. For more information on BMSB, see Chapter 5.

Colorado Potato Beetle (CPB)

Leptinotarsa decemlineata

CPB prefers eggplant over tomato crops.

Identification: Adult beetles are somewhat rounded. They are approximately 10 mm (~½ in.) long and 7 mm (~¼ in.) wide. The wing covers are yellow-cream with 10 black, lengthwise stripes.

Eggs are yellow-to-orange, elongated and cylindrical. Egg masses contain 25–40 individual eggs. They are usually laid on the underside of the leaves. Recently laid eggs are bright yellow, turning dark orange close to hatching time.

Larvae are orange-red with a distinct black head and a humped back. They have two rows of black spots on both sides of their bodies. Larvae range in size from 2–12 mm (⅛–½ in.) long.

Damage: Beetles and larvae feed primarily on the foliage. They chew irregular holes in and along leaf margins. When no leaves are left, beetles eat pieces of stems or fruit. Eggplant is most susceptible to yield losses during the seedling, transplant and/or bloom stages.

Biology: Adult potato beetles overwinter in the soil of the previous year's host crops or in protected areas surrounding these fields. The first generation of adult beetles starts emerging in early May. Emergence occurs over a period of 4–6 weeks. The specific timing of the beetle emergence depends on the area and weather conditions.

Immediately after emergence, most beetles walk to the crop. A few are able to fly longer distances to a host field. Signs of infestation and feeding damage first appear along the edges of fields close to the overwintering sites.

Mating and egg-laying occur shortly after emergence. Females may lay as many as 400 eggs over 4–5 weeks. Eggs hatch into larvae in 4–9 days. The larvae pass through 4 stages (instars) reaching maturity in 10–20 days. The second generation of adults usually emerges in July. In very hot summers, a partial third generation may develop.

Scouting and Thresholds: There are no established thresholds for Colorado potato beetle on eggplant. The thresholds established for use in tomato crops may also be helpful as an initial guide. See *Colorado Potato Beetle (CPB)*, *Tomatoes*, for more information.

Management Notes: Crop rotation is very effective in reducing the first generation of CPB. Scout the field for CPB even if a systemic insecticide was used at planting.

This insect has developed resistance to most of the insecticides registered for its control. To determine the efficacy of an insecticide, flag any potential hot spots and assess these areas for beetle mortality as soon as the field re-entry interval has passed. Consider using spray tests or dip tests to determine the most effective insecticides against a population of beetles. For more information on dip tests, visit the OMAFRA website at www.ontario.ca/crops.

Non-chemical control options: Plastic-lined ditches may be used to trap emerging adults as they walk between the overwintering sites and the new host crop. Use propane flamers on border rows or entire fields until the crop is 15 cm (6 in.) high.

Cutworms

Agrotis ipsilon (black cutworm), *Euxoa messoria* (dark-sided cutworm), *Crymodes devastator* (glassy cutworm), *Euxoa detersa* (sandhill cutworm)

Early-season cutworms can severely impact eggplant transplants. Transplants appear as if they were cut off at the soil surface with scissors. For more information on cutworms, see Chapter 5.

Flea Beetles

Phyllotreta sp., *Epitrix cucumeris*

Flea beetles are small (2–3 mm (⅛ in.) long), shiny black beetles. Adults are active and jump when disturbed.

Flea beetle species including potato flea beetle (*Epitrix cucumeris*) and possibly palestriped flea beetle (*Systena blanda*) and spinach flea beetle (*Disonycha xanthomelas*) occasionally damage eggplant. Small plants in less-than-ideal growing conditions are more likely to be affected by flea beetle feeding. Most plants are able to outgrow the damage, though they can be a serious issue in organic production. For more information, see Chapter 5.

Slugs

Arion, *Deroceras*, *Helix* and *Limax* species

Slugs are soft-bodied, legless, grey molluscs that have variations in colour from dark brown and black to light grey. In Ontario, slugs range in size from 0.5–10 cm (¼–4 in.) in length, depending on the species, and have a slimy covering to prevent them from drying out. Slugs have rasping mouth-parts and will create ragged holes on the lower leaves. See Chapter 5 for more information.

Tarnished Plant Bug
Lygus lineolaris

The tarnished plant bug (TPB) feeds on over 300 species of fruit, vegetable and field crops, as well as numerous weed species. Most crops discussed in this publication are susceptible to attack. See Chapter 5, for more information.

Two-Spotted Spider Mite
Tetranychus urticae

Identification: The adult mite is approximately 0.5–1 mm (<1⁄16 in.) in length, barely visible to the naked eye. It is a translucent yellowish colour with two dark spots on the sides of its abdomen.

Damage: Spider mites feed through sucking mouth parts. Injury first appears as a bronzed, stippled effect. Severe feeding causes curling and drying of the leaves. Symptoms are often confused with drought stress.

Biology: Spider mites overwinter as female adults in crop residue or sheltered areas. In early spring, they lay eggs on grassy weeds, in fence rows and in wheat fields. Spider mites often move into vegetable crops as the wheat fields and other grasses begin to dry down. Under hot, dry conditions, spider mites may complete a generation in as little as 6 days, resulting in numerous generations each year.

Scouting and Thresholds: No thresholds have been established. Look for "bronzed" leaves and for signs of webbing, eggs or mites on the lower leaf surface. If spider mites are present, re-visit the field over a 3–5-day period to determine if the mite population is increasing.

Management Notes: Heavy rain or overhead irrigation often reduces mite populations to tolerable levels. Vegetables are most susceptible to mite damage in the period leading up to harvest as the crop is sizing.

Wireworms

See Chapter 5, for more information.

Disorders

Air Pollution

See *Potatoes*, in this chapter.

Lightning Injury

A circular patch of affected plants (generally 3–20 m (10–66 ft) in diameter) suddenly appears in the field. Plants toward the outer edge may show less damage.

In most vegetable crops, leaves at the ends of branches will begin to droop, followed by wilting, and in severe cases, death of the plant. One side of the stem may be caved in, like a furrow, down its length. If the stem is cut, it will appear hollow, or have a ladder-like arrangement of tissue.

Walnut Wilt

Walnut wilt can occur if a crop is planted within 12–15 m (39–49 ft) of walnut trees or in soil from which walnut trees have been removed within the last several years. The plants wilt and die; other susceptible plants in the immediate area may be affected.

Wind Damage (Sandblasting, Wind Whipping, Dessication)

Wind damage occurs in several different forms, including sandblasting, wind whipping and dessication. Sandblasting (sand abrasion) occurs when light, sandy or exposed soils are eroded by high winds. Stems and leaves on the windward side of the plant develop light, tan-coloured, roughened areas. If severe, sandblasting can stunt or kill plants and significantly reduce yield.

Wind whipping occurs on any type of soil. The whipping and twisting of young plants by strong winds can severely damage or kill the plants. Overly tall eggplant transplants are also very susceptible to wind whipping.

Dessication is most common on tender, young transplants during strong wind conditions and extreme temperatures. Proper hardening-off of the transplants before field setting helps minimize these effects.

All types of wind damage can predispose plants to foliar diseases. Wind-strips, cover crops and windbreaks will minimize problems due to wind and sand movement. For more information, see Chapter 2.

Garlic

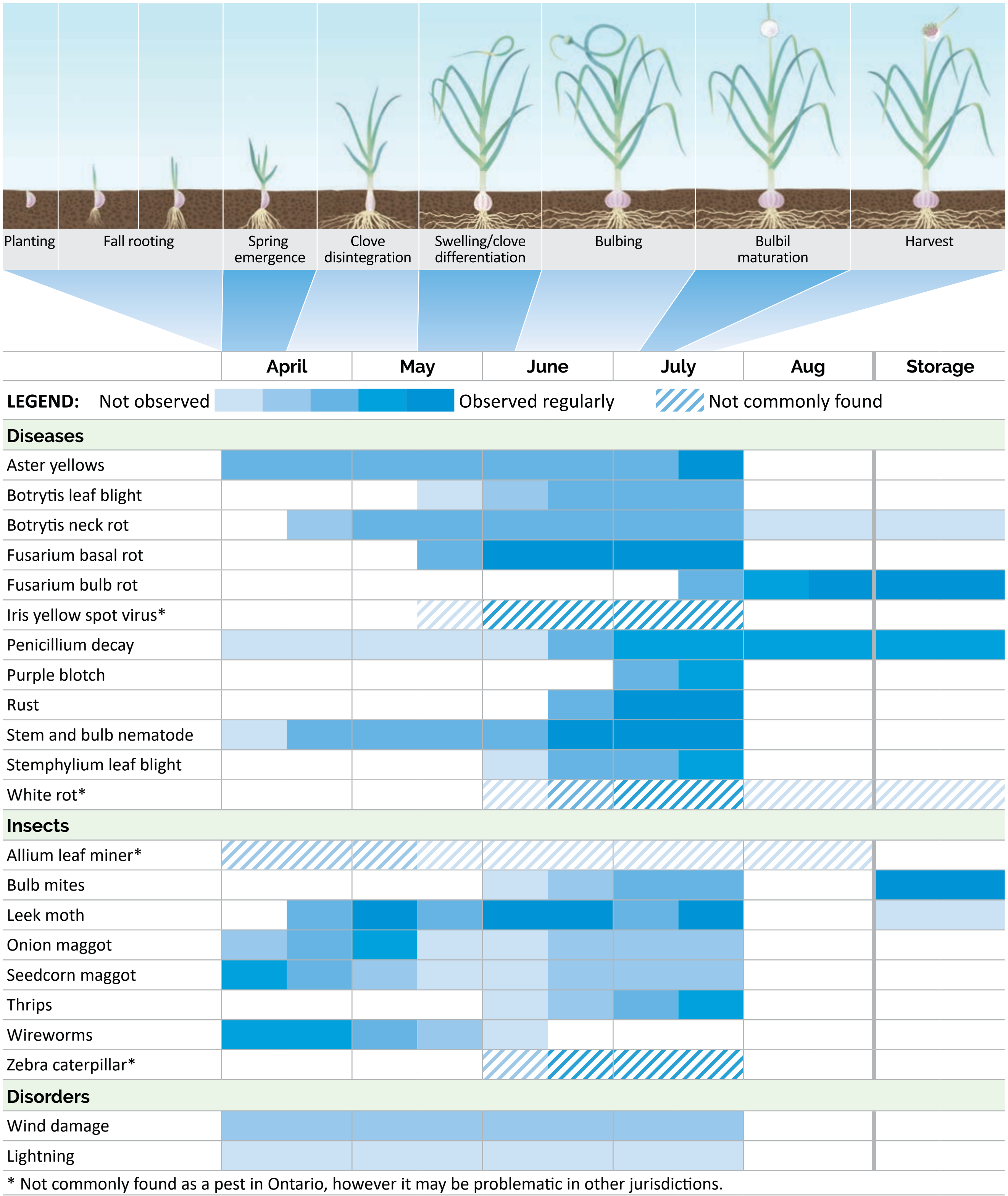

Figure 7–69. Garlic stages of development and pest activity calendar. The actual period of activity for any given pest will vary significantly from year to year, depending on environmental factors.

Production Requirements

Soil types:	mineral soils from sandy to clay loams
Soil pH:	5.5–8.0
Suitable rotational crops:	brassica crops, carrots, corn, parsnips, leafy greens, oats
Do not rotate with:	other allium crops
Optimum air temperature:	13°C–24°C (55°F–75°F)
Earliest planting date:	September to late October

Cultivars and Planting Stock

Cultivated garlic plants do not reliably produce true seed. All commercially grown garlic is propagated vegetatively through cloves or bulbils.

Both hardneck and softneck garlic cultivars are grown in Ontario; however, hardneck garlic cultivars make up the majority of Ontario grown garlic. Hardneck garlic produces a scape inside a false stem while softneck does not (Figure 7–70). Hardneck cultivars can be propagated by planting the bulbils formed in the scape. There are seven main cultivar groups divided into strong bolting (Porcelains, Rocamboles and Purple Stripes), weak bolting (Turbans, Creoles, Asiatics) and non-bolting, softneck varieties (Artichokes and Silverskins).

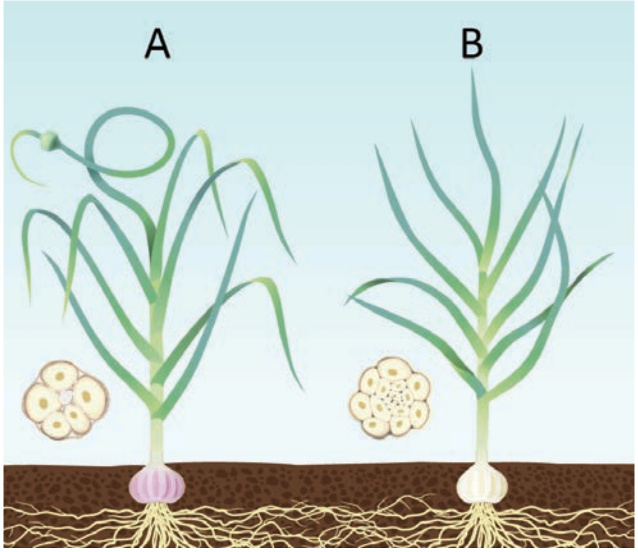

Figure 7–70. Hardneck garlic (A) has rings of cloves surrounding a centre stalk, whereas softneck garlic (B) has multiple rings of cloves with no central stalk.

Growers should conduct their own field trials to evaluate varieties under local growing conditions. Planting stock should test negative for stem and bulb nematode prior to planting. Nematode-free seed should always be used for planting stock. Consult the Garlic Growers Association of Ontario at www.garlicgrowersofontario.com for planting stock sources including clean seed.

Clean seed is garlic propagated from tissue culture that is free of viruses. Roundels are the product of the clean seed program that are virus-free and pathogen-free planting stock. Roundels produced from the SPUD Unit at the Ontario Crops Research Centre — New Liskeard, formally the New Liskeard Agricultural Research Station, are available to order for members of the Garlic Growers Association of Ontario. Since the planting stock is free of all detectable viruses and pathogens, a 25%–50% increase in bulb weight is expected, compared to conventionally grown bulbs of the same cultivar.

The incidence of many of the garlic pathogens described in the pathology section will be greatly reduced in future generations by the use of this planting stock. Aphid, thrips and tulip bulb mite should be managed to limit the re-introduction of viruses to this planting stock.

Planting and Spacing

To estimate the planting date, growers should plan to plant slightly before the average date for the first fall frost for their area. Root establishment before winter often results in greater yields. Many cultivars require a vernalization period, where they are exposed to temperatures below 2°C (46°F) and a long-day photoperiod to induce bulbing and clove differentiation. Spring-planted cloves that do not receive a vernalization period or a long-day photoperiod may result in large, round, single-clove bulbs (known as rounds) that do not differentiate into multiple cloves. In many hardneck cultivars, there is a direct correlation between the size of the clove planted in the fall and the size of the bulb the following year. Plant cloves within 1 week of cracking the bulbs to reduce the establishment of pathogens colonizing the wound sites created by the cracking process.

Bulbils, originating from the scape, can be planted the following season to multiply planting stock. The number of bulbils per scape and the size of each bulbil varies between cultivars. Bulbils generally take 2–3 years to reach a full size bulb under ideal growing conditions.

Roundels may be grown similarly to bulbils and under ideal growing conditions can reach full size after three generations.

Spacing depends on methods of weed management and harvest. Average bulb size is greater at a lower density, and average yield per acre Is greater at a higher density. See Table 7–56.

Table 7–56. Garlic Crop Spacing

Crop	Row Spacing	In-Row Spacing[1]	Depth[2]	Seeding Rate[3]
Garlic (increased yield)	20 cm (8 in.)	10 cm (4 in.)	2.5–5 cm (1–2 in.)	1,800 kg/ha (1,600 lb/acre)
Garlic (increased bulb size)	45 cm (18 in.)	15 cm (6 in.)	2.5–5 cm (1–2 in.)	1,345 kg/ha (1,200 lb/acre)

[1] Use wider spacing in lighter, drought-prone soils.
[2] Between soil surface and top of clove.
[3] Seeding rate based on an average clove weight of 9 g/clove.

In-row spacing of 10 cm (4 in.) has been shown to allow for an average-to-large yield without a significant compromise to bulb size when the row spacing was kept at 65 cm (25.6 in.). When planted at an in-row spacing of 10 cm (4 in.), there were no significant differences to bulb size when the row spacing was decreased from 45 cm (18 in.) to 25 cm (10 in.) (Figure 7–71).

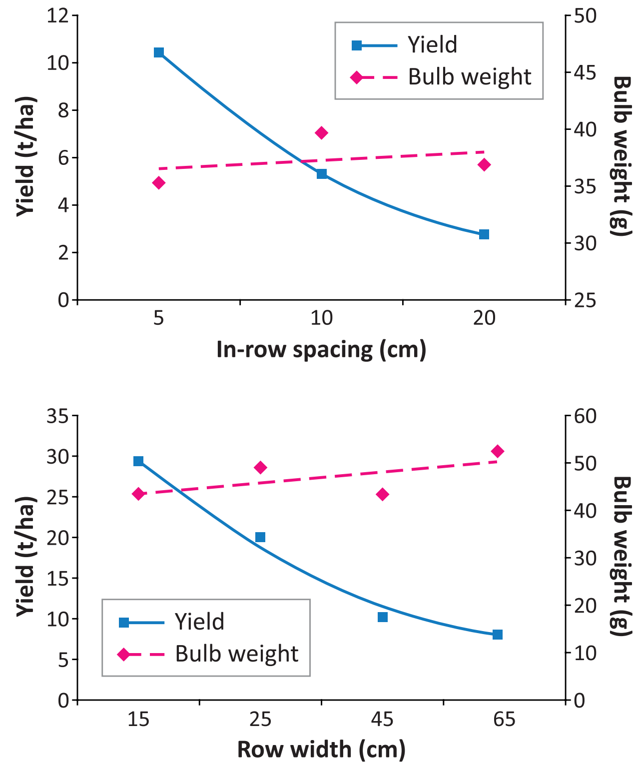

Figure 7–71. Influence of row width and spacing on yield and bulb weights of the cultivar ‘Music’ planted in clay loam, (10% organic matter, pH = 7.8) in Ridgetown, Ontario. Zandstra, 2000.

Planting depth differs depending on soil type. The clove should be covered by at least 2.5 cm (1 in.) in heavier soils and 5 cm (2 in.) in lighter soils. Planting deeper provides greater overwintering protection by avoiding frost heaving, however, a reduction in yield is typical, the deeper the clove is planted. Inverted cloves may produce plants with crooked necks, which may reduce yield and require manual trimming.

Fertility

Macronutrients

Nitrogen

See Table 7–57.

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. See Table 1–12 and Table 1–13, Chapter 1, for more information. Apply the final side-dress application in mineral soils prior to the fifth leaf stage to avoid bulbs with mini cloves on the outside of the bulb and premature sprouting in storage. Excessive nitrogen can stimulate top growth but can inhibit and delay bulb formation.

Table 7–57. Garlic Nitrogen Requirements

Soil Type	Actual N
Mineral Soils	
Early spring	56 kg/ha (50 lb/acre)
Side-dress (before the fourth leaf stage)	56 kg/ha (50 lb/acre)
Total	**112 kg/ha (100 lb/acre)**
Muck Soils	
Early spring	90 kg/ha (80 lb/acre)
Side-dress (before the fifth leaf stage)	30 kg/ha (27 lb/acre)
Total	**120 kg/ha (107 lb/acre)**

Phosphorus and Potassium

OMAFRA soil test results are not specific to garlic. However, phosphorus and potassium requirements for garlic are similar to onions. See Table 7–78 and Table 7–79, *Onions*, for more information.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. See *Micronutrients*, Chapter 1, for more information.

Plant Tissue Analysis

When used in conjunction with a soil analysis, plant tissue analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. Plant tissue analysis does not replace soil testing or a sound soil fertility program.

Garlic tissue analysis ranges are not currently available. However, expected ranges for onion crops are listed in Table 7–80. For more information, see *Plant Tissue Analysis*, Chapter 1.

Irrigation

Garlic plants are very responsive to irrigation. An average yield loss of 30% is common in dry years, 15% in an average year and 5%–10% in a wet year. Irrigate early morning to allow the crop to dry before nightfall — 2.5 cm (1 in.) of water per week in heavier, clay soils and 5 cm (2 in.) of water per week in sandy, well-drained soils is optimal.

Effects of moisture stress: reduced quality and undersized cloves

Critical irrigation period: vegetative growth and bulbing (mid-May to mid-July)

Rooting depth: 30–60 cm (12–24 in.)

If the available soil moisture level in the root zone reaches 60% during the critical irrigation period, irrigation could help maintain crop yield and quality. For drip irrigation systems, consider irrigating when the available soil water drops below 85%. Stop irrigating when 2–3 leaves start to senesce, as this should allow the soil to dry out prior to harvest and reduce cleaning time as well as reduce staining of the exterior bulb leaf sheaths. If plastic mulch is used, cut and/or remove black plastic and allow the soil to dry prior to harvest.

For more information on irrigation scheduling, see the *Irrigation Management* BMP (order number BMP08E) and the OMAFRA factsheet, *Monitoring Soil Moisture to Improve Irrigation Decisions*.

Scaping

Scaping, the removal of the scape in hardneck cultivars, can increase the yield by 20%–30% when removed by hand. Yield benefits are greater when the plant is under water or nutrient stress.

The timing of scape removal directly influences the resulting yield of the crop and average size of the bulb. In Ontario, hard neck cultivars generally produce a scape the first to second week of June.

Snapping the scape by hand above the top leaf, opposed to pulling the scape, reduces the chance of the top leaves of the plant falling over without the support of the scape and reduces the chance of bacteria and other pathogens entering the neck. Avoid mechanical removal using knives, such as a sickle bar mower, as knives may spread pathogens as well as injure leaves. Inadvertently cutting the top leaves of the plant at scaping can reduce the average bulb size by approximately 13% (one leaf) or 25% (two leaves), which greatly reduces any yield boost achieved by scaping (Zandstra 2000). Scaping by hand can produce 340–500 kg/ha (300–450 lb/acre).

Harvest

Harvesting begins when 40% of the leaves begin to dry, discolour, senesce and bend towards the ground. In hardneck cultivars, garlic should be harvested early enough that more than three layers of bulb wrapper/leaf sheaths remain. Another indication of bulb maturity is the reduced thickness of the sheath leaves surrounding the bulb.

Early-maturing cultivars tend to have a reduced storage life. Most cultivars mature around mid- to late July. Late harvests may cause the bulb wrapper/leaf sheaths to split or deteriorate. Remove harvested bulbs from direct sun as soon as possible. Treat bulbs gently to avoid bruising, as bruised bulbs deteriorate more quickly and are at a greater risk for infection from storage pathogens.

Bulb wrappers are often removed for cleaning, but too many wrappers removed exposes the cloves and lowers the grade. Ontario #1 grade is considered to be a bulb that is greater than 8 cm (1½ in.) in diameter, mature, clean, bright, firm, with cloves filled out and no staining on the wrapper. Bulbs must be well cured, dry, not damp and less than 2% shattered cloves with no decay present.

Average Yields: 2,200–4,500 kg/ha (2,000–4,000 lb/acre)

Curing

Removing excess moisture from the bulb will increase storage life and reduce storage rot. Ventilation of air with a lower relative humidity is essential, and curing is not dependent on temperature. Proper curing results in the outer skins becoming dry and crisp, the centre of the cut false stem between the cloves is hard and the neck is constricted at the bulb. The slower the curing process, the easier it is for storage pests and pathogens to survive, go dormant and cause problems in storage.

Storage

Garlic stores well in room coolers with 25 air changes per hour. Storage conditions depend on the end use. Higher humidity in storage promotes *Penicillium*, bulb mites, sprouting and root growth. Lower humidity and higher temperatures increase the rate of bulb weight loss. Sprouting occurs most rapidly with a relative humidity above 70% and a temperature of 4°C–10°C (39°F–50°F). See Table 7–58.

Table 7–58. Garlic Storage Requirements

Type	Temperature	Relative Humidity	Time in Storage[1]
Table stock	−2°C–1°C (28°F–34°F) or 14°C–16°C (57°F–61°F)	55%–65%	6–7 months
Planting stock	14°C–18°C (57°F–61°F)	55%–65%	3–4 months

[1] Potential number of months in storage is dependent on cultivar and quality of crop going into storage.

Pest Management and Disorders

See Figure 7–69. *Garlic stages of development and pest activity calendar*.

Diseases

Aster Yellows

Candidatus phytoplasma asteris

Identification: Bright yellow top and mid-canopy leaves with leaves senescing from the top downward. Bulb wrappers may appear red or dark brown with streaks. Plants appear stunted with poor bulb development. Similar to herbicide carryover damage but often found sporadically throughout fields (Figure 7–72).

Biology: Phytoplasma overwinters inside perennial weeds and is vectored by aster leafhopper.

Management Notes: Remove infected plants throughout season. Monitor leafhoppers with sticky cards and target leafhoppers if outbreak begins. Use light-coloured or reflected plastic mulches to disorient leafhoppers and reduce feeding. Floating row covers can exclude aster leafhopper. See Chapter 5 for more information.

Figure 7–72. Stunted garlic plant with aster yellows.

Botrytis Leaf Blight

See *Onions, Leeks and Shallots*, in this chapter.

Botrytis Neck Rot

Botrytis aclada, *Botrytis allii*

Identification: Botrytis-infected neck tissue of the bulb becomes soft and greyish. White or grey mould may also develop. Black sclerotia eventually appear in affected tissue.

Biology: Botrytis neck rot is most commonly found on bulbs after harvest, but it can appear on maturing bulbs in the field. The fungi survive in the soil for several years. Botrytis infections occur during cool, wet conditions.

Management Notes: Follow a 2–3-year crop rotation and remove cull onions from the field. Proper curing and drying reduces disease development in storage. Artificial heat curing may reduce problems in humid areas of the province.

Fusarium Basal Rot, Fusarium Bulb Rot

Fusarium oxysporum f. sp. *cepae*,
Fusarium culmorum

Identification: Early symptoms include the yellowing of leaves and tip dieback. As the disease progresses, the whole plant may collapse. In fusarium basal rot, the basal plate of the bulb becomes rotten and white fungal growth may appear on the basal plate. Roots easily detach from the infected bulb, but unlike stem and bulb nematode where all the roots easily detach, with fusarium basal rot, typically not all roots detach (Figure 7–73). In bulb rot, *F. culmorum* produces a sunken tan lesion with little white mycelial growth while *F. proliferatum* starts as a tan stain with white mycelial growth avoiding the basal plate. Secondary bacterial rots may also develop. Fusarium basal rot may also accompany stem and bulb nematode infections. If white mycelial growth produces small, black, pinhead-sized sclerotia, the pathogen is not *Fusarium* but white rot. See *White Rot*, also in *Garlic*.

Figure 7–73. Tan-coloured roots of basal plate with *Fusarium oxysporum* f. sp. *cepae* present (A), and the sunken, tan lesions of *Fusarium culmorum* (B).

Biology: Spores lie dormant in soil residue or on cloves throughout the winter. Basal rot develops under warm soil temperatures, with 29°C (84°F) being the optimum for disease development. Bulb rot is often found under humid conditions in storage.

Management Notes: Follow a long crop rotation and use disease-free planting stock. Avoid injury of bulbs at harvest, and plant cloves in the fall as soon after cracking as possible.

Figure 7–74. Streaking symptoms of garlic mosiac virus (A and B).

Garlic Mosaic Virus Complex (GCLV, OYDV, LYSV)

Identification: Garlic mosaic virus complex can be symptoms caused by garlic common latent virus (GCLV), onion yellow dwarf virus (OYDV) and/or leek yellow stripe virus (LYSV). The leaves often yellow from the tip downward with streaks or dashes along the levels. Infected plants appear stunted, and in some cases, may not develop a bulb (Figure 7–74).

Biology: Aphids are the primary vector followed by bulb mites, onion thrips or machinery that creates wounds on living tissue (cutting knives used in scape removal). Disease symptoms tend to appear in July or August.

Management Notes: Manage onion thrips populations throughout the season to mitigate the spread of this disease. Good sanitation practices and removal of cull and volunteer onions and weeds are also important to help reduce the incidence of viruses. See *Northern Root Knot Nematode*, Chapter 6, or *Aphids*, Chapter 5, for more information.

Iris Yellow Spot Virus (IYSV)

Identification: Straw-coloured, diamond and spindle-shaped lesions form on scapes and leaves depending on cultivar. Active lesions may have a yellow halo surrounding a green island of tissue (Figure 7–75).

Figure 7–75. IYSV-infected leaf (A) and scape (B) with a yellow halo surrounding a green island.

Biology: Onion thrips pick up the virus from infected onion, garlic, leek, jimsonweed, tobacco and redroot pigweed and are able to transmit the virus for the remainder of their life. The virus weakens plants and makes them more susceptible to other pathogens.

Management Notes: Manage onion thrips throughout the season to mitigate the spread of IYSV. Purchase clean seed if available. See *Cultivars and Planting Stock*, also in *Garlic*.

If purchasing conventional planting stock, talk to the distributor about the disease and consider testing for IYSV before planting. Rogue out plants showing symptom development.

Penicillium Decay

Penicillium spp.

Identification: Also referred to as blue or green mould. Infected cloves often fail to emerge in the spring or may produce weak, stunted plants that soon die. The fungus sporulates on the surface of decaying cloves, producing bluish-green masses of spores.

Biology: The fungus attacks cloves in late fall and early spring, prior to emergence, causing poor stands and winterkill in the spring. Infected plants may appear stunted with yellow leaves. Optimal temperature for disease development is 25°C (77°F). This disease primarily survives on bulbs, not in the soil.

Management Notes: Plant clonal cultivars known to be vigorous under Ontario growing conditions. Avoid damaging plant stock during cracking. Many mechanized cracking devices cause excessive amounts of clove damage. Plant cloves as soon as possible after cracking. The pathogen also infects through wounds during harvest, sorting and bruising from movement within storage. Proper curing will also reduce the amount of viable spores that develop in storage.

Purple Blotch

Alternaria porri

Identification: Small 1–3-mm (~1⁄16 in.) brown to black spots on senescing leaf tips.

Biology: Infection occurs on premature leaf tip dieback due to environmental stress or herbicide damage.

Management Notes: Practice a 2–3-year crop rotation with non-host crops. Reduce damage to the leaves by providing adequate moisture to the crop and avoid herbicide damage to the leaf tips.

Rust
Puccinia allii

Identification: Rust-coloured spores develop on the upper and lower leaf surfaces. Severely infected leaves turn yellow and senesce prematurely (Figure 7–76).

Figure 7–76. Raised orange and black lesions of garlic rust.

Biology: Garlic rust occurs during high humidity, cool temperatures and prolonged periods of low light or cloud cover often near windbreaks or in shady areas.

Management Notes: Follow at least a 4-year crop rotation with no allium species. Avoid planting in headlands or areas that are shaded. Plant crop at a lower density to promote better airflow.

Stem and Bulb Nematode
Ditylenchus dipsaci

Identification: This microscopic plant parasitic nematode enters the bulb and injects an enzyme into the plant as it feeds, resulting in a rotting around the root plate. Often infestations go unnoticed for 2–3 years until the number of nematodes is high enough to cause decay. In severely infected plants, lower leaves turn yellow prematurely starting from the bottom of the plant, moving upwards. Plants with severe infections appear stunted and senesce prematurely. Often, the basal plate on infected garlic has a dry rot that easily separates from roots when pulled (Figure 7–77).

Figure 7–77. Basal plate missing and rotting of the lower bulb of a plant infected with stem and bulb nematode.

Biology: During wet conditions, the nematode can swim to neighbouring garlic plants and enter the garlic bulb near the soil line. One life stage of the nematodes can resist desiccation and freezing and can persist for many years under dry or cold conditions. A single female can lay up to 500 eggs within her life span and several generations can be produced within one growing season. It only takes 19 days for these nematodes to develop into mature adults when temperatures average around 15°C (59°F).

Management Notes: The key to management of this pest is prevention. Prevention includes planting nematode-free cloves and planting into uninfected soil. Test planting stock and take a soil nematode test specific to stem and bulb nematode before planting. Isolate new plantings for 3 years to confirm stem and bulb nematode is not present before planting beside existing stock. Stem and bulb inhabits the top 5–7.5 cm (2–3 in.) of the soil profile. If the field or area where garlic is to be planted is less than 500 m^2 or 0.05 ha (⅛ acre), take at least 8–10 soil samples; if it is between 500 m^2 and 0.5 ha (1¼ acres), take 25–35 soil samples, and between 0.5 and 2.5 ha (6¼ acres), take 50–60 samples, and mix samples in a bucket. The mixed soil sample should represent no more than 2.5 ha. Keep the soil sample in a cool place and submit the sample to a pest diagnostic lab qualified for nematode extraction, identification and enumeration as soon as possible and no later than 1–2 days after sampling. Do not let the sample heat up or dry out before submitting to the lab.

Once introduced, a 4-year crop rotation with non-susceptible crops such as a cereal crop, fumigating soil or planting a nematode-suppressing cover crop such as brown mustard before planting garlic can help suppress this nematode in soil. Once in the soil, the nematode can spread through irrigation water, planting stock, soil, on equipment and overland flow.

Stemphylium Leaf Blight

See *Onions, Leeks and Shallots*, in this chapter.

White Rot

Sclerotium cepivorum

Identification: Foliar symptoms include premature yellowing, tip dieback, wilting and stunted plants. White fungal growth with small, black, pinhead-sized sclerotia may be visible at the base of the plant. The fungus causes a watery rot and disintegration of infected bulbs. This disease is not always present at harvest but may show up in storage (Figure 7–78).

Figure 7–78. White fungal growth (A) and black sclerotia (B) on garlic bulbs.
Source: Dr. Mary Ruth McDonald.

Biology: The sclerotia and mycelium overwinter in soil and plant debris, and the sclerotia can lay dormant for up to 40 years and germinate when a susceptible crop is planted. Soil infested with allium white rot is spread by machinery, animals, pallet boxes, wind and water. Infected garlic cloves can also spread this disease. Disease development is localized on the basal plate and is favoured by cool, moist soil conditions. Warm soil temperatures, greater than 24°C (75°F) are less conducive to allium white rot.

Scouting and Thresholds: Place suspected samples in a sealable bag and leave at room temperature out of direct sunlight for 48 hours. The white fungal growth of white rot will produce small, black, pinhead-sized sclerotia; the white fungal growth of *Fusarium* will not produce black sclerotia. Send suspect samples to a lab for confirmation.

Management Notes: Avoid planting in fields with a history of allium white rot. In the field, rogue out infected plants. Wash all implements used in infested fields. Avoid planting alliums in areas where white rot has historically been present for 40 years.

Insects

Allium Leaf Miner

Phytomyza gymnostoma

Identification: As of publication, allium leaf miner has not been positively identified in Ontario. Larvae are slender, yellowish-green in colour, and up to 8 mm at maturity. The reddish-brown pupa is 3 mm (⅛ in.) long, and is found within the stem of the plant after leaves have been peeled back. The adult fly is small (3 mm (⅛ in.), with a black body and yellow tips on the distal end of the hind legs (Figure 7–79).

Damage: The larvae tunnel mines and create pinholes in the leaf tissue, causing distortion. As the crop dries down, the larvae may be attracted to the bulb. Damage to garlic cloves may predispose them to secondary bacterial or fungal diseases.

Biology: There are two generations, the first in April to May, and the second in September to November. The fly overwinters as a pupae in crop debris.

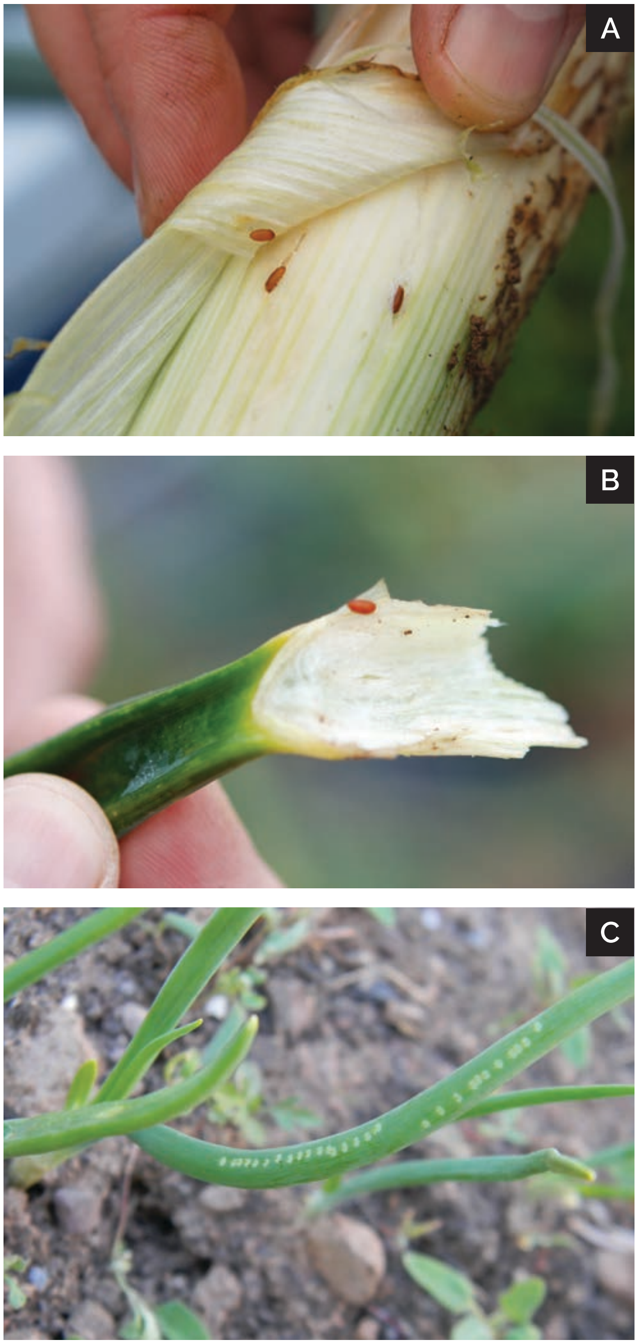

Figure 7–79. Allium leaf miner pupa (A, B) and damage caused by adult fly (C).
Source: L. Barringer, D. Roberts.

Management Notes: If found, please contact the Agriculture Information Contact Centre at 1-877-424-1300 for management information. Cultural controls including crop rotation and removal of old and infested leaves. Lightweight floating row covers can protect plants from allium leaf miner damage.

Aphids

See Chapter 5.

Bulb Mites

Eriophyes tulipae, *Rhizoglyphus* spp.

Identification: Adult mites are 0.1–1 mm (<1/32 in.) in length and are extremely difficult to see without a hand lens.

Damage: Bulb mites can cause leaf curling in young plants and stunting. Later infestations of bulb mites can lower storage quality, storage length, reduce germination, decrease yield and increase stress (Figure 7–80).

Biology: Bulb mites overwinter on garlic and can also survive in crop debris on the soil. They prefer high humidity and can complete a life cycle in as little as 10 days.

Management Notes: Avoid successive onion and garlic crops and implement a 4-year crop rotation. Mites can survive on the residues of a number of crops. Plant in fields where crop residue is thoroughly decomposed. Humidity controlled, short cures are less favourable for bulb mite establishment before the crop moves to storage. Cure crop quickly in 48–72 hours.

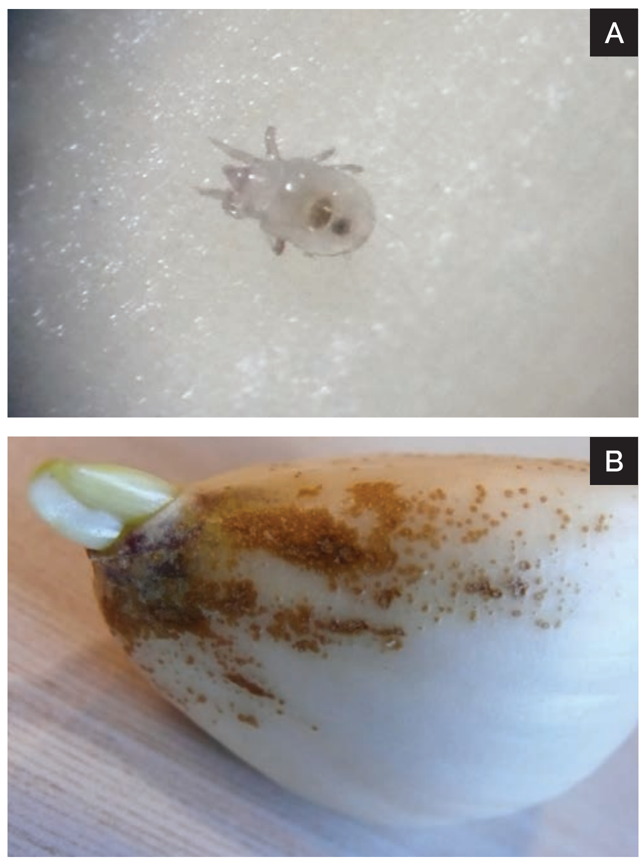

Figure 7–80. Eriophyid bulb mite (A) and bulb mite scars on a clove (B) after several months in storage.

Figure 7–81. Tulip dry bulb mites are white, canoe-shaped (A) and attack almost all parts of the plant causing virus-like leaf distortion that can resemble fungal hyphae (B).

Leek Moth
Acrolepiopsis assectella

Identification: Larvae are slender, yellowish-green in colour, and up to 14 mm (½ in.) at maturity. They produce copious amounts of pale frass as they feed. The reddish-brown pupa is encased in a loosely netted cocoon that is usually found on the leaves or stem. The adult moth is small, around 5–7 mm (~¼ in.), brown, and has a white triangle-shaped spot that is visible when the wings are folded at rest (Figure 7–82).

Damage: The larvae tunnel mines and create pinholes in the leaf tissue and the scapes, sometimes causing distortion. As the crop dries down, the larvae may be attracted to the bulb. Damage to garlic cloves may predispose them to secondary bacterial or fungal diseases.

Figure 7–82. Leek moth larvae (A), cocoon (B and C) and adult moth (D).

Biology: There are three generations in Ontario, the first in June, the second in July and the third in August. Adult moths overwinter in sheltered areas and emerge in the spring when temperatures reach 9.5°C (49°F) for two consecutive days, typically in late April to mid-May.

Scouting and Thresholds: Monitor for leek moth using commercially available pheromone trapping systems with removable sticky cards (Figure 7–83). The timing of an insecticide application is often most effective 7–10 days days after the peak pheromone trap capture. Install pheromone lures around the field edge in early to mid-April and monitor until harvest.

Figure 7–83. Leek moth delta trap with pheromone lure and removable sticky cards placed just above the crop canopy.

Management Notes: Cultural controls including crop rotation, delayed planting, removal of old and infested leaves, destroying pupae or larvae, early harvesting (to avoid damage by last generation larvae and population build-up), positioning susceptible crops away from infested areas and destruction of plant debris following harvest may be effective in reducing populations below damaging levels. Lightweight floating row covers can protect plants from leek moth damage. Apply insectcide 7–10 days following a peak of captured leek moth adults using a pheromone trap.

Onion Maggot & Seedcorn Maggot

Delia antiqua, *Delia platura*

Identification: These two maggots are the larvae stage of the onion and seedcorn maggot fly. The adult onion maggot is a small (5-mm (<¼ in.)), grey-black fly, and the adult seedcorn maggot slightly smaller and is black. The female lays eggs around the base, and several days later those larvae, often referred to as maggots, immediately start feeding on the host plant's roots. Small amounts of feeding at the initial crop development stages can lead to severe reductions in yield.

Damage: Larvae tunnel into the roots and basal plate of the plant. The type of damage is related to crop development at the time of attack. Small garlic plants are most susceptible in March and April. Feeding injury at this stage may cause the plants to wilt and die and may be mistaken for winterkill. Damage to plants at the bulb formation stage may produce unmarketable misshapen bulbs.

Biology: The onion and seedcorn maggot overwinters as a pupa in the top 15 cm (6 in.) of the soil. The three generations of onion and seedcorn maggot found in Ontario emerge in early June, July and late August (Figure 7–84).

Figure 7–84. Seedcorn maggot larvae (A) and adult seedcorn maggot fly (B).

Scouting and Thresholds: First-generation onion and seedcorn maggot thresholds are a combination of trapping and visual scouting. Place four traps (of 3 sticky boards each) centrally along each field edge. Check traps weekly. Assess the per cent damage using plots containing 100 garlic plants repeated four times within the field to monitor levels.

A degree day (DD) model has been developed to predict emergence of adult onion and seedcorn maggot flies. Using a base of 4°C for both flies, onion maggot adults emerge at 210, 1,025 and 1,772 DDs for first, second and third generations, respectively. Seedcorn maggot adults emerge at 200, 600 and 1,000 DDs for first, second and third generations, respectively. For more information, see *Growing Degree Days*, Chapter 4.

Management Notes: Implement a 3-year crop rotation and avoid planting garlic close to last year's crop. Avoid planting into fields that observed high maggot fly pressure the year prior. Floating row covers/exclusion nets will significantly reduce damage but are hard to implement. Treatments against adult flies have shown to not be effective.

Sterile Insect Technology (SIT) has been developed for onion maggot management by Phytodata. Sterile male onion maggot flies are released into the field weekly and as a result, the eggs that pre-existing female flies will lay will not be fertile and the population of wild, fertile flies decreases over time. As of publishing date, no sterile insect management methods have been commercialized for seedcorn maggot fly.

Spittlebugs

See Chapter 5.

Springtails

See Chapter 5.

Thrips

Thrips tabaci, *Frankliniella occidentalis*

Identification: Thrips are small, less than 3 mm (⅛ in.) long, soft-bodied insects. Adult thrips have straw-brown bodies and four wings fringed with hairs. Nymphs are smaller, wingless and pale white in colour.

Damage: Thrips have sucking-rasping mouth parts and cause tissue damage when they feed on the leaves. On garlic, the population of thrips is generally low throughout the vegetative stage. During bulbing, populations of thrips may increase, causing premature senescence.

Biology: In Ontario, both adults and nymphs overwinter on winter grains, clover and alfalfa. They migrate into vegetable fields as the weedy roadsides dry down and the winter wheat and alfalfa are harvested. Females insert white, bean-shaped eggs into the leaf tissue. Development from egg to adult requires from 10–30 days, depending on temperature. Once mature, females begin to lay eggs. The females reproduce asexually (without mating). Consequently, increases in the thrips population can occur very rapidly, especially during periods of hot, dry weather. There are several overlapping generations per year.

Scouting and Thresholds: For garlic, sample 25–50 plants across a representative section of the field. The threshold for bulb vegetables is 3 thrips per leaf.

Management Notes: Early detection of thrips is key to successful control. Spray applications made in the evening have provided better control than applications made during the day. Heavy rainfall is effective in knocking thrips off the plant for a short time but management tools may still be required under high pest populations. Natural predators such as minute pirate bugs, lacewings, predatory mites, ladybird beetles and spiders have been shown to prey on thrips. Insecticides are often not used to manage thrips in commercial garlic production in Ontario unless the planting stock originates from clean seed and the spread of viruses is a concern.

Wireworm

Limonius spp.

Identification: Wireworms are the larvae of click beetles. They are copper-coloured, cylindrical and hard-bodied, with three pairs of tiny legs. Wireworms are commonly confused with multi-legged millipedes and symphylans. They can reach 2–3 cm (¾–1¼ in.) in length (Figure 7–85).

Damage: Wireworms can be seen burrowing into the ungerminated seeds, as well as underground roots and stems of plants. Infested plants do not develop well, and seedlings lack vigour or fail to emerge. Damage is often scattered randomly across the field.

Figure 7–85. Copper-coloured wireworm found feeding on a garlic plant.

Biology: Wireworms take up to 5 years to complete development from egg to adult. Most of this time is spent as a larva in the soil. Adult beetles are active in the spring, laying eggs in the soil or near grass roots. Eggs hatch 2–4 weeks later, and larvae move in search of food. Movement within the soil profile is affected by temperature, moisture and the presence of a food source or carbon dioxide. After 3–5 years, wireworm larvae pupate near the soil surface. New adult wireworms overwinter in the soil and emerge the following spring to lay eggs and continue the cycle.

Scouting and Thresholds: Wireworms may be monitored in the fall (or in the early spring for later-planted crops) prior to planting using bait stations. Bury whole carrots, 7.5 cm (3 in.) deep, at 10 marked stations across the field. Check the stations in 2–3 days. In the spring, use a spade to dig up wilted plants and inspect the roots for wireworms or potential feeding damage.

An average count of 0.5–1 wireworm per station indicates a potential problem. Make your planting and seed treatment decisions accordingly. Areas of the field where seedlings have not emerged should be checked for damage to the seed.

Management Notes: Avoid planting in fields where wireworm damage was recorded the previous season.

Herbs

Herbs are a diverse category of plants. Optimum production requirements will vary, depending on the plant itself and its use in the marketplace. It is important to ensure the production requirements used are appropriate for the end use of each herb. For example, dill can be grown for dill seed, dill weed or dill flowers. The production system used for each is vastly different. Avoid following production advice from other sources that do not specify the end use of the herb. The guidelines provided in this chapter are geared towards production of fresh culinary herbs unless otherwise stated.

Production Requirements

The production requirements of culinary herbs vary depending on the production type (e.g., annual vs. perennial), the plant family, the available equipment, how they are propagated, their end use and how they are marketed. Due to the limited acreage required to satisfy the market demand of most culinary herbs, minimal research has been conducted on optimal production requirements in Ontario. The guidelines provided in this section are mostly compiled from other jurisdictions where market preferences, available equipment and climate vary widely. On-farm research may be required to adapt the guidelines to the growing conditions and available equipment of each farm.

Propagation

Site selection and establishment requirements for culinary herbs are summarized in Table 7–59. There are three main propagation methods for herbs:

Seed: Sow directly in the field or into trays for transplanting. Transplanting allows for a uniform stand and faster establishment but comes at an added cost for establishing the transplants (e.g., greenhouse), specialized equipment and labour for planting. It can also allow for the use of plastic mulches for weed control. Direct seeding comes at an added cost for seed due to an increased seeding rate but allows for a much denser stand. Direct seeding is necessary for some of the short-duration annual bunched herbs such as dill, cilantro (Figure 7–86), parsley (Figure 7–87) and methi (fenugreek leaves) (Figure 7–88).

Cuttings: Take 5–10 cm (2–4 in.) cuttings from the tips of vegetative growth or from the stem. Remove leaves and buds from the bottom half of the cutting, dip in rooting hormone and stick into sterilized horticultural sand or vermiculite. Cover or use misting systems to keep humidity high during rooting. Depending on the herb, heating (e.g., heated mats) and lighting systems may also be necessary.

Divisions: Division is usually performed in the spring. Divide crowns (the junction of the root and stem) into clumps. Cut rhizomes into nodes or root clusters that contain nodes. Separate bulbs into clusters.

Cuttings and divisions ensure the offspring are identical to the parent plant and may be necessary for some herbs that do not produce viable seed (e.g., mint).

Figure 7–86. Due to their short life cycle and small size, bunched herbs such as cilantro are exclusively direct seeded for commercial production.

Figure 7–87. Parsley can be transplanted but is usually direct-seeded to maximize productivity.

Figure 7–88. A direct seeding of methi (fenugreek leaves) for bunching.

Table 7–59. Guidelines for Establishing Herbs

LEGEND: Crop type: A = annual B = biennial P = perennial GA = grown as an annual under Ontario conditions
Soil type: E = every mineral soil type S = sand L = loam C = clay M = muck

Crop	Type	Soil Type	Optimal pH Range	Propagation and Other Establishment Notes*	Row Spacing	In-row Spacing	Irrigation**
Carrot Family Herbs							
Cilantro	A	E	6.5–8.0	◦ Direct seed April to September at 20–55 (up to 100) kg/ha (18–49 up to 89 lb/acre). ◦ Harvest 40–60 days after seeding.	20–60 cm (8–24 in.) between bands	2–5 cm (1–2 in.) in bands approx. 10 cm (4 in.) wide	required
Dill flower heads	A	E	5.6–6.5	◦ Direct seed April to July at 4–5 kg/ha (3.6–4.5 lb/acre). ◦ Harvest 80–90 days after seeding.	54–61 cm (22–24 in.)	3–4 cm (1⅛–1⅔ in.)	required
Dillweed	A	E	5.6–6.5	◦ Direct seed April to September at 9–11 kg/ha (8–10 lb/acre). ◦ Harvest 30–55 days after seeding.	54–61 cm (22–24 in.) between bands	1–2 cm (⅓–¾ in.) in bands approx. 10 cm (4 in.) wide	required
Fennel (sweet)	A	E	7.0–8.0	◦ Direct seed April to July at 6 kg/ha (5.3 lb/acre). ◦ Harvest 40–60 days after seeding.	30–40 cm (12–16 in.)	3–10 cm (1⅛–4 in.)	required
Parsley	GA	E	6.0–7.0	◦ Direct seed April to May at 22–45 kg/ha (20–40 lb/acre). ◦ Transplant 35–45 days after seeding when air temperatures are above 10°C (50°F). ◦ Harvest 60–80 days after seeding, 40–60 days after transplanting.	30–50 cm (12–20 in.)	15–20 cm (6–8 in.)	required

* Days to harvest provided for annual crop planning purposes.
** Requirements after the crop is established under normal Ontario conditions.

Table 7–59. Guidelines for Establishing Herbs

LEGEND: Crop type: A = annual B = biennial P = perennial GA = grown as an annual under Ontario conditions
Soil type: E = every mineral soil type S = sand L = loam C = clay M = muck

Crop	Type	Soil Type	Optimal pH Range	Propagation and Other Establishment Notes*	Row Spacing	In-row Spacing	Irrigation**
Mint Family Herbs							
Basil	A	S, L	5.5–7.0	◦ Establish as transplants from seed. ◦ Multiple harvests, beginning 60 days after transplanting.	60 cm (24 in.)	30 cm (12 in.)	required
Lavender (flowers)	P	S, L	6.5–7.5	◦ Establish as transplants from cuttings.	120–210 cm (48–84 in.)	45–60 cm (18–24 in.)	beneficial
Lemon balm	P	S, L	5.0–7.5	◦ Establish as transplants from seeds or cuttings, and transplant in May.	50–75 cm (20–30 in.)	30–60 cm (12–34 in.)	beneficial
Mint	P	E	6.0–7.0	◦ Establish by division or rhizome cuttings in May.	60 cm	30 cm	beneficial
Oregano/ marjoram	P, GA	E	6.0–8.0	◦ Establish as transplants from seed (will reduce consistency), cuttings or division in May.	60–90 cm (24–36 in.)	45 cm (18 in.)	beneficial
Perilla	A	S, L	6.0–8.0	◦ Direct seed or establish as transplants from seeds beginning in May. ◦ Harvest 60 days after seeding or 40 days after transplanting.	30–45 cm (12–18 in.)	15–30 cm (6–12 in.)	required
Rosemary	GA	E	6.0–7.5	◦ Establish as transplants from seeds or cuttings in May after danger of frost has passed. ◦ Harvest multiple times, beginning 60–90 days after transplanting.	50–100 cm (20–40 in.)	50 cm (20 in.)	not required
Sage	P, GA	E	5.5–6.5	◦ Establish as transplants from seed in May. ◦ Harvest multiple times beginning 60–90 days after transplanting.	70–100 cm (28–40 in.)	25–40 cm (10–16 in.)	beneficial
Summer savory	A	S, L	6.0–7.5	◦ Establish as transplants from seed. Multiple harvests beginning 40 days after transplanting.	60–80 cm (24–32 in.)	30–45 cm (12–18 in.)	not required (except sandy soils)
Thyme	P, GA	S, L	4.5–8.0	◦ Establish as transplants from seed. Multiple harvests beginning 105 days after transplanting.	30–50 cm (12–20 in.)	15–25 cm (6–10 in.)	beneficial
Winter savory	P	S, L	6.0–8.0	◦ Establish as transplants from seeds, cuttings or division.	80–120 cm (32–48 in.)	40–60 cm (18–24 in.)	not required
Other Herbs							
Chives	P	S, L	6.0–8.0	◦ Establish as transplants from seed or by division.	40–50 cm (16–20 in.)	20–30 cm (8–12 in.)	beneficial
Methi (fenugreek leaves)	A	L	5.3–8.2	◦ Direct seed April to September at 30 kg/ha (26.7 lb/acre). ◦ Soak seeds in warm water for 12 hr prior to sowing. Harvest 30–40 days after seeding, earlier under the heat of summer to avoid flowering.	50 cm (20 in.)	5–10 cm (2–4 in.)	beneficial
Tarragon	P	S, L	5.0–7.5	◦ Establish as transplants from cuttings. ◦ Harvest 60–80 days after transplanting, early summer and early fall thereafter.	60–90 cm (24–36 in.)	30 cm (12 in.)	not required

* Days to harvest provided for annual crop planning purposes.
** Requirements after the crop is established under normal Ontario conditions.

Fertility

No current Ontario fertility recommendations exist for herbs. Research and recommendations from outside Ontario do not necessarily apply to Ontario growing conditions. Table 7–60 provides suggested starting points based on Ontario field trials, similar crops or from other jurisdictions. See Table 7–61, and Table 7–62 for the reference crop for the phosphorus and potassium guidelines, based on soil test values.

Table 7–60. Fertility Guidelines for Herbs

Crop Species	Nitrogen Guidelines	Notes	Phosphorus and Potassium Reference Crop
Carrot Family Herbs			
Cilantro	50–100 kg/ha (45–89 lb/acre)	for each planting through the growing season	*Carrots*
Dill (weed and flowers)	30–65 kg/ha (27–58 lb/acre)	for each planting through the growing season	*Carrots*
Fennel (sweet)	See *Dill*.		*Carrots*
Parsley	90–120 kg/ha (80–107 lb/acre)	Split: among several applications	*Carrots*
Mint Family Herbs			
Basil	50–100 kg/ha (45–89 lb/acre)		*Lettuce*
Lavender	80–100 kg/ha (71–89 lb/acre)[1]		*Lettuce*
Lemon balm	90–120 kg/ha (80–107 lb/acre)[1]		*Lettuce*
Mint	150 kg/ha (134 lb/acre)[1]		*Lettuce*
Oregano/marjoram	80–120 kg/ha (71–107 lb/acre)	Split: 50% preplant and 25% in each of two side-dress applications over the season	*Lettuce*
Perilla	Not available.		*Lettuce*
Rosemary	150 kg/ha (134 lb/acre)[1]		*Lettuce*
Sage	0–100 kg/ha (0–89 lb/acre)[1]		*Lettuce*
Summer savory	100–150 kg/ha (89–134 lb/acre)[1]		*Lettuce*
Thyme	200 kg/ha (178 lb/acre)[1]		*Lettuce*
Winter savory	Not available. Avoid excess.		*Lettuce*
Other Herbs			
Chives	75–110 kg/ha (67–98 lb/acre)	Preplant: 55–80 kg/ha (49–71 lb/acre) PLUS Sidedress: twice at 10–15 kg/ha (9–13 lb/acre) over the season	*Onions, Leeks and Shallots*
Methi	25 kg/ha (22 lb/acre)	for each planting through the growing season	*Beans*
Tarragon	Not available.		*Lettuce*

[1] Optimal timings of the nitrogen applications are not known, but experience suggests that it is best to split this into two or three applications from May to early August with at least one application after bloom.

HERBS

Table 7–61. Reference Crops for Herbs – Phosphorus Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Sodium Bicarbonate Phosphorus Soil Test (ppm)													
	0–3	**4–5**	**6–7**	**8–9**	**10–12**	**13–15**	**16–20**	**21–25**	**26–30**	**31–40**	**41–50**	**51–60**	**61–80**	**81+**
Beans (Lima and Snap)														
Mineral Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	80 (71) (HR)	60 (54) (HR)	50 (45) (HR)	40 (36) (HR)	30 (27) (MR)	20 (18) (MR)	0 (LR)	0 (LR)	0 (RR)	0 (RR)	0 (RR)	0 (RR)	0 (NR)	0 (NR)
Carrots, Lettuce, Onions														
Mineral Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	180 (161) (HR)	170 (152) (HR)	170 (152) (HR)	160 (143) (HR)	160 (143) (MR)	150 (134) (MR)	140 (125) (LR)	120 (107) (LR)	100 (89) (RR)	80 (71) (RR)	50 (45) (RR)	30 (27) (RR)	0 (NR)	0 (NR)
Muck Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	100 (89) (HR)	100 (89) (HR)	100 (89) (HR)	100 (89) (HR)	90 (80) (MR)	90 (80) (MR)	80 (71) (MR)	70 (63) (MR)	60 (54) (MR)	50 (45) (LR)	30 (27) (LR)	20 (18) (LR)	0 (RR)	0 (NR)

Table 7–62. Reference Crops for Herbs – Potassium Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Ammonium Acetate Potassium Soil Test (ppm)											
	0–15	**16–30**	31–45	**46–60**	**61–80**	**81–100**	**101–120**	**121–150**	**151–180**	**181–210**	**211–250**	**250+**
Beans (Lima and Snap)												
Mineral Soils												
Potash (K_20) required kg/ha (lb/acre)	120 (107) (HR)	110 (98) (HR)	90 (80) (HR)	80 (71) (HR)	60 (54) (MR)	40 (36) (MR)	30 (27) (MR)	0 (MR)	0 (MR)	0 (LR)	0 (RR)	0 (NR)
Carrots, Onions												
Mineral Soils												
Potash (K_20) required kg/ha (lb/acre)	230 (205) (HR)	220 (196) (HR)	210 (187) (HR)	190 (170) (HR)	160 (143) (MR)	130 (116) (MR)	100 (89) (MR)	80 (71) (MR)	50 (45) (MR)	0 (LR)	0 (RR)	0 (NR)
Muck Soils												
Potash (K_20) required kg/ha (lb/acre)	230 (205) (HR)	220 (196) (HR)	210 (187) (HR)	200 (178) (HR)	170 (152) (MR)	150 (134) (MR)	120 (107) (MR)	80 (71) (MR)	40 (36) (MR)	0 (LR)	0 (RR)	0 (RR)
Lettuce												
Mineral Soils												
Potash (K_20) required kg/ha (lb/acre)	230 (205) (HR)	220 (196) (HR)	210 (187) (HR)	190 (170) (HR)	160 (143) (MR)	130 (116) (MR)	100 (89) (MR)	80 (71) (MR)	50 (45) (MR)	0 (LR)	0 (RR)	0 (NR)
Muck Soils												
Potash (K_20) required kg/ha (lb/acre)	100 (89) (HR)	100 (89) (HR)	90 (80) (HR)	80 (71) (HR)	60 (54) (MR)	40 (36) (MR)	30 (27) (MR)	20 (18) (MR)	20 (18) (MR)	0 (LR)	0 (RR)	0 (RR)

Harvest and Storage

Harvest and storage requirements for herbs along with expected yields are summarized in Table 7–63, Table 7–64 and Table 7–65. If practical, herbs should be harvested early in the morning after the dew has dried from the crop and before the sun dissipates the essential oils; leaves should be clean and free of dust and soil. For perennial herbs or annuals that will be harvested more than once, do not completely strip the stems of the entire leaf crop as remaining leaves are necessary to keep the plants growing. Remove field heat as soon as possible after harvest to prevent wilting and prolong shelf-life. There are no established grades for harvest of fresh herbs. Quality is determined by the market.

Table 7–63. Harvesting Herbs

LEGEND: H = Hand M= Machine

Crop Species	Harvest Indicators (e.g., frequency, duration)	Harvest Method
Carrot Family Herbs		
Cilantro	Harvest at the beginning of stem elongation before bolting. One-time harvest from each seeding.	H
Dillweed	Harvest at the beginning of stem elongation before bolting. One-time harvest from each seeding.	H
Dill flowers	Harvest flower heads when fully expanded and seeds have begun to form.	H
Fennel	Harvest at the beginning of stem elongation before bolting. One-time harvest from each seeding.	H
Parsley	Harvest once many leaves have fully matured by cutting all the leaves 3–4 cm (1–1½ in.) above the ground, leaving the crown to re-grow. Multiple harvests from one seeding.	H
Mint Family Herbs		
Basil	Harvest just before flowering by cutting off branches individually, leaving the core of the plant intact to regrow. Harvest again after regrowth just before flowering. Typically 2 harvests per planting.	H
Lavender	Harvest for culinary buds at the start of flowering when most buds have fully developed. Harvest stems approximately above the second-highest pair of leaves on the stem into small bundles tied with elastic bands and hang to dry in a dark, dry area with good air flow. One harvest per year.	H
Lemon balm	Harvest 20–25 cm (8–10 in.) long stems before flowering. leaving 15–20 cm (6–8 in.) of stem intact for regrowth. One harvest in the first year and 2–3 harvests per year thereafter.	H
Mint	Harvest 20–25 cm (8–10 in.) long stems before flowering, leaving 15–20 cm (6–8 in.) of stem intact for regrowth. 1–2 light harvests in the first year and 2–3 harvests per year thereafter. Harvest mint for oil once per year beginning in the second year at 10% bloom.	H
Oregano/ marjoram	Harvest 20–25 cm (8–10 in.) long stems before flowering leaving 15–20 cm (6–8 in.) intact for regrowth. 1–2 light harvests in the first year and 2–4 harvests per year thereafter.	H
Perilla	To prevent wilting, harvest whole tops for bunching. One-time harvest from each planting.	H
Rosemary	Harvest 20–25 cm (8–10 in.) long stems, leaving 15–20 cm (6–8 in.) intact for regrowth. 1–3 harvests from a single planting.	H
Sage	Harvest 20–25 cm (8–10 in.) long stems, leaving 15–20 cm (6–8 in.) intact for regrowth. 1–3 light harvests in the first year and 2–3 per year thereafter beginning before bloom (if grown as a perennial).	H
Summer savory	Harvest 20–25 cm long (8–10 in.) stems, leaving 15–20 cm (6–8 in.) intact for regrowth. 2–3 harvests from a single planting.	H
Thyme	Harvest 15–20 cm (6–8 in.) long stems leaving 10–15 cm (4–6 in.) intact for regrowth. 1 harvest in the first year and 2–3 harvests in subsequent years beginning just before flowering.	H
Winter savory	Harvest 20–25 cm (8–10 in.) long stems leaving 15–20 cm (6–8 in.) intact for regrowth. 1–3 light harvests in the first year and 2–3 per year thereafter beginning before bloom.	H
Other Herbs		
Chives	Harvest all leaves 3–5 (1–2 in.) cm above the ground once or twice in the first year, before flowering and every few weeks thereafter in subsequent years.	H, M
Methi	Harvest whole plants before flowering. One-time harvest from each seeding.	H
Tarragon	Harvest 20–25 cm (8–10 in.) long shoots before flowering in early summer and again in the fall each year after a single planting.	H

HERBS

Table 7–64. Average Yields for Herbs

Crop Species	Expected Yield/Yield Range
Carrot Family Herbs	
Cilantro	3,700–10,000 kg/ha/crop (3,290–8,900 lb/acre/crop)
Dillweed	3,000–5,500 kg/ha/crop (2,700–4,500 lb/acre/crop)
Dill flowers	Not available
Fennel	Not available
Parsley	10,000–20,000 kg/ha (8,900–17,800 lb/acre)
Mint Family Herbs	
Basil	14,000 kg/ha (12,500 lb/acre)
Lavender	500–1,500 kg/ha (450–1,340 lb/acre) (dry weight) 10–40 kg/ha (9–36 lb/acre) oil (angustifolia cultivars) 40–100 kg/ha (36–89 lb/acre) oil (lavandin cultivars)
Lemon balm	10,000–25,000 kg/ha (8,900–22,300 lb/acre) fresh 3–7.5 kg/ha (2.7–6.7 lb/acre) oil
Mint	7,000–19,000 kg/ha (6,200–16,900 lb/acre) fresh 30–45 kg/ha (27–40 lb/acre) oil
Oregano/ marjoram	9,000–19,000 kg/ha (8,000–16,900 lb/acre)
Perilla	Not available
Rosemary	3,000 kg/ha (2,700 lb/acre)
Sage	20,000–40,000 kg/ha (17,800–35,600 lb/acre)
Summer savory	5,000–15,000 kg/ha (4,500–13,500 lb/acre)
Thyme	1,100–2,200 kg/ha (980–1,960 lb/acre)
Winter savory	Not available
Other Herbs	
Chives	9,000–19,000 kg/ha (8,000–16,900 lb/acre)
Methi	Not available
Tarragon	16,000 kg/ha (14,200 lb/acre)

Table 7–65. Storage Conditions for Herbs

LEGEND: RH = relative humidity

Crop Species	Storage Conditions
Carrot Family Herbs	
Cilantro	0°C (32°F) at 95%–100% RH for 10–14 days
Dillweed	0°C (32°F) at 95%–100% RH for 10–14 days
Dill flowers	0°C (32°F) at 95%–100% RH for 10–14 days
Fennel	0°C (32°F) at 85%–100% RH for 10–14 days
Parsley	0°C (32°F) at 95%–100% RH for 14–21 days
Mint Family Herbs	
Basil	10°C–15°C (50°F–59°F) at 95%–100% RH for 7–14 days
Lavender	Store dried buds in sealed containers in the dark with desiccant packs at <5°C (41°F) for 1–2 years.
Lemon balm	0°C (32°F) at 95%–100% RH for 14–21 days
Mint	0°C (32°F) at 95%–100% RH for 14–21 days
Oregano/ marjoram	0°C (32°F) at 95%–100% RH for 21–28 days
Perilla	0°C (32°F) at 95%–100% RH for unknown duration
Rosemary	0°C (32°F) at 95%–100% RH for 14–21 days
Sage	0°C (32°F) at 95%–100% RH for 14–21 days
Summer savory	0°C (32°F) at 95%–100% RH for 14–21 days
Thyme	0°C (32°F) at 95%–100% RH for 14–21 days
Winter savory	0°C (32°F) at 95%–100% RH for 14–21 days
Other Herbs	
Chives	0°C (32°F) at 95%–100% for 7–14 days
Methi	0°C (32°F) at 95%–100% RH for 10–14 days
Tarragon	0°C (32°F) at 95%–100% RH for 14–21 days

Crop-Specific Comments

Basil

Sweet basil is sensitive to frost and cold temperatures. Transplant in late May after the danger of frost has passed. Cut stalks just before flowering, leaving at least 4 sets of leaves. Chilling injury will occur if basil is exposed to temperatures below 10°C (50°F) in the field or after harvest. Harvest fields twice a year, beginning at 80 days after planting. Stagger harvests across the field for continuous supply.

Chives

Divide chive plants after 3 years of production and plant in a new location. Harvest by cutting 3–5 cm (1¼–2 in.) above the soil surface, up to 3–4 times per year. Stagger harvests across the field for continuous supply. Fresh tips are sold 15–20 cm (6–8 in.) long. Remove any flower stems or wilted leaves. Machinery is available for harvest of large plantings but may not be economical on a small scale.

Cilantro

Hot weather induces flowering in cilantro. Cut cilantro just before flowering. Whole plants are usually harvested to prevent wilting. Refrigerate leaves immediately after harvest. Plant successively for continuous harvest from May through to October.

Dill

Bunched dill plants can be planted successively for continuous harvest from May through to October. Whole plants are usually harvested to prevent wilting. Dill performs best in cool growing conditions. For harvest of flowers for pickling, pick umbels as the plants flower and while the seed is still green. Dill can be invasive if grown to seed, so harvesting before seeds mature is important.

Fennel

Fennel grown for fresh herb (sweet fennel) has similar production requirements as dill. For Florence fennel (bulb) production, see *Specialty Vegetables*, in this chapter.

Lavender

Good soil drainage is essential for overwintering success. Row covers are advised for improving overwintering success. *Lavandula angustifolia* cultivars are preferred for most culinary purposes, although *L. x intermedia* (lavandin) cultivars can sometimes be used in cuisines accustomed to the higher camphor content of the buds (e.g., South Asian cuisines). Plants are often grown on strips of solid or woven black plastic mulch with grass between rows to minimize manual labour for weeding (Figure 7–89). For culinary buds, harvest at the beginning of flowering, starting in the second year when buds (calyxes) have fully matured, but less than 10% of flowers (corollas) have opened. Open flowers will dry and turn brown after harvest and detract from the quality of the buds. Bud stripping equipment is available for removing buds from the stem after drying. Small seed cleaning equipment can also be used to remove debris after stripping. Store buds in sealed containers in the dark below 5°C (41°F) to prolong shelf-life.

After harvest, lavender should be pruned to help maintain a rounded shape and prevent plants from getting too woody. In Ontario, this is usually done in early August after harvest activities are completed. Remove 33%–50% of the green material at this time.

Figure 7–89. Lavender plants grown on black plastic mulch in the row with mowed grass between rows.

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Lemon Balm

Seeds of lemon balm germinate more successfully if they are not covered. Ensure even soil moisture during germination. Mulching or row covers may be required to improve overwintering success. Harvest by cutting off the top growth, leaving 5 cm (2 in.) of stem for regrowth. Avoid bruising leaves during harvest.

Methi (Fenugreek Leaves)

Methi is often sold in bunches of whole plants prior to flowering. As a legume, methi can fix its own nitrogen through an association with a bacterium called a rhizobium. It is unknown if the strains of rhizobia are the same as used for other leguminous crops such as soybeans. Crops may be weaker and more prone to pests without an associated rhizobium. Populations in the soil may build over time as more methi crops are grown.

Mint

Mint is highly invasive. Rotate with a small grain every 3 years. Leaves can be picked any time for fresh market, up to 2 or 3 times per year. There are many types and species of mint. Ensure the type grown matches the market preferences. The most common types are spearmint and peppermint. Neither spearmint nor peppermint produces viable seed, so plantings are established as cuttings. Mint spreads by underground rhizomes. A single transplant can reach 1 m (39 in.) in diameter within 2 years.

Oregano/Marjoram

Harvest in the first year at the start of bloom. Cut plants at a 15–20-cm (6–8-in.) height, 2–4 times per year with fewer harvests in the first year. Harvest is suspended during flowering. Stagger harvests across the field for more continuous supply. Renovate oregano every 3–5 years. Oregano and marjoram are two separate species within the genus *Origanum* and have similar production requirements. Ensure you grow the type that matches the preferences of your market.

Parsley

Plant into a rich, deep soil. Begin harvest approximately 75 days after seeding. For fresh market, harvest manually and bunch older leaves. Wash and cool immediately to 0°C–2°C (32°F–36°F) and store at high relative humidity. Stagger harvests across the field for continuous supply.

Perilla

Chill seeds at 5°C (41°F) for 3 days in moist soil prior to sowing. Seeds need light to germinate. Do not bury seeds after planting and keep the surface evenly moist. Leaves wilt rapidly and plants are often harvested whole to reduce wilting. Single leaves can be harvested and sold for culinary use.

Rosemary

Rosemary will not overwinter in the field in Ontario. Plant into dry, well-drained sites. Never harvest more than half the plant. Stagger harvests across the field for continuous supply.

Sage

Harvest leaves and tops in late summer or early fall in the first year. Late harvests can decrease winter survival. Cut above the woody portion of the stem. In subsequent years, multiple harvests can occur. Stagger harvests across the field for more continuous supply. Harvest is suspended during flowering. Sage plantings will last 4–5 years before becoming too woody.

Summer Savory

Summer savory may need irrigation until established. It performs best on well-drained soils. Cut just above the lowest branches, up to 2 times per year. Stagger harvests across the field for continuous supply.

Tarragon

Grow tarragon on well-drained soils. Cut in the first year when plants are 40–60 cm (16–24 in.) high. Two cuttings are possible in following years. Cut plants 15 cm (6 in.) above the ground.

Thyme

Two cuttings per year are possible just before flowering and in late summer. Thyme can be grown as an annual or short-lived perennial. Older plantings become woody. Some winter protection may be required in colder regions. Stagger harvests across the field for more continuous supply. Harvest is suspended during flowering. In subsequent years it is grown as a perennial.

Winter Savory

Winter savory is sometimes considered inferior in flavour to summer savory, but more robust and able to withstand more cooking. Plants should be divided and moved to a new field every 2–3 years. Stagger harvests across the field for continuous supply. Harvest is suspended during flowering.

Pest Management and Disorders

Table 7–66 lists the common insects, diseases and disorders identified on herbs in Ontario. Some pests affect all members of the carrot or mint family and are indicated separately. To help manage the build-up of pests in the field, always rotate to other crops not in the same family. For example, avoid rotating carrot family herbs with other members of the carrot family including carrots, celery, parsnips, celeriac and other carrot-family herbs. See Chapter 5 for information on pests listed in the table that are not specifically described in this section.

Table 7–66. Major Insects, Diseases and Disorders of Herbs in Ontario

Crop Species	Insects, Diseases & Disorders
Carrot Family Herbs	
All carrot family herbs	parsleyworm, leafhoppers, aphids, cutworms, damping-off, itersonilia blight. **NOTE:** Itersonilia blight has mostly been reported on dill but can affect all other members of the carrot family.
Cilantro	bacterial leaf spot, thrips
Dill (weed and flowers)	phoma blight, root and crown rots
Fennel	bacterial leaf spot
Parsley	carrot weevil, cabbage looper, septoria leaf spot, alternaria leaf blight, bacterial leaf spot
Mint Family Herbs	
All mint family herbs	four-lined plant bug, aphids, leafhoppers, two-spotted spider mites, tarnished plant bug, spittle bugs. **NOTE:** Four-lined plant bug affects most members of the mint family but is not an issue on annual crops where eggs cannot overwinter unless there is another perennial host nearby.
Basil	Japanese beetles, downy mildew (*Peronospora belbahrii*), white mould (*Sclerotinia sclerotiorum*), anthracnose (*Colletotrichum* sp.)
Lavender	garden fleahopper, septoria leaf spot (*Septoria lavandulae*), phytophthora root rot (*Phytophthora nicotinae*), root rot (*Pythium* and *Fusarium* spp.)
Lemon balm	no specific pests identified to date
Mint	powdery mildew, rust (*Puccinia menthae*), verticillium wilt (*Verticillium dahlia*)
Oregano/marjoram	garden fleahopper, leafrollers, phomopsis leaf and stem blight
Perilla	Japanese beetles
Rosemary	no specific pests identified to date
Sage	phomopsis leaf and stem blight
Summer savory	no specific pests identified to date
Thyme	garden fleahopper
Winter savory	no specific pests identified to date
Other Herbs	
Chives	thrips, leafminers, leek moth, onion maggot, rust (*Puccinia allii*). **NOTE:** See *Onions, Leeks and Shallots* in this chapter for more information on chive pests.
Methi	leafhoppers (hopperburn), tarnished plant bug, alternaria leaf spot, root rots. **NOTE:** Leafhopper feeding leads to extensive hopperburn.
Tarragon	crown and root rots (e.g. rhizoctonia, sclerotinia)

Diseases

Bacterial Leaf Spot of Cilantro, Parsley and Fennel

While primarily a disease on cilantro in Ontario, bacterial leaf spot can also occur on parsley and fennel. It is caused by several different pathovars (strains) of *Pseudomonas syringae*. These strains have only been reported to affect cilantro, parsley, fennel and celery.

Identification: Bacterial leaf spot appears as distinctive circular lesions on leaves that eventually coalesce and become irregular in shape (Figure 7–90). They often have a darker border. Newly formed lesions have a water-soaked appearance. Eventually whole leaves may be killed.

Figure 7–90. Bacterial leaf spot on cilantro.

Biology: Bacterial leaf spot is transmitted primarily on infected seeds. It moves from plant to plant through splashing from overhead irrigation or rainfall. Once in the field, it can survive in the soil on crop residues.

Scouting and Thresholds: There are no thresholds for this disease in Ontario. Since this disease occurs on the harvested portion of the plant, there is little or no tolerance for the disease in the field.

Management Notes: There are few if any products registered to manage this disease once it occurs in the crop. Preventing its introduction to the field and its spread once in the field are the main strategies to reduce symptoms. Purchase seed that is indexed to be free of the pathogen. Always rotate to non-host crops after each herb crop to ensure the disease cannot survive on alternative hosts. While cilantro is the most affected crop, other carrot-family species like parsley, fennel and celery could increase populations of the pathogen even if disease symptoms are not as severe. If the disease is present in the field, avoid overhead irrigation to minimize further spread. Avoid excess nitrogen fertilizer, which appears to increase the susceptibility of the crop to the disease.

Basil Downy Mildew

Basil downy mildew was first identified in the field in Ontario in 2010 and causes significant damage on an annual basis.

Identification: Sections of leaves defined by the veins turn olive-green or yellow (Figure 7–91) with purplish-grey sporulation on the underside of the affected sections early in the morning (Figure 7–92). Eventually the whole leaf turns yellow and falls off the plant. Complete defoliation can occur within 2–3 weeks of the initial appearance of symptoms if not protected.

Figure 7–91. Sections of a basil leaf turning yellow due to downy mildew.

Figure 7–92. Purplish-grey sporulation on the lower leaf surface due to downy mildew.

Biology: Basil downy mildew is caused by the oomycete (water mould) *Peronsopora belbahrii*. It produces airborne spores that often move up from the southern U.S. each year but can also come from the greenhouse on transplants or nursery-grown plants for home gardens. If introduced from the greenhouse in May, conditions are usually not conducive to spread because canopies are wide open and dew periods are shorter in June and early July. Initial symptoms in commercial fields often appear in mid- to late July when dew periods increase in length. Symptoms can become widespread in August or September, depending on weather conditions. Spores often re-enter greenhouses in the fall.

Scouting and Thresholds: There is no tolerance for downy mildew on basil due to the risk of further spread once symptoms appear and continued progression of the disease post-harvest. Basil should be scouted regularly throughout the growing season for the initial symptoms to verify that protective measures are being successful. Once symptoms are identified in the area, targeted fungicides are required to protect sensitive cultivars.

Management Notes: New cultivars are being released that have tolerance or resistance to this pathogen. For organic growers, use of these cultivars will be the only effective option for management of this disease. Resistant cultivars may not have the same desired characteristics for the market as older cultivars due to crossing with less desirable relatives, although this may only be an issue for discerning customers. Improved cultivars with resistance continue to be released, but resistance stability is unknown, and the pathogen may be able to overcome the resistance over time. Continued vigilance in monitoring for downy mildew symptoms is required. Unless the cultivar has complete resistance to the disease, fungicides will still be required to manage the disease, but the frequency of sprays may be reduced.

For production of susceptible varieties, use protectant fungicides when conditions are conducive for disease development. Employ stronger curative fungicides when symptoms of the disease are detected in Ontario and/or the canopy begins to close. Growing plants with a wider spacing may delay the onset of the disease in organic production.

Fungal Blights of Herbs

There are several fungal blights affecting herbs in Ontario. Not all of these have been diagnosed to species due to the limited research conducted on herbs. Specific blights that have been diagnosed include septoria leaf spot of lavender caused by *Septoria lavandulae*, septoria leaf spot of parsley caused by *Septoria petroselini*, phoma blight of dill caused by *Phoma anethi* and itersonilia blight on dill and other carrot-family herbs caused by *Itersonilia perplexans*. There are several other blights that have only been identified to genus such as anthracnose on basil, phomopsis blight of several mint family herbs such as oregano and sage, and alternaria blight on methi.

Identification: The symptoms of fungal blights vary depending on the herb and the causal organism. Symptoms usually begin as circular or irregular brown spots on leaves and/or stems, sometimes with a yellow halo. On narrow-leaved herbs such as dill, fennel, lavender or curled leaf parsley, the lesions might traverse the leaf leading to death of the leaf tip (Figure 7–93). The older leaves are often most affected by fungal blights due to a thicker canopy lower in the plant, more humidity in the area and weakened defence responses. Some fungal pathogens produce black fruiting bodies within the lesions (e.g., *Septoria* spp., *Phomopsis* spp.) which lead to black specks, usually on the upper leaf surface.

Figure 7–93. Curled parsley with septoria leaf spot. While distinct lesions are present, leaf tips have died where the lesions have traversed the narrow leaves.

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Biology: Fungal blights usually originate from old infected leaves and stems within the field or they blow in with wind-borne spores from wild areas, nearby host crops or from more distant sources. Occasionally, they can originate from contaminated seeds or transplants. Spores germinate on leaf surfaces under moist conditions and will penetrate the leaf if given a sufficient period of leaf moisture. Dew periods are often long enough for infection to occur, especially in the last half of summer. Most of the pathogens produce asexual spores after a week or two of infection after which they spread within the field. Under ideal conditions, complete loss of the crop may occur after a few weeks if the crop is unprotected.

Scouting and Thresholds: There are no thresholds for fungal blights in herbs. Since leaves are the harvested portion, the tolerance for damage is very low. Regular scouting can catch initial infections before they become widespread. Samples may need to be submitted to a diagnostic clinic for identification.

Management Notes: The following preventive strategies can reduce the impact of fungal blights on herbs:

- Purchase clean seed or transplants from a reputable supplier.
- Purchase cultivars that have some resistance to the disease, if available.
- Avoid planting herbs in shaded and sheltered conditions where herbs may be weaker and wet periods longer.
- Widen plant spacing to encourage good airflow through the canopy.

Fungicides may be available, depending on the herb and the disease, and should be used preventively in crops with a history of fungal blights.

Phytophthora Root Rot of Lavender

Phytophthora root rot is potentially the most destructive disease of lavender in Ontario.

Identification: Look for plants that wilt after they green up in the spring, turn pale in colour and eventually die (Figure 7–94). The disease often progresses across the plant in sections, leaving dead, wilted and healthy sections all on the same plant. This type of damage has also been found in association with spring freeze damage. Unlike freeze damage, phytophthora often progresses down the row from plant to plant in wet conditions.

Figure 7–94. Phytophthora root rot progressing down a row of lavender. Note the sudden collapse of sections of the plant.

Biology: Phytophthora root rot of lavender is caused by the oomycete (water mould) *Phytophthora nicotianae*. This pathogen has a wide host range including several other horticultural crops such as strawberries, tobacco and peppers. Oomycetes have swimming spores called zoospores that can move wherever water moves in and on top of saturated soils. Phytophthora root rot can occur any time during the year when conditions are wet. Prolonged periods of saturated soils result in the most severe outbreaks.

Scouting and Thresholds: Continual scouting for this disease should occur in both newly purchased plants and established plants in the field, especially after wet periods. There are no thresholds for this disease in Ontario because its presence cannot be tolerated. Once the disease is present in the field it has the potential to spread wherever water moves in the soil, including irrigation lines.

Management Notes: The key to management of phytophthora root rot is prevention to avoid introducing the pathogen to the field. *Phytophthora nicotianae* does not appear to survive cold winters in

Ontario. Avoid growing lavender immediately after another host crop with a history of the disease in the field. Purchase lavender plants from a reputable propagator that monitors for the disease and has a proper sanitation program. If plants are coming from a less trusted source, quarantine plants outside of the field for 2 weeks and monitor for any plants suddenly wilting even if the soil is moist. Have the plants tested at a diagnostic laboratory to determine if phytophthora may be the cause. Destroy affected plants or trays of plants and quarantine the remaining plants for a further 2 weeks if phytophthora is confirmed.

The best way to avoid the pathogen in the field is to keep the root system dry year-round by improving drainage. If symptoms appear in the field, remove the affected plants. Since neighbouring plant roots may already be infected with the pathogen, remove at least one plant in either direction down the row. Do not re-plant in the same spot for at least 1 year to confirm the pathogen is no longer present. Unlike fields in warmer climates that must be abandoned after phytophthora is confirmed, problems with the disease in Ontario can disappear after a year or two of cold weather. This can allow replanting to commence without further issues, but fields should be continually monitored for symptoms thereafter, especially after rainy periods.

Powdery Mildew

Powdery mildew affects several culinary herbs including most herbs in the mint family and tarragon. Different fungal species can cause powdery mildew on different herbs, so the disease may not necessarily spread from one herb to the next.

Identification: Powdery mildew usually begins as white or grey patches on the upper leaf surface, usually lower in the plant canopy (Figure 7–95). Eventually the whole leaf surface may be covered. While the disease is more prevalent on the upper leaf surface, lower leaf surfaces may also be affected. Eventually the leaf becomes chlorotic in the affected areas. In some mint species, the powdery growth can be very faint, and yellow spots may appear that resemble downy mildew, but downy mildew is only known to be an issue on basil in Ontario.

Figure 7–95. Powdery mildew developing on the upper leaf surface on spearmint.

Biology: Powdery mildews grow on leaf surfaces, penetrating the leaf to feed. They produce asexual spores called conidia that spread on the wind. While powdery mildews can be caused by different species, each species has a wide host range. As a result, it is impossible to prevent the introduction of spores from outside of the field. Plants are most susceptible during periods of stress, and it is common to have severe powdery mildew during periods of moisture stress. Powdery mildew spores can infect plant tissue during periods of high humidity, but leaf wetness is not always required for infection. The pathogen overwinters on infected plant material.

Scouting and Thresholds: Powdery mildew is relatively easy to identify. Regular scouting is required to identify initial lesions while they can still be controlled with fungicides. There are no thresholds for powdery mildew in herbs. Since the leaves are the harvested portion of the plant, there is low tolerance for the disease. Since older leaves are affected first, harvest may still be possible with low disease severity.

Management Notes: Since powdery mildew is worse on plants that are stressed, avoid plant stress through regular irrigation and proper fertilization. Promote good airflow through the canopy to reduce relative humidity around older leaves. This can be achieved by planting crops in open fields and with wider plant spacing in crops affected annually. Fungicides should be applied preventively when conditions are conducive to the disease, but especially when the disease is first identified in the field.

Insects

Four-Lined Plant Bug (FLPB)

Four-lined plant bug is a pest on most herbs in the mint family. It mainly affects perennial species. It is not a common pest on any other agricultural crop.

Identification: Tiny lines of white eggs overwinter in slits cut in the side of the stem (Figure 7–96). In mid- to late May, the eggs hatch and develop through four stages of nymph. First instar nymphs are mostly pale to bright red and very small — 1–2 mm (<⅛ in.) in length. As the nymphs develop through the instars, black wing pads develop making them black and red in appearance. The red colouration usually becomes duller in later instars. Adults are yellow or dull green with four black stripes down their back and 7 mm (¼ in.) in length.

Damage: All stages of the insect feed by sucking leaves and stems and continually move around, leading to a series of circular brown lesions on leaves and elongated lesions on stems. These can be confused with a disease. Most of the damage is concentrated in the new growth at the tip of the shoots. Damage to young leaves can cause curling and deformation of the leaves. Damage is mostly aesthetic and does not lead to significant yield losses but will affect the marketability of fresh herbs and the appearance of lavender plants for agritourism.

Biology: Eggs hatch in mid- to late May. Nymphs progress through about one instar per week. Adults emerge in mid- to late June. Adults feed for a couple of weeks, then mate. Females lay eggs in slits cut into the side of green stems. There is only one generation per year and by mid-July feeding ends until the following spring.

Scouting and Thresholds: Begin scouting in mid-May before the expected egg hatch. The most obvious symptoms initially are the twisting and browning of the young leaves at the tips of new shoots. There are no thresholds for FLPB on herbs. While plants can tolerate considerable damage, marketability of most herbs will be affected, so even low numbers can cause economic losses.

Management Notes: Since eggs overwinter in the side of stems, there will be minimal damage to annual mint-family herbs or perennial species grown as an annual, unless they are grown in proximity to perennial hosts. FLPB is also a pest of many perennial members of the *Asteraceae* family, such as asters and daisies, that are common in pastures, roadsides and fence rows. Avoid planting annual mint-family herbs near field edges or near perennial host crops.

For perennial hosts, if you are already pruning the plant as part of regular maintenance (e.g., trimming lavender to prevent from going woody), removing and composting any pruned materials may remove some of the egg clusters from the field. For vegetative perennial species such as mint and lemon balm, in which the above-ground biomass dies over winter and new shoots emerge from the soil in the spring, manual removal of dead stems in late fall or spring may reduce populations the following year. It could be possible to burn the dead stems in the field using flamers normally used for weed control.

Insecticides may help manage populations but should be applied during the first or second instars when they are most susceptible. Once damage is obvious in the field, it is usually too late to manage the insects. Scouting is key to ensure FLPB are identified early and can be sprayed at the correct stage.

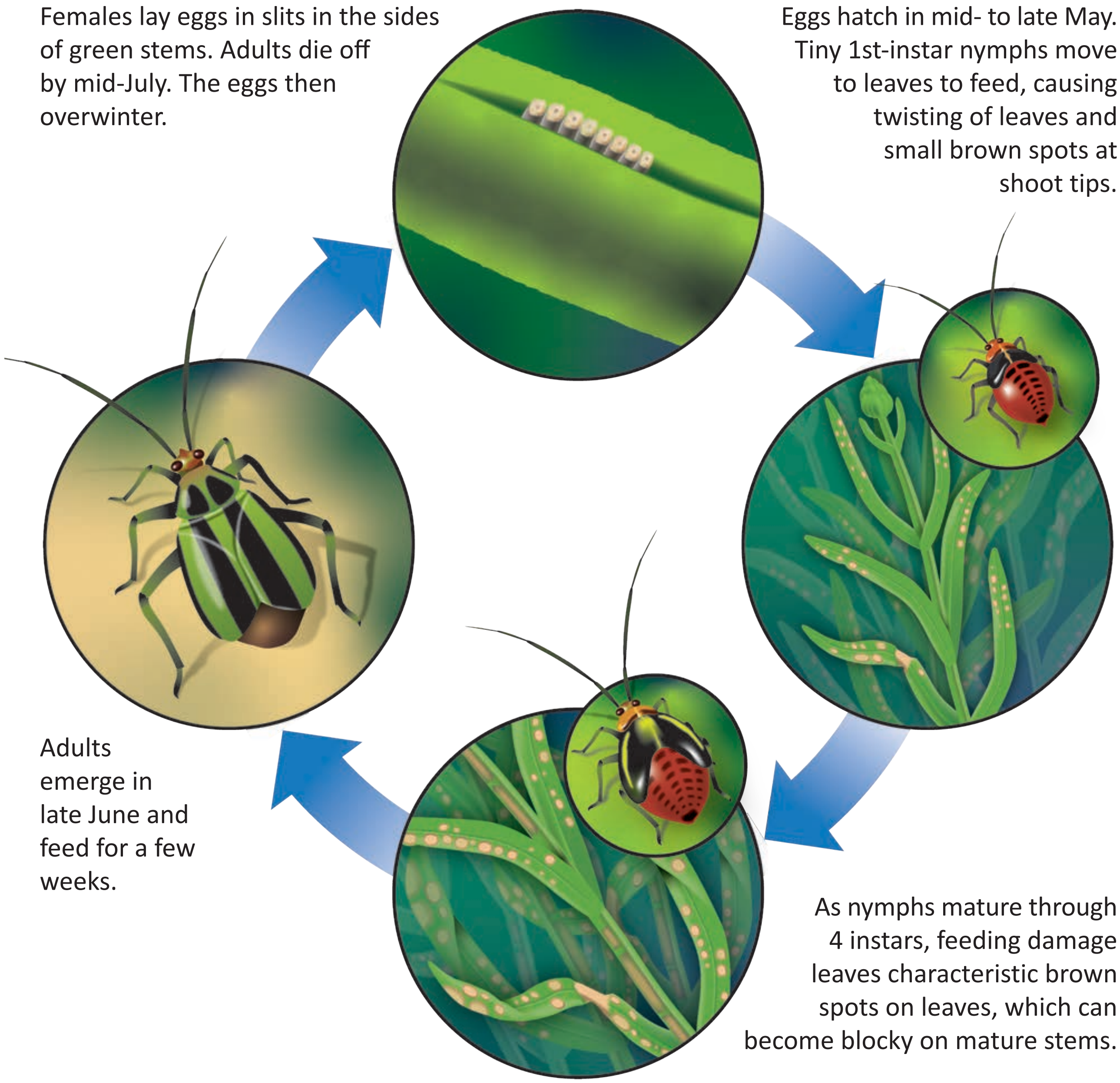

Figure 7–96. Life cycle of the four-lined plant bug on lavender.

Garden Fleahopper

Garden fleahopper (*Microtechnites bractatus*) is an occasionally severe pest of lavender and potentially other perennial members of the mint family, especially when grown over black plastic mulch where warmer temperatures likely promote faster development and more generations per year.

Identification: Nymphs of garden fleahopper progress through five instars (stages), which are pale green in the first four instars (Figure 7–97) and darker green in the final instar. Adults are black with prominent hind legs used for jumping (Figure 7–98). Both the jumping habit and the appearance resemble fleabeetles, but the antennae of fleahoppers are longer than the body, whereas fleabeetle antennae are much shorter than the body. Adults are about 2 mm (⅛ in.) long.

Damage: Damage appears as white or yellow flecking on the leaf surface (Figure 7–99).

Biology: Garden fleahoppers are in the *Hemiptera* or True Bug Order of insects. They overwinter as eggs inserted into stems or leaves. Nymphs hatch in May and progress through the five instars at a rate of about one instar per week. Adults mate, and females lay eggs into plant surfaces. Eggs hatch within 2 weeks to continue the cycle. There are several overlapping generations per year, with all stages present on the same plant beginning in early summer.

Scouting and Thresholds: Garden fleahoppers lead to white flecking on the leaf surface, beginning with the leaves in the centre of the canopy. There are no thresholds for damage. Plants can tolerate considerable damage, but populations have been known to build and severely weaken plants by late summer. Once damage becomes obvious from a distance, control measures may be warranted. Since nymphs and adults are tiny and difficult to see within the canopy, they are best identified by shaking the plant vigorously over a white sheet of paper.

Management Notes: There are few options for management of this pest in herbs. Insecticides used to control other true bugs such as four-lined plant bug or tarnished plant bug may suppress populations if applied multiple times during the growing season.

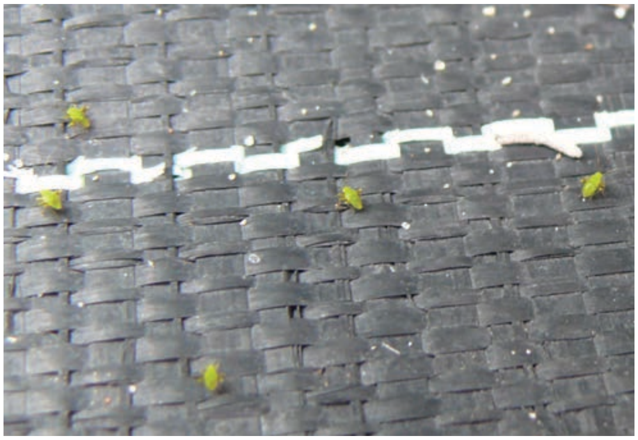

Figure 7–97. Early instar garden fleahopper nymphs.

Figure 7–98. Adult garden fleahopper.

Figure 7–99. Garden fleahopper feeding damage appears as fine white flecking on leaves within the canopy.

Japanese Beetles on Basil and Perilla

Japanese beetles are an invasive insect that have become widespread in much of Southern and Eastern Ontario. Adults can feed for an extended period causing leaf damage and defoliation of a wide range of hosts. Basil appears to be one of its preferred hosts. Damage to perilla has also been noted. Occasional minor damage may also occur on other herbs.

Identification: Japanese beetle adults are a distinctive shiny, metallic green on the head and thorax with copper coloured wings. Larvae appear as white grubs in the soil under lawns and natural areas.

Damage: Japanese beetles usually feed on the highest leaves in the canopy, leaving irregular holes over the leaf surface.

Biology: Japanese beetles overwinter as larvae and pupate in late spring. They emerge beginning around the end of June or early July and will feed well into August or as late as early September. They mate during the summer and females lay eggs back into lawns or natural areas where larvae have the opportunity to feed on roots.

Scouting and Thresholds: Japanese beetles and their damage are distinctive in affected herbs. No other known pest results in holes and ragged chewing mostly on the upper leaves. Eventually only the veins of the leaves remain, giving the leaf a skeletonized appearance. Since these crops are sold for their leafy shoots, there is very low tolerance for Japanese beetle damage in herbs, but no thresholds have been established.

Management Notes: There are few to no insecticides for control of Japanese beetles in herbs. Management of the larvae is usually not an option because they often occur outside of the field.

Japanese beetle pheromone traps are available to help reduce populations, but some studies suggest they may pull in more adults to the field and increase damage. If traps are to work properly, they would have to be set far outside of the field. Since adults find the host by scent, setting traps downwind of the field may lure and trap adults outside the cropping area. Traps can fill with adults rapidly and should be changed regularly to remain effective.

Avoid planting susceptible herbs near areas of extensive turf (e.g., lawns, orchards, pastures, roadsides) where larvae may be present. However, adults can fly considerable distances and may still find the crop even if far away from the field. Some cultivars may be more affected than others. Trial different cultivars if the issue cannot be resolved with other strategies.

Lettuce

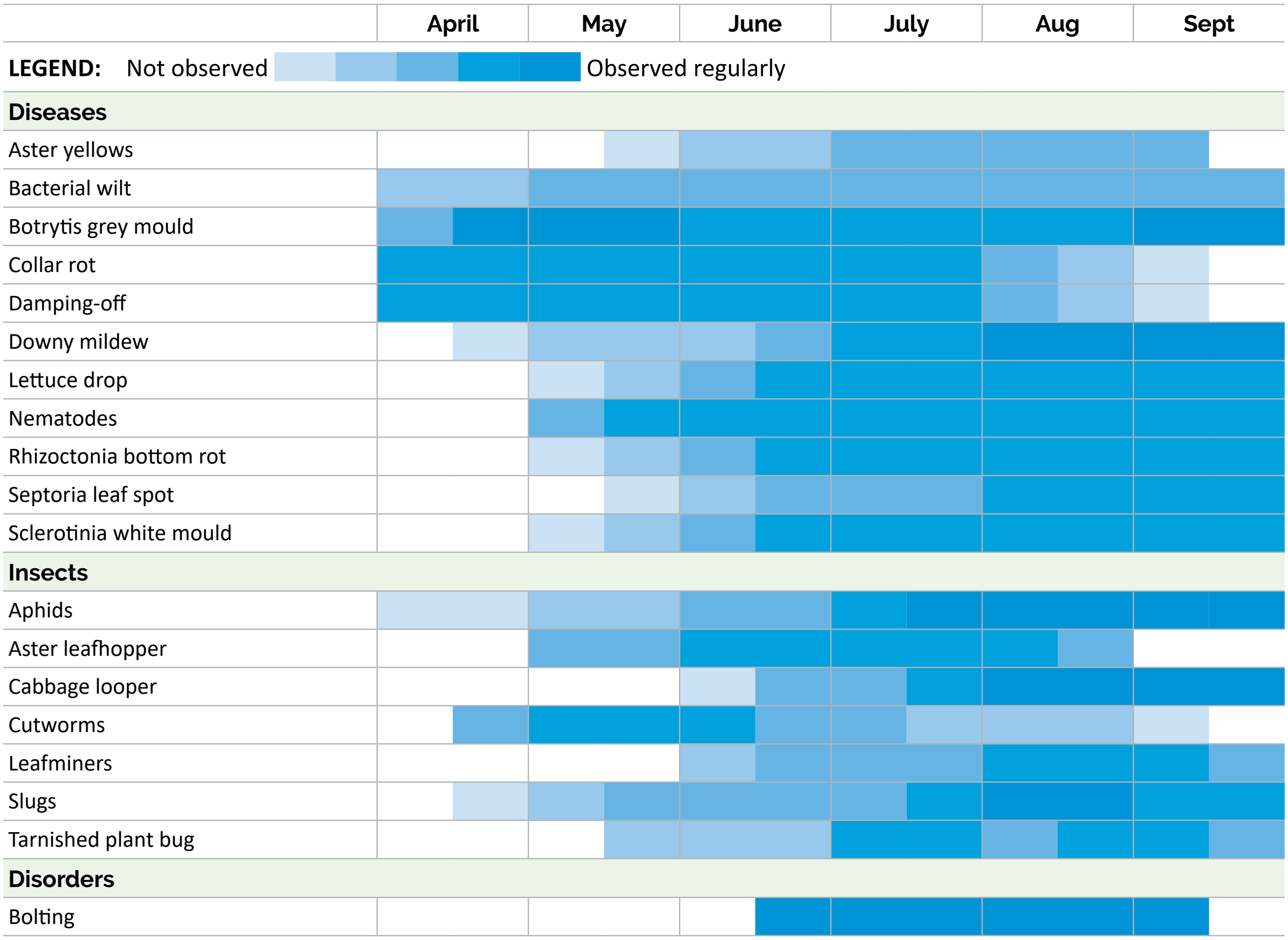

Figure 7–100. Lettuce pest activity calendar. The actual period of activity for any given pest will vary significantly from year to year, depending on environmental factors.

Production Requirements

Soil types:	mineral and muck soil
Soil pH:	mineral soil: 6.1–6.5
	muck soil: 5.5
Suitable rotational crops:	celery, corn, onions, peas, cereal crops
Do not rotate with:	leafy greens or fields with a history of sclerotinia white mould
Minimum soil temperature:	2°C (36°F)
Optimum air temperature:	15°C–18°C (59°F–64°F)
Earliest planting date:	early to late April

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Seeding and Spacing

Use coated or pelleted seed with a precision seeder to ensure a more uniform stand. This also reduces thinning costs and provides higher yields at harvest time.

Seeding time is important on both muck and mineral soils. Immature plants will recover from a frost event. The wrapper leaves on mature heads are very susceptible to frost and can only be marketed at a lower grade if they are damaged.

Properly hardened transplants, when set in the field in the early spring, can tolerate temperatures as low as –7°C (19°F). Transplants allow for the desired density to be achieved without thinning. See Table 7–67.

See Table 7–68.

Table 7–67. Lettuce Transplant Requirements

Seed Required for 10,000 Transplants	Seeding Depth	Germination Temperature			Days to Germination[1]	Optimum Growing Temperature		pH Tolerance	Time
		Min.	Opt.	Max.		Day	Night		
28 g	0.3 cm (⅛ in.)	4.5°C (40°F)	24°C (75°F)	27°C (81°F)	2	13°C–18°C (55°F–64°F)	10°C–13°C (50°F–55°F)	6.0–6.8	4 weeks

[1] At optimum germination temperature.

Table 7–68. Lettuce and Endive Crop Spacing and Seeding Rates

LEGEND: — = not applicable

Crop	Row Spacing	In-Row Spacing	Depth	Seeding Rate	
				Transplants	Direct Sown
Butterhead lettuce	30 cm (12 in.)	20–30 cm (8–12 in.)	0.25 cm (⅛ in.)	0.37 kg/ha (0.33 lb/acre)	2.24 kg/ha (2 lb/acre)
Crisphead lettuce	40 cm (16 in.)	30–35 cm (12–14 in.)	0.25 cm (⅛ in.)	0.28 kg/ha (0.25 lb/acre)	1.68 kg/ha (1.5 lb/acre)
Cos/romaine lettuce	40 cm (16 in.)	30–35 cm (12–14 in.)	0.6 cm (¼ in.)	0.28 kg/ha (0.25 lb/acre)	1.68 kg/ha (1.5 lb/acre)
Leaf lettuce	30 cm (12 in.)	20–30 cm (8–12 in.)	0.25 cm (⅛ in.)	0.28 kg/ha (0.25 lb/acre)	1.68 kg/ha (1.5 lb/acre)
Endive/escarole	40 cm (16 in.)	20– 30 cm (8–12 in.)	0.25 cm (⅛ in.)	—	2.8 kg/ha (2.5 lb/acre)

Fertility

Macronutrients

Nitrogen

Broadcast and incorporate the required preplant nitrogen with the required potash and phosphate. On mineral soils, side-dress the remaining nitrogen 3 weeks after transplanting or thinning the crop. See Table 7–69.

If manure is applied or legume sod is plowed down, reduce the nitrogen application. See Table 1–12 and Table 1–13, Chapter 1, for more information.

Phosphorus and Potassium

Test the soil to determine phosphorus and potassium requirements. See Table 7–70 and Table 7–71.

Calcium

Under hot, dry conditions, lettuce may benefit from foliar applications of calcium to prevent tipburn symptoms.

Table 7–69. Lettuce Nitrogen Requirements

Soil Type	Actual N
Mineral soils	
Preplant broadcast	55 kg/ha (49 lb/acre)
Side-dress (3 weeks after transplanting/thinning)	55 kg/ha (49 lb/acre)
Total	**110 kg/ha (98 lb/acre)**
Muck soils	
Preplant broadcast[1]	120 kg/ha (107 lb/acre)

[1] Reduce to 100 kg/ha (89 lb/acre) for mid- to late season plantings.

Table 7–70. Lettuce Phosphorus Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Sodium Bicarbonate Phosphorus Soil Test (ppm)													
	0–3	4–5	6–7	8–9	10–12	13–15	16–20	21–25	26–30	31–40	41–50	51–60	61–80	81+
Mineral Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	180 (161) (HR)	170 (152) (HR)	170 (152) (HR)	160 (143) (HR)	160 (143) (HR)	150 (134) (HR)	140 (125) (HR)	120 (107) (MR)	100 (89) (MR)	80 (71) (MR)	50 (45) (LR)	30 (27) (RR)	0 (RR)	0 (NR)
Muck Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	100 (89) (HR)	100 (89) (HR)	100 (89) (HR)	100 (89) (HR)	90 (80) (MR)	90 (80) (MR)	80 (71) (MR)	70 (63) (MR)	60 (54) (MR)	50 (45) (LR)	30 (27) (LR)	20 (18) (LR)	0 (RR)	0 (NR)

Table 7–71. Lettuce Potassium Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Ammonium Acetate Potassium Soil Test (ppm)											
	0–15	16–30	31–45	46–60	61–80	81–100	101–120	121–150	151–180	181–210	211–250	251+
Mineral Soils												
Potash (K_2O) required kg/ha (lb/acre)	230 (205) (HR)	220 (196) (HR)	210 (187) (HR)	190 (170) (HR)	160 (143) (HR)	130 (116) (HR)	100 (89) (MR)	80 (71) (MR)	50 (45) (MR)	0 (LR)	0 (RR)	0 (NR)
Muck Soils												
Potash (K_2O) required kg/ha (lb/acre)	100 (89) (HR)	100 (89) (HR)	90 (80) (HR)	80 (71) (HR)	60 (54) (MR)	40 (36) (MR)	30 (27) (MR)	20 (18) (MR)	20 (18) (MR)	0 (LR)	0 (RR)	0 NR)

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. See *Micronutrients*, Chapter 1, for more information.

Copper

Copper (Cu) deficiency may show up on organic (peat and muck) soils. Mix copper with the fertilizer and apply at 14–29 kg/ha (12.5–26 lb/acre) on newly cultivated muck. Subsequent applications may be made every 2 or 3 years at about one-third the rate required for new muck. See Table 1–9, Chapter 1, for more information.

Manganese

Manganese-deficient lettuce appears as yellowing between the veins, which remain dark green. Manganese deficiency usually shows up on slightly acid or alkaline muck, peat and dark-coloured sandy soils. Soil applications of this nutrient may not be effective due to the large amounts required. If a deficiency is identified, apply foliar manganese sprays starting after thinning or transplanting. See Table 1–9, Chapter 1, for more information.

Plant Tissue Analysis

When used in conjunction with soil analysis, plant tissue analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. Plant tissue analysis does not replace soil testing or a sound soil fertility program. See Table 7–72 and *Plant Tissue Analysis*, Chapter 1.

Table 7–72. Lettuce and Endive Nutrient Ranges

LEGEND: – = no data available

Plant Part	Time of Sampling	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu	Mo
		Per Cent (%)						Parts Per Million (ppm)					
Boston Lettuce													
Oldest undamaged leaf	8-leaf stage	4–6	0.4–0.6	5–6	1.7–2	0.4–0.6	–	50–100	10–20	40–60	15–25	5–10	0.1–0.2
	maturity	3–4	0.4–0.5	5–6	1.7–2	0.3–0.6	–	50–100	10–20	20–40	15–25	5–10	0.1–0.2
Cos													
Oldest undamaged leaf	8-leaf stage	4–5	0.5–0.6	4–6	1.7–2	0.3–0.7	–	40–100	10–20	40–60	20–40	5–10	–
	maturity	3–4	0.4–0.6	4–6	1.7–2	0.3–0.7	–	20–50	10–20	20–40	20–40	5–10	–
Endive													
Oldest undamaged leaf	8-leaf stage	4.5–6	0.5–0.8	4.5–6	2–4	0.25–0.6	–	–	15–25	30–50	25–35	5–10	–
	maturity	3.5–4	0.4–0.6	4–6	1.8–3	0.3–0.4	–	–	15–20	20–40	30–40	5–10	–
Escarole													
Oldest undamaged leaf	8-leaf stage	4.2–5.0	0.5–0.6	5.7–6.5	1.7–2.2	0.25–0.35	–	–	15–25	30–50	20–30	4–6	–
	maturity	3.0–4.5	0.4–0.5	5.5–6.5	2–3	0.25–0.35	–	–	15–25	20–50	30–45	4–6	–
Head Lettuce													
Most recently mature	8-leaf stage	4–5	0.4–0.6	5–7	1–2	0.3–0.5	0.3	50–150	20–40	25–50	15–30	5–10	–
Wrapper leaf	heads half size	2.5–4	0.4–0.6	4.5–8	1.4–2	0.3–0.7	0.3						–
	maturity	2–3	0.3–0.5	2.5–5	1.4–2	0.3–0.7	0.3						–
Romaine Lettuce													
Oldest undamaged leaf	8-leaf stage	5–6	0.4–0.8	5–6	2–3	0.25–0.35	–	–	15–25	20–50	30–45	5–10	–
	maturity	3.5–4.5	0.4–0.6	5–6	2–3	0.25–0.4	–						0.1–0.4

Adapted from G. Hochmuth, et al. 2018. *Plant Tissue Analysis and Interpretation for Vegetable Crops in Florida*. University of Florida IFAS Extension. HS964.

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Irrigation

Lettuce crops are moderately responsive to irrigation.

Effects of moisture stress: poor germination, poor head size and reduced quality
Critical irrigation period: germination, head formation and sizing
Rooting depth: 30–60 cm (12–24 in.)

If the available soil moisture level in the root zone reaches 60% during the critical irrigation period, irrigation could help maintain crop yield and quality.

For more information on irrigation scheduling, see the *Irrigation Management* BMP (order number BMP08E) and the OMAFRA factsheet, *Monitoring Soil Moisture to Improve Irrigation Decisions*.

Harvest

Head lettuce: Typically harvested by hand 70–80 days after seeding. Heads are grown until the head is well formed and reach about 1 kg (~2 lb) in weight. Heads are cut and trimmed, leaving three wrapper leaves on each head in the field or on a processing line.

Cos/romaine lettuce: Harvested by hand in the field 70–80 days after seeding or when the heads feel firm. Heads are cut and trimmed in the field or on a processing line.

Leaf lettuce: Typically hand-harvested 40–50 days after planting. Avoid delaying harvest, as toughness and a bitter taste become more apparent as the crop becomes over-mature.

Table 7–73. Average Yields of Lettuces

Crop	Average Yield
Butterhead lettuce	2,000–2,500 cases/ha (800–1,000 cases/acre) OR 28,000–45,000 kg/ha (25,000–40,000 lb/acre)
Cos/romaine lettuce	2,500–3,000 cases/ha (1,000–1,200 cases/acre) OR 28,000–45,000 kg/ha (25,000–40,000 lb/acre)
Crisphead lettuce	2,000–2,500 cases/ha (800–1,000 cases/acre) OR 28,000–45,000 kg/ha (25,000–40,000 lb/acre)
Endive/escarole	13,500–18,000 kg/ha (12,000–16,000 lb/acre)
Leaf lettuce	13,500–18,000 kg/ha (12,000–16,000 lb/acre)

Storage

Leafy green crops are not adapted to long-term storage. Vacuum cooling or hydrocooling can help maintain a fresh appearance. Package icing will help maintain quality during transportation.

See Table 7–74.

Table 7–74. Lettuce and Endive Storage Requirements

Crop	Storage Temperature	Relative Humidity	Duration
Lettuce	0°C (32°F)	98%–100%	2–3 weeks
Endive	0°C (32°F)	95%–100%	2–3 weeks

Pest Management and Disorders

See Figure 7–100. *Lettuce pest activity calendar*.

Diseases

Aster Yellows

Candidatus phytoplasma asteris

Identification: On lettuce, aster yellows causes a bright yellowing and twisting of leaves. Infected crisphead types suffer poor head formation. Secondary bacterial rots often follow aster yellows.

Biology: The aster leafhopper vectors and transmits aster yellows.

Management Notes: Removing infected plants is an effective way to reduce in-field sources of diseases. Control measures are targeted at aster leafhopper, the vector of aster yellows. See *Aster Leafhopper*, Chapter 5, for more information.

Bacterial Wilt

Xanthomonas campestris pv. *vitians*

Identification: Water-soaked, wedge-shaped spots form along the leaf margins. Spots may become olive-coloured.

Biology: Bacterial wilt is a seed-borne pathogen. It requires a wound, such as frost injury, sandblasting or mechanical damage, to infect healthy plants.

Management Notes: Obtain pathogen-free seeds. Excessive nitrogen or overhead irrigation may increase disease levels. Irrigate in the early morning to allow the crop to dry out. Follow good sanitation practices in all greenhouse areas used for transplant production.

Botrytis Grey Mould

Botrytis cinerea

Identification: On lettuce and endive, white-to-grey downy fungi first develop on older, outer leaves. This rapidly reduces the leaf to a water-soaked, slimy mass of tissue and causes the plant to completely collapse.

Biology: The pathogen responsible for grey mould has a wide host range. It is spread by wind and also grows on organic matter in or on the soil. It generally needs a wound or dead tissue to begin an infection into live tissue. Grey mould overwinters in the soil and on plant debris. Periods of prolonged high humidity and cool weather between 18°C–24°C (64°F–75°F) promote grey mould activity.

Management Notes: In most vegetable crops, this disease is sporadic and control measures are rarely required. Some registered fungicides have activity on this pathogen, but it can be difficult to get adequate coverage of the lower leaves, where infection first occurs. Grow lettuce and endive on raised beds to increase air movement and decrease disease pressure. Follow a good crop rotation with cereals and other non-host crops.

Collar Rot

Alternaria spp., *Botrytis cinerea*, *Sclerotinia* spp.

Identification: Infections may be associated with:

- transplants that have been held beyond their target transplanting date
- tall, lanky transplants
- transplanting into very hot soils, with or without plastic mulch
- wind damage
- rough handling

These conditions may create stem damage that allows the pathogen to become established. High moisture levels in the transplant canopy may also contribute to infection in the transplant greenhouse.

Serious infections girdle the stem, causing the plant to wilt and die. In some cases, infections cause a stem restriction that becomes evident once the plant reaches a size that can no longer be supported by the damaged stem. The plant then wilts and collapses.

Management Notes: High-quality, hardened-off transplants with strong stems should have few collar rot problems. Manage humidity in the greenhouse to minimize moisture in the transplant canopy. Wind protection practices in the field reduce infection through wind-related stem injuries.

Corky Root Rot

Rhizomonas suberifaciens

Identification: Yellow lesions appear on the roots. These lesions enlarge until the entire taproot is brown, rough and cracked.

Biology: There are two types of corky root with similar symptoms: infectious corky root caused by a bacterium and non-infectious corky root caused by excess levels of ammonia and nitrates. Infectious corky root rot builds up with continual lettuce cropping and is more severe in warm conditions.

Management Notes: Allow sufficient time between lettuce crops for the plant residues to decompose completely. Raised beds and reduced irrigation are recommended to encourage deep rooting. Resistant cultivars are available. For non-infectious corky root, avoid applying excessive amounts of nitrogen, especially urea.

Damping-Off

Pythium sp., *Phytophthora* sp., *Rhizoctonia* sp., *Fusarium* sp.

Identification: Seeds infected prior to emergence rot and typically fail to produce a seedling. Post-emergence infections cause the seedlings to rot at soil line. This usually occurs within 2–4 weeks of emergence (or transplanting). Affected plants tend to curl downward or melt into the soil. Other symptoms include mouldy seeds and lesions or cankers on the roots, hypocotyl or lower stem.

Biology: *Pythium* and *Phytophthora* are water moulds. They are particularly destructive in wet and cool soil conditions. Infections commonly occur on heavier soil types, or in poorly drained fields

Fusarium is found in most agricultural soils. The overwintering spores remain in the soil for long periods of time. Infections occur under a wide-range of soil and temperature conditions, depending on the species and the crop. Many fusarium species also cause foliar or fruit infections later in the season.

Rhizoctonia solani persists in soil as a hard, resting structure (sclerotia) and grows as microscopic threads through the soil. This damping-off pathogen tends to prefer slightly warmer and dryer soil than the water moulds. Often, *Rhizoctonia solani* will girdle the stems of susceptible crops slightly above and below the soil line.

Management Notes: Ensure vegetable transplants are grown in sterilized flats and in sterile soil-less mixture in the greenhouse. Do not over-water seedlings and transplants. Before planting into the field, ensure all transplants are healthy, disease-free and vigorous.

When direct-seeding vegetables, plant seeds treated with a registered fungicide seed treatment that controls damping-off pathogens. Do not seed too deep. Plant only when soil and weather conditions are favourable for quick germination, emergence and vigorous crop development. Consider applying a biological control product with an active ingredient that suppresses the development of damping off pathogens.

Downy Mildew

Bremia lactucae, Plasmopara lactucae-radicis

Identification: Infection usually begins on the mature leaves and spreads inward toward the central leaves. Yellow or pale-green areas appear on the upper surface of the leaves. White, velvety areas are found on the lower leaf surface. Older lesions turn tan and papery. Infected tissue usually dies (Figure 7–101).

Biology: The fungus overwinters in wild lettuce plants and on crop debris. Spores are spread by wind or splashing rain. For germination to occur, the leaf surface must be moist. As a cool-season disease, the optimum temperature for infection occurs from 15°C–20°C (59°F–68°F). The time from infection to the production of new spores varies from 5–18 days.

Figure 7–101. Lettuce downy mildew.

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Scouting and Thresholds: A forecasting model called BREMCAST helps to predict downy mildew outbreaks (available for select areas). See *Disease Prediction Models*, Chapter 4. During regular scouting, look for the presence of downy mildew, especially on older leaves. Take preventive control measures when there is the risk of downy mildew based on BREMCAST (where available) or when field conditions are conducive for downy mildew development.

Management Notes: Select resistant cultivars and follow a 2–3-year crop rotation. Plowing infected residue may reduce the soil inoculum.

Lettuce Mosaic Virus (LMV)

Identification: Leaves develop chlorotic, yellow spotting. Plants grown from infected seed or infected early in their development have pale green-to-yellow mottled leaves.

Biology: Lettuce mosaic is generally introduced to an area by seed and is then transmitted to new plants by aphids.

Management Notes: Mosaic-indexed or mosaic-tested seed is available from most sources. This seed is produced in special areas where it is carefully checked to ensure that it is virtually free from seed-borne mosaic. Control aphids, which spread the disease from infected lettuce plants. Weeds such as groundsel, shepherd's-purse and lamb's-quarters are alternate hosts.

Nematodes

Identification: The symptoms and thresholds vary, depending on both the causal nematode and the host crop. See *Nematodes*, Chapter 6, for more information. In some cases, several types of nematodes may be present and causing damage in the crop. The presence of nematodes may also exacerbate the impact of certain soil-borne fungal diseases, such as verticillium.

Management Notes: Before deciding upon a management strategy for nematodes, complete a nematode soil test to determine the levels of nematodes present. In Ontario, nematode populations in soil and roots are usually at their highest in May to June and again in September to October. The fall months are a good time to soil sample for nematodes, as the populations are high and controls can be taken well in advance of planting the crop.

Rhizoctonia Bottom Rot
Rhizoctonia solani

Identification: Rust-coloured sunken lesions appear on the midrib of lower lettuce leaves. Infected leaves decay under favourable environmental conditions. Bottom rot is most commonly observed on mineral soils.

Biology: This species of *Rhizoctonia solani* is a ubiquitous soil-borne fungi. It can survive in the soil for many years. Infections can occur throughout the season under warm and wet or very humid conditions. The fungus is active during warm, humid weather.

Rhizoctonia solani is one of the fungal species that cause damping off. See *Damping-Off*, Chapter 6, for more information.

Management Notes: Avoid planting susceptible crops in previously infected areas. Rotate for several years with legumes, cereals, grasses or other non-host crops. Practice strict sanitation procedures to avoid spreading infected soil between fields. Plant in areas with good soil drainage and avoid fields with a history of bottom rot. Growing lettuce on raised beds will improve air circulation near the base of the plant, where infection is likely to begin.

Septoria Leaf Spot
Septoria spp.

Identification: Greyish-brown spots with yellow margins appear on leaves and petioles. Small, black specks (pycnidia) are often noticeable in the centre of the lesions.

Biology: Septoria is spread by infected seed, crop residues and on weed hosts. Spores germinate at temperatures above 12°C (54°F). Infection requires the presence of water or high humidity (greater than 90% relative humidity) for 24 hours.

Management Notes: Seed-borne infections decrease in 2-year-old (or older) seed. Bury infected crop residues and follow a 2–3-year rotation to reduce soil-borne infections.

Sclerotinia White Mould/Lettuce Drop
Sclerotinia sclerotiorum

Identification: Lettuce drop (wilting of the entire plant) is most often observed as plants approach maturity. The limpness of the entire plant resembles the symptoms of grey mould. Cottony-white fungi develop on the underside of the lower leaves. Black sclerotia are often embedded within it.

Biology: White mould overwinters in the soil and on plant debris as small, black (pea-sized) sclerotia. The initial infection occurs during flowering and early pod development. Temperatures ranging from 20°C–25°C (68°F–77°F) and continuous leaf wetness (high humidity and/or heavy dews) favour sclerotinia white mould development. Overwintering sclerotia may survive for several years in the soil. Lettuce drop is most prevalent during cool, wet weather.

Scouting and Thresholds: No established thresholds.

Management Notes: Practice a 3–4-year crop rotation away from susceptible crops (cucurbits, edible beans, soybeans, canola, carrots and lettuce). Good drainage and growing lettuce on raised beds increases air movement around the plants. Flooding infested land for 3–4 weeks causes the breakdown of sclerotia and may reduce soil populations. Avoid applying high rates of nitrogen fertilizer. Excess nitrogen promotes an exceptionally dense crop canopy, resulting in restricted air movement and more favourable disease development conditions.

Turnip Mosaic Virus (TuMV)

Identification: Older leaves turn yellow and drop prematurely. Leaves emerging after infection are stunted and wrinkled and show a yellow, mottled pattern. Roots become "goosenecked" and do not reach normal size.

Biology: TuMV is spread mechanically and by aphids. A rapid increase in infection usually begins in early July, when large numbers of winged aphids become active. Volunteer rutabagas and winter canola are the main overwintering sources of the virus.

Scouting and Thresholds: Scout fields and rogue infected plants regularly. Plant resistant varieties when available.

Management Notes: Avoid planting susceptible crops in fields adjacent to perennial forage crops. Control weeds within and around fields. Aphid control does not completely prevent the spread of the virus. Applications of mineral oil may deter the feeding of virus-spreading aphids.

Insects

Aphids
Aphididae family

Identification: There are several aphid species affecting vegetable crops in Ontario. Aphids are small, soft-bodied, pear-shaped insects, with cornicles or "tail-pipes" near the tip of their abdomen. They have relatively long legs and prominent antennae. Colour may vary depending on the species.

Damage: Aphids often congregate on new growth. They pierce the leaves and suck the sap from the plant, causing leaf distortion, stunting, delayed maturity and wilting. Feeding damage interferes with the uptake of water and nutrients. While feeding, they exude a sticky substance called "honeydew." Honeydew, and the moulds associated with it, may affect the marketability of the harvested product. Aphids also act as a primary vector of several economically significant virus diseases in either a persistent or non-persistent manner. See *Northern Root Knot Nematode*, Chapter 6, for more information.

Biology: Most aphids overwinter as eggs on primary hosts and migrate to vegetable crops in the summer. Under hot and dry weather, the populations of aphids can increase rapidly.

Scouting and Thresholds: Aphid distribution may be patchy within a field. Populations are often higher along field margins and hedgerows. Inspect the undersides of leaves from the top, middle and bottom of plants. Note the presence of aphid honeydew on the foliage and fruit. Look for beneficial insects (aphid predators or parasites) as well. Look closely to distinguish live aphids from dead aphids and moulted skins.

Management Notes: When controlling other insect pests, select pest control products that are safer for beneficial insects. Broad-spectrum insecticides may also kill natural enemies, resulting in higher aphid populations.

Lamb's-quarters and pigweed are alternative hosts of some root aphids; crop rotation and weed management may help reduce their numbers. Destruction of infested crops following harvest may prevent excessive dispersal.

Aster Leafhopper

Macrosteles quadrilineatus

Identification: Aster leafhoppers are small, greenish-grey insects with six spots arranged in pairs on top of the head. Its wings are transparent and heavily veined.

Damage: Aster leafhoppers transmit aster yellows leafy greens by feeding on crops. See *Aster Yellows*, also in *Lettuce*.

Biology: The aster leafhopper overwinters as an egg in the leaf tissue of winter grains such as wheat and rye. Approximately 130 degree days, base 9°C, are required for egg maturation. An additional 270 degree days are required for development to adulthood. See *Growing Degree Days*, Chapter 4, for your information.

As the winter grains mature in late May and early June, local first-generation leafhoppers disperse into vegetable crops. Leafhopper populations from the U.S. are also carried into Ontario on weather systems. Both local dispersal and long-distance movement influence the incidence and severity of the aster leafhopper and aster yellows.

Scouting and Thresholds: The Aster Yellows Index (AYI) determines the need to treat a crop. To use the AYI, monitor aster leafhoppers with a sweep net. Multiply the number of aster leafhoppers captured in 100 sweeps by the percentage of leafhoppers carrying aster yellows in your area (4%–5% is the currently recommended per cent infectivity in Ontario). Use this formula:

Infectivity rate (4%–5%) x # of leafhoppers/100 sweeps) = AYI

Use the following AYI thresholds.

Head lettuce:	20–25
Cos/Romaine lettuce:	30–35

Management Notes: Grow resistant cultivars and remove perennial weeds from fields that may act as reservoirs. Rogue out plants that show aster yellows symptoms.

Cabbage Looper

Trichoplusia ni

Identification: The cabbage looper larvae is smooth and pale green, with a thin white line along each side and two faint lines down the middle of the back. They are up to 4 cm (2 in.) long. They move in a very distinctive "looping" manner. The pupa is initially light green in a loose cocoon, darkening in color as it matures. Adult moths are mottled greyish-brown with a wingspan of 4 cm (2 in.). They have a distinctive silvery figure-eight pattern on their forewings and a slight tuft of hair behind the head. Eggs are small, rounded and greenish-white. They appear in small groups on the underside margins of leaves.

Damage: Small larvae feed on the undersides of leaves, while more mature larvae chew large, irregular holes throughout the plant. Large amounts of dark, brown-green frass can also be found. Its presence is virtually unpredictable and may show up in one field and not in the adjacent field.

Biology: Cabbage loopers do not overwinter in Ontario. The adults travel on weather patterns from the south in midsummer to early fall.

Scouting and Thresholds: Count the number of cabbage loopers on 25 randomly selected plants in the field. The suggested threshold for leafy greens is 5%.

Management Notes: Insecticides are most effective against small larvae. Begin application of insecticides when young larvae are found. Continue on a 5–10-day schedule, or as determined by scouting.

Cutworms (Early-Season)

Agrotis ipsilon (Black Cutworm),
Euxoa messoria (Dark-Sided Cutworm),
Crymodes devastator (Glassy Cutworm)
Euxoa detersa (Sandhill Cutworm)

Identification: Species commonly found in Ontario vegetable crops include: black cutworm, dark-sided cutworm and the sandhill cutworm. Cutworm larvae are soft and fat, and they roll up when disturbed. Mature larvae can be as large as 3–4 cm (1½–2 in.) in length. Black cutworms are grey to black with no striping on the body, whereas most other cutworms have stripes along their back or sides.

Damage: Cutworm damage occurs most often in late April and early May, coinciding with early-season planting and emergence of seedlings. Larvae cut the petioles or stems of seedling plants below or at the soil surface. Most of their damage is found at the field edge or in weedy fields. One cutworm can kill several plants before it reaches full size and pupates. Most species of cutworms feed at night, hiding during the day in the soil near the base of the plant.

Biology: Most species of cutworm do not overwinter in Ontario. In the early spring, adult moths are transported on the trade winds from more southerly areas. Females are attracted to dense, green cover to lay their eggs. Often, when they arrive in Ontario in early spring, the main source of habitat for the females are winter annual or perennial weeds. Cutworms are therefore more frequent in fields with green cover early in the spring before primary tillage. Egg hatching and larval feeding often coincide with planting and crop emergence.

Scouting and Thresholds: Most species of cutworms feed at night, hiding during the day under loose stones or in the soil near the base of the plant. Scouting is best done in the middle of the day, when the water demand of plants is high. Check for cutworm damage by walking through the field and looking for wilted and/or fallen plants. If any are found, dig around in the soil at the base of the plant. The cutworm, if present, will be found 2.5 cm (1 in.) deep and within 10 cm (4 in.) of the damaged plant(s). Make control decisions based on the number and size of larvae found. Look for cutworm larvae in the top 2.5 cm (1 in.) of soil surrounding the damaged plant. For most vegetable crops, the control guideline is 5% damaged plants.

Management Notes: Cutworm control is most effective on small, <2.5 cm (<1 in.) long larvae. Larger larvae are difficult to control with insecticides. At more mature stages at greater than 2.5 cm (1 in.) in length, they cease feeding as they prepare to pupate, and control becomes unnecessary. Apply insecticides in the early evening, as the cutworms come to the surface to feed at night. Insecticides are more effective on moist soils.

Leafminers

Liriomyza spp.

Identification: Generally, leafminers are small (2–3 mm (~⅛ in.)), shiny, black-and-yellow flies that lay their eggs in leaves. The larvae of leafminers are small, pale yellow maggots.

Damage: Female leafminers lay their egg on the leaves, leaving small "bronzed" puncture marks. Females pierce the leaves to feed on plant sap. Larvae feed between the upper and lower surface of the leaves. Depending on the species, mines can be straight (pea leafminer) or serpentine (other leafminers). Leafminer feeding reduces the plant's photosynthetic capacity. The mines also affect marketability and provide an entrance for disease organisms.

Leafminers are most likely to attack head and leaf lettuce types. Mining of the leaves by pea leafminer larvae is not as common.

Biology: Optimal temperatures for leafminer development range from 21°C–32°C (70°F–90°F). Egg-laying is reduced at temperatures below 10°C (50°F). Leafminers can be a problem throughout the season. The pea leafminer is typically a late-season pest with populations peaking from the end of August through the middle of September.

Scouting and Thresholds: None have been established. Scout for mines and larvae or for eggs on the underside of leaves. Yellow sticky traps placed in the crop can be used to monitor adult flies.

Management Notes: Lamb's-quarters is an alternate host for leafminers. Good weed control can reduce infestations. Crop rotation is an effective pest management tool. Alternating leafminer-susceptible crops with leafminer-resistant crops reduces the population.

For pea leafminer, reduce severe damage by harvesting susceptible crops before the beginning of September when populations tend to rise. Apply insecticides as soon as pea leafminer adults first appear.

Slugs

Arion sp., *Deroceras* sp., *Helix* sp., *Limax* sp.

Identification: Slugs are soft-bodied, legless, grey molluscs that have variations in colour from dark brown and black to light grey. In Ontario, slugs range in size from 0.5–10 cm (¼–4 in.) in length, depending on the species, and have a slimy covering to prevent them from drying out.

Damage: Slugs have rasping mouth-parts and will create ragged holes on the lower leaves, sometimes leaving a "window-pane" of waxy cuticle behind. Severely affected plants may become skeletonized. Under high populations, slugs also attack seeds and emerging seedlings. A slime trail is usually observed at the feeding location. Slug damage is most severe in years when there is prolonged cool, wet weather during May and June. They feed above or below ground, depending on the soil moisture level.

Biology: There is one generation per year, but two populations: one maturing as adults in the spring and one maturing in the fall. Both may cause crop injury. Under dry conditions, slug eggs can lay dormant for long periods of time. Slugs travel by gliding on a secreted stream of mucus.

Scouting and Thresholds: Scout for slugs at night or early morning, when they are active. Check under debris near damaged plants, and look for slime trails. Population levels in a field may be determined using monitoring boards. If slugs are commonly found under monitoring boards, the field should be considered at risk for slug injury. No thresholds have been established.

Management Notes: Most plants can successfully outgrow light feeding damage. Cultivating fields where slug pressure is high can help reduce the slug population. Tillage exposes the slugs to dehydration and predation by birds and mammals.

Removing weeds and crop residue from the zone immediately surrounding young seedlings may also help reduce damage. Zone tillage can remove slug habitat while maintaining the benefits of reduced tillage.

Tarnished Plant Bug

Lygus lineolaris

Identification: Tarnished plant bug (TPB) nymphs are greenish in colour, with well-developed legs and moderately long antennae. Late instars have wing pads and four black spots on the thorax, behind the head, as well as one on the abdomen. Adults are pale green or yellow-to-dark brown, with dark markings and have a small triangle shape on their back.

Damage: TPB have sucking mouthparts that they use to pierce into plant tissue and inject saliva that helps break down plant tissue. In many cases, damage from the TPB is seen before the insect itself, thus, recognition of the damage symptoms is very important. Feeding on flowers may cause them to abort. TPB causes symptoms including small holes with brown margins on lettuce leaves. Leafy vegetables are susceptible to attack throughout the growing season.

Biology: TPB overwinter as adults in plant debris and leaf litter in protected areas such as woodlots, fence rows and ditches. Emerging adults feed and oviposit on broadleaf weeds in the spring, before moving into crops. TPB is a sporadic pest, present in Ontario throughout the growing season. Two generations occur per year, with a partial third in parts of Southern Ontario. First-generation adults emerge in July, second generation in August and September.

Scouting and Thresholds: For lettuce, inspect the heart leaves of 50–100 plants per field at least twice a week. Few crops have established thresholds, and in many cases, management decisions are based on presence or absence.

Management Notes: TPB breed on many common weed species, including pigweed, chickweed, dandelion, lamb's-quarters, ragweed and fleabane. Weed control in and around vegetable plantings will help reduce potential infestations. Alfalfa is also a very attractive host. After the alfalfa is cut, TPB adults may disperse and invade nearby vegetable crops.

Disorders

Bolting

See *Brassica Crops*, in this chapter.

Onions, Leeks and Shallots

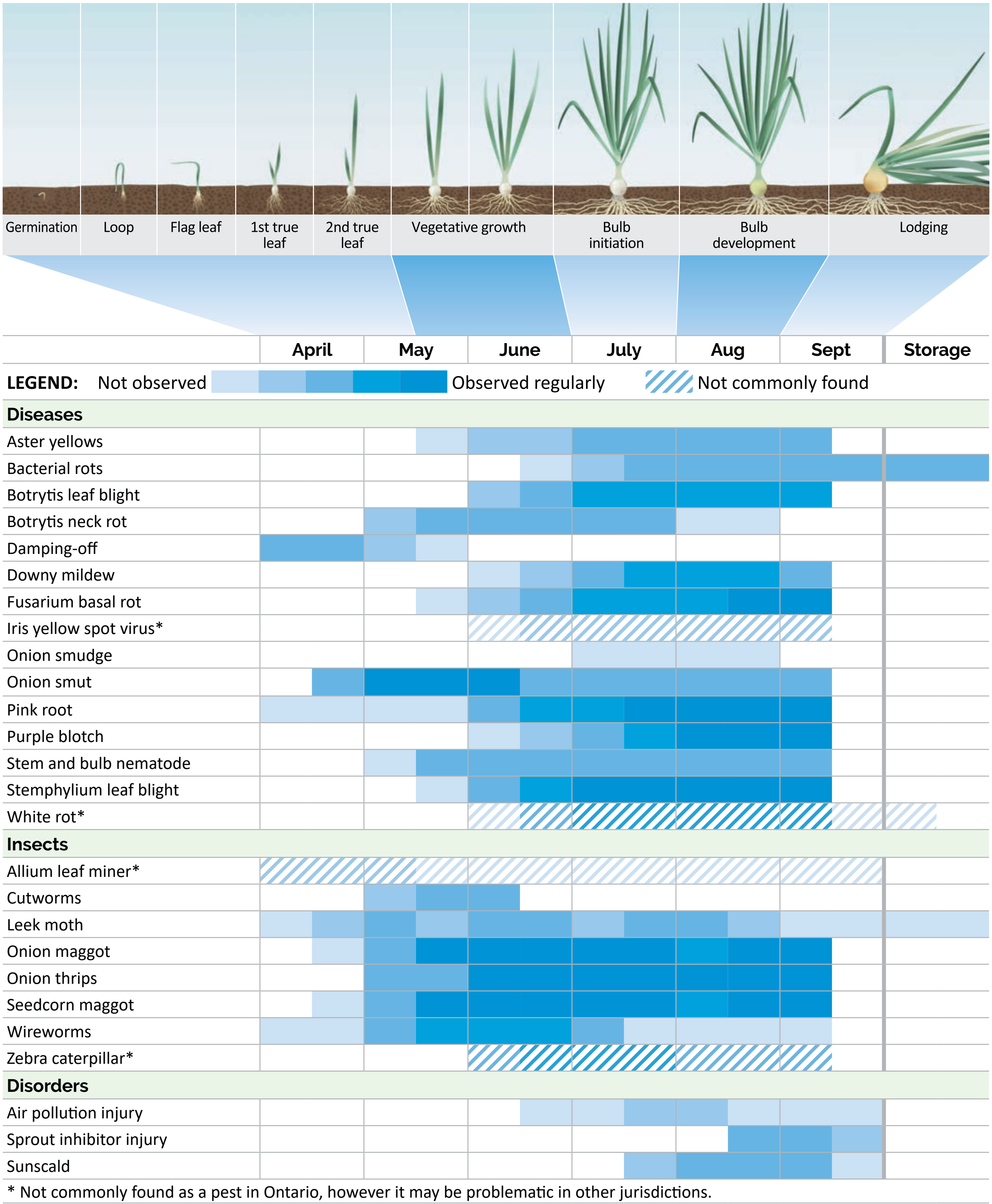


Figure 7–102. Onion stages of development and pest activity calendar. The actual period of activity for any given pest will vary significantly from year to year, depending on environmental factors.

Production Requirements

Soil types:	mineral and muck soil
Soil pH:	mineral: 5.8–7 muck: 5.0–7
Suitable rotational crops:	carrots, parsnips, leafy greens
Do not rotate with:	other allium crops
Minimum soil temperature:	2°C (36°F)
Optimum air temperature:	13°C–24°C (55°F–75°F)
Earliest planting date:	early to late April

Allium Types

There are multiple types of onions grown in Ontario. Yellow and red cooking onions are commonly direct-seeded, however, some are grown from transplant with the purpose of coming to market earlier. Cooking onions are most often grown on muck soil. Spanish onions are cultivars of onions that grow larger than cooking onions given the right conditions, and generally have a milder flavour and higher moisture content (softer bulbs). Spanish onions are often grown on mineral soil, take longer to mature and are most often started from transplants. Shallots are torpedo-shaped onions that do not grow as large as cooking onions. Shallots tend to have a milder flavour than cooking onions and are grown on both muck and mineral soils.

Sweet onions are specific cultivars of onions that contain more sugar and are grown in sulfur-deficient soils to reduce pungency. Sweet onion cultivars also take a long time to reach maturity compared to cooking onion and Spanish onion cultivars. Some sweet onions, such as the branded Vidalia onion, are "short day" onions that struggle to produce proper bulbs under longer day lengths in Canada. For these reasons, sweet onions are not grown commercially in Ontario.

Leeks are grown for their stem and do not produce a bulb. Leeks are started from transplants and are mainly grown on mineral soil. Plants are hilled to promote a tall, white stem. Choose frost-tolerant cultivars for later plantings. Overwintering cultivars are available but are not generally grown commercially in Ontario.

Green onions are commonly referred to as bunching onions or scallions. Seeds are planted densely and harvested before they form a bulb. Many dry bulb cultivars can be used as green onions when they are harvested before bulbing starts and open-pollinated cultivars are often used since they are more economical.

Onion sets are seeded at a high seeding rate to promote controlled, uniform growth. These smaller bulbs are harvested and used as planting stock the following year. Sets are sold to market gardeners or homeowners who require a quick-maturing onion or are growing onions in a less-than-ideal environment

Other alliums are covered in this guide. See *Chives*, *Herbs* and *Garlic* for more information.

Seeding and Spacing

To achieve an earlier crop, dry bulb onions can be grown in plug trays and transplanted into the field when soil conditions permit. Transplants have some advantages in managing disease and weeds, as well as producing an earlier crop. Transplants are often sold for fresh market and are not stored for long periods of time. Early-maturing cultivars are chosen for growing transplants and are generally not suitable for long-term storage compared to direct-seeded onions. Spanish onion transplants are seeded one seed per cell, but bulb onions to be grown on muck soils are often seeded 3 seeds per cell as the onions can easily push apart as they grow in the field, and there is no negative effect on size or shape. See Table 7–75, and the OMAFRA Factsheet *Growing Vegetable Transplants in Plug Trays*.

Onion transplants require moderate fertility. Apply 100–200 ppm nitrogen weekly. Fertilize less frequently under cool, cloudy conditions. See Table 7–76.

Table 7–75. Onions, Leeks and Shallots Transplant Requirements

Seed Required for 10,000 Transplants	Seeding Depth	Germination Temperature			Days to Germination[1]	Optimum Growing Temperature		pH Tolerance	Time (weeks)
		Min.	Opt.	Max.		Day	Night		
85 g	0.6 cm (¼ in.)	10°C (50°F)	24°C (75°F)	35°C (95°F)	4	16°C–18°C (61°F–64°F)	8°C–15°C (46°F–59°F)	5.5–6.8	8–12

[1] At optimum germination temperature.

Table 7–76. Onions, Leeks and Shallots Crop Spacing and Seeding Rates

LEGEND: – = not applicable

Crop	Row Spacing	In-Row Spacing	Depth[1]	Seeding Rate	Planting Density plants per ha (plants per acre)
Direct-seeded cooking onion	35–43 cm (14–17 in.)	2.5–3.5 cm (1–1.5 in.)	0.5–2.5 cm (0.2–1 in.)	4–4.5 kg/ha (3.5–4 lb/acre)	990,000 (400,000)
Transplant cooking onion	35–43 cm (14–17 in.)	10–12.5 cm (4–5 in.)	–	1.7–3.5 kg/ha[2] (1.5–3 lb/acre)	850,000 (345,000)
Spanish onion	35–43 cm (14–17 in.)	10–12.5 cm (4–5 in.)	0.5–2.5 cm (0.2–1 in.)	1.7–3.5 kg/ha[2] (1.5–3 lb/acre)	250,000 (100,000)
Leeks (transplants)	50–90 cm (20–35 in.)	10–15 cm (4–6 in.)	–	1.0–2.2 kg/ha[2] (1–2 lb/acre)	120,000 (50,000)
Bunching (green)	30–38 cm (12–15 in.)	1–2.5 cm (0.4–1 in.)	0.5–2.5 cm (0.2–1 in.)	7 kg/ha (6.3 lb/acre)	1,100,000 (450,000)
Set onions	Solid seeded		2 cm (1 in.)	75–90 kg/ha (67–80 lb/acre)	20,000,000 (8,000,000)
Pickling onions	Solid seeded		2 cm (1 in.)	75–90 kg/ha (67–80 lb/acre)	20,000,000 (8,000,000)
Shallots	46–60 cm (18–24 in.)	7.5–10 cm (3–4 in.)	0.5–2.5 cm (0.2–1 in.)	220–330 kg/ha[3] (196–295 lb/acre)	250,000 (100,000)
Seed shallots	10–20 cm (4–8 in.)	3–4 cm (1.2–1.6 in.)	2 cm (1 in.)	2.5 kg/ha (2.2 lb/acre)	800,000 (320,000)

[1] Use shallow seeding depths on heavy mineral or crust-prone soils. In drier soil and in areas where wind and water erosion are problems, sow seeds at a depth of 3–4 cm (1–1½ in.).
[2] Listed seeding rates will produce enough transplants for 1 ha (1 acre).
[3] Bulbs.

Fertility

Macronutrients

Nitrogen

Avoid fertilizers with a high salt index, as seed injury can occur. See Table 7–77.

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. See Table 1–12, and Table 1–13, Chapter 1, for more information.

Phosphorus and Potassium

Test the soil to determine phosphorus and potassium requirements. See Table 7–78 and Table 7–79.

Table 7–77. Onions and Leeks Nitrogen Requirements

Soil Type	Actual N
Onions on Mineral Soils	
Apply up to	110 kg/ha (98 lb/acre)
Onions on Muck Soils	
Preplant	90 kg/ha (80 lb/acre)
Side-dress[1]	30 kg/ha (27 lb/acre)
Total	**120 kg/ha (107 lb/acre)**
Leeks	
Preplant	100 kg/ha (89 lb/acre)
Side-dress, early June	60 kg/ha (54 lb/acre)
Side-dress, late June	40 kg/ha (36 lb/acre)
Total	**200 kg/ha (178 lb/acre)**

[1] Side dressing is only necessary if there has been higher than usual rainfall.

Table 7–78. Onion Phosphorus Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Sodium Bicarbonate Phosphorus Soil Test (ppm)													
	0–3	4–5	6–7	8–9	10–12	13–15	16–20	21–25	26–30	31–40	41–50	51–60	61–80	81+
Mineral Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	180 (161) (HR)	170 (152) (HR)	170 (152) (HR)	160 (143) (HR)	160 (143) (HR)	150 (134) (HR)	140 (125) (HR)	120 (107) (HR)	100 (89) (MR)	80 (71) (MR)	50 (45) (LR)	30 (27) (RR)	0 (RR)	0 (NR)
Muck Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	100 (89) (HR)	100 (89) (HR)	100 (89) (HR)	100 (89) (HR)	90 (80) (MR)	90 (80) (MR)	80 (71) (MR)	70 (63) (MR)	60 (54) (MR)	50 (45) (LR)	30 (27) (LR)	20 (18) (LR)	0 (RR)	0 (NR)

Table 7–79. Onion Potassium Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Ammonium Acetate Potassium Soil Test (ppm)											
	0–15	16–30	31–45	46–60	61–80	81–100	101–120	121–150	151–180	181–210	211–250	251+
Mineral Soils												
Potash (K_2O) required kg/ha (lb/acre)	230 (205) (HR)	220 (196) (HR)	210 (187) (HR)	190 (170) (HR)	160 (143) (HR)	130 (115) (HR)	100 (89) (MR)	80 (71) (MR)	50 (45) (MR)	0 (LR)	0 (RR)	0 (NR)
Muck Soils												
Potash (K_2O) required kg/ha (lb/acre)	230 (205) (HR)	220 (196) (HR)	210 (187) (HR)	200 (178) (HR)	170 (152) (MR)	150 (134) (MR)	120 (107) (MR)	80 (71) (MR)	40 (36) (MR)	0 (LR)	0 (RR)	0 (NR)

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. See *Micronutrients*, Chapter 1, for more information.

Copper

Copper (Cu) deficiency occurs on organic (peat and muck) soils. Bulbs show pale-coloured skins. Copper may be mixed with the fertilizer and applied at 14–29 kg Cu/ha on newly cultivated muck. Subsequent applications may be made every 2 or 3 years at about one-third the rate required for new muck.

Manganese

Manganese deficiency shows up as a yellowing between leaf veins and general yellowing of the leaves. Apply foliar manganese sulfate, starting when plants are at the 3-leaf stage. Use 1.5–2.75 kg manganese sulfate/ha in 300 L water. Repeat for 4–5 sprays, 10 days apart. Use the low rate on small plants, increasing the rate as the season progresses. Soil applications are not an efficient way to supply onion crops with manganese. See Table 1–10, Chapter 1, for more information.

Molybdenum

Molybdenum deficiency may occur when onions are grown on moderate-to-strongly acid muck soils (pH 5.5 or lower, and especially in soils with pH below 5.0). The plants will be very small and almost stop growing. For raw (non-pelleted) seed, a seed treatment has proven beneficial. The treatment is accomplished by dissolving 15 g of sodium molybdate in 45 mL of water. Spray this solution from an atomizer bottle on 2.3 kg seed spread thinly on a plastic sheet. Do not use excessive water, as this can cause the chemical to penetrate the seed embryo and cause injury. Mix seed thoroughly and let dry. For pelleted seed, a foliar application after planting before the plants have reached 10 cm in height can also be effective.

Zinc

Zinc-deficient plants develop yellow-striped foliage. They become stunted, twisted and bent. Deficiencies occur mainly in soils with a pH above 7.2, which are often shallow muck soils or where calcareous subsoils are mixed with the muck. See Table 1–11, Chapter 1, for more information.

Plant Tissue Analysis

When used in conjunction with a soil analysis, plant tissue analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. Plant tissue analysis does not replace soil testing or a sound soil fertility program.

For more information, see *Plant Tissue Analysis*, Chapter 1, and Table 7–80.

Table 7–80. Onion Nutrient Ranges

LEGEND: – = no data available

Plant Part	Time of Sampling	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu
		Per Cent (%)						Parts Per Million (ppm)				
Most recently mature leaf	just prior to bulb initiation	2–3	0.2–0.5	1.5–3	0.6–0.8	0.15–0.3	0.2–0.6	–	10–20	15–20	10–25	5–10

Adapted from G. Hochmuth, et al. 2018. *Plant Tissue Analysis and Interpretation for Vegetable Crops in Florida*. University of Florida IFAS Extension. HS964.

Irrigation

Allium crops are responsive to irrigation.

Effects of moisture stress:	smaller bulbs, lower yields and reduced quality
Critical irrigation period:	bulb formation and enlargement
Rooting depth:	30–60 cm (12–24 in.)

If the available soil moisture level in the root zone drops to 60% during the critical irrigation period, irrigation could help maintain crop yield and quality. For drip-irrigated onion crops, use an irrigation threshold of 85% available soil water.

On deep muck soils, maintain the water table at 85 cm (34 in.) below the soil surface. Irrigation after bulb maturity may not be beneficial and may reduce yield and/or quality.

For more information on irrigation scheduling, see the *Irrigation Management* Best Management Practices (order number BMP08E) and the OMAFRA factsheet, *Monitoring Soil Moisture to Improve Irrigation Decisions*.

Harvest

Dry bulb cooking onions: Typically reach maturity in 90–110 days. Harvest occurs from late August to October. Cultivar, weather and soil conditions often determine the timing of harvest and quality of dry bulb cooking onions. Signs of maturity are soft neck tissues, fallen-over (lodged) tops and dead roots. Mature onions have better longevity in storage.

The proper use of maleic hydrazide (Royal MH 60) inhibits sprouting and lengthens the storage life of many onion cultivars. Cultivars with a naturally short storage life do not benefit from maleic hydrazide applications.

The optimum time for spraying maleic hydrazide is when 50% of the tops have fallen, but tops are still green (5–8 green leaves). This usually occurs 8–14 days before harvest. Do not apply within 10 days of harvest. Plants with fewer than three green leaves and/or severely diseased foliage will not absorb maleic hydrazide.

Onions are typically windrowed in the field and then placed into pallet boxes to be cured. Optimum curing occurs in a forced-air facility with heat to 30°C (86°F) and a 60% relative humidity for 3–4 days.

Spanish onions: Typically reach maturity in 110–125 days. Harvest occurs from late September to October. Conditions similar to cooking onions are used to determine the timing of harvest, however, some tops may not fall at maturity due to the thickness of the stem.

Sweet onions: Typically are difficult to grow in Ontario, given that they take at least 125 days to reach maturity and are slow to reach a size desirable for market. Plants are always started as transplants and are harvested prior to fall frost. Cultivars grown for sweet onions contain more sugar, however, their sweetness is best when they are grown on soils deficient in sulfur.

Green onions: Typically, plants are harvested 45–60 days after seeding when the base is 0.5–1.25 cm (¼–½ in.) in diameter. Bunches that include the leaves often consist of 6–10 onions held together by a band. Green onions store best when they are moved out of the field immediately after harvest and field heat is removed with chilled water within 2–3 hours after harvesting.

Shallots: Seeded in the spring as seeds or grown from sets. If planted by seed, they are not a true shallot, but a hybrid onion with some characteristics of a shallot. A true, traditional shallot is propagated vegetatively. A mother bulb of a traditional shallot will produce a clump of 4–15 daughter bulbs, depending on the cultivar. Most commercial shallots are the seed type. Seeded shallots typically reach maturity in 80–100 days after seeding making them harvested in late August to October depending on the seeding density.

Leeks: Typically reach maturity in 150 days or more. Whole plants are harvested once they reach a desired size in August to October. Roots are trimmed close to the base of the bulb and older, outer scales are removed. Leeks are typically bunched in groups of three with 24 bunches per case.

Table 7–81. Average Yields of Onions

Crop	Yield	Standard Container
Direct-seeded cooking onion	1,500–2,700 bags/ha (600–1,100 bags/acre)	50-lb bags
Transplant cooking onion	1,500–2,500 bags/ha (600–1,100 bags/acre)	50-lb bags
Spanish onion	1,500–2,500 bags/ha (600–1,000 bags/acre)	50-lb bags
Leeks	1,250 cases/ha (500 cases/acre)	2 dozen bunches of 3 leeks each per case
Bunching green onion	1,000–1,500 kg/ha (900–1,200 lb/acre)	pallet box
Set onions	22,400–33,600 kg/ha (20,000–30,000 lb/acre)	pallet box

Storage

Cooling methods suitable for use with dry onions include room cooling and forced air cooling. Onions should be cooled gradually to prevent condensation forming in storage. Temperatures should be dropped one or two degrees per week so it may take one or two months to cool the onions to the desired storage temperature of 0°C (32°F). For green onions, use hydrocooling, package icing or vacuum cooling.

See Table 7–82.

Table 7–82. Onion Crop Storage Conditions

Crop	Storage Temperature	Relative Humidity	Duration
Dry onions	0°C (32°F)	65%–70%	1–8 months
Green onions	0°C (32°F)	95%–100%	3–4 weeks
Onion sets	0°C–5°C (32°F–41°F)	70%–80%	6–8 months

Pest Management and Disorders

See Figure 7–102. *Onion stages of development and pest activity calendar.*

Diseases

Bacterial Soft Rot, also known as Slippery Skin, Sour Skin

Pantoea sp. (centre rot)
Burkholderia gladioli pv. *alliicola* (slippery skin)
Dickeya chrysanthemi (soft rot)
Pectobacterium carotovorum subsp. *carotovorum*
Erwinia rhapontici
Pseudomonas marginalis pv. *marginalis*
Burkholderia cepacia (sour skin)

Identification: These diseases are characterized by a watery rot and strong smell. Onions with slippery skin may appear sound on the surface. However, the inner rotted portions will slide out through the neck when squeezed. One or two leaves in the centre of the plant may appear yellowed and wilted. Sour skin first appears as tan or brown rotted leaves followed by a soft rot near the neck.

Biology: These diseases are caused by soil-borne bacteria. Infections begin during wet field conditions and are favoured by warm temperatures. Tissues damaged by onion maggot and leaves damaged by herbicide burn, irrigation, hail or other diseases are most prone to infection by these bacteria.

Management Notes: Bury infected residue or volunteer onions. Choose cultivars with thinner necks and avoid cultivars that have trouble lodging. Practice a 4-year crop rotation with non-host crops such as cereals. Use drip irrigation, opposed to overhead irrigation. Stop irrigation at 3 weeks prior to lodging. Reduce nitrogen amounts per acre, especially later in the season. Control onion downy mildew and manage the level of thrips throughout the season. Minimize all types of injury to leaves (sunscald, bruising, mechanical and herbicide damage). Lift onions once the majority have lodged. Allow the tops to dry completely in the field before harvesting. Pull onions from the field before large precipitation events and force air dry for 5 days if non-ideal weather is forecasted. Ensure onions are properly cured before placing in storage.

Botrytis Leaf Blight

Botrytis squamosa

Identification: White, oval-shaped spots (1–5 mm (~⅛ in.) long) with silvery halos develop on infected leaves. The presence of halos indicates that the lesion is relatively new and "active." Old lesions tend to be brownish-white and desiccated. Severely infected leaves tend to dieback from the tips. Infection is more likely to occur if the leaves are injured, bruised or starting to die back (Figure 7–103).

Figure 7–103. White, oval-shaped spots with silvery halos develop on leaves.

Biology: Botrytis leaf blight typically develops after mid-June. Optimum conditions for infection are 12 hours of leaf wetness at 15°C–18°C (59°F–64°F). Levels of infection are reduced at temperatures above 27°C (81°F). Botrytis overwinters in crop debris. Dormant botrytis sclerotia can remain viable for many years.

Scouting and Thresholds: A forecasting model called BOTCAST helps predict botrytis leaf blight outbreaks. See *Disease Prediction Models*, Chapter 4. If BOTCAST is not available, count the number of "active" lesions on the three oldest leaves on 50–100 plants and begin the fungicide spray program when there is an average of three lesions per leaf on those three leaves.

For dry bulb and Spanish onions, treatment is warranted when conditions are optimal for disease development. After the first spray is applied, subsequent applications should be applied 8 days later if the probability of rain is greater than 30%.

Management Notes: Management is primarily preventive. Practice a 4-year crop rotation and remove cull onions from the field. To help reduce foliar diseases, minimize leaf wetness and permit better air movement in the field (i.e., plant spacing and irrigation at night or during mid-day when the leaves will dry quickly).

Botrytis Neck Rot

Botrytis aclada, *Botrytis allii*

Identification: Botrytis-infected neck tissue of the bulb becomes soft and greyish. White or grey mould may also develop. Black sclerotia eventually appear on affected tissue.

Biology: Botrytis neck rot is most commonly found on bulbs after harvest, but it can appear on maturing bulbs in the field. The fungi survive in the soil for several years. Botrytis infections occur during cool, wet conditions.

Management Notes: Follow a 2–3-year crop rotation and remove cull onions from the field. Proper curing and drying reduces disease development in storage. Artificial heat curing often reduces problems in humid areas of the province.

Prior to storage, grade out onions with thick necks, nicks or bruises. Do not allow condensation to occur inside the storage facility. Most commercial onion cultivars are susceptible to neck rot, particularly Spanish and white types.

Damping-Off

Pythium sp., *Phytophthora* sp., *Fusarium* sp.

Identification: Pre-emergence damping-off occurs when seeds are infected prior to emergence rot and typically fail to produce a seedling. Post-emergence damping-off is when the seedlings do emerge, but are weak, lack vigour and the plants may have a lesion develop at soil line. Affected plants tend to curl downward or melt into the soil. Other symptoms include mouldy seeds and lesions or cankers on the roots, hypocotyl or lower stem.

Biology: Pythium and phytophthora are water moulds. They are particularly destructive in wet and cool soil conditions. Infections commonly occur on heavier soil types or in poorly drained fields.

Fusarium is a true fungus, that is found in most agricultural soils. The overwintering spores remain in the soil for several years. Infections occur under a wide range of soil and temperature conditions, depending on the species and the crop.

Management Notes: Ensure vegetable transplants are grown in sterilized flats and in sterile soil-less mixture in the greenhouse. Do not overwater seedlings and transplants. Before planting into the field, ensure all transplants are healthy, disease-free and vigorous.

When direct seeding onions, plant seeds treated with a registered fungicide seed treatment that controls damping-off pathogens. Do not seed too deep.

Scout fields early in the spring soon after planting to assess the plant stand and its establishment. Look for areas of patchy or poor emergence. Dig up non-emerged seedlings or plants and look for symptoms of rotting.

Downy Mildew

Peronospora destructor

Identification: Infections usually occur in patches within the field. A violet or greyish growth develops on green leaves and the tissue dies quickly, resulting in straw-coloured lesions and eventual plant death (Figure 7–104).

Biology: This disease is more common in cool, wet seasons. Infection occurs when the foliage remains wet for 2–6 hours at 3°C–14°C (37°F–57°F). Onion downy mildew has an incubation period of 10–16 days. A relative humidity of 95% or greater will also promote sporulation and further infections. This disease overwinters in crop debris.

Scouting and Thresholds: A forecasting model called DOWNCAST helps to predict downy mildew outbreaks. See *Disease Prediction Models*, Chapter 4. If DOWNCAST is not available, apply preventive fungicides during cool and humid weather conditions, or if onion downy mildew has been found in other fields in your area. Scout for downy mildew while looking for botrytis or stemphylium leaf blight.

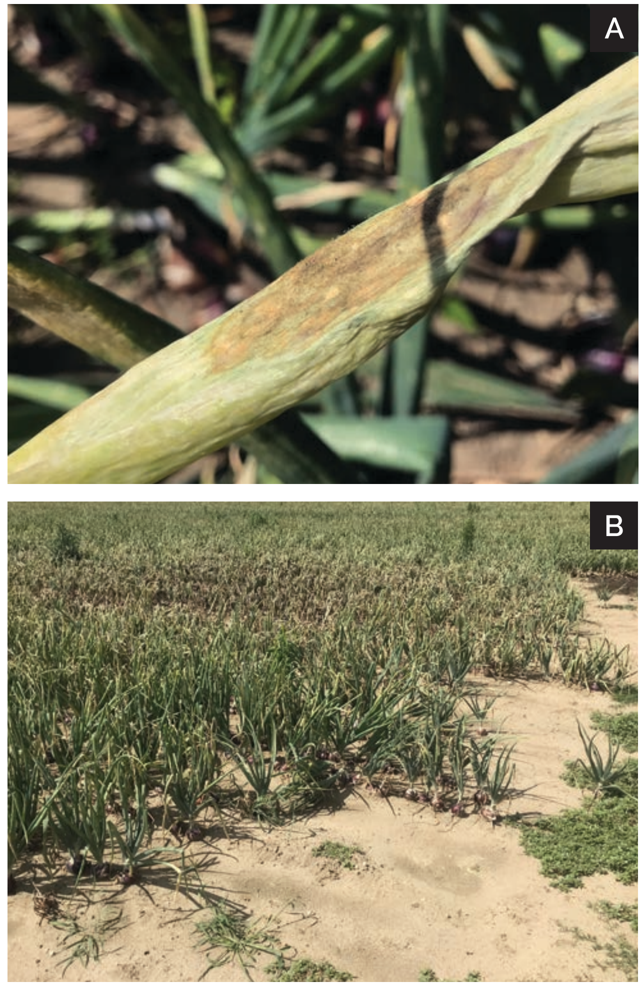


Figure 7–104. Grey, velvety growth on the leaf (A) resulting in straw-coloured lesions. Plants die quickly and infect other plants, creating patches in the field (B).

Management Notes: Management is primarily preventive. If DOWNCAST is not available, apply protective fungicides during cool and humid conditions. Practising a 4-year crop rotation, if onions are not planted in nearby fields, may help reduce the incidence of downy mildew. Sporangia spread in wind currents are able to travel far distances given the right conditions. Always remove cull onions from the field and avoid onion cull piles. Use cultural practices such as plant spacing and irrigation scheduling to minimize leaf wetness and permit better air movement in the field.

Fusarium Basal Rot

Fusarium oxysporum f. sp. *cepae*

Identification: Early symptoms include the yellowing of leaves and tip dieback. As the disease progresses, the whole plant may collapse. The basal plate of the onion becomes pinkish-brown. Under moist conditions, white fungal growth may appear on the basal plate. Under certain conditions, orange-to-tan spores may also appear. Secondary bacterial rots may also develop. If the infection occurs late in the season, the symptoms may not show up until the onions are in storage (Figure 7–105).

Figure 7–105. An infected basal plate turning brown with roots breaking off as the onion is pulled from the field.

Biology: Basal rot occurs under warm soil temperatures. A temperature of 29°C (84°F) is optimum for disease development. Basal rot is not prevalent every year in all areas.

Management Notes: Follow a long crop rotation and use disease-free transplants that were grown in sterile growing media. Clean transplant equipment frequently. There are some onion cultivars with tolerance to *Fusarium oxysporum*. Grow tolerant cultivars if *Fusarium oxysporum* f. sp. *cepae* has been found in your field. Consider using a biological product that suppresses *Fusarium* development. Allow the soil to dry out between irrigation events.

Iris Yellow Spot Virus (IYSV)

Identification: Iris yellow spot virus (IYSV) symptoms include bleached or straw-coloured diamond-shaped lesions on leaves, or uneven bleached areas. Some active lesions have a yellow halo surrounding a green island of leaf tissue, but this is most common on flower stalks. Lesions often appear on the youngest leaves, where the majority of thrips feeding occurs. Infected plants can produce good quality bulbs under Ontario conditions. However, under stressful conditions, such as drought and high heat, plants will prematurely lodge and bulb sizing ceases. The disease has been found in Ontario but is rare.

Biology: Onion thrips, the only known vector of IYSV, are prevalent in all onion-growing regions in Ontario. Thrips multiply rapidly in hot, dry weather conditions and are present throughout the growing season. Onion thrips pick up the virus from infected onion, garlic, leek, jimsonweed, tobacco and redroot pigweed and are able to transmit the virus for the remainder of their life. The symptoms of IYSV often appear on younger leaf tissues first, because that is where most thrips feeding occurs. The virus weakens plants and makes them more susceptible to other pathogens.

Disease symptoms tend to appear in late July or August in onion crops grown from seed or transplant. Onions grown from sets often display symptoms earlier in July.

Management Notes: Manage populations of onion thrips throughout the season to mitigate the spread of this disease. Good sanitation practices, including the removal of cull and volunteer onions and weeds, are also important to help reduce the incidence of IYSV. If purchasing onion sets, talk to your distributor about the disease and consider testing for IYSV.

Onion Smudge

Colletotrichum circinans

Identification: Smudge appears as black concentric rings near the neck and on the outer scales of the bulb. This disease is most commonly found on bulbs of white or Spanish onions after harvest, but can also appear on maturing bulbs in the field.

Biology: Smudge is a soil-borne fungus that can survive in the soil for several years. The spores are spread by splashing rain and in the air. Development of this disease is favoured by warm, wet weather.

Management Notes: Follow a 3-year crop rotation and remove cull onions from the field. Proper curing and drying reduces disease development in storage, as does maintaining optimum relative humidity (60%–70% in storage). Smudge develops more quickly when the relative humidity in storage is high. Artificial heat curing may reduce problems in humid areas of the province. Grade out onions with thick necks, nicks or bruises prior to storage. Yellow and red-skinned onions are resistant to smudge, while white onions tend to be more susceptible.

Onion Smut

Urocystis colchici, *Urocystis cepulae*

Identification: Infected plants appear stunted, thickened, darker and slightly twisted. Cut leaves expose a mass of black teliospores on the inside of the leaf. Plants may die prematurely (Figure 7–106).

Figure 7–106. Leaves appear darker, thickened and leaves may split open to expose masses of black teliospores (A and B).

Biology: The smut spores are long-lived and may last up to 20 years in the soil. Infection occurs when spores infect the flag leaf as it emerges from the soil. Temperatures 10°C–12°C (50°F–54°F) within 2–3 weeks of seeding favour infection. A cool, wet spring increases the incidence of smut infection because onion seedlings grow slowly and the flag leaf is in the soil for a longer period. As leaves senesce, spores are returned to soil where they are spread by surface runoff, equipment, wind and animals.

Management Notes: Most muck soils are infected with onion smut spores. When untreated, resulting losses may be as high as 50%–80%. The only practical means of controlling onion smut on seeded onions is the use of a seed treatment or fungicide in-furrow. However, onion transplants that are grown in soil-less mix will be resistant to smut by the time they are planted in the field. Rogueing out plants will lower potential spore available to infect onions that are planted in the field in future years, but this is only practical if the field has recently been infected with the onion smut organism.

Pink Root

Pyrenochaeta terrestris

Identification: Infected roots have a pinkish-red colour and eventually turn purplish-black. Infections compromise and later kill the root system, causing the plant to turn yellow, wither and become stunted (Figure 7–107).

Figure 7–107. Pink roots are visible when plants are pulled.

Biology: Pink root survives in the soil for several years in the absence of host plants. It mainly attacks onion roots when soil temperatures are between 24°C–28°C (75°F–82°F). Pink root commonly occurs on the roots of mature plants; however, if soil temperatures are warm enough in the spring, the pathogen can infect the roots of young plants, resulting in severe losses. *Pyrenochaeta terrestris* infects a variety of host plants including many broadleaf weeds, peas, peppers, potato, spinach and tomato.

Management Notes: Problem fields require a rotation of 3–5 years out of peas, spinach as well as allium and solanaceae crops. Certain onion cultivars have tolerance to pink root.

Purple Blotch
Alternaria porri

Identification: Small 1–3 cm (½–1¼ in.) brown spots with purplish centres are characteristic of this disease. Spots form into oval lesions. There may be a yellow zone around the lesions. Infected leaves become weakened and are easily blown over. May be confused with stemphylium leaf blight, but stemphylium does not have the purple colour (Figure 7–108).

Figure 7–108. Purple blotch lesions are contained and have a sunken tan lesion with a purple hue.

Biology: Infection occurs when warm weather, 18°C–30°C (64°F–86°F), coincides with prolonged leaf wetness. Older leaves that have been damaged by herbicide burn or hail are very susceptible. It is common to see alternaria infect leaves that were previously damaged by onion downy mildew.

Purple blotch overwinters in crop debris, either in the field or in storage sheds. Fungal spores spread by wind, splashing water, implements, insects or workers.

Scouting: Scout fields regularly. Look specifically at older leaves as they are more commonly affected than younger tissues. However, when plants are infested by onion thrips, younger leaves are more susceptible, and the severity of the disease is much higher when compared to infected plants that are not infested by onion thrips.

Management Notes: Practise a 4-year crop rotation with non-host crops. Reduce inoculum by removing cull onions from the field. Monitor and control onion thrips levels to reduce damage to leaves.

Stem and Bulb Nematode
Ditylenchus dipsaci

Identification: This is a microscopic plant parasitic nematode that enters the plant through the roots or wounds on the bulb. Once in a suitable host, it injects a toxin into the plant as it feeds, causing lesions and resulting in distorted growth. Severely infected plants have thicker leaves and necks, turn yellow, appear stunted and senesce prematurely. The basal plate of the bulb may start to rot and the entire bulb may turn black or rot away. Some symptoms can be confused with fusarium basal rot.

Management Notes: The key to management of this pest is prevention. Prevention includes planting into non-infected soil. Take a soil nematode test before planting and follow a 3-year rotation with non-host crops. Once in the soil, the pest can be spread through irrigation water, on contaminated seed, equipment, humans and animals. In Ontario, nematode populations in soil and roots are usually at their highest in May to June and again in September to October. The fall months are a good time to soil sample for nematodes, as the populations are high and controls can be taken well in advance of planting the crop.

Stemphylium Leaf Blight

Stemphylium vesicarium

Identification: Symptoms start as small, yellow-to-tan, water-soaked lesions that develop into elongated spots that turn dark olive brown to black when spores develop. Leaves may be completely blighted as the lesions coalesce. Onion leaves may die prematurely, resulting in reduced yield.

Additionally, onions going into storage are typically sprayed with a sprout inhibitor before lodging. Plants need 5–8 green leaves to take up the sprout inhibitor. If stemphylium leaf blight kills most of the leaves, then sprout inhibitor cannot be applied, resulting in reduced storage and shelf life. The symptoms of stemphylium leaf blight are sometimes confused with purple blotch, which is caused by *Alternaria porri* (Figure 7–109).

Figure 7–109. Purple blotch lesions are tan to white with purple centres (A), while stemphylium leaf blight causes tan lesions with streaking black centres (B and D). Botrytis leaf blight lesions are smaller and irregular in shape with a greyish/white appearance (C).

Biology: This fungus can infect healthy leaves but easily infects damaged, diseased or dying leaf tissue. Spores are dispersed by wind, and development of this disease is favoured by warm (18°C–25°C (64°F–77°F)), humid conditions. It is favourable to avoid long periods of leaf wetness by irrigating in the early morning or by implementing drip irrigation.

Management Notes: Rotate away from allium crops for 3 years. Remove culls and volunteer plants from the field. Other cultural management strategies include limiting the leaf wetness period by irrigating in mid-day or irrigating in the early morning and allowing the crop to dry out as soon as possible to avoid prolonged periods of leaf wetness. Since the pathogen is more likely to infect leaves that have been physically damaged, impacted by herbicides or infected by other diseases, it is important to maintain healthy plant stands and control other foliar diseases of onion.

Use fungicide groups in rotation. Where possible, incorporate effective broad-spectrum, multi-site fungicides as well as biofungicides, as these have a low risk of resistance development. Like other foliar diseases of onions, prevention of infection is essential.

White Rot

Stromatinia cepivorum

Identification: Foliar symptoms include yellowing, tip dieback, wilting and stunted plants. White fungal growth with small, black, pinhead-sized sclerotia may be visible at the base of the plant. To differentiate from fusarium, put sample in a sealed plastic bag for 3 days and look for black sclerotia development. The fungus colonizes the root plate and produces white mycelial growth, accompanied by a watery rot and disintegration of infected bulbs. This disease is not always present at harvest but may show up in storage (Figure 7–110).

Figure 7–110. White mycelial growth near the base of the plants (A) and bulbs with black, pinhead-sized sclerotia (B). *Source:* Dr. Mary Ruth McDonald.

Biology: The sclerotia and mycelium overwinter in soil and plant debris. Soil infected with allium white rot can be spread by machinery, animals, pallet boxes, wind and water. Infected garlic cloves, onion sets and transplants also spread this disease. Disease development is favoured by cool, moist soil conditions. Warm soil temperatures, greater than 24°C (75°F) are less conducive to allium white rot.

Management Notes: Avoid the introduction of the pathogen to fields by washing soil from equipment before moving from an infected field to a clean field. Allium white rot survives in the soil for up to 40 years. In the field, rogue out infected plants and remove cull onions from field areas. Spot soil fumigation, solarization or flooding during warm conditions can reduce sclerotia survival in the soil.

Insects

Cutworms

Agrotis ipsilon (Black Cutworm)
Euxoa messoria (Dark-Sided Cutworm)
Crymodes devastator (Glassy Cutworm)
Euxoa detersa (Sandhill Cutworm)

Identification*:* Species commonly found in Ontario vegetable crops include: black cutworm, dark-sided cutworm and the sandhill cutworm. Cutworm larvae are soft and fat caterpillars, and they roll up when disturbed. Mature larvae can be as large as 3–4 cm (1½–2 in.) in length. Black cutworms are grey to black with no striping on the body, whereas most other cutworms have stripes along their back or sides.

Damage: Cutworm damage occurs most often in late April and early May, coinciding with early-season planting and emergence of seedlings. Larvae cut the petioles or stems of seedling plants below or at a few centimetres above the soil surface. Most of the damage is found at the field edge or in weedy fields. One cutworm can kill several plants before it reaches full size and pupates. Most species of cutworms feed at night, hiding during the day in the soil near the base of the plant.

Biology: Most species of cutworm do not overwinter in Ontario. In the early spring, adult moths are transported on the trade winds from more southerly areas. Females are attracted to dense, green cover to lay their eggs. Often, when they arrive in Ontario in early spring, the main source of habitat for the females are winter annual or perennial weeds. Cutworms are therefore more frequent in fields with green cover early in the spring before primary tillage. Egg hatching and larval feeding often coincide with planting and crop emergence.

Scouting and Thresholds: Most species of cutworms feed at night, hiding during the day under loose stones or in the soil near the base of the plant. Scouting is best done in the middle of the day, when the water demand of plants is high. Check for cutworm damage by walking through the field and looking for wilted and/or fallen plants. Cutworm damage can look as if the seedlings were cut off by scissors at the base. If any damaged plants are found, dig around in the soil at the base of the plant. The cutworm, if present, will be found 2–3 cm (~1 in.) deep and within 10 cm (4 in.) of the damaged plant(s). Look for cutworm larvae in the top 2.5 cm (1 in.) of soil surrounding the damaged plant.

For most vegetable crops, the control guideline is 5% damaged plants.

Management Notes: Make control decisions based on the number and size of larvae found. Cutworm control is most effective on small <2.5 cm (1 in.) larvae. Larger larvae are difficult to control with insecticides. At more mature stages, >2.5 cm (1 in.) in length, they cease feeding as they prepare to pupate, and control becomes unnecessary. Apply insecticides in the early evening, as the cutworms come to the surface to feed at night. Insecticides are more effective on moist soils.

Leek Moth

Acrolepiopsis assectella

Identification: Larvae are slender, yellowish-green in colour, and up to 14 mm (½ in.) at maturity. They produce large amounts of pale frass as they feed. The reddish-brown pupa is encased in a loosely netted cocoon. These cocoons are usually found on the underside of leaves. The adult moth is small (5–7 mm (⅛–¼ in.)), reddish brown, and with a white triangle-shaped spot that is visible when the wings are folded at rest.

Damage: The larvae tunnel mines and create window-paning in onions and sometimes cause leaf distortion. As the crop dries down, the larvae may be attracted to the bulb. Damage to onions predisposes them to secondary bacterial or fungal diseases (Figure 7–111).

Biology: There are three generations in Ontario, the first in June, the second in July and the third in August. Adult moths overwinter in sheltered areas and emerge in the spring when temperatures reach 9.5°C (49°F) for two consecutive days, typically in late April to mid-May.

Figure 7–111. Window-paning of onion leaves (A) caused by leek moth larvae that can be seen when the leaves are sliced open (B).

Scouting and Thresholds: Monitor for leek moth using commercially available pheromone trapping systems with removable sticky cards. Research in Ontario indicates that an insecticide application is often most effective 7–10 days after the peak pheromone trap capture. Install pheromone lures around the field edge in early to mid-April and monitor until harvest.

Management Notes: Cultural controls including crop rotation, delayed planting, removal of old and infected leaves, destroying pupae or larvae, early harvesting (to avoid damage by last generation larvae and population build-up), positioning susceptible crops away from infested areas and destruction of plant debris following harvest may be effective in reducing populations below damaging levels.

Onion Maggot and Seedcorn Maggot
Delia antiqua, *Delia platura*

Identification: These two maggots are the larvae stage of the onion and seedcorn maggot fly. The adult onion maggot is a small 5 mm (¼ in.), grey-black fly, and the adult seedcorn maggot is black and about half the size. The female lays eggs around the base of the plant, and several days later the larvae, often referred to as maggots, immediately start feeding on the host plant's roots (Figure 7–112).

Damage: Larvae tunnel into the basal plate of the plant. The type of damage is related to crop development at the time of attack. Small onion plants are most susceptible in April and May and will die as a result of the feeding. There may be several dead seedlings in a row as the larvae kill one seedling and move to another. Damage to plants at the bulb formation stage may produce unmarketable, misshapen bulbs.

Biology: The onion and seedcorn maggot overwinters as a pupa in the top 15 cm (6 in.) of the soil. The three generations of onion and seedcorn maggot in Ontario emerge in late May or early June, July and late August.

Scouting and Thresholds: Scouting can indicate the risk of maggot damage, but seed treatments are applied before the risk of damage is known. In most areas of commercial onion production in Ontario, the onion maggot will always be present. Populations can be monitored with yellow sticky traps. Place four traps (of 3 sticky boards each) centrally along each field edge to determine if the seed treatments have been effective. Assess the per cent damage using plots containing 100 onions, repeated four times within the field to monitor levels.

A degree day (DD) model has been developed to predict emergence of adult onion and seedcorn maggot flies. Using a base of 4°C for both flies, onion maggot adults emerge at 210, 1,025 and 1,772 DDs for first, second and third generations, respectively. Seedcorn maggot adults emerge at 200, 600 and 1,000 DDs for first, second and third generations, respectively. For more information, see *Growing Degree Days*, Chapter 4.

Figure 7–112. Onion wilting due to onion maggot larvae feeding on the roots (A). Onion maggot larvae feeding on onion (B). Adult onion maggot fly (C).

Management Notes: Implement a 4-year crop rotation and avoid planting onions close to last year's crop. Avoid planting into fields that observed high maggot fly pressure the year prior. Use treated seed. With effective seed treatments, first-generation damage may be negligible. Seedlings killed by the first generation are often compensated for with more rapid growth in adjacent onions.

Treatments against adult flies of the first and second generation are not recommended on dry, cooking or Spanish onions. Historically, spraying for adult flies does not prevent or reverse onion maggot damage.

Sterile insect technology (SIT) has been developed for onion maggot management by Phytodata. Sterile male onion maggot flies are released into the field on a weekly basis and as a result, the eggs that pre-existing female flies will lay will not be fertile and the population of wild, fertile flies decreases over time. No sterile insect management methods have been commercialized for seedcorn maggot flies.

Onion Thrips

Thrips tabaci, *Frankliniella occidentalis*

Identification: Thrips are small (<3 mm (⅛ in.) long), soft-bodied insects. Adult thrips have straw-brown bodies and four wings fringed with hairs. Nymphs are smaller, wingless and pale white in colour (Figure 7–113).

Damage: Thrips have sucking-rasping mouth parts and cause tissue damage when they feed on the leaves. The feeding results in silvery marks on the leaves and heavily damaged leaves may appear completely silver. During bulbing, populations of thrips may increase, causing premature senescence.

Figure 7–113. Onion thrips hiding between the leaf axils.

Biology: In Ontario, both adults and nymphs overwinter on winter grains, clover and alfalfa. They migrate into vegetable fields as the weedy roadsides dry down and the winter wheat and alfalfa are harvested. Females insert white, bean-shaped eggs into the leaf tissue. Development from egg to adult requires 10–30 days, depending on temperature. Once mature, females begin to lay eggs. The females reproduce asexually (without mating). Consequently, increases in the thrips population can occur very rapidly, especially during periods of hot, dry weather. There are several overlapping generations per year.

Scouting and Thresholds: For onions, sample 50 plants across a representative section of the field. The threshold for bulb vegetables is 3 thrips per leaf.

Management Notes: For bulb vegetables, early detection of thrips is key to successful control. High water volumes help insecticides penetrate into the leaf axils where the majority of onion thrips are found. Also, spray applications made in the evening have provided better control than applications made during the day. Heavy rainfall is effective in knocking thrips off the plant for a short time, but management tools may still be required under high pest populations. Natural predators such as minute pirate bugs, lacewings, predatory mites, ladybird beetles and spiders have been shown to prey on onion thrips.

Seedcorn Maggot

See *Onion Maggot and Seedcorn Maggot*, *Onions, Leeks and Shallots*.

Spittlebugs

See Chapter 5.

Springtails

See Chapter 5.

Wireworms

Limonius spp.

Identification*:* Wireworms are the larvae of click beetles. They are copper-coloured, cylindrical and hard-bodied, with three pairs of tiny legs. Wirewoms are commonly confused with multi-legged millipedes and symphylans. They can reach 2–3 cm (~1 in.) in length.

Damage: Wireworms can be seen burrowing into seeds, underground roots and stems of plants. Infested plants do not develop well, and seedlings lack vigour or fail to emerge. Damage is often scattered randomly across the field. In the fall, wireworm feeding may render sweet potatoes, carrots and potatoes unmarketable.

Wireworms are present all season. Young plants are most susceptible, therefore early-season control is critical. They are likely to be present in fields that have recently had sod crops, or following years of high grassy-weed pressure.

Biology: Wireworms take up to 5 years to complete development from egg to adult. Most of this time is spent as a larva in the soil. Adult beetles are active in the spring, laying eggs in the soil or near grass roots. Eggs hatch 2–4 weeks later, and larvae move in search of food. Movement within the soil profile is affected by temperature, moisture and the presence of a food source/carbon dioxide. After 3–5 years, wireworm larvae pupate near the soil surface. New adult wireworms overwinter in the soil and emerge the following spring to lay eggs and continue the cycle.

Scouting and Thresholds: Wireworms may be monitored in the fall (or in the early spring for later-planted crops) prior to planting, using bait stations. Bury whole carrots, 7.5 cm (3 in.) deep, at 10 marked stations across the field. Check the stations in 2–3 days. An average count of 0.5–1 wireworm per station indicates a potential problem. Check for damage to the seed in areas of the field where seedlings have not emerged.

Management Notes: Planting into well-prepared, warm soils and avoiding unnecessarily deep planting depths will help encourage early-season growth, reducing the incidence of this pest. There are several species of wireworms present in Ontario, with varying degrees of susceptibility to registered insecticide seed treatments**.** Research is under way to reduce wireworm populations through the use of crop rotations to discourage egg-laying, as well as bait traps to pull wireworms out of crop rows and into areas where they can be controlled by insecticides or other amendments.

Disorders

Air Pollution Injury

Air pollution injury may be confused with symptoms of disease, insect feeding, nutrient deficiencies or toxicities, herbicide injury or damage caused by weather extremes. Plant damage caused by air pollution is usually most severe during warm, clear, calm, humid weather, when barometric pressure is high, as these conditions can cause an air inversion. During an air inversion, warm air above the earth's surface traps cooler air at ground level, allowing pollutants to accumulate. Injury may also be more severe during foggy conditions, heavy dews or in fields near very busy highways.

Ozone: Ozone is the main pollutant in the oxidant smog complex. Levels vary significantly throughout the growing season, as evidenced by alerts of smog days in Ontario. Mild ozone injury appears as yellow flecking on the tips of green leaves. More severe ozone injury causes the damaged tissue to die.

Sprout Inhibitor Injury

Maleic hydrazide applied to immature crops may result in spongy bulbs. The optimum time for applications is when 50% of the tops have fallen, but tops are still green, usually 8–14 days before harvest. Green tops are necessary for absorption of maleic hydrazide. See label for detailed directions of use.

Sunscald

Sunscald of onions often occurs when harvested onion bulbs are exposed to bright sunlight and high temperatures during field curing. Affected tissue often appears bleached and becomes soft to touch. Turn onions during curing to avoid injury. Sunscald injury leads to secondary bacterial infections, which can result in severe storage losses.

Parsnips

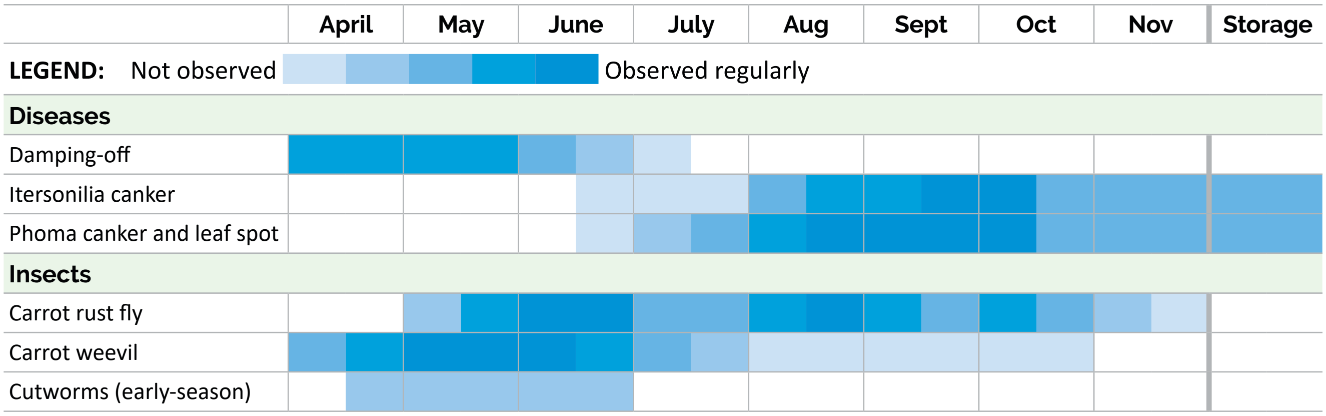


Figure 7–114. Parsnips pest activity calendar. The actual period of activity for any given pest will vary significantly from year to year, depending on environmental factors.

Production Requirements

Soil types:	deep, loose, fertile, sandy loam soil & well-drained muck soils
Soil pH:	muck soil – 5.5 sandy loam – 6.5
Suitable rotational crops:	onions, beets, spinach, cereal crops
Do not rotate with:	brassica crops, other *Apiaceae*/umbellliferous crops (e.g., carrot, celery, parsley)
Minimum soil temperature:	2°C (36°F)
Optimum air temperature:	15°C–18°C (59°F–64°F)
Earliest planting date:	early to late April

Table 7–83. Parsnip Crop Spacing

Crop	Row Spacing	In-Row Spacing	Depth[1]	Seeding Rate
Parsnips	45–75 cm (18–30 in.)	3–6 cm (1–2½ in.)	6–20 mm (<1 in.)	3–5.5 kg/ha (3–5 lb/acre)

[1] Always plant into moisture.

Seeding and Spacing

Optimum planting conditions occur when soil temperatures reach 10°C–21°C (50°F–70°F). Planting into cool soil conditions may result in reduced stands due to poor germination, low vigour and increased seed decay.

Poor stands occur in over-worked soil surfaces (e.g., baked or crusted). For more information on how to improve soil structure and prevent crusting, see Chapter 2.

Figure 7–115. An emerging stand of parsnips.

Fertility

Macronutrients

Nitrogen

Fertilizer requirements are similar to those for carrots.

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. See Table 1–12 and Table 1–13, for more information.

Phosphorus and Potassium

Test the soil to determine phosphorus and potassium requirements. See Table 7–85 and Table 7–86.

Table 7–84. Parsnip Nitrogen Requirements

Soil Type	Actual N
Mineral Soils	
Preplant	70 kg/ha (62 lb/acre)
Side-dress	40 kg/ha (36 lb/acre)
Total	**110 kg/ha (98 lb/acre)**
Muck Soils	
Preplant	60 kg/ha (54 lb/acre)

Table 7–85. Parsnip Phosphorus Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Sodium Bicarbonate Phosphorus Soil Test (ppm)													
	0–3	4–5	6–7	8–9	10–12	13–15	16–20	21–25	26–30	31–40	41–50	51–60	61–80	81+
Mineral Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	180 (161) (HR)	170 (152) (HR)	170 (152) (HR)	160 (143) (HR)	160 (143) (HR)	150 (134) (HR)	140 (125) (HR)	120 (107) (MR)	100 (89) (MR)	80 (71) (MR)	50 (45) (LR)	30 (27) (RR)	0 (RR)	0 (NR)
Muck Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	100 (89) (HR)	100 (89) (HR)	100 (89) HR)	100 (89) (HR)	90 (80) (MR)	90 (80) (MR)	80 (71) (MR)	70 (63) (MR)	60 (54) (MR)	50 (45) (LR)	30 (27) (LR)	20 (18) (LR)	0 (RR)	0 (NR)

Table 7–86. Parsnip Potassium Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Ammonium Acetate Potassium Soil Test (ppm)											
	0–15	16–30	31–45	46–60	61–80	81–100	101–120	121–150	151–180	181–210	211–250	251+
Mineral Soils												
Potash (K_2O) required kg/ha (lb/acre)	230 (205) (HR)	220 (196) (HR)	210 (187) (HR)	190 (170) (HR)	160 (143) (HR)	130 (116) (HR)	100 (89) (MR)	80 (71) (MR)	50 (45) (MR)	0 (LR)	0 (RR)	0 (NR)
Muck Soils												
Potash (K_2O) required kg/ha (lb/acre)	230 (205) (HR)	220 (196) (HR)	210 (187) (HR)	200 (178) (HR)	170 (152) (MR)	150 (134) (MR)	120 (107) (MR)	80 (71) (MR)	40 (36) (MR)	0 (LR)	0 (RR)	0 NR)

Irrigation

Parsnips are usually responsive to irrigation.

Effects of moisture stress: poor germination, reduced size and quality
Critical irrigation period: germination and root enlargement
Rooting depth: 30–60 cm (12–24 in.)

If the available soil moisture level in the root zone reaches 60% during the critical irrigation period, irrigation could help maintain crop yield and quality.

For more information on irrigation scheduling, see the *Irrigation Management* Best Management Practices (order number BMP08E) and the OMAFRA factsheet, *Monitoring Soil Moisture to Improve Irrigation Decisions*.

Harvest

Parsnips are a long-season crop typically needing 110–130 days for maturity. In Ontario, some parsnips are lifted in late August and sold fresh. Most of the crop is harvested in October and November for winter storage. A portion of the crop may be left in the ground over the winter and harvested in early spring the following year.

Roots can be harvested with a top-pull harvester like the ones used for carrots and beets, or the crop can be topped and dug using a potato-type digger.

The sweet, nut-like flavour of parsnips develops after exposure to temperatures near freezing (late September and October). Harvest in the late fall (October and November) after several moderate freezes or mulch heavily for winter flavour.

Storage

If mature roots are not exposed to low field temperatures, store for 2 weeks at 0°C–1°C (32°F–34°F) to develop flavour prior to shipping.

Storage temperature: 0°C (32°F)
Relative humidity: 98%–100%
Duration: 4–6 months
Chilling injury symptoms: damaged root tissues
Parsnips will freeze at –1.7°C (29°F).

Caution

Some individuals may be sensitive to furocoumarins, the natural chemicals found in parsnip foliage. The level of furocourmarins increases in diseased parsnips. Using rubber gloves when handling parsnip foliage and leg protection when walking in the field will prevent the development of skin rashes.

Pest Management and Disorders

See Figure 7–114, *Parsnip pest activity calendar*.

Diseases

Damping-Off — also known as Root Rots

Pythium sp., *Phytophthora* sp., *Rhizoctonia* sp., *Fusarium* sp.

See Chapter 6.

Itersonilia Canker

Itersonilia perplexans, I. pastinacae

Identification: Itersonilia cankers typically form on the crown and shoulder of the root. They are reddish brown with a rough surface that eventually turns black (Figure 7–116).

Figure 7–116. Reddish-brown root lesions of itersonilia canker.

Biology: Itersonilia canker requires cool, wet conditions (temperatures around 20°C (68°F)). The fungus overwinters in infected roots and is spread within the field by spores. Itersonilia can also spread through infected seed.

Management Notes: To minimize itersonilia canker infections, cover the shoulder of the roots with high soil ridges. Control of carrot rust fly will help reduce secondary itersonilia infections.

Follow a long rotation and bury infected residue.

Phoma Canker and Leaf Spot
Phoma complanata

Identification: Leaf symptoms include small (1-mm) spots with yellow-green halos. On the petioles, light-brown elliptical lesions form. As the disease progresses, the lesions coalesce, causing the leaves to yellow, wither and die and cankers to form on petioles. Brown cankers embedded with small, black spores typically appear on the crown and shoulder of infected parsnips roots.

Biology: Phoma canker and leaf spot appear in mid-August. Development is favoured by moderate temperatures, rain and high humidity. This disease overwinters on crop residue. It is also seed-borne. Phoma canker and leaf spot is spread by rain, heavy dews and insects.

Management Notes: Harvest before maximum root and shoulder sizing to reduce phoma canker development. Follow a long rotation and bury infected residue.

Root Knot Nematode
Meloidogyne hapla

Identification: Plants may appear stunted, yellow or lighter green and weak in patches. White, irregularly shaped galls of various sizes form along roots. Abundance of secondary and tertiary roots form slightly below the galls, giving the root a "hairy" appearance.

In some cases, several types of nematodes may be present and causing damage in the crop. The presence of nematodes may also exacerbate the impact of certain soil-borne fungal diseases, such as verticillium.

Scouting and Thresholds: Parsnip threshold is 500/kg soil.

Management Notes: Before deciding upon a management strategy for nematodes, complete a nematode soil test to determine the levels of nematodes present. In Ontario, nematode populations in soil and roots are usually at their highest in May to June and again in September to October. The fall months are a good time to soil sample for nematodes, as the populations are high and controls can be taken well in advance of planting the crop.

Insects

Carrot Rust Fly
Psila rosae

Identification: The adult rust fly is shiny and black, measuring approximately 6 mm (¼ in.) in length. It has an orange head, brown eyes and pale, yellow legs. The larva is cream-white and legless with dark mouthhooks.

Damage: Larvae feed on the root hairs for up to a month before tunnelling into the parsnip, where they continue feeding. Feeding damage from rust fly larvae is usually limited to the lower two-thirds of the root.

Biology: The carrot rust fly overwinters as a pupa in the soil and usually has two generations per year. The first generation often coincides with lilac bloom, the second begins in mid-August. Occasionally, sufficient heat units are accumulated so that a third generation emerges in late September or October. This third generation usually occurs too late in the season to have any serious effect on the crop.

Scouting and Thresholds: Control adults if populations reach a level of 0.1 flies/trap/day as determined through monitoring. For more information on carrot rust fly trapping, see *Trapping*, Chapter 4. Rust flies are no longer a concern once the crop is within 21 days of harvest.

Growing Degree Days (base of 3°C) are used to predict the emergence of carrot rust flies. First-generation adults emerge between 329 and 395 GDDs. Second-generation adults emerge between 1,399 and 1,711 GDDs. For more information on GDD models, see *Growing Degree Days*, Chapter 4.

For parsnips, control adults if monitoring indicates a need.

Management Notes: Crop rotation will reduce background populations of the carrot rust fly. Consider late seeding to avoid first-generation damage. Avoid growing parsnips in sheltered areas where rust flies are more prevalent.

Carrot Weevil

Listronotus oregonensis

Identification: The carrot weevil adult is a dark-brown snout beetle about 6 mm (¼ in.) long. Larvae are legless and creamy white with an amber-coloured head about 5–8 mm (approximately ¼ in.) long.

Damage: Larvae of the carrot weevil create tunnels in the roots of parsnips. Feeding damage commonly occurs in the upper third of the root. Developing larvae tunnel into young, slender roots, causing the plants to wilt and die.

Biology: Carrot weevil adults overwinter in the plant debris of previously infested fields. Egg-laying occurs from mid-May to early June. Eggs hatch in 1–2 weeks, and larvae feed on the roots for at least 3 weeks and then pupate. Adults emerge 2 weeks later. A second generation may occur on early crops under warm weather conditions.

Scouting and Thresholds: Growing Degree Days (base of 7°C) are used to predict carrot weevil activity. First egg-laying is expected at 147 GDDs, which occurs from mid-May to early June. Expect 90% egg-laying at 455 GDDs. For more information on GDD models, see *Growing Degree Days*, Chapter 4.

Monitor adult carrot weevil activity using either wooden traps baited with carrots or mature carrot roots buried in the field. Set traps in the field by the beginning of May in central Ontario, earlier in southern regions. For wooden traps, keep an accumulated total of the number of weevils found in each trap:

- greater than 1.5 weevils/trap = apply a treatment at the second-leaf stage
- greater than 5 weevils/trap = apply a treatment at the second-leaf stage and an additional treatment at the fourth-leaf stage

For buried carrot root sections, consider treatments when 25% of the carrots have oviposition damage, which presents as small pits in the carrot.

Management Notes: Time treatments to target adults prior to egg-laying. Adult females are not attracted to the crop prior to the first true leaf stage. Crop rotation and weed control around field edges may reduce overwintering populations. The egg parasite *Anaphes sordidatus* (a small braconid wasp) provides some biological control.

Cutworms (Early-Season)

Agrotis ipsilon (black cutworm),
Euxoa messoria (dark-sided cutworm),
Crymodes devastator (glassy cutworm),
Euxoa detersa (sandhill cutworm)

See Chapter 5.

Peas

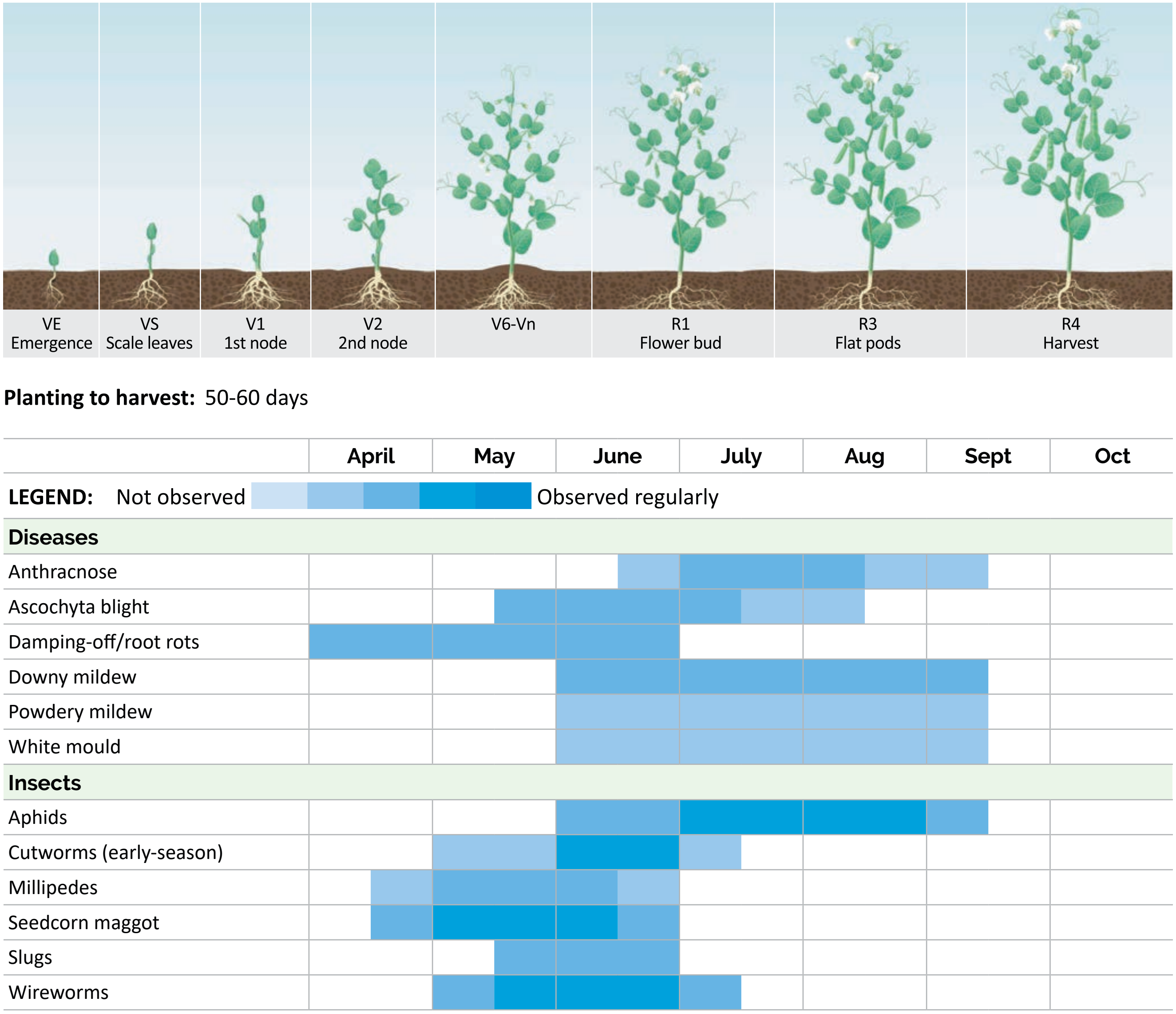


Figure 7–117. Pea stages of development and pest activity calendar. The actual period of activity for any given pest will vary significantly from year to year, depending on environmental factors.

PEAS

Production Requirements

Soil types: Peas are suited to well-drained soils. Avoid planting the early crop into heavy soils or variable fields, as they are more prone to root rots and seed insects.
Soil pH: 5.8–6.8
Suitable rotational crops: corn, cereal crops, brassica crops, cucurbit crops, tomatoes, peppers, root vegetables
Do not rotate with: peas, beans
Minimum soil temperature: 4°C (39°F)
Optimum air temperature: 15°C–18°C (59°F–64°F)
Earliest planting date: when soil moisture and temperature conditions are fit

Pea Development

Processing peas make up the majority of the pea acreage in Ontario. Wholesale and retail fresh market opportunities also exist for both shelled and edible podded cultivars. Shelled peas require specialized harvest equipment.

Peas are a cool-season crop. Heat stress starts to occur at temperatures above 24°C (75°F), especially during harvest. Planting occurs as soon as the soils warm up in the spring, with the early processing crop frequently beginning in late March. Sequential planting will continue until early June in Southwestern Ontario and late June in other parts of the province.

Problem weeds include Canada thistle and eastern black nightshade, which can become a crop contaminant during harvest.

For processing crops, the processor determines the cultivar, planting and harvest dates. Afila peas are commonly grown for processing. They have a large number of tendrils and do not require trellising.

Seeding and Spacing

Seed size varies considerably between cultivars. Adjust the planting rate according to both seed size and per cent germination. Always plant into moisture. See Table 7–87.

Inoculation

In peas, nodules are formed by the bacterial *Rhizobium leguminosarum* bv. *viciae*. If peas have not recently been grown in a field, inoculation may be required. In general, vegetable legumes do not form robust root systems, and nodulation can be limited. The short duration of growth and maturity for these cultivars also reduces the potential to fix large amounts of nitrogen from the atmosphere, limiting the nitrogen credit for rotational crops. In fields where peas have been grown in the past, it is unusual to see a yield benefit to inoculation.

Cover Crops

Early-harvested peas offer the ideal opportunity to incorporate cover crops into the rotation. Selecting a mixture of deep (tap)-rooted and fiberous-rooted species can help alleviate compaction caused during harvest activities. Cover crops are especially important after activities such as deep ripping to keep the soil "open" and friable. They also help to scavenge and hold onto residual nitrogen as the pea crop breaks down. See *Cover Crops*, Chapter 2, for more information.

Table 7–87. Pea Crop Spacing

Crop	Row Spacing	In-Row Spacing	Depth	Seeding Rate
Peas	15–20 cm (6–8 in.)	4–5 cm (1½–2 in.)	2.5–5 cm (1–2 in.)	100–300 kg/ha (90–270 lb/acre)

Table 7–88. Pea Phosphorus Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Sodium Bicarbonate Phosphorus Soil Test (ppm)													
	0–3	4–5	6–7	8–9	10–12	13–15	16–20	21–25	26–30	31–40	41–50	51–60	61–80	81+
Mineral Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	80 (71) (HR)	60 (54) (HR)	50 (45) (HR)	40 (36) (HR)	30 (27) (MR)	20 (18) (MR)	0 (LR)	0 (LR)	0 (RR)	0 (RR)	0 (RR)	0 (RR)	0 (NR)	0 (NR)

Table 7–89. Pea Potassium Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Ammonium Acetate Potassium Soil Test (ppm)											
	0–15	16–30	31–45	46–60	61–80	81–100	101–120	121–150	151–180	181–210	211–250	251+
Mineral Soils												
Potash (K_2O) required kg/ha (lb/acre)	120 (107) (HR)	110 (98) (HR)	90 (80) (HR)	80 (71) (HR)	60 (54) (MR)	40 (36) (MR)	30 (27) (MR)	0 (LR)	0 (RR)	0 (RR)	0 (RR)	0 (NR)

Fertility

Macronutrients

Nitrogen

Where phosphate and potash are required, apply 15 kg N/ha (13 lb N/acre) at seeding. If no phosphate and potash are required, the nitrogen may be omitted.

Phosphorus and Potassium

Test the soil to determine phosphorus and potassium requirements. See Table 7–88 and Table 7–89.

Micronutrients

Manganese deficiency may be a problem on peas, especially on soils with pH values above 6.5. Symptoms include a yellowing of the leaf tissue while the veins remain dark green. On fields known to be deficient, consider using a foliar manganese spray. Soil application is not advised for manganese because of the large amounts of fertilizer required. Peas are known to be sensitive to boron. Avoid growing peas in fields where boron fertilizer is used on rotational crops.

Irrigation

Pea crops are not typically irrigated. However, crops grown during mid-summer may benefit from irrigation.

Effects of moisture stress: blossom abortion, poor seed set and blank pods
Critical irrigation period: flowering and pod fill
Rooting depth: 30 cm (12 in.)

If the available soil moisture (ASM) level in the root zone reaches 60% during the critical irrigation period, irrigation could help maintain crop yield and quality.

For more information on irrigation scheduling, see the *Irrigation Management* Best Management Practices (order number BMP08E) and the OMAFRA factsheet, *Monitoring Soil Moisture to Improve Irrigation Decisions*.

Harvest

Most pea cultivars mature 50–60 days after planting. Monitor fields daily as they approach maturity. Peas rapidly become over-mature and lose quality, especially under warm weather conditions. Harvest when the pods are fully green and well filled, but still tender. Processing peas are assessed (and paid) based on their tenderometer rating. The tenderometer measures the force required to crush a standard sized sample of peas. It can range from 80 to 133. The tenderness of the sample decreases as the rating increases. The price per ton also decreases as the tenderometer rating increases. The optimum range is approximately 105 to 115. For average pea yields (processing), see Table 7–90.

Table 7–90. Average Yields of Shelled Peas

Production System	Yield
Conventional	4.7 tonnes/ha (2.1 tons/acre)
Organic	2.7 tonnes/ha (1.2 tons/acre)

Storage

Processing peas are processed as soon after harvest as possible. For the fresh market, remove the field heat from harvested peas as soon as possible. The sugar content of peas quickly converts to starch unless they are promptly cooled or processed. Cooling methods suitable for use on peas include forced air, package icing and vacuum cooling. For fresh market peas, morning harvest will help reduce the field heat in the harvested product and helppreserve quality.

Storage temperature: 0°C (32°F)
Relative humidity: 95%–98%
Duration: 1–2 weeks

Pest Management and Disorders

See Figure 7–117. *Pea stages of development and pest activity calendar*.

Diseases

Anthracnose

Colletotrichum lindemuthianum

Identification: Anthracnose infections first occur as a reddish-brown to purple discolouration along the leaf veins on the leaf underside. Severe infections spread to the upper leaf surface, causing large, irregular-shaped brown lesions to develop. Stem and petiole lesions are circular-to-elliptical with a dark red-brown border.

Pod infections appear as small brown specks, enlarging into circular, sunken lesions. These lesions often have a pale brown centre and a darker brown margin. Small black spores (acervuli) may be visible in the centre of the lesion. Under very humid conditions, these spores may turn pinkish.

Biology: Anthracnose is spread through infected seed and in crop residue. Survival on crop residue is limited. Wet, windy weather with a relative humidity of at least 92% favours disease development. Temperatures around 17°C (63°F) are most conducive to spread, although spores can be produced at any temperature from 13°C–26°C (55°F–79°F).

Management Notes: Use only certified, treated seed. Avoid rotating with other host crops, including beans. Avoid working in wet fields. Low levels of infection can be quickly spread by field machinery and foot traffic.

Ascochyta Blight, also known as Mycosphaerella Blight

Ascochyta sp.
Mycosphaerella pinodes
Phoma pinodella (peas)
Phoma exigua (beans)

Identification: Infected seedlings develop symptoms similar to damping-off. The stem tissue above the soil-line turns black, reducing water and nutrient uptake. Plants become stunted and weakened.

Infections on established plants cause tan-to-light-brown spots on the leaves and stems. The spots have a distinctive dark border. Light-brown spores (pycnidia) may be visible in the centre of the lesion. Infected leaves eventually turn yellow and dry off. Plants remain standing and become straw-like.

Biology: This disease complex is transmitted through seed-, soil- and wind-borne spores. Spores travel for long distances and can infect large areas. Infections occur at a range of temperatures from 15°C–25°C (59°F–68°F) and a minimum of 2 hours of leaf wetness.

Management Notes: Use only certified disease-free seed. Follow a 4–5-year rotation away from peas and other legume crops. Promote vigorous early-season growth by planting into warm soils and minimizing compaction.

Damping-Off — also known as Root Rot
Pythium sp.
Phytophthora sp.
Rhizoctonia sp.
Fusarium sp.

Root rots can be a significant problem in processing peas. Peas have a delicate root system — even low levels of root rot may impact the crop vigour and yield. Compromised root systems may also result in a rapid degradation in the crop quality (tenderometer rating). A long crop rotation is a vital tool for managing root rots in peas. See Chapter 6, for more information.

Downy Mildew
Peronospora viciae f. sp. *pisi*

Identification: Foliar infections start as a pale yellow, irregular-shaped lesion on the upper leaf surface. A dense grey mould develops on the underside of the leaf and on the stem. Severe infections combined with wet weather conditions cause the plants to turn slimy and fall over. White fungal growth develops inside infected pods, and the peas become discoloured and misshapen (Figure 7–118).

Figure 7–118. Downy mildew fungal hyphae on the underside of a pea leaf.

Biology: Downy mildew in peas is both seed-borne and soil-borne, although most infected seeds fail to emerge, or become stunted and die shortly after emergence. Oospores in the soil become active at temperatures of 10°C–15°C (50°F–59°F), infecting leaves in the lower canopy. The disease is further spread by windy, rainy conditions. Optimal levels of infection occur at temperatures of 8°C–20°C (46°F–68°F) and 6 hours of leaf wetness.

Management Notes: It is difficult to control downy mildew in peas with foliar fungicides. Follow a 3–4-year rotation between pea crops. Certain pea cultivars are more susceptible to the disease. Wherever possible, grow resistant cultivars.

Powdery Mildew
Erysiphe pisi, *Oidium* sp.

Identification: In most vegetable crops, initial symptoms usually appear on the older, shaded leaves. A dense, white fungal (powdery) growth develops on the lower leaf surface. A pale green-to-yellow discolouration may also appear on the corresponding upper leaf surface. The white, powdery growth spreads to the upper leaf surface and down the petiole. Infected leaves and stems turn yellow, wither and die prematurely.

Biology: The pathogens causing powdery mildew do not overwinter in the field in Ontario. Wind-borne spores usually arrive from the southern U.S. and Mexico in mid-summer. Peak infection periods occur when temperatures are in the range of 20°C–26°C (68°F–79°F). Disease development slows when temperatures climb above 26°C (79°F).

Infections can develop at relatively low humidity levels, although humid weather conditions and heavy dews lead to more rapid disease development. Under these conditions, visual symptoms may appear 3–7 days after the initial infection.

Management Notes: There are varying levels of tolerance among vegetable cultivars. Fungicides are available that may offer suppression of the disease, but good coverage on both the upper and lower leaf surfaces is essential.

Powdery mildew is difficult to detect in its early stages. The underside of leaves must be checked to detect spore growth. Once mildew and yellowing are present on the upper leaf surfaces, the disease is quite advanced and unlikely to respond to fungicide applications.

Due to its wide host range, it can be difficult to control with cultural practices.

White Mould
Sclerotinia sclerotiorum

Identification: Dark-green, water-soaked lesions develop on the pods, branches or stems. The lesions enlarge rapidly, encompassing the branches and stems, causing leaves to turn yellow and die. As the crop nears harvest, white, cottony fungal growths develop on pods and stems. Hard, black pea-sized sclerotia are usually embedded in the fungal growth. If the sclerotia form inside the pod, they may become a contaminant during processing.

Biology: White mould overwinters in the soil as sclerotia. The initial infection occurs during flowering and early pod development. Temperatures ranging from 20°C–25°C (68°F–77°F) and continuous leaf wetness (high humidity and/or heavy dews) favour sclerotinia white mould development. Overwintering sclerotia may survive for several years in the soil.

Management Notes: Practise a 3–4-year crop rotation away from susceptible crops (cucurbits, edible beans, soybeans, canola, carrots and lettuce). Avoid applying high rates of nitrogen fertilizer. Excess nitrogen promotes an exceptionally dense crop canopy, resulting in restricted air movement and more favourable disease development conditions. See *White Mould*, Chapter 6.

Insects

Aphids
Aphididae family, various species

See Chapter 5.

Cutworms (Early-Season)
Agrotis ipsilon (black cutworm),
Euxoa messoria (dark-sided cutworm),
Crymodes devastator (glassy cutworm),
Euxoa detersa (sandhill cutworm),

See Chapter 5.

Millipedes
Cylindroiulus caeruleocinctus,
Blaniulus guttulatus,
Pseudopolydesmus spp.

See Chapter 5.

Seedcorn Maggot
Delia platura

Identification: The juveniles are small, translucent white maggots (<5 mm or ¼ in.). They are legless and oblong-shaped with a pointed anterior. Pupae are 4–5 mm (¼ in.) long, brown and oblong. The adult is a small (5 mm (¼ in.)) slender, grey-black fly.

Damage: Maggot larvae burrow into germinating seeds and the below-ground parts of emerging seedlings. Infested seed may fail to emerge, or quickly die after emergence. Poor stand establishment is often a symptom of infestation.

Biology: The seedcorn maggot overwinters as a pupa in the soil. Adults emerge in early spring. Female flies are attracted to moist soils that give off an odour of decaying organic matter. This includes crop residues, freshly applied or newly tilled soil. There are 3–6 generations per year in Ontario, however the first generation is generally the most damaging. First-generation females lay their eggs from April until the middle of June. Larvae hatch in 7–10 days and remain in the field for 1–3 weeks, feeding on residue, seeds and young seedlings. Damage is often most significant in cold, wet growing conditions.

Scouting and Thresholds: Look for signs of poor stand emergence and feeding damage at the base of emerging plants. No thresholds have been established.

Management Notes: Rescue treatments are not available. Management often relies on the use of an insecticide seed treatment. Egg-laying females are attracted to moist soils and the odour of decaying organic matter. Discourage egg-laying by applying manure or incorporating winter cover crops well in advance of planting.

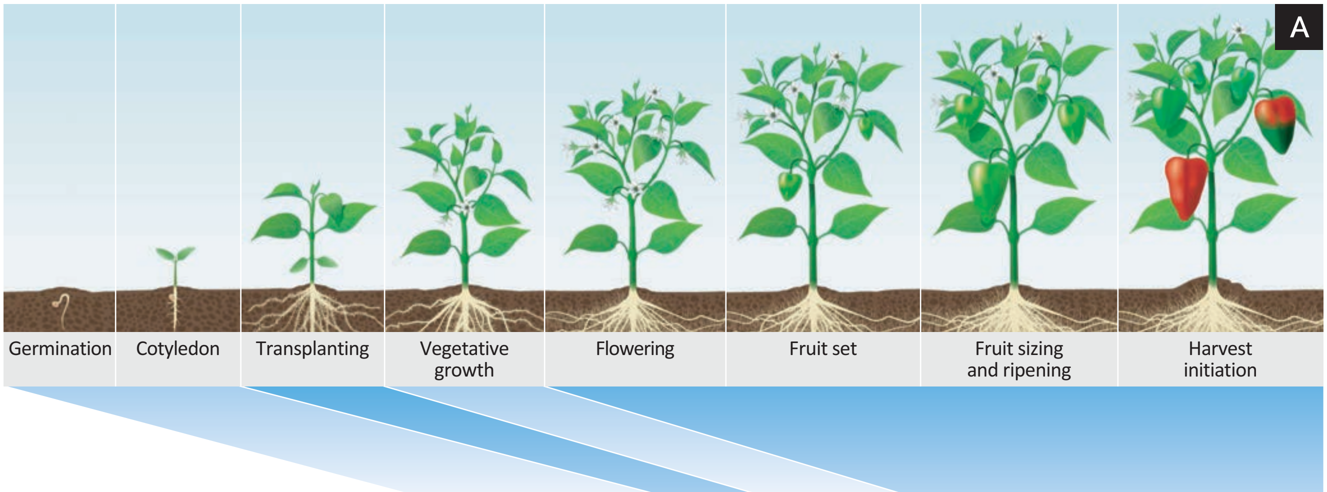
Slugs
Various species

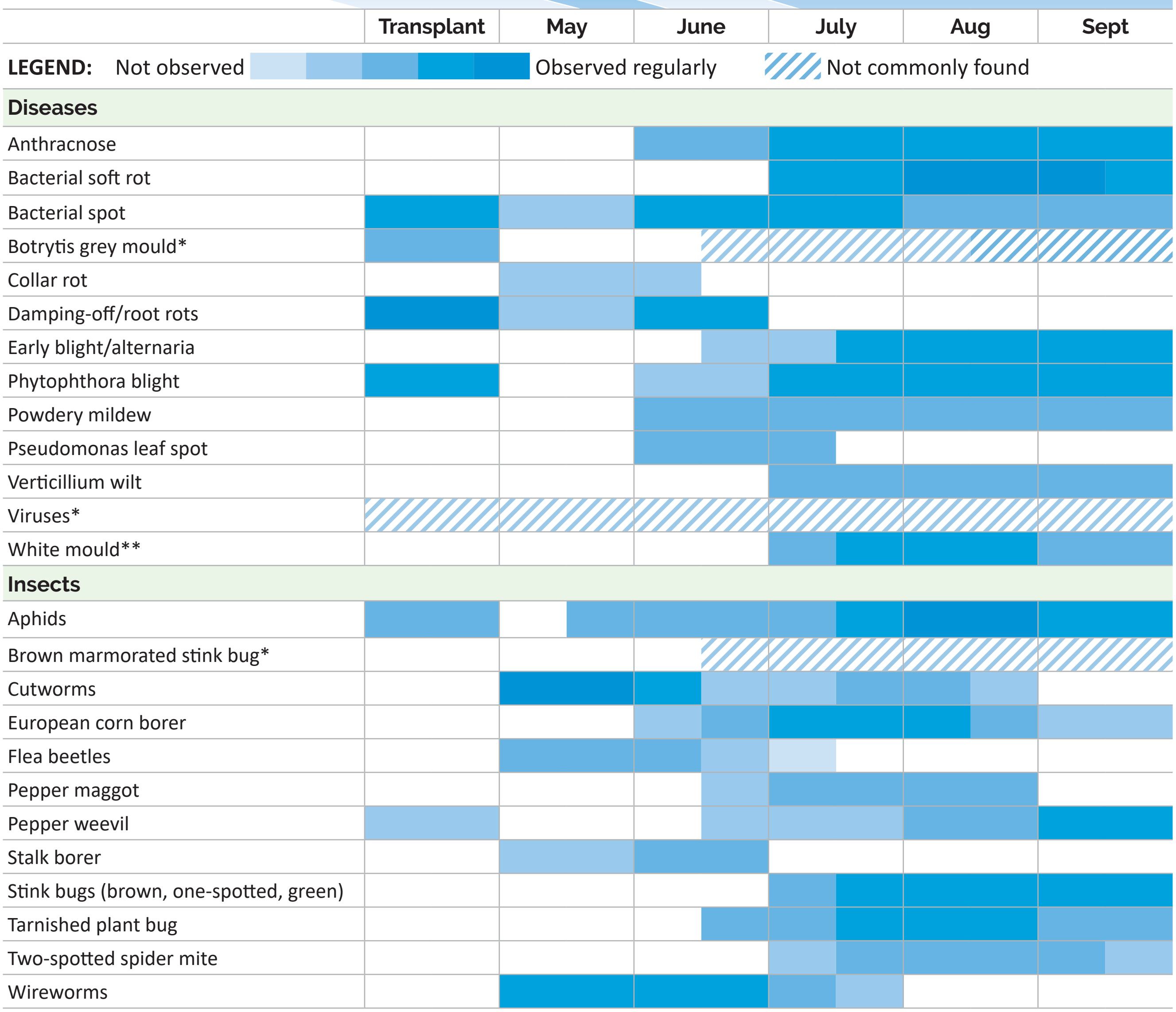
See Chapter 5.

Wireworm
Various species

See Chapter 5.

Peppers





* Not commonly found as a pest in Ontario, however it may be problematic in other jurisdictions.

** Can also cause a collar rot in seedlings and young plants. See Collar Rot.

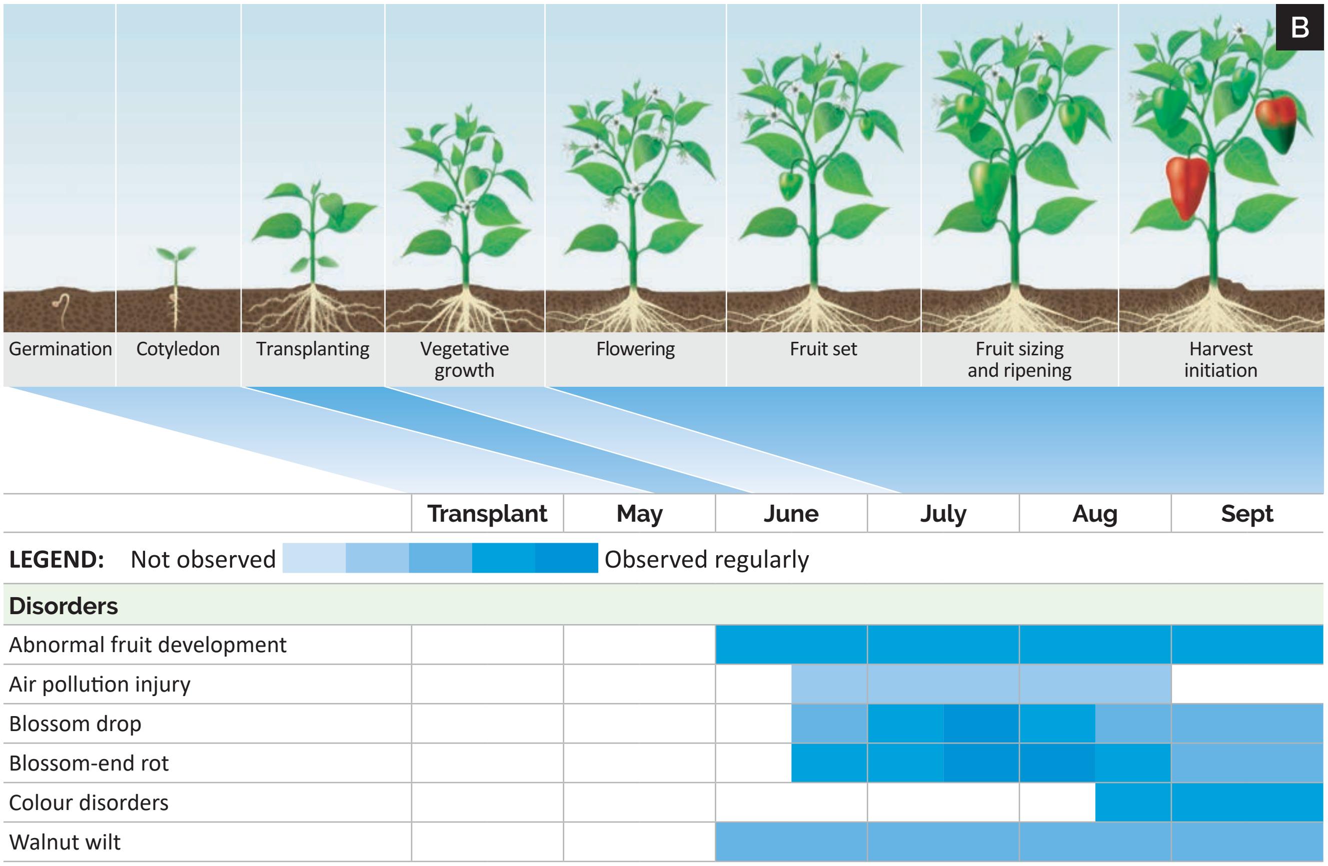


Figure 7–119. Pepper stages of development and pest activity calendar. The actual period of activity for any given pest will vary significantly from year to year, depending on environmental factors.

Pepper Crop Growth

Peppers in Ontario are planted in the field as transplants. Transplants are grown in greenhouses for approximately 8–10 weeks. Seeds germinate 8–10 days after seeding and sprout two initial leaves called cotyledons, which have an elongated oval shape. The next two leaves to grow are called the first true leaves and will have the shape of a traditional pepper leaf. Transplants for the processing industry are typically planted in the field when they reach 5–10 cm (2–4 in.) tall and have 4 or more true leaves. Fresh market transplants are slightly larger, around 10–20 cm (4–8 in.) tall, and usually have 6 or more true leaves prior to planting.

Once transplanted, pepper plants continue the establishment of root systems and vegetative growth, or growth of leaf tissue. Once the first flowers are visible, the plants have entered the flowering stage. The first flower on a pepper plant is called the "king" flower. Flowers are pollinated primarily by insects and, 7–10 days later, small green fruit are visible. The presence of flowers and small green fruit signifies the flowering and fruit set stage. Once the fruit is set, the next stage is sizing, where the fruit are still green but are getting larger. Once the fruit starts to show a slight hint of colour, the fruit has begun to ripen. Harvest is initiated for processing peppers once approximately one-third of the fruit on the plant is the correct colour. Colour at the time of harvest will depend on market demands. Processing peppers are usually picked 2 or 3 times per season. For fresh market peppers, fruit are picked when they have more than 75% colour. Ripe fruit are picked one to two times per week until the temperature drops and the crop is no longer productive.

PEPPERS

Production Requirements

Soil types: wide variety of well-drained mineral soils
Soil pH: 5.5–6.8
Suitable rotational crops: beans, brassica crops, cereal crops, corn, peas, soybeans
Do not rotate with: eggplant, potatoes, tomatoes, cucurbit crops, tobacco
Minimum soil temperature: 16°C (61°F)
Optimum air temperature: 22°C–30°C (72°F–86°F)
Earliest planting date: late May, after risk of frost has passed

Table 7–91. Pepper Transplant Requirements

Seed Required for 10,000 Transplants	Seeding Depth	Germination Temperature[1]			Days to Germination	Optimum Growing Temperature		pH Tolerance	Time (weeks)
		Min.	Opt.	Max.		Day	Night		
198 g (7 oz)	0.6 cm (¼ in.)	18°C (64°F)	29°C (84°F)	35°C (95°F)	8	18°C–24°C (64°F–75°F)	15°C–18°C (59°F–64°F)	5.5–6.8	5–9

[1] Germination may be possible for many vegetables at lower or higher temperatures, but percentage, speed and uniformity of germination will suffer.

Transplant Production

Pepper transplants for early production fields are typically grown in 50- or 72-cell trays. Smaller cell sizes (128 to 200's) are used for the main crop. Plant 200 g (7 oz) of seed to get enough transplants for 1 ha (2½ acres). See Table 7–91.

Pepper transplants are very responsive to fertilizer. If feeding at every watering, use approximately 100 ppm nitrogen. Increase the concentration if feeding less often. See Table 1–14.

Water quality is an important component of transplant production. See Table 1–16, Chapter 1.

Field Spacing

Plant only properly hardened-off, healthy, actively growing transplants. Do not withhold water or fertilizer as a means of hardening-off or storing the plants. Instead, reduce daytime temperatures, increase air flow and, if possible, move the flats to a sheltered location outside for a few days prior to planting. See Table 7–92.

Table 7–92. Pepper Crop Spacing

Crop	Row Spacing	In-Row Spacing
Single Rows		
Early cultivars	100 cm (39 in.)	30 cm (12 in.)
Standard cultivars	100 cm (39 in.)	45 cm (18 in.)
Twin rows[1]	45 cm (18 in.)	45 cm (18 in.)

[1] Grown on 1.5-m (5-ft) bed centres.

Plasticulture

Peppers respond well to plastic mulch, row covers and drip irrigation. However, keep in mind that peppers are very sensitive to low temperatures. Row covers may not provide significant frost protection. Monitor the temperature inside the row cover regularly and ventilate when it reaches 35°C (95°F) or higher. Remove the cover once conditions are favourable for good growth and prior to pollination. To control weed growth under the mulch, choose one that blocks most light transmission, such as black, white on black or infrared-transmitting mulch.

Fertility

Macronutrients

Nitrogen

For peppers grown without fertigation, broadcast and incorporate the required preplant nitrogen, along with the required phosphate and potash, prior to planting. Side-dress the remainder of the nitrogen after first fruit set. See Table 7–93.

For fertigated peppers, broadcast and incorporate the required preplant nitrogen, along with all the required phosphate and half the required potash. Apply equal rates of nitrogen and potash through the drip tape according to the schedule in Table 7–93.

Reduce the nitrogen (N) application if manure is applied or legume crops plowed down. See Table 1–12 and Table 1–13, Chapter 1.

Table 7–93. Pepper Nitrogen Application Schedule

Method	Actual N
Soil-applied	
Preplant	35 kg/ha (31 lb/acre)
Side-dressed	35 kg/ha (31 lb/acre)
Total	**70 kg/ha (62 lb/acre)**
Fertigated	
Preplant (broadcast)	35 kg/ha (31 lb/acre)
Transplanting to fruit set	3–5 kg/ha/week (3.5–4.5 lb/acre/week)
Fruit sizing	7–10 kg/ha/week (6–9 lb/acre/week)
Harvest	3–5 kg/ha (3.5–4.5 lb/acre/week)

Phosphorus and Potassium

Test the soil to determine phosphorus and potassium requirements. See Table 7–94 and Table 7–95.

Table 7–94. Pepper Phosphorus Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Sodium Bicarbonate Phosphorus Soil Test (ppm)													
	0–3	**4–5**	**6–7**	**8–9**	**10–12**	**13–15**	**16–20**	**21–25**	**26–30**	**31–40**	**41–50**	**51–60**	**61–80**	**81+**
Mineral Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	270 (241) (HR)	260 (232) (HR)	250 (223) (HR)	240 (214) (HR)	230 (205) (HR)	220 (196) (HR)	200 (178) (HR)	170 (152) (HR)	140 (125) (MR)	110 (98) (MR)	80 (71) (MR)	50 (45) (LR)	0 (RR)	0 (RR)

Table 7–95. Pepper Potassium Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Ammonium Acetate Potassium Soil Test (ppm)											
	0–15	**16–30**	**31–45**	**46–60**	**61–80**	**81–100**	**101–120**	**121–150**	**151–180**	**181–210**	**211–250**	**251+**
Mineral Soils												
Potash (K_2O) required kg/ha (lb/acre)	270 (241) (HR)	250 (223) (HR)	230 (205) (HR)	200 (178) (HR)	170 (152) (HR)	130 (116) (HR)	100 (89) (MR)	80 (71) (MR)	50 (45) (MR)	0 (LR)	0 (RR)	0 (NR)

Starter Solution

At transplanting, apply a high-phosphorus starter solution. Starter fertilizer is especially important when planting in cool soils. See *Starter Fertilizers for Vegetable Crops*, Chapter 1. Adjust application rates according to the temperatures listed in Table 7–96.

Table 7–96. Pepper Transplant Starter Solution Adjustments

Soil Temperature	Starter Concentration[1]
Below 18°C (64°F)	Use the full rate specified on the label.
18°C–27°C (64°F–81°F)	Use half of the rate specified on the label.
Above 27°C (81°F)	Starter not normally required.

[1] Under dry conditions or in sandy soils with less than 2% organic matter, use half the labeled rates.

Plant Tissue Analysis

When used in conjunction with a soil analysis, plant tissue analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. Plant tissue analysis does not replace soil testing or a sound soil fertility program.

For more information, see Table 7–97 and *Plant Tissue Analysis*, Chapter 1.

Irrigation

Note: You must have a Permit to Take Water issued by the Ministry of the Environment to use more than 50,000 L (13,209 gal) of water in a day from either surface or groundwater sources.

Most vegetable crops require a uniform supply of moisture throughout the growing season. The average rainfall in Ontario is 70 mm/month (2¾ in./month) during the growing season. For most vegetable crops, this provides only 65% of the water needed for optimum yield. Historically, moisture levels are often at their lowest in July and August when the crop water demand is at its highest.

Peppers are usually responsive to irrigation. Common defects caused by moisture stress include blossom drop, blossom end rot, sunscald and reduced fruit size, yield and quality. The critical irrigation period for pepper is during flowering, fruit set and sizing. If the available soil moisture level in the root zone (30–60 cm (1–2 ft) rooting depth) reaches 50% during the critical irrigation period, irrigation could help maintain crop yield and quality. For drip irrigation systems, consider irrigating when the available soil moisture drops below 85%.

Table 7–97. Pepper Nutrient Ranges

LEGEND: – = no data available

Plant Part	Time of Sampling	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu
		Per Cent (%)						Parts Per Million (ppm)				
Most recently mature leaf	prior to blossoming	4–5	0.3–0.5	5–6	0.9–1.5	0.35–0.6	0.3–0.6	30–150	30–100	25–80	20–50	5–10
	first blossom opens	3–5	0.3–0.5	2.5–5	0.9–1.5	0.3–0.5	0.3–0.6					
	early fruit set	2.9–4	0.3–0.4	2.5–4	1–1.5	0.3–0.4	0.3–0.4					
	early harvest	2.5–3	0.2–0.4	2–3	1–1.5	0.3–0.4	0.3–0.4					

Adapted from G Hochmuth, et al. 2018. *Plant Tissue Analysis and Interpretation for Vegetable Crops in Florida*. University of Florida IFAS Extension. HS964.

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There are a number of types of irrigation systems that have been adapted for use in vegetable crops. They include hand-moved sprinklers, travelling gun systems, centre-pivot and lateral systems, and drip (trickle) irrigation. Whichever type of irrigation system is used, it is important to schedule irrigation to avoid drought stress and provide water when it is most needed. Timely application of water will reduce the potential for nutrient loss or disease pressure due to excess water. There are two basic methods of scheduling irrigation: the water budget method and measuring soil moisture.

For more detailed information on irrigation see:

- *Best Management Practices — Water Management*
- *Best Management Practices — Irrigation Management*
- OMAFRA Factsheet, *Monitoring Soil Moisture to Improve Irrigation Decisions*
- OMAFRA Factsheet, *How to Prepare for Irrigation During Water Shortages*

Fertigation

Fertigation is a method of applying water and nutrients through a drip irrigation system. It can be used to increase the yield and quality of many vegetable crops.

Dissolve a stock solution of soluble fertilizer in a tank and introduce it through a valve into the irrigation system, either by suction or pressure. Feed the fertilizer solution through the system slowly. After the fertilizer has passed through the system, continue to irrigate to flush the lines. Do not apply phosphorus through the drip tape. Certain forms of phosphorus will clog the drip emitters. Phosphorous fertilizers encourage the growth of algae in the drip lines. Algae may also cause emitters to plug.

Fertigation applications are usually made weekly. However, depending on the design of the irrigation system, the soil type and time constraints, applications may be made more or less frequently. It is important that the irrigation cycle is run for ample time to adequately flush the system after each fertigation. Avoid over-watering after fertigation. Excess water has the potential to leach the fertilizer below the crop rooting zone. For a weekly fertigation schedule, see Table 7–93.

Harvest

Bell peppers reach maturity within 65–80 days after transplant. Harvest green peppers when the fruits are large and firm with a glossy skin, before they start to ripen. Harvest coloured peppers once full, ripe colour has developed.

Banana peppers reach maturity within 60–80 days after transplant. Harvest green peppers when the fruits have reached full size, before they start to ripen. Harvest coloured peppers once full, ripe colour has developed.

There are a wide variety of specialty peppers with wide ranges in maturity. Typically, maturities are 65–85 days after transplanting. Cultivar and market requirements will determine at what stage of maturity the crop should be harvested.

Peppers are a non-climacteric fruit. They do not produce ethylene after harvest and will not fully ripen off the plant, although they may undergo slight colour changes.

Harvest typically begins by early August and continues until the first frost (October, depending on the region). Growers using season extension techniques may be able to advance harvest and extend harvest beyond these dates. Average yields for processing and fresh market pepper can be found in Table 7–98.

Table 7–98. Average Yields for Ontario Field Peppers

Type	Yield
Processing	22–27 tonnes/ha (10–12 tons/acre)
Fresh market	13–18 tonnes/ha (6–8 tons/acre)

Table 7–99. Pepper Storage Conditions

Crop	Storage Temperature	Relative Humidity	Duration	Chilling Injury Symptoms
Sweet peppers	7°C–13°C (45°F–55°F)	90%–95%	2–3 weeks (green) ~1 week (fully ripe)	water-soaked appearance, darkening flesh, fruit rot
Chilli peppers (dry)	0°C–10°C (32°F–50°F)	60%–70%	6 months	

Storage

After harvest, wash fresh-market peppers in chlorinated water (100–150 ppm chlorine) or another labeled surface disinfectant to eliminate fruit-rotting organisms. Rapid and efficient cooling is the most effective management practice for maintaining the quality and shelf-life of fresh peppers. It is essential that only good quality produce is placed in cold storage. Room cooling and forced-air cooling are the most common methods used for pepper fruit. See Table 7–99.

Room Cooling

Containers of produce are placed into a refrigerated room, and cold air from the evaporator coils slowly cools the product. It takes considerable time to cool produce to acceptable storage temperatures. The cold air does not always penetrate deep within the container. Highly perishable produce may suffer significant quality loss and hence shelf life.

Forced-Air Cooling

Vegetables are placed in a refrigerated room, and cold air is pulled through the containers using high-capacity fans. An effectively designed system allows good contact between the cold air and the produce. Forced-air cooling is not as rapid as hydro-cooling. However, it is adaptable to more types of produce and more flexible for smaller-scale operations. Forced-air cooling should be done quickly so produce does not lose too much moisture.

Vacuum Cooling

This method involves water evaporation at very low atmospheric pressure. Vegetables that have a large surface area-to-volume ratio, such as lettuce and leafy greens, are best suited for vacuum cooling. There is approximately 1% product weight loss (mostly water) for every 6°C (43°F) of cooling, so some coolers are equipped with a water spray system that adds water to the product surface during cooling. Capital equipment costs are high, so vacuum cooling is suited primarily to large operations.

Pest Management and Disorders

See Figure 7–119, *Pepper stages of development and pest activity calendar.*

Diseases

Alternaria Fruit Rot
Alternaria solani

Alternaria is not an important pathogen of field pepper and generally only infects fruit that has been wounded or damaged (i.e., by blossom-end rot or sunscald).

Anthracnose
Colletotrichum coccodes, *C. gloeosporioides*, *C. dematium*, *C. acutatum*, *C. scovellei*

Identification: Leaf lesions are inconspicuous. Fruit symptoms on tomato, pepper and eggplant appear as small, sunken, water-soaked, circular spots. Lesions gradually expand to 20 mm (¾ in.) in diameter, developing a pattern of concentric rings. The lesions darken, and small black fungal structures appear in the centre (Figure 7–120). Advanced lesions can begin to produce salmon-coloured spores as well.

Biology: Anthracnose overwinters in infected plant debris. It can also survive in the soil for a short time. Many common weeds and some crops are symptomless hosts. Anthracnose is also seed-borne. Once leaf or fruit lesions are present, they act as inoculum for more infections.

Infections take place under a wide range of temperatures from 10°C–30°C (50°F–86°F). Rapid development occurs during periods of prolonged leaf wetness. In pepper, both immature and mature fruit can develop symptoms.

Figure 7–120. Anthracnose lesion on bell pepper fruit.

Management Notes: Follow a minimum 3-year rotation with non-solanaceous crops. Control weeds that act as hosts. Use disease-free or treated seed.

Fungicide programs must begin before fruit infection occurs — well before the onset of symptoms. Where available, use the TOMcast program for scheduling fungicide applications (see *Disease Prediction Models*, Chapter 4). Properly timed fungicide sprays are effective at reducing losses to this disease.

If TOMcast is unavailable, begin a preventive spray program when the first fruits are about pea size. Repeat at 5–7-day intervals during continuous moist weather. Extend the schedule to 10–12 days in warm, dry weather when disease pressure is low. Applications should continue until close to harvest as anthracnose lesions can appear on unprotected fruit within 5–6 days, in favourable conditions.

Bacterial soft rot

Pectobacterium carotovorum **subsp.** ***carotovorum***
(formerly known as ***Erwinia carotovora*****)**

Identification: Sunken water-soaked lesions develop around damaged areas on the pepper fruit. The water-soaked areas expand rapidly. Bacterial ooze may develop, and secondary organisms may invade. The entire fruit may deteriorate to a watery soft slimy mass that is kept intact by the thin outer skin (Figure 7–121).

Infection may begin without previous damage, possibly due to moisture entering the fruit under the calyx or stem. However, pepper infection is most often associated with insect damage.

Figure 7–121. Bacterial soft rot on banana pepper fruit.

Biology: Bacterial soft rot causes serious losses in the field, in transit and in storage. Insect damage, mechanical damage or hail predispose plants to soft-rot infection. Soft rot spreads rapidly in warm, humid conditions. It is spread by direct contact, hands, tools, soil, insects and splashing rain or irrigation.

The soft rot bacteria overwinter in infected tissues in the soil, and on contaminated equipment and containers. They also overwinter in insects such as the seedcorn maggot.

Warm, moist weather is favourable for infection by the bacterial soft rot pathogens.

Management Notes: Plant into well-drained soils and maximize air flow through the plant canopy. Once the disease is identified in a field, avoid overhead irrigation. Rotate with less-susceptible crops (cereals or corn) and control chewing insects. Excess nitrogen may promote soft rot infections.

Post-harvest infections may occur if water used during post-harvest operations is not treated to kill pathogens, especially if the fruit imbibe the water. In dump-tanks, maintain water temperature at 5°C (42°F) above fruit temperature and do not immerse fruit for more than 3 minutes to reduce the risk of water entering the fruit. Dry stem scars are more resistant to water imbibition post-harvest. Fruit harvested in wet conditions have a higher risk of post-harvest infection.

Bacterial Spot

Xanthomonas euvesicatoria, *Xanthomonas perforans*, *Xanthomonas gardneri*, *Xanthomonas vesicatoria*

Identification: The bacterial spot pathogen may produce lesions on all above-ground parts of the plant: leaves, stems, flowers and fruit.

On peppers, foliar symptoms are variable. Initial leaf symptoms are small, circular to irregular, water-soaked or greenish lesions. Occasionally a yellow halo is present around a lesion, but often general leaf yellowing occurs. The spots darken and may increase in diameter up to 5 mm (¼ in.). Foliar lesions often show a pale, tan central area, which may become a hole in the leaf. When spots are numerous, leaves develop a ragged appearance or may turn yellow and drop off. Fruit symptoms are similar to those described for tomatoes.

Biology: Sources of infection and methods of spread are similar to pseudomonas leaf spot (see *Pseudomonas Leaf Spot (Bacterial Speck)*, also in *Peppers*).

Bacterial spot thrives under warm temperatures of 24°C–30°C (75°F–86°F). Abundant rainfall and high humidity aid infection. The time for concern is from transplanting through to early flowering and fruit set.

Management Notes: All seed should be disinfected by the supplier, using acid or chlorine treatment. Do not plant diseased transplants. Bacterial spot populations in Ontario have shown some resistance to copper. Some pepper cultivars have resistance to one or more races of bacterial spot.

Botrytis Grey Mould

Botrytis cinerea

Identification: Grey mould are ghost spots on the fruit. Ghost spots show a pale halo or ring with a brown to black pinpoint spot in the centre. Fruit rotting occasionally occurs. A grey, velvety covering of spores may also appear on leaves, stems, dying flowers or fruit. Infection appears first on leaves in contact with soil, damaged leaves or flowers. Infection on stems may girdle the plant.

This pathogen also affects transplants (see *Damping-Off*, Chapter 6).

Biology: The pathogen responsible for grey mould has a wide host range. It is spread by wind and also grows on organic matter in or on the soil. It generally needs a wound or dead tissue in order to begin an infection into live tissue.

Periods of prolonged high humidity and cool weather (18°C–24°C (64°F–75°F)) promote grey mould activity.

Management Notes: In peppers, this disease is sporadic, and control measures are rarely required. Some registered fungicides have activity on this pathogen, but it can be difficult to get adequate coverage of the lower leaves, where infection first occurs.

Follow a good crop rotation with cereals and other non-host crops.

Collar Rot

See Chapter 6.

Damping Off and Root Rots

See Chapter 6.

Early Blight/Alternaria

See *Tomatoes*, in this chapter.

Figure 7–122. *Phythophthora capsici* fruit rot symptoms on pepper fruit.

Phytophthora Blight

Phytophthora capsici

Identification: Depending on the time of infection, phytophthora symptoms include crown rot, foliar blight, fruit rot and stunting (Figure 7–122).

In peppers, stem lesions are first dark green and water-soaked, later becoming dry and purplish-brown. A brown discolouration of the vascular tissue can be seen if the main stem is cut open. Typically, the part of the plant above the affected area wilts. Irregular water-soaked lesions may appear on the leaves, later drying to a tan or bleached appearance.

Infected fruit develop water-soaked patches that shrivel and darken. A white-to-greyish mould may appear on the lesion or inside the fruit. Fruit typically shrivel but remain attached to the plant. Fruit symptoms do not always occur on infected plants.

Biology: Phytophthora survives between crops as a thick-walled oospore in the soil or as mycelium on crop residue. The oospores can survive in the soil for 5–10 years. Under intensive solanaceous and cucurbit production systems with short crop rotations, the levels of inoculum build up over time, potentially becoming a significant production problem.

Spores are spread long distances by air and splashing water. Under saturated conditions, zoospores are released. They are mobile and can move on the plant surface when moisture is present and in the soil water. They are also attracted towards the root exudates of host crops. Phytophthora problems often follow field drainage patterns. They are most likely to occur in low-lying or poorly drained areas of the field. Irrigation water may also be a source of zoospores.

Phytophthora spreads rapidly during warm, wet weather. Ideal conditions for infection are moist soils above 18°C (64°F) and air temperatures of 24°C–29°C (75°F–84°F).

Management Notes: Phytophthora issues are becoming more common in certain areas of Ontario. Once established in a field, phytophthora is extremely difficult to control. Prevention is critically important.

Rotate fields for a minimum of 3 years away from all host crops. Do not plant peppers or cucurbits in a field that has a history of phytophthora infections. Select well-drained fields. Where drainage problems do exist, use a grassed waterway to divert surface water away from the crop.

Plant resistant cultivars if possible. Some pepper cultivars have tolerance to foliar or root infections.

Minimize soil compaction and avoid excessive irrigation, especially in overhead systems. Always clean farm equipment if travelling between infected and non-infected fields.

Raised beds and the use of plastic mulch significantly reduce *Phytophthora capsici* infections. Beds must be dome-shaped, to prevent water collecting at the base of the plant. Ensure that the planter does not leave a depression at the base of the plants.

Powdery Mildew

Leveillula taurica

Unlike other vegetable crops, powdery mildew is usually found on the underside of pepper leaves and only a slight yellow blotch can be seen on the upper surface. Symptoms are usually found on lower, older leaves first. See Chapter 6 for more information.

Pseudomonas Leaf Spot (Bacterial Speck)
Pseudomonas syringae

Identification: This bacterial pathogen causes severe spots and yellowing on pepper foliage. Little information is available about this disease, but it has not been known to cause fruit lesions or have an economic impact. Although symptoms can initially look very severe, once conditions become less favourable for the pathogen, new growth is unaffected.

Biology: Pseudomonas leaf spot develops most rapidly at temperatures of 16°C–24°C (61°F–75°F) and high humidity. Leaf wetness encourages disease development.

Scouting and Thresholds: If dark, necrotic lesions and yellowing are seen on foliage, check for fruit lesions. *Pseudomonas syringae* is not known to cause fruit lesions on pepper, while *Xanthomonas* spp. (the bacterial spot pathogen) may cause scabby fruit lesions.

Laboratory diagnosis may be necessary to distinguish this disease from bacterial spot. *Xanthomonas* spp. prefers warmer temperatures than *Pseudomonas syringae*.

Verticillium Wilt
Verticillium albo-atrum, *V. dahliae*

Identification: Wilting initially occurs, and plants become stunted. Wilted plants may recover at night, or when moisture is plentiful. Lower leaves turn yellow and drop off as the disease progresses. Eventually necrotic areas develop, starting at the leaf tips and edges, progressing to leaf drop. A darkening of the vascular tissue may be observed if the stem is split lengthwise near the soil line.

Biology: The fungal inoculum survives in the soil and on debris from host plants. Weed species such as ragweed, lamb's-quarters, pigweed, velvetleaf and solanaceous weeds are also hosts.

Symptoms are often more severe after fruit set or during dry periods. The presence of plant parasitic nematodes may increase the severity of the disease.

Management Notes: Follow a 4–6-year crop rotation. Do not rotate with other host crops. Cereals and grasses are non-hosts. Keep fields clean of host weeds, such as nightshades.

Take soil samples to test for verticillium and nematodes. Soil fumigation may be required if verticillium and nematode counts are high. The best times to sample are in May to June and September to October. Try to sample at the same time of year each time, using the same laboratory, so that you can compare the counts from year to year. Counts will be lower in the spring than in the fall. The established thresholds are based on spring sampling.

White Mould
Sclerotinia sclerotiorum

Identification: In peppers, bleached stems is the first sign of white mould. When the stem is cut lengthwise, white fungal growth can be seen inside along with hard, black sclerotia. Fluffy white fungal growth can be seen in advanced stages on the outside of the stem (Figure 7–123).

Figure 7–123. Stem bleaching and white fungal growth caused by white mould on pepper.

Biology: White mould overwinters in the soil as small, black sclerotia. Temperatures ranging from 20°C–25°C (68°F–77°F) and continuous leaf wetness (high humidity and/or heavy dews) favour sclerotinia white mould development. Overwintering sclerotia may survive for several years in the soil.

Management Notes: In peppers, this disease may be seen in very wet seasons but is not usually a serious concern. Practice a 3–4-year crop rotation away from susceptible host plants. Avoid applying high rates of nitrogen fertilizer. Excess nitrogen promotes an exceptionally dense crop canopy, resulting in restricted air movement and more favourable disease development conditions.

Insects

Aphids

Aphididae family

Aphids are a common pest in many crops and are often found feeding on young leaves. Feeding damage can cause leaf distortion and the production of sticky honeydew from aphids promotes the growth of sooty mould on leaves. There is no established threshold for peppers, but more than 10 aphids per leaf could be potentially damaging. See Chapter 5 for more information.

Brown Marmorated Stink Bug

Halyomorpha halys

Brown marmorated stink bug (BMSB) is a new pest to Ontario. It has the potential to damage a wide variety of agricultural crops but has not yet caused economic damage to peppers. For more information on BMSB, see Chapter 5.

Cutworms (Early-Season)

Agrostis ipsilon (black cutworm)

Black cutworms are the most common cutworm observed in peppers and are an early-season pest that can severely affect transplants. Transplants appear as if they were cut off at the soil surface with scissors. See Chapter 5 for more information.

European Chafer

Amphimallon majale

See Chapter 6.

European Corn Borer

Ostrinia nubilalis

Identification: Adults are a light-brownish coloured moth, with patterns of wavy lines on the wings. The eggs are shiny, white and laid in clusters of 30 that resemble fish scales. Full-grown corn borer larvae are 2.5 cm (1 in.) in length. They are greasy white in colour, with a dark head and spots on each segment (Figure 7–124).

Figure 7–124. European corn borer larva inside of pepper fruit.

Damage: In peppers, the larvae are the damaging life stage and enter the fruit under the calyx (stem cap). The larvae develop inside the fruit, feeding on the seeds. Pepper fruit are susceptible to damage by European corn borer once fruit reach about 1.5–3 cm (½–1¼ in.) in diameter. Infested peppers are more prone to fungal diseases and bacterial soft rot. Prior to fruit set, larvae may tunnel into pepper stems, but this is not usually economically significant.

European corn borer larvae produce yellowish-brown sawdust-like droppings known as frass. Frass may or may not present at the entry hole near the stem-end of pepper fruit.

Biology: Borers overwinter as mature larvae in corn stubble. Southwestern Ontario experiences two generations per year (bivoltine). Usually, the first-generation adults emerge in mid-June, and the population peaks in mid-July. Second-generation populations peak in August. In unusually warm years, the bivoltine strain can go on to produce a partial third generation.

In the rest of the province, single-generation (univoltine) corn borers usually emerge in late June or early July. Populations peak in late July to early August.

Many areas within Southwestern Ontario (Lambton, Middlesex, Oxford, Brant, Norfolk and Niagara) have an overlap of the bivoltine and univoltine corn borer populations. These areas experience a sustained peak flight for much of July and August.

Growing degree days is another method of predicting corn borer development. Using GDDs, base 10, the developmental stages are shown in Table 7–100.

Table 7–100. Degree Day Forecasting for European Corn Borer with a Base of 10

Event	Univoltine	Bivoltine First Generation	Bivoltine Second Generation
First catch	300	150	700
Peak catch	650–700	300–350	1,050–1,100

Scouting and Thresholds: It is very difficult to find signs of European corn borer in peppers by scouting. The only reliable way to detect European corn borer activity in pepper is by using monitoring traps.

Monitor adult populations using black-light traps or pheromone traps. Set up traps in unmowed grassy areas near the edge of the field. Use either heliothis traps or sticky traps (wing or milk carton models are often used). In Ontario, corn borers are attracted to the Iowa strain of pheromone lure (Z strain). Check traps twice a week and replace lures weekly.

Management Notes: There is no tolerance for this pest in peppers. Monitor populations using pheromone traps and apply insecticides soon after flowering as the young fruit begin to develop. Pepper crops need to be protected from European corn borer whenever moths are flying and pepper fruit are present. The second generation attacks peppers.

European Pepper Moth
Duponchelia fovealis

Identification: Adults are 12 mm (½ in.) long, grey with two yellowish-white lines, the outermost of which has a pronounced “finger” that points towards the back edge of the wing. The abdomen curves upwards at rest. Larvae are cream to brown coloured, 20–30 mm (¾–1¼ in.) long when fully developed, and often spin webbing in and around the base of plants. The larvae spin a cocoon in which to pupate, incorporating bits of soil and other debris, which makes them difficult to detect.

Damage: Feeding by larvae may cause damage to leaves or stems. The larvae prefer highly organic soils or growing media used in greenhouses and do poorly in mineral soils. They are unlikely to cause crop damage in the field but may pose a risk to greenhouse vegetables such as peppers grown for fruit or transplant production.

Biology: European pepper moth (EPM) is an introduced pest. It is not able to survive Ontario winters. In northern climates, it is mainly a pest of greenhouse crops, although it may be found outside during the summer months.

Scouting and Thresholds: Pheromone traps are available for monitoring adults. In greenhouses with a resident population of EPM, check transplants for the presence of larvae. There are no thresholds available.

Management: Apply a registered insecticide to pepper and tomato transplants in the greenhouse to prevent feeding damage.

Flea Beetles
Phyllotreta sp.

Flea beetles are very small (2–3 mm (⅛ in.) long), shiny black beetles. Adults are active and jump when disturbed.

Flea beetle species, including potato flea beetle (*Epitrix cucumeris*) and possibly palestriped flea beetle (*Systena blanda*) and spinach flea beetle (*Disonycha xanthomelas*), occasionally damage pepper crops. Small plants in less-than-ideal growing conditions are more likely to be affected by flea beetle feeding. Most plants are often able to recover from early feeding damage, which does not result in economic losses. See Chapter 5 for more information.

Pepper Maggot
Zonosemata electa

Identification: Identification of this pest will primarily be through observing the damage on the fruit. The larvae are whitish maggots, 12 mm (½ in.) or less in length (Figure 7–125). The adult is similar in size to a house fly. Wings are clear with distinct black markings. Three yellow stripes run along its back. If trapping for adults, note that many other fly species that are attracted to ammonia bait have a similar appearance (e.g., apple maggot, walnut husk fly).

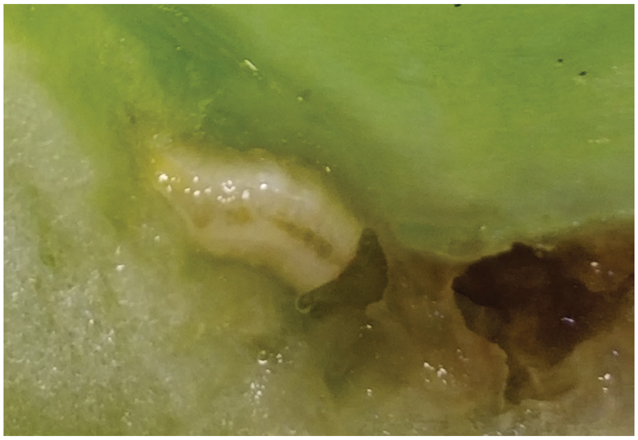


Figure 7–125. Pepper maggot larvae inside of pepper fruit.

Damage: The first signs of damage are small punctures on the surface of the pepper fruit, caused by the female laying eggs in the fruit wall. As the fruit grows, a dimple develops at the site. Larvae emerge directly into the fruit and feed mostly in the placenta or core of the pepper. Mature larvae exit the side of the fruit to pupate in the soil. Damaged fruit begins to rot, but the maggot has often left the fruit by this time.

Biology: The insect is a sporadic pest in Southwestern Ontario, but its range may extend east into the Niagara Peninsula. The insect overwinters in the pupal stage. Adult emergence depends on soil temperatures but is typically in late June. Eggs are laid soon after emergence and hatch in 8–10 days. Maggots feed in the fruit for 2–3 weeks. There is only one generation per year.

Scouting and Thresholds: With careful scouting, the egg-laying scars may be found, but it is too late to treat at this stage. Yellow sticky cards with ammonia lures can be used to monitor for adults. These need to be placed in nearby trees, ideally 6.5 m (21 ft) high in the canopy of maple trees. A number of similar fly species are also attracted to this lure, so traps need to be inspected closely to confirm the presence of pepper maggot adults. Visual assessments or sweep nets may be useful for monitoring as well. There is no tolerance for maggots in pepper fruit.

Management Notes: Some insecticides used for European corn borer do not control pepper maggot. Insecticides with pepper maggot activity need to be included in the spray program if pepper maggot adults are present. If monitoring indicates the presence of adults, treat the crop when the first flies are found and reapply at 5–8-day intervals if flies continue to be detected. If monitoring data is unavailable, but there is a history of damage, pepper maggot insecticides may need to be included in the spray program in late June and early July. Pepper maggots prefer hot cherry peppers and these have been used successfully as perimeter trap crops in some areas. The pest also prefers fleshy, blocky fruit over thin-walled, slender fruit. Horse nettle, an alternative host plant, should be controlled near pepper fields.

Pepper Weevil
Anthonomus eugenii

Identification: It is very difficult to distinguish pepper weevil from similar non-pest species (Figure 7–126). Weevils found in field peppers should be collected and submitted to OMAFRA horticultural staff for identification.

Damage: This pest does not overwinter in Ontario fields (it requires living hosts year round), so its presence is of concern to field pepper growers only if it escapes a greenhouse/packing shed or is present on waste plant material transported from these operations during the field growing season.

Adults feed on fruit and flowers but will feed on stems and leaves prior to flowering. Larvae presence in the fruit is of greatest concern and leads to premature fruit drop due to internal feeding.

Figure 7–126. Pepper weevil adult on pepper plant (A), pepper weevil larvae inside pepper fruit (B).

Biology: Adult pepper weevil lay eggs in the wall of the pepper fruit but can also lay eggs on flowers and buds. Once the egg hatches, the larva moves directly into the fruit, making detection difficult and protecting it from insecticide applications. Once the larva completes feeding and development, it pupates inside the pepper and an adult emerges by chewing a hole through the skin of the fruit. The pest can complete several generations during the growing season. Host plants include pepper, nightshade and eggplant. It will also feed on tomato, petunia, horsenettle and other solanaceous weeds. It cannot overwinter outdoors in Ontario.

Scouting and Thresholds: If pepper weevil is suspected to be in the area, pheromone traps can help monitoring for the pest. A partial list of pest monitoring equipment suppliers can be found on OMAFRA's website at ontario.ca/tn30. The pheromone lures and yellow sticky cards are required (available as a kit from Trécé suppliers). These traps can be used both in the field and in the transplant greenhouse. Pepper weevil damage to transplants is not a concern, but adults could be moved to the field when plants are shipped. In the field, two traps should be used per acre. Traps should be placed either on the downwind side of the field or on the side from which weevils are expected to enter (e.g., from a site where they have been found, cull piles, patches of solanaceous weeds). Traps should be placed 3–4 rows into the field to intercept adults as they enter the field. Replace lures every 2–4 weeks. Install traps before bloom and replace sticky cards every 2 weeks or as needed if dirt or insects build up.

When field scouting, inspect flower bud clusters for damage and the plants for the presence of adults. Fallen fruit can be cut open to look for larvae.

Management Notes: The greenhouse industry has implemented a monitoring/management protocol for pepper weevil to protect their crops and nearby field crops. Contact the Ontario Greenhouse Vegetable Growers at 519-326-2604 or 1-800-265-6926 or admin@ontariogreenhouse.com for more information.

Slugs

Arion, *Deroceras*, *Helix* and *Limax* species

Slugs are soft-bodied, legless, grey molluscs that have variations in colour from dark brown and black to light grey. In Ontario, slugs range in size from 0.5–10 cm (¼–4 in.) in length, depending on the species, and have a slimy covering to prevent them from drying out. Slugs have rasping mouth-parts and will create ragged holes on the lower leaves. See Chapter 6.

Stalk Borer

Papaipema nebris

Identification: Only the larval stage causes significant damage in peppers. Young larvae are brownish-purple with three white strips running down the body. A large purplish "saddle" is present on the front half of the body. Older larvae are uniformly grey. They move in a looping manner when disturbed. They are often referred to as "common stalk borer."

Damage: The stalk borer attacks over 100 species of plants. In Ontario, damage from the larvae has been seen in pepper and tomato. Larvae tunnel into the stems of host plants, leading to wilting or breakage of stem and are most likely seen near field edges.

Biology: The pest overwinters in the egg stage, with larvae emerging in May and June. The larval stage lasts about 9–12 weeks.

Scouting and Thresholds: Inspect the stem of wilted or broken plants for entry holes. Cut open the stem to look for evidence of tunnelling or to find the larvae, if it is still present. European corn borer may also enter pepper stems, so it is important to be able to distinguish between the two larvae.

Management Notes: Damage is usually confined to field edges near grassy borders or grassy weed patches and is unlikely to warrant treatment. Insecticides are not effective once larvae have entered the stem.

Stink Bug (Brown, One-Spotted, Green)

Euchistus servus (brown stink bug)
Euchistus variolarius (one-spotted stink bug)
Chinavia hilaris (green stink bug)

Identification: Green stink bugs are bright green with a narrow yellow-to-orange border at the edge of the "shield." Adults reach 12–19 mm (½–¾ in.) long. Brown stink bugs are brownish with a pale underside and reach about 12 mm (½ in.) in length. One-spotted stink bugs resemble the brown stink bug, but males have a single dark spot on the underside. Stink bug nymphs are smaller and more rounded than adults and are wingless. Depending on species, they may be a different colour than the adult.

Some stink bugs feed on insect pests and are beneficial. Plant feeding (pest) stink bugs can be distinguished from predatory (beneficial) stink bugs by their proboscis (mouthparts). Predatory stink bugs have a wide proboscis for attacking other insects, while plant-feeding species have a narrow, needle-like proboscis for probing plants.

Damage: Stink bug adults and nymphs feed on pepper fruit, causing cloudy yellow blotches just under the skin of the fruit.

Biology: These stink bugs overwinter as adults, emerging early in the spring. They may have one or two generations per year, depending on species and location. Stink bugs often move into tomatoes or peppers from wheat fields or weedy areas as they dry out in mid-summer.

Scouting and Thresholds: Inspect pepper fruit for damage. Search for the pest (adult and nymphs) in the lower parts of the plant and on the soil under the plant. Shake the foliage onto a tray or sheet. Damage often occurs along field edges.

Management Notes: For fresh market and whole processing peppers, insecticide treatment may be required to maintain fruit marketability. Stink bug damage is not a major concern for processing peppers destined for slicing. Trap crops have been used in some areas to reduce damage, but this method has not been tested in Ontario.

Tarnished Plant Bug

Lygus lineolaris

Identification: Nymphs are greenish in colour, with well-developed legs and moderately long antennae. Late instars have wing pads and four black spots on the thorax, behind the head, as well as one on the abdomen. Adults are pale green or yellow-to-dark brown, with dark markings and have a small triangle shape on their back.

Damage: Tarnished plant bugs (TPBs) have sucking mouthparts that they use to pierce into plant tissue and inject saliva that helps break down plant tissue. In many cases, damage from the TPBs is seen before the insect itself, thus, recognition of the damage symptoms is very important. TPBs cause stings and blemishes on pepper fruit with corky tissue underneath, similar to stink bug damage.

Biology: TPBs overwinter as adults in plant debris and leaf litter in protected areas such as woodlots, fence rows and ditches. Emerging adults feed and oviposit on broadleaf weeds in the spring, before moving into crops. TPB is a sporadic pest, present in Ontario throughout the growing season. Two generations occur per year, with a partial third in parts of Southern Ontario. First-generation adults emerge in July and second-generation in August and September.

Scouting and Thresholds: Check the growing points of pepper plants and ripening fruit for feeding damage. There is no threshold established for TPB in peppers.

Management Notes: TPBs breed on many common weed species, including pigweed, chickweed, dandelion, lamb's-quarters, ragweed and fleabane. Weed control in and around vegetable plantings will help reduce potential infestations. Alfalfa is also a very attractive host. After the alfalfa is cut, TPB adults may disperse and invade nearby vegetable crops.

Two-Spotted Spider Mite

See Chapter 5.

Wireworm

Limonius spp.

Wireworms are an early-season pest that can affect pepper transplants by feeding on stems at the soil line and/or burrowing into the stem. This can cause entire transplants to die. Larvae are smooth and copper coloured. See Chapter 5, for more information.

Disorders

Abnormal Fruit Development

Peppers that are exposed to high temperatures (32°C (90°F) day, 21°C (70°F) night) for several days while flower buds are forming can develop blocky fruit with extra segments (locules). Exposure to cool conditions (15°C (59°F) day, 5°C (41°F) night) during flowering may result in abnormally flattened, seedless peppers that may be pointed at the blossom end.

Colour development in peppers is affected by extreme temperatures during fruiting. The ideal temperature for red pigment development in pepper is 18°C–24°C (64°F–75°F). Above this range, more yellow colour develops. Below 13°C (55°F), colour development stops (Figure 7–127).

Figure 7–127. Flat pepper fruit caused by cool temperature conditions during pollination.

Air Pollution Injury

Air pollution injury may be confused with symptoms of disease, insect feeding, nutrient deficiencies or toxicities, herbicide injury or damage caused by weather extremes. Plant damage caused by air pollution is usually most severe during warm, clear, calm, humid weather, when barometric pressure is high, as these conditions can cause an air inversion. During an air inversion, warm air above the earth's surface traps cooler air at ground level, allowing pollutants to accumulate. Injury may also be more severe during foggy conditions, heavy dews or in fields near very busy highways. Causes of air pollution injury include: ozone, sulfur dioxide, peroxyacetyl nitrate (PAN) and ethylene.

Ozone: Ozone is the main pollutant in the oxidant smog complex. Levels vary significantly throughout the growing season, as evidenced by alerts of smog days in Ontario. Peppers are not usually sensitive to ozone.

Sulfur dioxide: Different plant species, cultivars and even individual plants may vary considerably in their sensitivity to sulfur dioxide. Variations occur because of the differences in location, climate, stage of growth and maturation. Peppers are not usually sensitive to sulfur dioxide.

Peroxyacetyl nitrate (PAN): Peppers are commonly affected by PAN. This pollutant typically causes a gradual glazing or silvering effect in bands or blotches, which may advance to bronzing within 2–3 days. Small plants and recently matured leaves (about 5 days after leaf emergence) are most susceptible to PAN injury.

Ethylene: Ethylene is present in exhaust gases from furnaces or heaters that burn fossil fuel or wood, used to heat transplant greenhouses or high tunnels. Ethylene influences plant tissue growth and development. Exhaust gases in a greenhouse or tunnel structure can cause damage to sensitive crops, such as tomatoes. Plants exposed to ethylene may exhibit twisting and curling, deformed foliage, defoliation and blossom drop.

Blossom Drop

Blossom drop and poor fruit set can occur at daytime temperatures above 30°C–32°C (86°F–90°F) or below 15°C (59°F). Nighttime temperatures above 21°C (70°F) or below 15°C (59°F) may also reduce fruit set. Blossom drop in peppers can also be caused by moisture stress, excessive nitrogen or tarnished plant bug feeding. Some cultivars may be more susceptible than others.

Blossom-End Rot

A small water-soaked or light brown area appears around the blossom-end or side of immature or maturing fruit. Lesions darken and enlarge rapidly, becoming sunken and black. They may affect over half the fruit. Fungal or bacterial pathogens may invade the lesion, causing it to look diseased (Figure 7–128).

Figure 7–128. Blossom-end rot on banana pepper fruit.

Blossom-end rot is thought to be triggered by a localized calcium deficiency in the blossom end of the fruit, generally associated with interruptions in water supply to the fruit, not by a deficiency of calcium in the soil. Research has shown, however, that other factors may be involved, including:

- high temperatures and intense sunlight, especially following cooler, overcast weather
- high ammonium-nitrogen levels in the soil
- susceptible cultivars
- stress occurring during periods of rapid fruit growth
- potassium/calcium ratios in the fruit
- high nitrogen fertilization
- fluctuations in levels of various growth hormones in the plant

Side-dressing with calcium nitrate or foliar sprays of calcium has not proven to be effective. Avoid deep cultivation, which can prune roots and cause plant stress. Choose less susceptible cultivars and properly schedule irrigation, ensuring steady movement of water and calcium into the plant.

Colour Disorders

Purple Striping: Purple pigments may develop under cool growing conditions, causing green fruit to exhibit purple striping.

Silvering: Silvering is caused by a separation of the outer epidermal cells of the pepper fruit. Certain cultivars seem to be more susceptible to silvering. The cause is unknown, but environmental conditions may be a factor. Nitrogen fertility seems to have no impact on silvering.

Stip or colour spotting: This is a physiological disorder resulting in small (<7mm (¾ in.) diameter), dark spots on the pepper fruit. The exact causes are unknown, but it is usually associated with cool temperatures. Low calcium or excessive nitrogen and potassium may be involved. Cultivars differ in susceptibility.

Cracking and Check

Fruit cracking appears as cracks at the stem end that spread out in a radial or concentric pattern. Depending on the cultivar, the cracks can appear from the mature green to the ripe stage of maturity. Cultivars vary in susceptibility. Fruit cracking may be

PEPPERS

caused by alterations in growth rate or fluctuations in moisture or temperature.

Rain check appears as tiny concentric cracks or russetting on the upper shoulder of the fruit. These may coalesce into larger cracks. The affected area feels rough, can become leathery and will not ripen properly. Rain check is less of a problem in cultivars with good canopy cover, protecting the fruit from rain and dews. Where the plant is covered, as in a high tunnel, rain check is greatly reduced.

Lightning Injury

A circular patch of affected plants (generally 3–20 m (10–66 ft) in diameter) suddenly appears in the field. Plants toward the outer edge may show less damage.

In most vegetable crops, leaves at the ends of branches will begin to droop, followed by wilting, and in severe cases, death of the plant. One side of the stem may be caved in, like a furrow, down its length. If the stem is cut, it will appear hollow, or have a ladder-like arrangement of tissue.

Sunscald

Sunscald may affect leaves, stems and fruit. Fruit that is suddenly exposed to the sun, due to defoliation, especially under high temperatures and humidity, can develop sunscald. Affected areas are sunken and light brown to white. The fruit can then be invaded by secondary organisms, causing fruit rot. Similar fruit symptoms may also occur in cucumber crops if the crop canopy has been thinned due to disease.

Figure 7–129. Moderate sunscald on bell pepper fruit.

In pepper, sunscald can resemble blossom-end rot lesions on the side of the fruit. Note the location of the damage and determine whether the site of the lesion has sun exposure.

Production practices that ensure adequate foliage cover over the fruit (irrigation, choice of cultivar, appropriate fertilization) will help reduce fruit damage due to sunscald. Prevent defoliation, which may occur due to disease, excessive heat, insect feeding or (in processing tomatoes) Ethrel use.

Walnut Wilt

Walnut wilt can occur if a crop is planted within 12–15 m (39–49 ft) of walnut trees or in soil from which walnut trees have been removed within the last several years. The plants wilt and die; other susceptible plants in the immediate area may be affected.

Wind Damage — also known as Sandblasting, Wind Whipping, Desiccation

Wind damage occurs in several different forms, including sandblasting, wind whipping and desiccation.

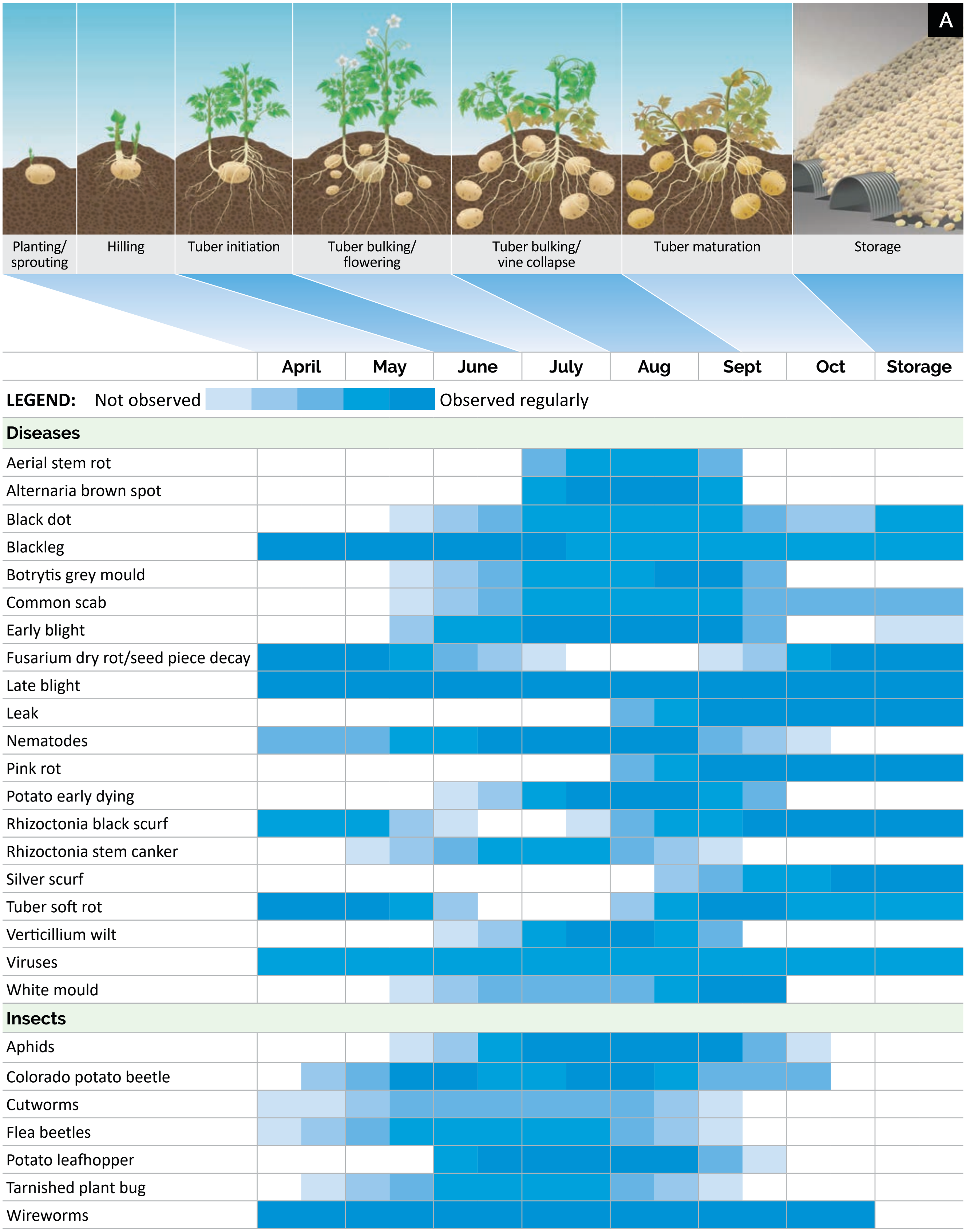
Sandblasting (sand abrasion) occurs when light, sandy or exposed soils are eroded by high winds. Stems and leaves on the windward side of the plant develop light, tan-coloured, roughened areas. If severe, sandblasting can stunt or kill plants and significantly reduce yield.

Wind whipping occurs on any type of soil. The whipping and twisting of young plants by strong winds can severely damage or kill the plants. Overly tall pepper transplants are very susceptible to wind whipping.

Desiccation is most common on tender, young transplants during strong wind conditions and extreme temperatures. Proper hardening-off of the transplants before field setting helps minimize these effects.

All types of wind damage can predispose plants to foliar diseases. Wind-strips, cover crops and windbreaks will minimize problems due to wind and sand movement.

Potatoes


A
Planting/ sprouting
Hilling
Tuber initiation
Tuber bulking/ flowering
Tuber bulking/ vine collapse
Tuber maturation
Storage
April
May
June
July
Aug
Sept
Oct
Storage
LEGEND: Not observed
Observed regularly
Diseases
Aerial stem rot
Alternaria brown spot
Black dot
Blackleg
Botrytis grey mould
Common scab
Early blight
Fusarium dry rot/seed piece decay
Late blight
Leak
Nematodes
Pink rot
Potato early dying
Rhizoctonia black scurf
Rhizoctonia stem canker
Silver scurf
Tuber soft rot
Verticillium wilt
Viruses
White mould
Insects
Aphids
Colorado potato beetle
Cutworms
Flea beetles
Potato leafhopper
Tarnished plant bug
Wireworms

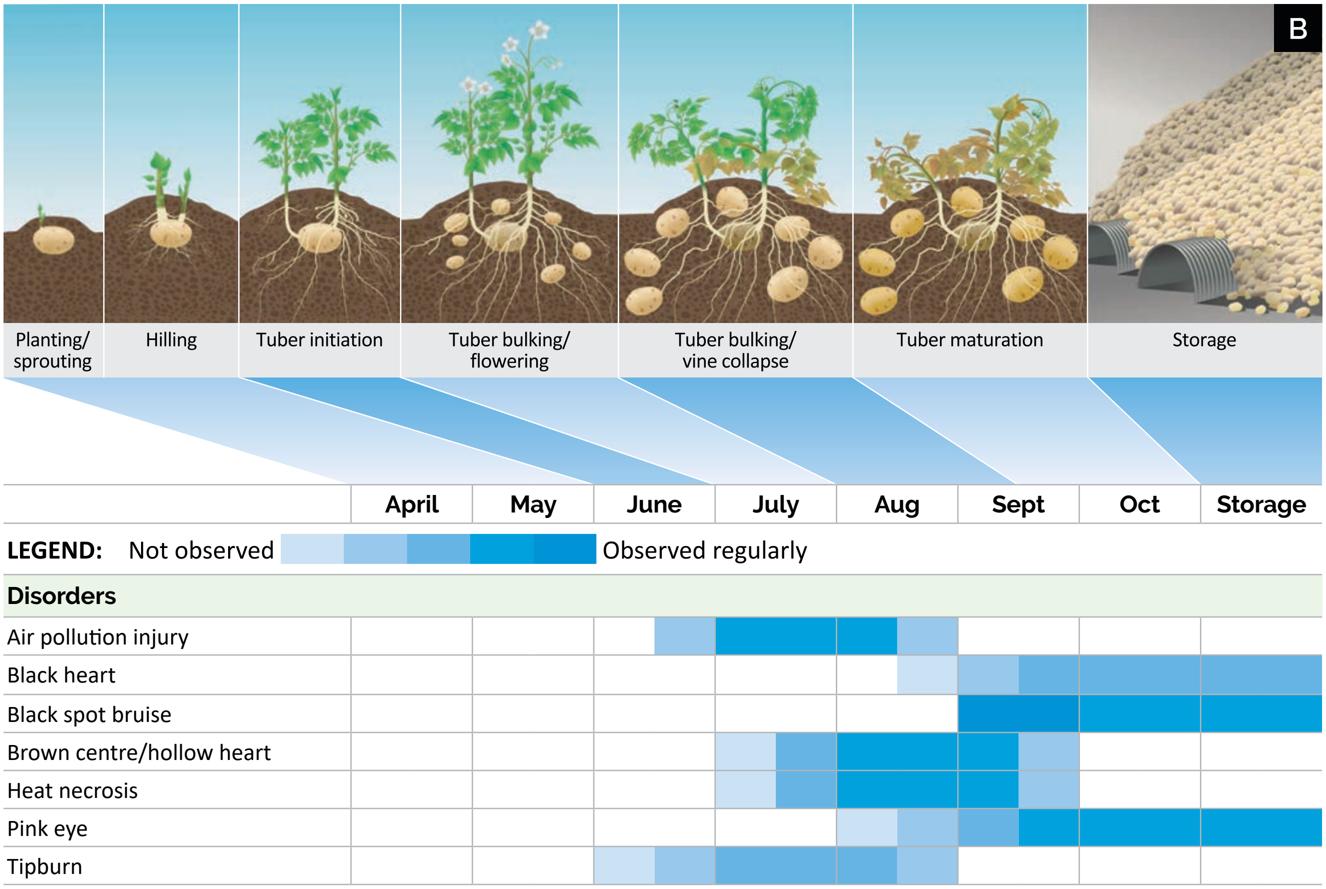


Figure 7–130. Potato stages of development and pest activity calendar. The actual period of activity for any given pest will vary significantly from year to year, depending on environmental factors.

Production Requirements

Soil types: a deep, friable, well-drained, sandy loam, high in organic matter and free of stones

Soil pH: 6–7

Suitable rotational crops: cereal crops (especially rye), corn, onions

Do not rotate with: tomatoes, peppers, soybeans, carrots

Minimum soil temperature: 8°C (46°F)

Optimum air temperature: 15°C–18°C (59°F–64°F)

Optimal planting date: mid-April to mid-June

Varieties

In Ontario, potatoes are mostly grown for processing (potato chip production), fresh market (tablestock) and seed potatoes. Round white potatoes are grown for chip production and tablestock. Yellow and Russet varieties are grown for tablestock and some processing uses. Red-skinned and specialty (coloured potatoes, fingerlings) varieties are grown for tablestock. There is also small but increasing production of creamer potatoes in Ontario.

Full variety descriptions of the commonly grown potato varieties are available at the Canadian Food Inspection Agency website: inspection.canada.ca/. Search for "Canadian potato varieties – descriptions."

The availability of Ontario seed for new or specialty varieties can often be limited. Information on contracting seed and seed availability lists is available on the Ontario Seed Potato Growers Association's website: www.ospga.ca/. For Ontario Variety Trial

Information, contact the OMAFRA potato specialist or the Ontario Potato Board.

Seeding and Spacing

Seed potato production in Canada uses a limited generation system, which means that seed passing inspection advances to a lower class with each generation of production.

Nuclear seed, minitubers produced in controlled environments, is at the top of the seed potato production pyramid. In the field, seed can be increased for 7 years. Therefore, there are 7 sequential classes of seed potatoes. Each class has a defined tolerance level for the presence of certain diseases. See Table 7–101 and Figure 7–131.

Table 7–101. Canadian Seed Potato Classes

Class	Field Generations[1]
Pre Elite (PE)	1
Elite I (EI)	2
Elite II (E2)	3
Elite III (E3)	4
Elite IV (E4)	5
Foundation (F)	6
Certified (C)	7

[1] Seed drops a class each year in the field if it passes inspection.

Figure 7–131. Nuclear stock potato cuttings in test tubes.

A healthy 55-g (1.9-oz) seed piece will establish a vigorous plant. Plants from seed pieces smaller than 40 g (1.4 oz) are generally slower to emerge and have less vigour. Small seed pieces are also more likely to decay before the plant becomes established. Seed pieces cut larger than 55 g (1.9 oz) result in higher seed costs with little additional benefit.

Plant potatoes into hills and seed pieces covered with least 5 cm (2 in.) of soil. Shortly after emergence, hill the potatoes to a final depth of 10–15 cm (4–6 in.) to allow space for maximum tuber set and to prevent tuber greening. In some cases, beds will have to be re-hilled multiple times to build up soil or for weed control. Some planters also have the ability to plant and hill in one pass. See Table 7–102.

Table 7–102. Potato Crop Spacing

Assuming a row spacing of 91 cm (36 in.)

Crop	In-Row Spacing	Estimated Seeding Rate
Varieties with high tuber set	30 cm (12 in.)	2,018 kg/ha (16 cwt/acre)
Varieties with low tuber set	20–25 cm (8–10 in.)	2,385–3,012 kg/ha (19–24 cwt/acre)
Varieties for creamer production	10 cm (4 in.)	4,770 kg/ha (38 cwt/acre)

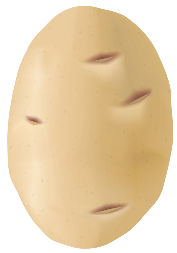
Several physiological factors influence stand establishment.

Apical Dominance: Apical buds will normally be the first to sprout. The eye at the apical end of the tuber may inhibit other eyes from sprouting. The delay in emergence from non-apical buds will produce uneven stands when using cut seed from varieties with strong apical dominance such as Jemseg and Yukon Gold. Varieties with weak apical dominance, such as Superior, produce more uniform stands from cut seed.

Physiological Age of Seed: Growing conditions from tuber initiation onwards determine the physiological age of potato tubers. Crop stress during the growing season has the biggest impact on physiological age. Seed grown during a season that was hot and/or dry will be physiologically older at harvest than tubers grown under more favourable growing conditions. Storage temperature also highly affects physiological age. Storage temperatures above 10°C (50°F) will speed the aging process of the tubers. Stresses like rough handling, pre-cutting and warming/cooling can all push seed pieces further through the aging process.

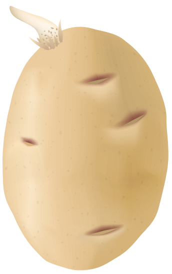
Seed tubers can be classified by their physiological age:

- Young seed has strong apical dominance. It produces 1–2 sprouts that emerge slowly from the bud, or apical, end of the seed tuber. Low stem number leads to a low tuber set and a harvest of fewer, larger tubers. Young seed has an extended bulking period. This is an advantage with late-maturing varieties.
- Middle-age seed emerges faster than young seed; multiple sprouts are produced because there is no clear apical dominance. The multiple stems lead to higher tuber set and higher yields.
- Old seed produces branched sprouts. It does not have clear apical dominance. Typically, plants from old seed will produce high tuber sets but the plants lack the vigour to bulk the tubers to a desirable size.



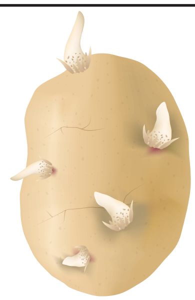
Dormancy

- Potatoes do not sprout at all.
- Dormancy period varies depending on cultivar.
- Chemical and non-chemical means of breaking dormancy.



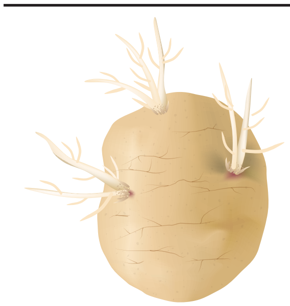
Young seed piece

- Young seed has strong apical dominance.
- It produces 1–2 sprouts that emerge slowly from the bud, or apical, end of the seed tuber.
- Low stem number leads to a low tuber set and a harvest of fewer, larger tubers.
- Young seed has an extended bulking period. This is an advantage with late-maturing varieties.



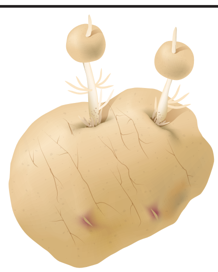
Middle-aged seed piece

- Middle-aged seed emerges faster than young seed; multiple sprouts are produced because there is no clear apical dominance.
- The multiple stems lead to higher tuber set and higher yields.



Old seed piece

- Old seed produces branched sprouts.
- It does not have clear apical dominance.
- Typically, plants from old seed will produce high tuber sets but the plants lack the vigour to bulk the tubers to a desirable size.



"No top"

- Small tubers form on the sprouts giving rise to the little tuber disorder.
- This seed age should not be used.

Figure 7–132. Potato seed considerations — physiological age of potato seed.

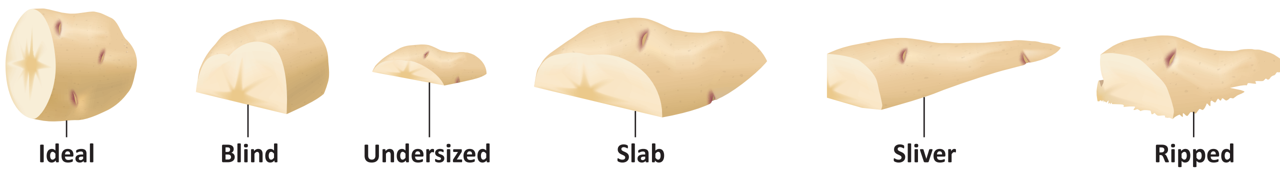


Figure 7–133. Potato seed considerations — cut seed piece shapes.

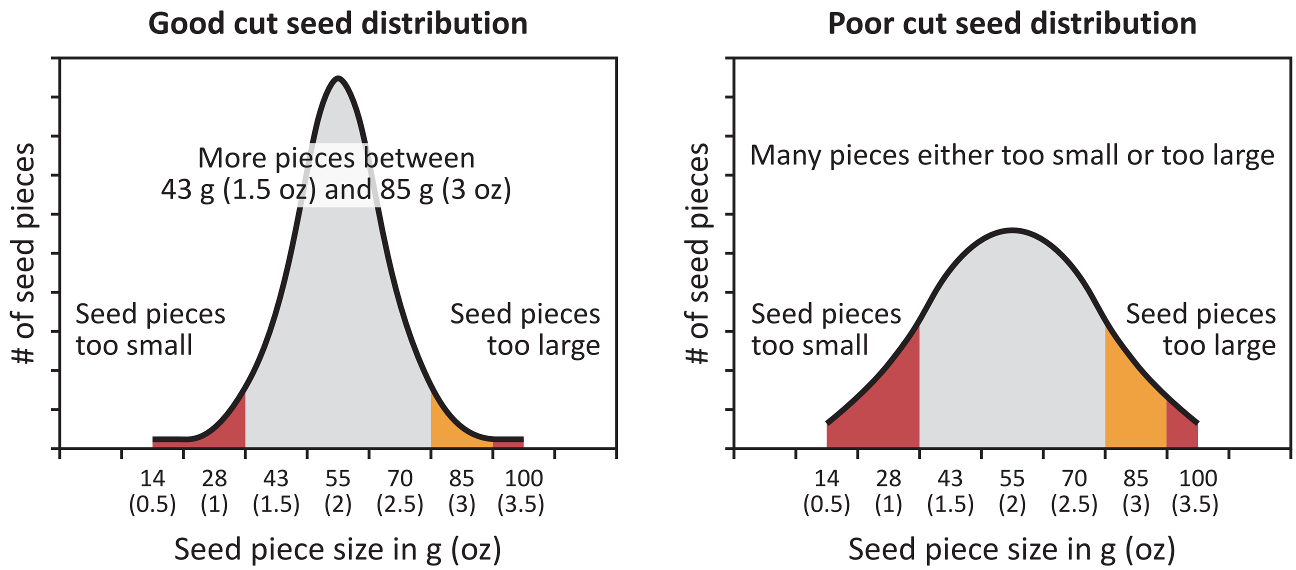


Figure 7–134. Potato seed considerations — optimal size distribution of cut potato seed.

Eye Distribution: Eye distribution on seed tubers is important. Some varieties have even eye distribution (Superior) while others have eyes concentrated at the apical end (Ambra). When cut by machine, the latter varieties produce a large proportion of blind seed pieces. Large tubers accentuate the problem and should be graded out and cut by hand.

Check seed coming off the cutter frequently for size, blind pieces and slivers (Figure 7–133 and Figure 7–134).

Seed Handling and Management

Plant Elite or Foundation Class seed to reduce leaf-roll, mosaic, *Fusarium* spp. and bacterial diseases. Inspect seed on arrival for heating, freezing, grade and visual signs of tuber disease. Seed lots can be regraded by a local Agriculture and Agri-Food Canada seed potato inspector. Requests for reinspection must be made within two working days of the receipt of the seed potatoes.

Request at least two certification tags with each bulk load — one for your bin and one for your files. The tag number provides direct access to the seed grower. Handle, store and plant the seed carefully. Poor stands and field performance are not always the seed grower's fault.

To help prevent disease, discard all tubers and seed pieces showing signs of rot. Follow good sanitation practices in storage areas and on all knives, containers and handling equipment.

Pad all seed-handling equipment as you would harvest equipment. Reduce drops to less than 15 cm (6 in.) to minimize bruising. Ensure that cutter knives are sharp. Cold storage temperatures make seed tubers more sensitive to bruising. Warm seed to at least 7°C–10°C (45°F–50°F) prior to handling. Bruising acts as an entry site for pathogens, leading to seed piece decay. Mishandling may physiologically age seed, leading to more stems per plant, smaller tubers and more stress susceptibility.

Give special attention to cut seed not being planted immediately to ensure healing and suberization by:

- forced-air circulation through the shallow pile
- temperatures of 10°C–15°C (50°F–59°F)
- high relative humidity of 90%–95% (prevent free water from forming on tuber surfaces)

Maintain these conditions for 3–4 days. After this, the temperature may be lowered, but humidity must be maintained and fans run intermittently.

Never allow cut seed to stand in the hot sun or in drying wind. This causes minute cracks in the skin that allow bacteria and fungi to establish. Do not plant seed tubers that have been washed.

Chitting or Green Sprouting

This process may be used for limited plantings, where early emergence and yield are important, or in short-season areas. Chitting is the process of aging seed in the light to control sprout growth, resulting in earlier emergence and sizing. Chitting will take several weeks, so plan well ahead of the expected planting date.

Small, whole seed is placed in shallow containers, 2–3 tubers deep. Air movement and light penetration are essential. Seed can be chitted in a building with fluorescent lights or by natural light in a greenhouse. Short, stubby, dark-green sprouts are desirable to minimize sprout damage at planting. Chitting seed in cool temperatures (such as 8°C (46°F)) under fluorescent light results in shorter sprouts than using warmer temperatures. Seed taken from winter storage of 3°C–4°C (37°F–39°F) will require about 250 growing degree days (base 4°C). For the degree day (DD) calculation, see *Growing Degree Days*, Chapter 4.

If the daily maximum temperature is 15°C (59°F) and the daily minimum temperature is 5°C (41°F), using the 4°C base, it would take approximately 41 days (250 GDDs ÷ 6) to green-sprout the tubers. Plant green-sprouted tubers with cup or bell planters to reduce the chances of injuring the sprouts. Avoid pick planters. Sized seed will improve the uniformity of emergence. If a greenhouse is unavailable, seed can be chitted at 20°C (68°F) in natural shaded light for about 2 weeks with similar results. The same can be accomplished inside a heated building. Higher levels of fluorescent light are required than at cool temperatures. In all cases, relative humidity should be approximately 80% to prevent desiccation and premature rooting.

Fertility

Macronutrients

Nitrogen

If the total nitrogen-plus-potash applied is over 360 kg/ha (321 lb/acre), broadcast at least a portion before planting to avoid concentrating the fertilizer band near the seed piece and potato roots. Side-dress the remaining portion prior to re-hilling the potatoes to incorporate it into the hill. Broadcasting or side-dressing nitrogen after potatoes are 20 cm (8 in.) tall may delay maturity.

Each variety has different nitrogen requirements and responds differently to varying rates. Often breeders can provide information on optimal nitrogen requirements for their varieties. If you do not have that information, see Table 7–103. Use the recommendations as a guide based on what the crop is being grown for. Late-season, high-yielding varieties will require higher rates of nitrogen than an early-maturing variety and split applications. Don't over-apply nitrogen to potatoes grown for processing as excess nitrogen later in the season can reduce processing quality.

Table 7–103. Potato Nitrogen Requirements

Soil	Actual N kg/ha	Expected Marketable Yield
Mineral soil		
Main crop	50 kg/ha (45 lb/acre)	15 t/ha (120 cwt/acre)
	75 kg/ha (67 lb/acre)	20 t/ha (159 cwt/acre)
	130 kg/ha (116 lb/acre)	25 t/ha (199 cwt/acre)
	200 kg/ha (178 lb/acre)	>30 t/ha (239 cwt/acre)
Early crop	70 kg/ha (62 lb/acre)	—
Muck soil		
Early and main crop	up to 60 kg/ha (54 lb/acre)	—

If manure is applied or legume crops are plowed down, reduce the nitrogen application. See Table 1–12 and Table 1–13, Chapter 1.

Phosphorus

Test the soil to determine phosphorus requirements. See Table 7–104.

On mineral soils testing medium or low for phosphate, place some or all of the phosphate fertilizer in bands 2.5 cm (1 in.) below and 6 cm (2½ in.) to each side of the seed piece at planting time. On muck soils or on mineral soils testing high for phosphate, placement is less critical and fertilizer may be broadcast.

Potassium

Test the soil to determine potassium requirements. See Table 7–105.

Magnesium

Magnesium deficiency may occur on potatoes. The usual symptoms are yellowing of older leaves while the veins and margins remain dark green. See *Macronutrients*, Chapter 1.

Calcium

Calcium plays an important role in tuber set, suberization and skin set, and can help mitigate heat stress. The higher the amount of calcium available, the lower the tuber set. Calcium deficiency has been implicated in internal tuber disorders like hollow heart and internal brown spot. Calcium can often be tied up in insoluble forms and it is important to have soluble calcium available in the root zone for proper uptake. Top-dressing a form of soluble calcium when re-hilling is a good way to ensure the crop has an adequate supply.

Table 7–104. Potato Phosphorus Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Sodium Bicarbonate Phosphorus Soil Test (ppm)													
	0–3	4–5	6–7	8–9	10–12	13–15	16–20	21–25	26–30	31–40	41–50	51–60	61–80	81+
Mineral Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	200 (178) (HR)	200 (178) (HR)	190 (170) (HR)	190 (170) (HR)	180 (161) (HR)	170 (152) (HR)	160 (143) (HR)	140 (125) (MR)	120 (107) (MR)	90 (80) (MR)	50 (45) (MR)	30 (27) (LR)	30 (27) (LR)	30 (27) (LR)
Muck Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	100 (89) (HR)	100 (89) (HR)	100 (89) (HR)	100 (89) (HR)	90 (80) (MR)	90 (80) (MR)	80 (71) (MR)	70 (63) (MR)	60 (54) (MR)	50 (45) (LR)	30 (27) (LR)	20 (18) (LR)	0 (LR)	0 (LR)

Table 7–105. Potato Potassium Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Ammonium Acetate Potassium Soil Test (ppm)											
	0–15	16–30	31–45	46–60	61–80	81–100	101–120	121–150	151–180	181–210	211–250	251+
Mineral Soils												
Potash (K_2O) required kg/ha (lb/acre)	230 (205) (HR)	220 (196) (HR)	210 (187) (HR)	190 (170) (HR)	160 (143) (HR)	130 (116) (HR)	100 (89) (MR)	80 (71) (MR)	50 (45) (MR)	0 (LR)	0 (RR)	0 (NR)
Muck Soils												
Potash (K_2O) required kg/ha (lb/acre)	230 (205) (HR)	220 (196) (HR)	210 (187) (HR)	200 (178) (HR)	170 (152) (MR)	150 (134) (MR)	120 (107) (MR)	80 (71) (MR)	40 (36) (MR)	0 (LR)	0 (RR)	0 (NR)

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers, and deficiencies are usually seen in sandy soils with low organic matter. For complete information, see *Micronutrients*, Chapter 1.

Boron

Boron deficiency is usually only seen in sandy soils with low organic matter or muck soils with high pH. Boron plays a role in the translocation of sugars from the leaves down into the tuber. Foliar applications of boron later in the season when the crop is dying down and tubers are bulking may help increase sugar movement to the tubers.

Fertigation

Water-soluble fertilizers such as nitrogen, phosphorus, potassium and sulphur can be applied through a sprinkler irrigation system according to the needs of the crop. The nutrients are incorporated into the root zone with the irrigation water. Careful irrigation management is essential when using fertigation because of the risk of nutrient leaching. Check the compatibility of the fertilizers with the irrigation water beforehand, since precipitation of nutrients can reduce availability and clog nozzles.

Plant Tissue Analysis

When used in conjunction with a soil analysis, plant tissue analysis is a useful tool for diagnosing crop problems or evaluating a fertilizer program. The objective of a good fertilizer program is to maintain tissue nutrient concentrations on the lower side of the sufficiency range. Attempting to bring the nutrient analysis up to the higher end of the range could possibly result in over-fertilization and may not be economical. See *Plant Tissue Analysis*, Chapter 1.

Only use sufficiency ranges as a guideline. Plant tissue analysis does not replace soil testing or a sound soil fertility program. Samples for plant tissue analysis should be taken, in the morning, at early bloom. Sample at least 50 plants distributed throughout the chosen area. Take the fourth leaf from the top of the plant, including the petiole. Place the samples in a clean paper bag that should be sent immediately to a laboratory for tissue analysis. Sample problem areas separately. See Table 7–106.

Table 7–106. Potato — Interpretation of Plant Tissue Analysis

Values apply to the fourth leaf, including petiole, from the growing tip sampled at early bloom.

Nutrient	Critical Concentration[1]	Maximum Normal Concentration[2]
Nitrogen	2.50%	3.50%
Phosphorus	0.15%	0.50%
Potassium	1.20%	2.50%
Calcium	1.50%	—
Magnesium	0.10%	0.60%
Sulphur	0.14%	—
Boron	2.0 ppm (µg/g)	25.0 ppm (µg/g)
Copper	2.0 ppm	25.0 ppm
Manganese	15.0 ppm	150.0 ppm
Zinc	14.0 ppm	70.0 ppm

[1] Yield loss due to nutrient deficiency is expected with nutrient concentrations at or below the "critical" concentration.

[2] Maximum normal concentrations are more than adequate but do not necessarily cause toxicities.

Irrigation

Potatoes are a cool-weather crop that require about an inch of water a week to produce the highest possible yield. There are two main reasons potatoes are more sensitive to water stress than most other crops:

A shallow root system: Potatoes have a relatively shallow root system with most of the roots in the top 30 cm (12 in.) of soil.

Soil type: Potatoes do well in sands and sandy loams, soils that have low to medium water-holding capacity.

High yields of high-quality potatoes can only be achieved by maintaining optimal levels of available soil moisture throughout the growing season. Without regular rainfall, frequent irrigation is necessary. Soil moisture becomes critical when the available soil water drops below 60%–65%. The impact of water stress will depend on the severity, timing and duration of moisture stress.

Table 7–107 shows the crop growth stages of potatoes and the amount of available water required for a high yield of good quality potatoes. Research in the U.S. has shown that yield losses will occur if available soil water drops below required levels for more than 5 days.

Table 7–107. Amount of Available Water Required for Optimum Potato Yields

Growth Stage	Soil Available Water Requirement	Yield Losses IF Available Water Below Required Levels
Sprout development	75%	Short periods of drought stress do not reduce yield.
Vegetative growth	75%	5%
Tuber initiation	80%	10%
Tuber bulking	90%	40%–60% Highest demand for water. Adequate water is necessary for high yield. Dry conditions favour tuber malformations
Tuber maturation	60%–65%	Water deficit causes tuber dehydration

If there is insufficient rainfall, irrigation is required to keep the available soil water in the root zone above the allowable depletion level. This ensures that the crop will not suffer water stress and will produce maximum yield.

Vine Killing

Vine killing is necessary for maturation of the tuber skin, a process called "skin set." Skin set usually takes 14–21 days after the vines have been killed. It is advisable to wait at least 18 days after killing the vines to begin harvesting. A mature skin is an excellent protective barrier for the potato tubers and it is vital to the long-term storage crop.

The timing of vine killing is determined by a number of factors but especially marketable size. Once the crop has reached the marketable size desired by the grower, the vines are killed. Timing vine killing is especially important to seed and processing growers. For seed, an early kill controls tuber size and reduces the spread of virus diseases by aphids. For processing growers, vine killing once the crop has reached chemical maturity (sucrose and glucose content) and desired specific gravity improves processing quality.

Usually the vines of the first early potatoes, those harvested in July to the beginning of August, are not top killed. Early potatoes are consumed rapidly, and skin set is not so critical. However, where it is necessary to control size to reduce hollow heart, chemical vine killing may be of value for early potato crops.

An additional benefit to vine killling is weed control, as escaped weeds can be killed, preferably before setting seed.

Harvest

Once the skin is set, harvest should begin early enough to be completed before a hard frost is likely. Soil moisture and temperature must be monitored closely once harvest has begun. Optimal harvest conditions are at 60%–65% available soil moisture. Tubers harvested from wet, cold soils are susceptible to bruising, more difficult to cure and more prone to breakdown in storage. Tubers from wet soils may also become oxygen-starved and their lenticels may become enlarged; these conditions increase tuber susceptibility to decay. Dry, cloddy soil may cause severe tuber bruising at harvest.

Tuber pulp temperature should be between 10°C–18°C (50°F–64°F). Potatoes harvested with pulp temperature above 20°C (68°F) are very susceptible to bacterial soft rot. Moreover, it is difficult to remove the field heat from these tubers once they are in storage. Thus, in warm weather, early morning may be the best time for harvest.

Harvest scheduling is always unpredictable due to the weather. Base harvest decisions on soil conditions, weather forecasts and grower experience.

Sprout Inhibition

After completion of a rest (dormancy) period, potatoes sprout readily. Potatoes treated with chemical sprout inhibitors can be stored at 10°C (50°F) or higher without sprouting.

Do not use either of these treatments on potatoes grown for seed. Do not store seed potatoes in the same storage as tubers treated with chlorpropham (CIPC) or in crates that were in the storage when CIPC was applied.

Field-Applied

Maleic hydrazide is a plant-growth regulator, applied in the field to control sprouting of potatoes in storage. It should be applied in a manner that ensures complete and uniform coverage. Timing is important. Recent research has shown that too early an application on some varieties may result in phytotoxicity and reduced potato size. Consult the label for more detailed information on both rates and timing. Time of application may occur as early as 2–3 weeks past full bloom. Only apply to plants that are green and free from insects, disease and other damage.

Once in storage, tubers treated with maleic hydrazide will not affect seed potatoes stored in the same storage. Crates formerly used for the storage of maleic hydrazide-treated tubers will not affect seed potatoes.

Storage-Applied

CIPC (chlorpropham) is also widely used for sprout inhibition. Application as a gas to storage bins must be performed by a licensed applicator. Certain formulations of CIPC may be applied during grading and before packaging for market. Other non-CIPC products may also be applied in storage including 3-decen-2-once and 1,4-dimethylnaphthalene.

Storage

Store seed tubers separately from tablestock or processing potatoes, in a disinfected storage area. Do not store seed potatoes in the same storage area as CIPC-treated tubers.

Healing of cuts and bruises is most rapid at a tuber temperature of 15°C (59°F). Potatoes should be cured at this temperature for at least 10–14 days at the beginning of the storage period. After this, the temperature should be lowered by 1°C every 1–2 days to the desired temperature. Seed potatoes can be stored at 3°C–4°C (37°F–39°F) to prevent sprouting. Tablestock potatoes can be stored at 4.5°C–5.5°C (40°F–42°F). Potatoes intended for processing should be maintained at 10°C–12°C (50°F–53°F) and should never be subjected to temperatures below 5°C (41°F) to prevent the build-up of sugars. It will be necessary to use a sprout inhibitor if potatoes are to be stored at 10°C (50°F) for an extended period.

Maintain the relative humidity in the storage as high as possible without causing condensation of moisture on tubers and the storage structure. However, if soft rot is prevalent or if the tubers are wet when first put into storage, keep the humidity down until the tubers dry.

Pest Management and Disorders

See Figure 7–130, *Potato stages of development and pest activity calendar*.

Diseases

Aerial Stem Rot

Pectobacterium carotovorum **var.** ***carotovora***

Aerial stem rot infection starts on broken or damaged petioles or stems. Lesions are similar to those caused by blackleg lesions on stems (see *Blackleg*, also in *Potatoes*). The main difference between these two diseases is that blackleg originates from seed tubers. Blackleg is favoured by temperatures below 21°C (70°F). The development of aerial stem rot is favoured by temperatures above 21°C (70°F).

Also see *Tuber Soft Rot, Seed Piece Decay*, also in *Potatoes*.

Alternaria Brown Spot

Alternaria alternata

Identification: Tiny brown circles or "pepper spots" develop on potato leaves. Older lesions are round with concentric rings. As the disease progresses, lesions may coalesce to form larger necrotic areas with dark-brown margins near the edges of leaflets. The leaves in the middle of the plant are most susceptible to brown spot and they show the highest disease incidence. On stems, brown, elongated small lesions may develop when disease pressure is high. Tubers may be infected at harvest. Tuber infection results in small black holes (black pit). Such holes are similar to pits caused by common scab but are deeper, narrower and blacker.

Biology: The brown spot fungus overwinters in plant refuse in the soil, on weeds, and on other susceptible hosts such as cucurbits, beans and brassicas. Infection occurs when wind-borne spores germinate on potato foliage. Although brown spot symptoms typically develop in July or August, it can occur throughout the season. It is more prevalent in warm seasons. High humidity, leaf wetness such as prolonged dew, and warm temperatures are conducive to infection.

Management Notes: Practice a 2–3-year crop rotation away from all susceptible crops, avoid crop stress and do not over-irrigate. Harvest tubers when the skin is set and avoid mechanical injury. Crop protection materials applied to control early blight should also reduce the incidence of brown spot.

Bacterial Soft Rot

Pectobacterium carotovorum subsp. *Carotovorum* (formerly known as *Erwinia carotovora*), *P. parmentieri*

Identification: Bacterial soft rot is characterized by a soft, mushy wet rot starting on the outside the tuber. The internal infection is often differentiated with a dark brown or black margin. Soft rot is associated with a very bad smell due to secondary infections. It can also cause seed breakdown and result in wilting and plant death in the field.

Biology: Bacterial soft rot causes serious losses in the field and in storage. Insect damage, mechanical damage or bruising predispose plants to soft rot infection. Soft rot spreads rapidly in warm, humid conditions. It is spread by seed cutting, direct contact, hands, tools, soil water, insects and splashing rain or irrigation.

The soft rot bacteria overwinter in infected tissues, in the soil, and on contaminated equipment and containers.

Warm, moist weather is favourable for infection by the bacterial soft rot pathogens.

Management Notes: Plant into well-drained soils and maximize air flow through the plant canopy. Once the disease is identified in a field, avoid overhead irrigation. Rotate with less-susceptible crops (cereals or corn) and control chewing insects. Excess nitrogen may promote soft rot infections.

Storage temperatures below 4°C (39°F) inhibit the development of new infections in brassica crops and radishes. When infections appear in storage, remove and destroy infected plants. Practise good storage sanitation.

Black Dot

Colletotrichum coccodes

Identification: Symptoms can appear on the stem, roots, stolons and tubers of potatoes. Brownish-to-grey lesions initially develop on the stems, while older lesions have a bleached appearance. Microsclerotia that look like tiny black dots form on the lesions. Microsclerotia can form on any infected part of the plant. Infected stems and stolons may turn a distinct reddish/purple colour. Top leaves in the canopy of infected plants can start to die off and wilt later in the season. Tuber infection looks like brown-to-grey discolouration with tiny microsclerotia often formed in those areas.

Biology: The black dot fungus has a wide host range and is found in most soils where potatoes are grown. It can be both tuber- and soil-borne. The microsclerotia produced can survive long periods of time in the soil. Black dot is often associated with sandy soils, low nitrogen, high temperatures and poor drainage.

Management Notes: Plant disease-free seed. Avoid crop stress. Do not over-irrigate. Harvest tubers when the skin is set, to avoid mechanical injury.

Blackleg

Pectobacterium carotovorum var. *atrosepticum*, *Dickeya* sp.

Identification: On tubers, the lesions start at the stem end. The lesions are sunken, circular and black. The rot extends from the stem end into the pith. The infected flesh first appears cream coloured, turning greyish-black and mushy as the disease progresses (Figure 7–135).

Figure 7–135. Wilt and inky black stem rot typical of blackleg.

Young plants emerging from infected seed tubers are stunted and look stiff. Their foliage is yellowish, the leaflets tend to roll upward at the margins and the foliage eventually wilts and dies. A black decay extends from the seed piece up the stem. The decay is soft and slimy in wet weather. Infected tissue is often invaded by secondary bacteria that produce a fishy smell. See also *Bacterial Soft Rot*, also in *Potatoes*.

Biology: The blackleg bacterium is primarily seed-borne. It spreads quickly during seed cutting operations, especially if conditions for wound healing are not provided. After planting, infected seed pieces may either rot or produce infected plants. The disease is especially prevalent in the lower, wetter areas of a field. Tubers are susceptible to attack throughout the growing season and at harvest time. If diseased tubers are stored, they can be sources of inoculum in the following season.

Management Notes: Plant certified seed. Warm seed before cutting. Clean and disinfect seed cutters and planters between seed lots. Select well-drained fields and if possible, plant when soil temperature is no less than 10°C (50°F). Do not over-irrigate. Harvest tubers when the skin is set, avoid mechanical injury and avoid harvesting when conditions are wet. During storage, maintain the potatoes at a low temperature with adequate aeration to provide a dry environment and to prevent condensation of moisture on tuber surfaces.

Botrytis Grey Mould

Botrytis cinerea

See Chapter 6.

Common Scab

Streptomyces scabies, *S. scabiei*

Identification: In potatoes, there are no above-ground symptoms. Tuber lesions vary in size and shape. The spots may be few and scattered or may cover most of the surface. Superficial scab or russet scab produces superficial, corky lesions. Netted scab causes net-like, superficial lesions. In pitted scab, lesions form cavities as deep as 1 cm (½ in.). The tissue around the interior of the pith is corky. The lesions of erumpent scab are raised, rough and corky (Figure 7–136).

Figure 7–136. Common scab lesions on a tuber (A) and variation in severity and incidence of common scab (B).

POTATOES

Biology: The scab bacterium survives in the soil indefinitely. Warm, dry soils and a soil pH of 5.5–7.5 favour scab development (Figure 7–137).

In potatoes, most scab infections take place at tuber initiation. The bacterium enters newly forming tubers through immature lenticels. As tubers increase in size, lesions expand and scab severity increases. Planting scab-infected seed or spreading contaminated cattle manure will introduce the bacterium to scab-free fields. Tubers that look healthy may carry the bacterium on their skin.

In potatoes, the acid-tolerant scab species (*S. acidiscabies*) can infect tubers in soils with pH as low as 5 (Figure 7–137).

Scouting: To assess disease incidence, pull plants at random and examine the tubers or roots. Disease assessment can start when daughter tubers are about nickel size.

Management Notes: Plant scab-free seed and grow only resistant varieties in fields infested with scab. Varieties such as Superior, Dakota Pearl, Norland, GoldRush, Pike and Gemstar are resistant to scab. Scab incidence and severity may be reduced by maintaining available soil moisture at 80% of field capacity for about 3 weeks starting at tuber initiation until tubers are golf-ball sized. Side-dressing ammonium sulfate has been reported to reduce scab severity.

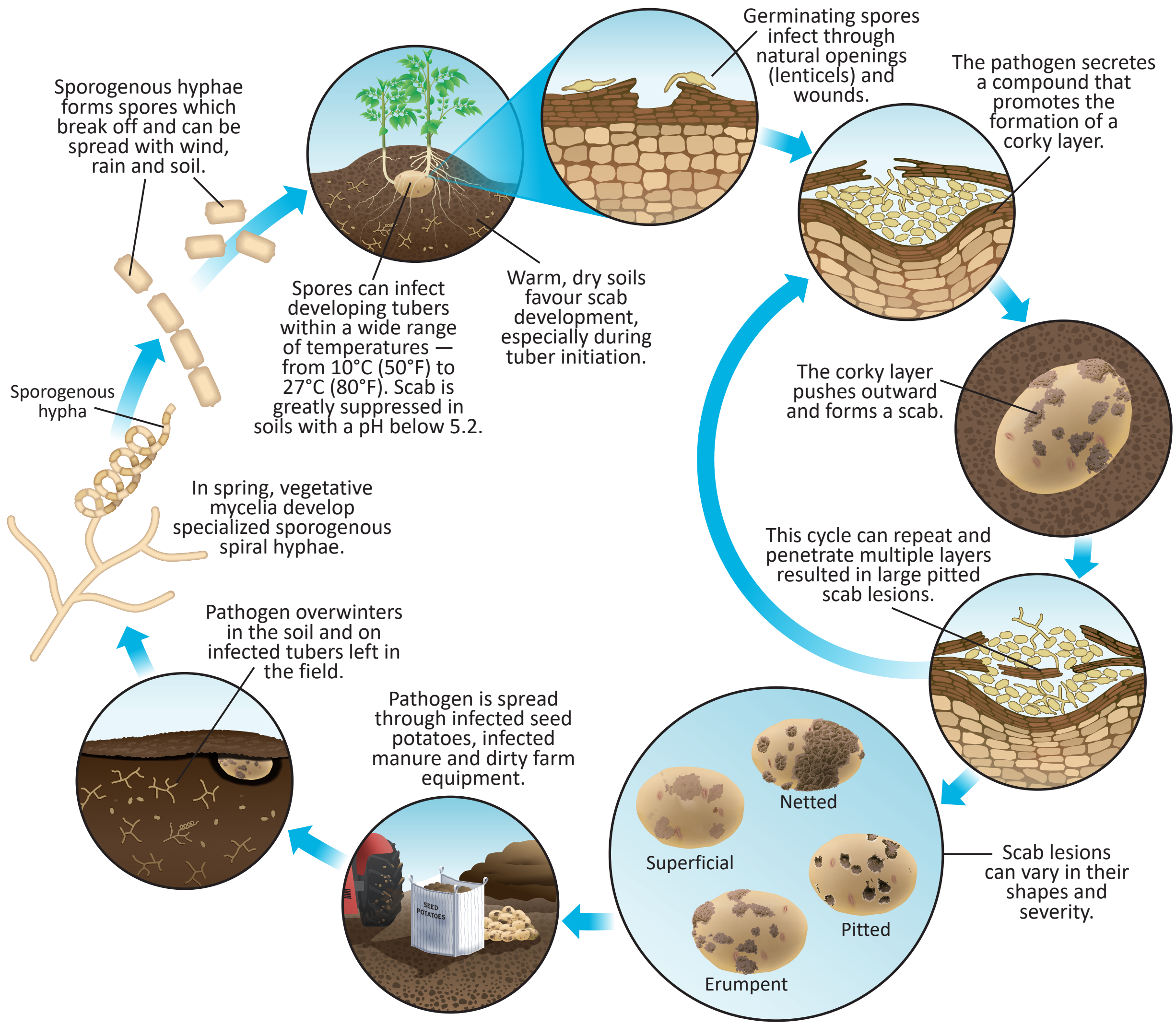


Figure 7–137. Life cycle of *Streptomyces* spp. causing common scab of potatoes.

Do not use manure from farm animals that have fed on scab-infected tubers. Liming the soil tends to increase scab incidence. Avoid moving infected soil on farm equipment from contaminated to healthy fields. Crop rotation is not very effective because the bacterium survives indefinitely in the soil.

Do not grow radish in rotation with potato, carrot or beets. Rotations with grains are partially effective at reducing scab levels in the soil. Maintaining high soil moisture levels during root development may reduce infection.

Early Blight

Alternaria solani

Identification: The first signs of disease often appear on older foliage, deep in the canopy where the leaves stay wet. Foliar lesions first appear as dark spots, 8–13 mm (¼–½ in.) in size. The lesions are circular-to-angular with dark, concentric rings (target spot) and enlarge over time. They are usually limited by large veins and surrounded by a narrow, light green-to-yellow halo. In severe infections, the foliage is completely covered by lesions and dries up (Figure 7–138).

Figure 7–138. Early blight lesions on the lower leaves with concentric rings or target spot lesions.

On potato tubers, early blight lesions are dark brown-to-black, slightly sunken and round-to-irregular in shape. They are often surrounded by a raised, violet-blue border. The internal decayed tissue is usually dark brown, dry and corky.

Biology: The early blight fungal spores overwinter in the field in crop residue, on infected tubers and on weed hosts such as hairy nightshade.

Infections occur under warm temperature conditions (20°C–30°C (68°F–86°F)) and periods of prolonged leaf wetness due to wet weather or heavy dewfall. Spores are spread primarily by wind and splashing water. As a result, the disease progresses rapidly during periods of alternating wet and dry weather.

Early blight is often more severe as the potato crop ages or if the crop has been under stress due to poor nutrition, insect damage, drought or other types of stress. Plants infected with *Verticillium* or expressing common mosaic symptoms are particularly susceptible to early blight.

At harvest, tuber infection occurs primarily through cuts, bruises or wounds.

Management Notes: Management of early blight requires an integrated program of cultural and chemical practices to minimize sources of inoculum and crop stress.

In potatoes, practise a 2–3-year crop rotation, and harvest tubers when the skin is set to avoid mechanical injury.

Fusarium Dry Rot, Seed Piece Decay

Fusarium solani var. *coeruleum* and *Fusarium sambucinum* are the primary soil fungi causing dry rot. In addition, *F. avenaceum, F. culmorum, F. oxysporum* and *F. graminearum* can also cause dry rot of potatoes.

Identification: Symptoms first appear as dark depressions on the surface of the tuber. As the lesions increase in size, the skin becomes wrinkled in concentric rings and the underlying rotted tissue desiccates. Rotted tissue is brown or grey-to-black, dry and crumbly. Often, cavities lined with white, yellow, pink or blue mould develop in the rotted tissue. The rot may involve most of the tuber resulting in mummification of the entire tuber. Fusarium dry rot has no smell.

Seed tubers infected with fusarium are usually invaded in the soil by soft rot bacteria. See *Bacterial Soft Rot*, also in *Potatoes*. Soft rot causes reddish-brown-to-black spots on the surface of seed pieces. Later these spots may become black and slimy. Entire seed pieces will rot, leaving only a smelly mass of rotten tissue.

Biology: *F. solani* and *F. sambucinum* are present in all soils and survive for many years as resistant spores. These pathogens cannot penetrate intact skin. Wounds are needed for infection.

Scouting: Start scouting fields immediately after crop emergence. To assess disease incidence, dig spots with poor emergence and check the seed pieces for fusarium infection.

Management Notes: Use clean seed and ensure that the storage facility has been properly disinfected. Prior to cutting, warm the seed tubers to promote rapid healing and remove any diseased seed. Disinfect seed cutting and handling equipment often. Sharp cutters make a clean cut that heals quickly. Do not store cut seed for more than 10 days before planting. Use a registered fungicide seed treatment and access any available local information on fungicide resistance related to fusarium.

Harvest tubers after their skins have set and when their core temperature is greater than 10°C (50°F). Minimize mechanical damage during harvest and handling operations. Apply a registered post-harvest fungicide treatment. Promote wound healing in storage. For the first 2–3 weeks of storage, hold tubers at 12.8°C (55°F) with good ventilation and a relative humidity of at least 95%. Monitor stored tubers often for dry rot.

Late Blight

Phytophthora infestans

Late blight is one of the most devastating diseases of potatoes. If left uncontrolled and if weather conditions favour disease development, it can devastate a potato field in 7 days.

Identification: Initial symptoms on leaves are small, light-to-dark green, circular-to-irregular shaped, water-soaked spots. Later, the lesions become grey-to-brown, surrounded by a light green halo. In humid conditions, a white and fuzzy fungal growth (mycelium and spores) develops at the edge of the lesions, usually on the underside of leaves. If the weather is wet, entire leaves can become blighted in a few days, as new infections occur and existing lesions coalesce.

Petiole and stem lesions appear as small, dark brown-to-black spots. They can be several inches long. The white fungal growth may also develop on these lesions if the weather is cool and humid (Figure 7–139 and Figure 7–140).

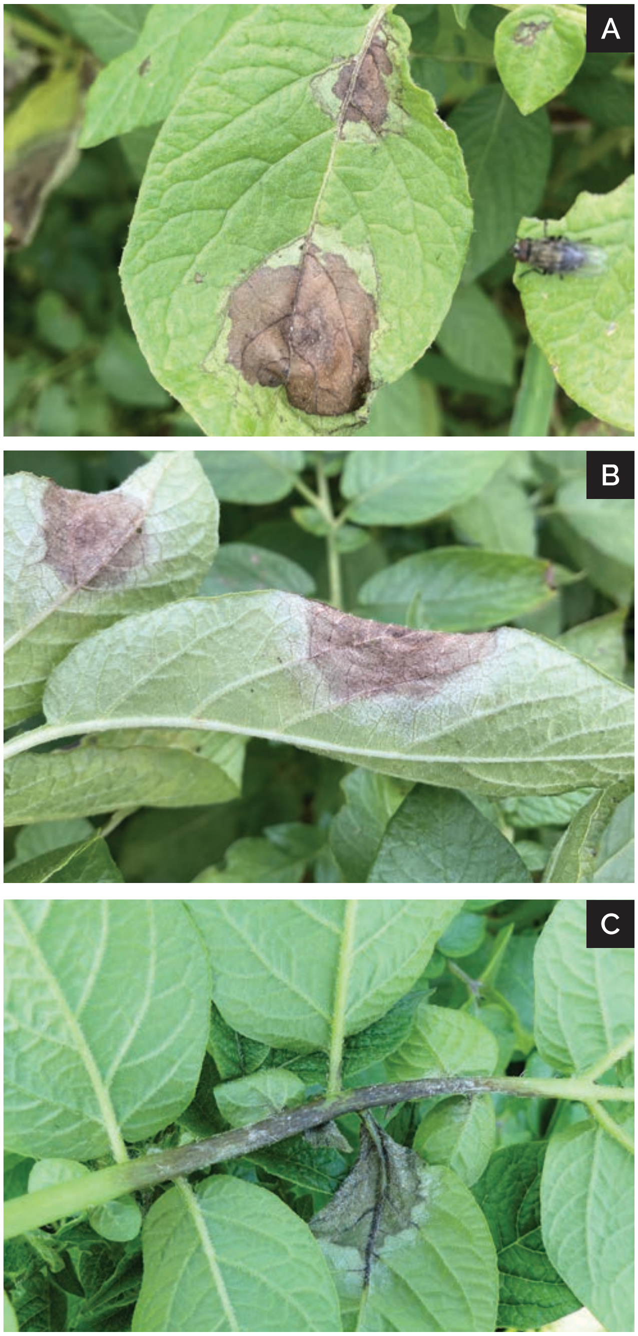


Figure 7–139. Late blight lesions with brown spots infecting the main vein and surrounding yellow halo (A), white and fuzzy sporulation on the underside of the late blight lesions (B) and late blight infecting the stem with water soaked lesions (C).

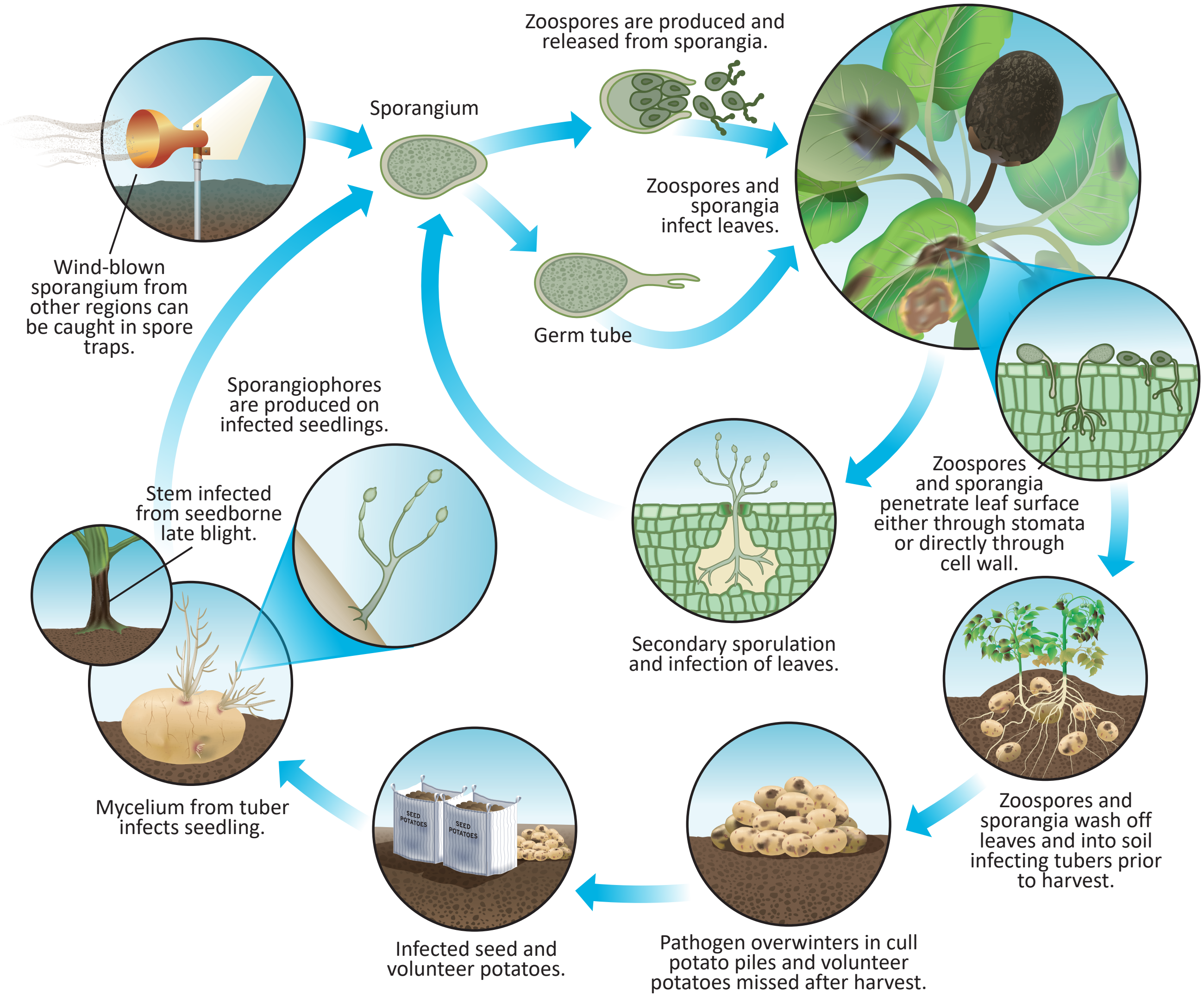


Figure 7–140. Life cycle of *Phytophthora infestans* causing late blight of potatoes.

Tuber lesions are of variable size, irregularly shaped, brown-to-purplish and slightly sunken. A reddish-brown, granular dry rot develops under the lesions. There is no clear separation between the infected and the healthy tissue. Following late blight infection, secondary bacteria infect the tubers, causing a slimy and foul-smelling rot.

Biology: Late blight is caused by the oomycete, *Phytophthora infestans*. Spores are produced from 10°C–27°C (50°F–81°F). It grows most actively from 18°C–21°C (64°F–70°F) and a relative humidity of 90%. A minimum of 8 hours of leaf wetness is required for the spores to germinate and penetrate the plant tissue. After infection takes place, late blight symptoms develop in 3–5 days.

Late blight survives only on living plant material (e.g., cull piles, potatoes left in the field after harvest, infected seed potatoes). Most infected seed tubers rot without sprouting. However, a few may sprout and produce infected plants. The pathogen produces spores on the lesions of infected plants at any time during the growing season. The spores are splashed by rain to neighbouring healthy plants or by wind to other areas of the field. Spores can travel great distances by wind.

Tuber infections occur when spores are washed into the soil when water runs off the infected foliage. Contamination also takes place if the tubers are dug while infected vines still have active lesions.

Late blight has two mating types (A1 and A2). If both become established in an area, they can mate and produce thick-walled spores (oospores) that can overwinter in the soil without a living host. In Ontario, oospores have not been detected. Numerous late blight strains exist, and new strains emerge over time. Late blight strains vary in virulence on tomato and potato and in fungicide sensitivity.

Scouting: There is no tolerance for this disease as it is easily spread by wind and can rapidly destroy the crop. Begin scouting for late blight as soon as green tissue emerges. Monitor fields closely, at least twice a week, to detect late blight at its early stages. Pay special attention to centre pivot tracks, low pockets and other areas that may experience prolonged periods of high humidity. Be sure to look for late blight in the lower portions of the plant, where the foliage stays wet longer and the disease is most likely to begin.

One infected plant in the entire field is enough to start an epidemic. Pull, bag and remove the first infected plants found. Mark these areas with a flag and revisit regularly. Always scout infected fields at the end of the work day to prevent carrying the infection into clean fields.

Management Notes: In potatoes, start a preventive fungicide program before row closure. It is important to schedule spray applications so the crop is protected before infection periods or prolonged wet weather conditions. For additional important information regarding late blight control in potatoes, see *Tips for Managing Late Blight in Potatoes*, also in *Potatoes*.

Immediately remove affected plant tissue as soon as it is identified in a field. If possible, wait until leaves are dry so there will be fewer spores. Dispose of infected plant tissue either in plastic garbage bags, tillage, burial or pile the residue and cover it with a tarp (heat will build up under the tarp to kill the plant tissue and pathogen).

Hose down all farm equipment after leaving an infected field. Farm equipment carrying contaminated plant material can spread the pathogen to healthy fields. Continue intensive scouting and remove any plants that develop symptoms.

It is important to monitor the strains that might occur in Ontario. If you suspect late blight in your field, contact the OMAFRA potato specialist to submit samples for strain identification.

Tips for Managing Late Blight in Potatoes

Plant only healthy seed and use a late blight specific seed treatment where available. Tagged seed (Elite or Foundation) gives no guarantee it is not carrying late blight.

Prior to crop emergence, destroy all cull piles (bury, chop, freeze or feed to livestock). Monitor the pile location and treat any emerging sprouts with a burndown herbicide. Control volunteer potatoes and nightshade weeds growing along field borders or in neighbouring fields.

To prevent tuber infections, create a good hill that ensures excellent tuber coverage and seal soil cracks.

Promote good airflow through the canopy by controlling weed escapes. If possible, irrigate during the day to avoid prolonged periods of wet foliage at night. Do not irrigate near the end of the season if new outbreaks of late blight are noticed.

Avoid harvesting under wet conditions. Only harvest once the vines are completely dead so living spores are not sprinkled on tubers at harvest. Handle tubers gently to avoid mechanical damage and to reduce risk of infection. Remove damaged or decaying tubers and apply phosphorous acid to tubers going into storage. Monitor the storages frequently. Look for water condensation on the walls and ceiling. Keep the temperature and the humidity at the lowest possible levels to reduce the spread of late blight in storage.

Leak, Pythium Leak

Pythium ultimum and other *Pythium* spp.

Identification: Grey-to-brownish lesions with a water-soaked appearance develop on the tubers. These lesions usually appear around wounds, cuts or bruises. Infected tuber tissue is cream-coloured. On exposure to air, the cream rot turns brown. A dark line is present at the margin of the rot. With time, the rot turns inky black. A clear, brownish liquid is readily released by the rotted tissue when the tuber is pressed. The entire inside of the tuber frequently rots, leaving a thin outer shell.

Biology: The leak fungus is soil-borne. It infects tubers through bruises and wounds, which usually occur at harvest. Harvesting the crop in hot humid weather or exposing the tubers to heat for several hours after harvest creates ideal conditions for leak development. Infection may also occur in the field prior to harvest.

Leak development is very rapid. It causes serious losses in storage, in transit and on the market. When infected potatoes are stored, juice from rotten tubers drips down through the pile, further spreading the infection.

Pythium leak may be responsible for the decay of seed tubers if conditions are warm and wet immediately after planting.

Scouting: Leak usually develops at harvest. Assess disease incidence prior to washing and bagging potatoes.

Management Notes: Avoid harvesting under hot, humid conditions. Minimize mechanical damage at harvest. Maintain good air circulation and keep the storage temperature as low as possible.

Nematodes

See Chapter 6.

Potato Early Dying

See the sections *Verticillium Wilt*, *Potatoes*, and *Root Lesion Nematode*, Chapter 6.

Pink Rot

Phytophthora cryptogea, *P. drechsleri*, *P. erythroseptica*, *P. megasperma*, *P. nicotianae* var. *parasitica*

Identification: Pink rot is a tuber decay that occurs sporadically, usually near the end of the season. It affects roots, stolons and tubers. Infected areas of the tuber surface turn purplish-black. The margin of the decay may be delineated by a dark line. Infected skin is easily rubbed off.

Initially, the affected internal tissue is cream-to-light brown and has a rubbery consistency. When exposed to the air, the rot turns salmon-pink, progressing to grey and then black. Occasionally, wilting of plants may occur as a result of pink rot infection (Figure 7–141).

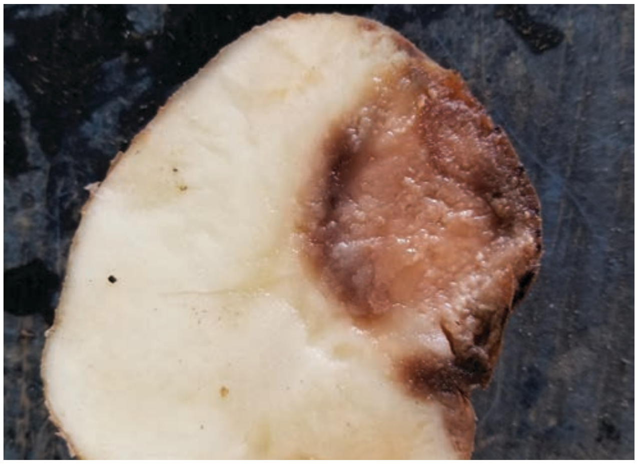


Figure 7–141. Pink rot tuber infection.

Biology: The pink rot fungus survives as thick-walled spores in the soil for many years. Tuber infection usually occurs before or at harvest. The disease is associated with excessive soil moisture, low spots in the field, over-irrigated areas and poorly drained soils. The fungus penetrates the tubers mainly through the stolons. However, infection through lenticels and eyes can occur. Tubers may also be infected through wounds made during harvest and handling.

The varieties Superior, Russet Norkotah, Goldrush, Snowden and Kennebec are very susceptible to pink rot.

Scouting: Pink rot develops late in the season. Dig tubers at random after top killing to assess disease incidence prior to harvest.

Management notes: Reduce the incidence of pink rot by applying an effective systemic fungicide when tubers are small. If pink rot is detected in the field, do not harvest affected areas of fields.

Avoid harvesting wet tubers. Keep the storage temperature as low as possible; the pink rot pathogen is inactive below 4.4°C (40°F). Maintain good air circulation in storage.

Rhizoctonia Stem Canker, Rhizoctonia Black Scurf

Rhizoctonia solani

Identification: *Rhizoctonia solani* causes two symptoms on potatoes at different times in the crop growth:

Rhizoctonia Stem Canker starts as brown lesions that pinch off the sprouts before the plant emerges, resulting in severe crop damage. Secondary sprouts develop from the pinched-off sprouts. They are less vigorous and emerge much later, causing irregular, uneven stands. Cankers on young stems cause the emergence of weak, spindly-looking plants. Mid- and late-season infections result in long, deep, sunken cankers on the stems. A white-to-grey mat of fungal mycelium may develop at the base of the stems. Infected leaves roll upwards and may turn reddish. Aerial tubers form on the leaf axils and/or at ground level.

Black Scurf is seen when sclerotia form on the skin of daughter tubers. Sclerotia are hard, black structures of irregular shapes and variable sizes that are tightly attached to the tuber skin, giving it an unsightly appearance.

Biology: *Rhizoctonia solani* is a ubiquitous soil-borne fungus. It can survive in the soil for many years. Infections can occur throughout the season under warm and wet or very humid conditions. In potatoes, rhizoctonia also survives on the surface of seed-potatoes.

Management Notes: Plant only certified, disease-free, potato seed. Fungicides are available that control rhizoctonia.

Silver Scurf

Helminthosporium solani

Identification: Silver scurf only affects tubers. Lesions appear first at the tuber stem end as small, circular or irregular spots of silvery appearance. Lesions may enlarge covering most of the tuber.

Tuber lesions that develop in storage are circular and dark brown to black. In storage, infected tubers lose water through the lesions, causing shrivelling and wrinkling (Figure 7–142).

Figure 7–142. Silver scurf lesions on the outside of the tubers.

Biology: The silver scurf fungus primarily overwinters on infected seed tubers. Spores produced on seed tubers wash onto new tubers, and infection takes place either through lenticels or directly through the skin. The infection remains confined to the skin tissue, causing it to loosen.

Disease incidence increases when potatoes are left in the ground after maturity and are harvested late. High humidity at the end of the season and in storage increases silver scurf damage. Silver scurf does not affect yield, but it compromises the quality of fresh-packed potatoes for the table market.

Scouting: Silver scurf develops late in the season. Lesions may be difficult to detect at harvest, particularly if the tubers are not washed. Dig tubers at random after top-killing and wash them to assess silver scurf incidence.

Management Notes: Use healthy seed free of silver scurf lesions. Harvest as soon as tuber skin is set and avoid mechanical injury. Thoroughly clean and disinfect storage before storing a new crop.

Tuber Soft Rot, Seed Piece Decay

Pectobacterium carotovorum var. *carotovora*, *Fusarium* spp.

Identification: Reddish brown-to-black spots develop on the surface of cut seed pieces. Later these spots may become black and slimy. Entire seed pieces will rot, leaving only a smelly mass of rotten tissue.

On stems, lesions first appear as water-soaked spots that ultimately turn light brown and slimy. Tuber infections typically occur on wounds, cuts or lenticels. Infected tubers develop a cream-coloured, odourless, soft decay. The margin of the decayed tissue is brown to black. Secondary bacteria invade the rotten tissue and give the rot a foul-smelling odour. Lesions around lenticels are sunken, water-soaked and circular. Lenticel lesions may dry up in storage.

See also *Aerial Stem Rot*, also in *Potatoes*.

Biology: Soft rot bacteria overwinter in infected tubers, in surface water sources or in the soil. The bacteria cannot penetrate intact skin, thus wounds are needed for infection.

High humidity and temperatures above 21°C (70°F) favour soft rot development

Scouting: Start scouting fields immediately after crop emergence. To assess seed decay incidence, dig spots with poor emergence and check the seed pieces for soft rot symptoms. In July to August, scout for aerial stem rot. Lesions are more common on plants damaged by tractors or sprayers.

Management Notes: Plant only certified seed. Disinfect seed cutting and handling equipment often and make sure cutters are sharp to ensure a smooth cut that heals easily. Avoid mechanical damage at planting, harvesting and during any handling operation.

Suberize tubers after harvest by holding them at 10°C–13°C (50°F–55°F) and 95% relative humidity for 10–14 days with good ventilation. See *Seed Handling and Management*, also in *Potatoes*.

Avoid moisture films on potatoes in bulk piles, dry them as much as possible before packing.

Verticillium Wilt

Verticillium albo-atrum, *V. dahliae*

Identification: The first symptom of verticillium wilt is yellowing of the leaves, possibly followed by wilting (especially during the heat of the day, with recovery at night). Yellow leaf lesions, extending between veins out to the leaf edge, develop initially on the lower leaves. The lesions often have a characteristic V-shape. Tissue within the lesions may die, but this is typically surrounded by an irregular yellow area. Surrounding leaves may show yellowing, initially without the browning. This helps distinguish the disease from early blight. Symptoms often appear on one side of the plant or one side of the leaf. When sliced lengthwise, the vascular tissue of the main stem will be brown, especially at the soil line. Symptoms often develop immediately after flowering.

Biology: The fungal inoculum survives in the soil and on debris from host plants. Many crop species are hosts, including potatoes, peppers, eggplant, strawberries, raspberries, beets, cucurbits, some crucifers and alfalfa. Weed species such as ragweed, lamb's-quarters, pigweed, velvetleaf and solanaceous weeds are also hosts.

Symptoms are often more severe during dry periods. The presence of root lesion nematodes may increase the severity of the disease.

Management Notes: Follow a 4–6-year crop rotation. Do not rotate with other host crops. Cereals and grasses are non-hosts. Keep fields clean of host weeds, such as nightshades.

The potato varieties Superior and Goldrush are very susceptible to verticillium.

Take soil samples to test for verticillium and nematodes. Soil fumigation may be required if verticillium and nematode counts are high. The best times to sample are in May to June and September to October.

Viruses

See Chapter 6.

White Mould

Sclerotinia sclerotiorum

See Chapter 6.

Insects

Aphids

See Chapter 5 and Figure 7–143.

Figure 7–143. Aphids found on the underside of the potato leaves.

Colorado Potato Beetle (CPB)

Leptinotarsa decemlineata

Identification: Adult beetles are somewhat rounded. They are approximately 10 mm (½ in.) long and 7 mm (¼ in.) wide. The wing covers are yellow-cream with 10 black, lengthwise stripes.

Eggs are yellow-to-orange, elongated and cylindrical. Egg masses contain 25–40 individual eggs. They are usually laid on the underside of the leaves. Recently laid eggs are bright yellow, turning dark orange close to hatching time.

Larvae are orange-red with a distinct black head and a humped back. They have two rows of black spots on both sides of their bodies. Larvae range in size from 2–12 mm (1⁄16–½ in.) long (Figure 7–144).

Damage: Beetles and larvae feed primarily on the foliage. They chew irregular holes in and along leaf margins. When no leaves are left, beetles eat pieces of stems, potato tubers or eggplant or tomato fruit. Crops are most susceptible to yield losses during the seedling, transplant and/or bloom stages.

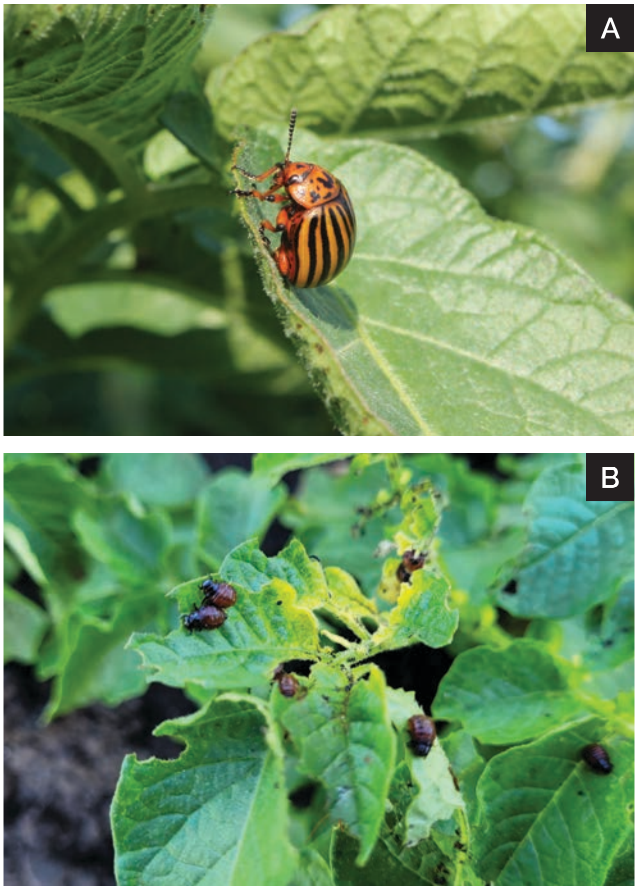


Figure 7–144. Colorado potato beetle adult (A) and early Colorado potato beetle instar larvae (B).

Biology: Adult potato beetles overwinter in the soil of the previous year's host crops or in protected areas surrounding these fields. The first generation of adult beetles start emerging in early May. Emergence occurs over a period of 4–6 weeks. The specific timing of the beetle emergence depends on the area and weather conditions.

Immediately after emergence, most beetles walk to the crop. A few are able to fly longer distances to a host field. Signs of infestation and feeding damage first appear along the edges of potato fields close to the overwintering sites.

Mating and egg-laying occur shortly after emergence. Females may lay as many as 400 eggs over 4–5 weeks. Eggs hatch into larvae in 4–9 days. The larvae pass through 4 stages (instars) reaching maturity in 10–20 days. The second generation of adults usually emerges in July. In very hot summers, a partial third generation may develop.

Scouting and Thresholds: Begin scouting for Colorado potato beetles when the crop emerges. Select 10 sites at random. At each site examine 5 plants; each plant must be from a different row.

Count the number of CPBs per plant until the plants are 15 cm (6 in.) high. For larger plants, count only the number of CPBs on one stem per plant. Keep track of the egg masses, adults and the larval stages separately. Early in the season, scout the border rows separately to determine if spot spraying or border sprays are an option.

Always check the entire plant carefully. Beetles and larvae often hide under the leaves or at the base of the stems during cool, hot or windy weather conditions. See Table 7–108.

Table 7–108. Colorado Potato Beetle Thresholds at Various Stages of Crop Development

Crop	Colorado Potato Beetle Stage	Threshold		
		Low	Medium	High
Potatoes	small larvae	—	1–74	> 75
	large larvae	1–30	31–74	> 75
	adults	1–15	16–24	> 25
	egg masses	4 egg masses in 50 plants is a potential problem.		

Management Notes: Crop rotation is very effective in reducing the first generation of CPB. If high populations are expected, apply a seed treatment or in-furrow insecticide at planting. Scout the field for CPB even if a systemic insecticide was used at planting.

This insect has developed resistance to most of the insecticides registered for its control. To determine the efficacy of an insecticide, flag any potential hot spots and assess these areas for beetle mortality as soon as the field re-entry interval has passed. Consider using spray tests or dip tests to determine the most effective insecticides against a population of beetles.

Cutworms

See Chapter 5.

European Corn Borer

See Chapter 5.

Flea Beetle

See Chapter 5.

Potato Leafhopper

Empoasca fabae

Identification: Adults are small, pale green, about 3 mm (⅛ in.) long and wedge-shaped, with a broad head and thorax. The body tapers along the wings. Leafhoppers are very active and quick to fly. Nymphs are similar to adults but lack fully developed wings. When disturbed, nymphs run sideways like crabs over the edge of the leaflet to the underside (Figure 7–145). Do not confuse leafhopper nymphs with aphids. Leafhopper nymphs move fast and walk sideways. Aphids move very slowly.

Figure 7–145. Potato leafhopper nymphs feeding on the underside of a potato leaf.

Damage: Adults and nymphs feed by sucking sap from the leaves and stems. Initially, the feeding damage causes yellowing and browning of the tips and margins of the leaves. Later, the leaf margins pucker and roll inward, resulting in the typical hopperburn damage. Hopperburn is usually noticeable 4–5 days after leafhopper feeding. To avoid yield losses, leafhoppers must be controlled before hopperburn is visible.

Biology: The potato leafhopper does not overwinter in Ontario. It is carried by upper-level winds from the U.S. and can arrive in Ontario as early as May. Females lay eggs on alfalfa. The nymphs hatch in about 10 days. There are 5 nymphal instars, which reach maturity in 10–25 days. Depending on weather conditions, 2–4 generations can develop during the season. Potatoes adjacent to alfalfa fields are at high risk of leafhopper infestation when hay is cut.

Scouting and Thresholds: In potatoes, monitor adult leafhoppers with a sweep net. Conduct a minimum of 25 sweeps per field. Each sweep consists of a single pass that just touches the top of the potato canopy but does not injure the plants. After each sweep, empty the net into a plastic bag and make a note of the number of leafhoppers in the net.

Nymphs can be monitored at the same sites selected for Colorado potato beetle. At each site, count the nymphs on one leaf from each of 5 plants. Early in the season, examine leaves from the mid-section or lower half of the plant. In July and August, examine only green leaves, not yellowing leaves. Report the number of immature nymphs on 50 leaves. The thresholds in potatoes are 1 or more adults per sweep and/or 20 nymphs per 50 leaves.

Management Notes: Leafhopper populations can increase rapidly in warm weather. Thus, field scouting is the first line of defence against this insect. Where potatoes are planted in the vicinity of an alfalfa field, scout twice weekly. Apply an effective insecticide when threshold is reached.

Tarnished Plant Bug

See Chapter 5.

Wireworms

See Chapter 5.

Disorders

Air Pollution Injury

Air pollution injury may be confused with symptoms of disease, insect feeding, nutrient deficiencies or toxicities, herbicide injury or damage caused by weather extremes. Plant damage caused by air pollution is usually most severe during warm, clear, calm, humid weather, when barometric pressure is high, as these conditions can cause an air inversion. During an air inversion, warm air above the earth's surface traps cooler air at ground level, allowing pollutants to accumulate. Injury may also be more severe during foggy conditions, heavy dews or in fields near very busy highways. Causes of air pollution injury include: ozone, sulfur dioxide, peroxyacetyl nitrate (PAN) and ethylene (Figure 7–146).

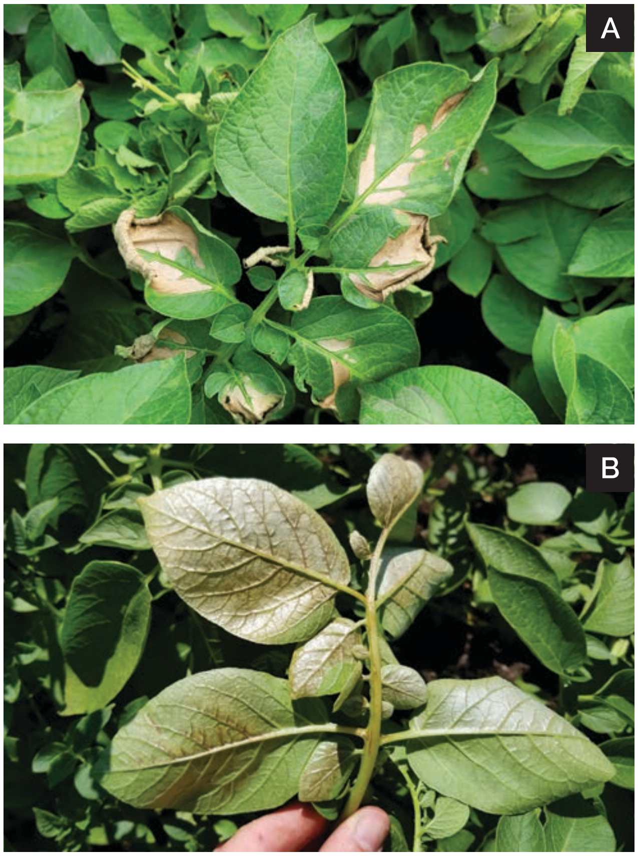


Figure 7–146. Interveinal bleaching and copper discolouration from ozone injury (A) and shiny metallic appearance caused by PAN (B).

Ozone: Ozone symptoms tend to occur on the upper surface of affected leaves, appearing as a flecking, bronzing or bleaching of the leaf tissues. Yield reductions are not always associated with injury symptoms. Susceptibility to ozone injury is influenced by many environmental and plant growth factors. High relative humidity, optimum soil-nitrogen levels and water availability increase susceptibility. Typically, young leaves are resistant to ozone injury. During expansion, they become successively susceptible at the middle and the base of the leaf. With age, leaves become resistant again.

Sulfur dioxide: Symptoms of acute injury appear as necrotic lesions between the veins and occasionally along the margins of the leaves. The colour can vary from a light tan or near white to an orange-red or brown depending on the time of year, the plant species affected and weather conditions. Recently expanded leaves usually are the most sensitive to acute sulfur dioxide injury, the very youngest and oldest being somewhat more resistant.

Chronic injury is caused by long-term absorption of sulfur dioxide at sub-lethal concentrations. The symptoms appear as a yellowing or chlorosis of the leaf, and occasionally as a bronzing on the under surface of the leaves.

Peroxyacetyl nitrate (PAN): This pollutant typically causes a gradual glazing or silvering effect in bands or blotches, which may advance to bronzing within 2–3 days. Small plants and recently matured leaves (about 5 days after leaf emergence) are most susceptible to PAN injury.

Black Heart

Black heart is a black, oddly shaped discolouration in the centre of the tuber with a distinct line between healthy and affected tissue. The discolouration is caused by low oxygen levels in waterlogged fields, transport containers or storage.

Black Spot Bruise

Black spot is caused by rough handling of tubers. The bruise can leave the skin intact but cause a round, greyish-black discolouration under the skin.

Brown Centre and Hollow Heart

Brown centre and hollow heart are two phases of the same disorder. Brown centre is most common when soils are cool and wet during tuber initiation. This causes the pithy tissue near the centre of the tuber to turn brown. If tuber growth is slow, the brown centre will disappear as the tubers mature. If tuber growth is rapid, the brown centre will split apart, leaving a cavity, commonly called hollow heart. The cavity walls are tan or brown, and the cavity will range from 1 cm (~½ in.) to the whole of the pithy tissue at the centre of the tuber. Hollow heart is most severe when soil moisture levels fluctuate. Wide plant spacing can increase the incidence of hollow heart as does boron deficiency. The varieties Atlantic and Yukon Gold are very susceptible to brown centre and hollow heart. Superior is susceptible to brown centre, but it rarely develops hollow heart.

Heat Necrosis

A period of slow tuber growth followed by sudden, high temperatures can cause heat necrosis. Round or irregular brown necrotic spots develop in the vascular tissue of the tuber. There is no skin discolouration. The varieties Atlantic and Chieftain are very susceptible to heat necrosis (Figure 7–147).

Figure 7–147. Internal browning of the tuber vasculature as a result of high temperatures during the growing season.

Pink Eye

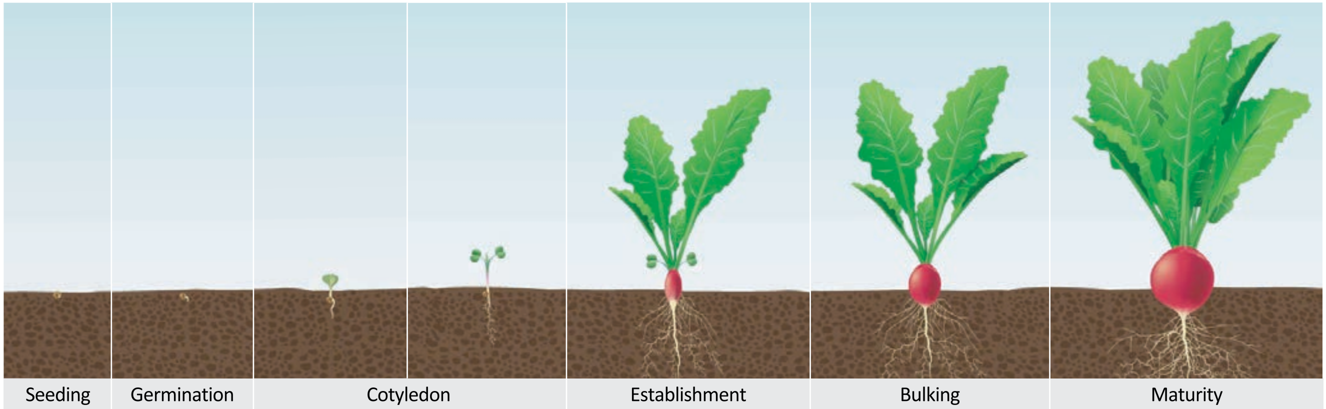
Pinkish swellings develop on the skin, usually around the eyes and at the apical (stem) end of the tubers. The underlying tissue is healthy unless pink eye is severe, in which case the underlying tissue will be reddish-brown, and cavities or soft rot may develop. Pink eye is easiest to see on freshly dug potatoes when the skin is still damp. This disorder is difficult to see on dry, unwashed potatoes. The affected skin dries out if tubers are stored under cool temperatures and low humidity with good air circulation.

Pink eye occurs sporadically. It usually develops late in the growing season under conditions of high soil moisture. This disorder is often associated with verticillium wilt and rhizoctonia. Good control of these diseases should reduce the incidence of pink eye. Varieties such as Kennebec, Superior and Shepody are very susceptible.

Tipburn

Leaf tips turn brown, and the affected leaves roll upward and eventually die. Tipburn occurs when excessive leaf moisture is lost during hot, dry, windy conditions following cool weather. Tipburn can be confused with late blight and/or leafhopper damage.

Radish



Planting to harvest: 22–30 days

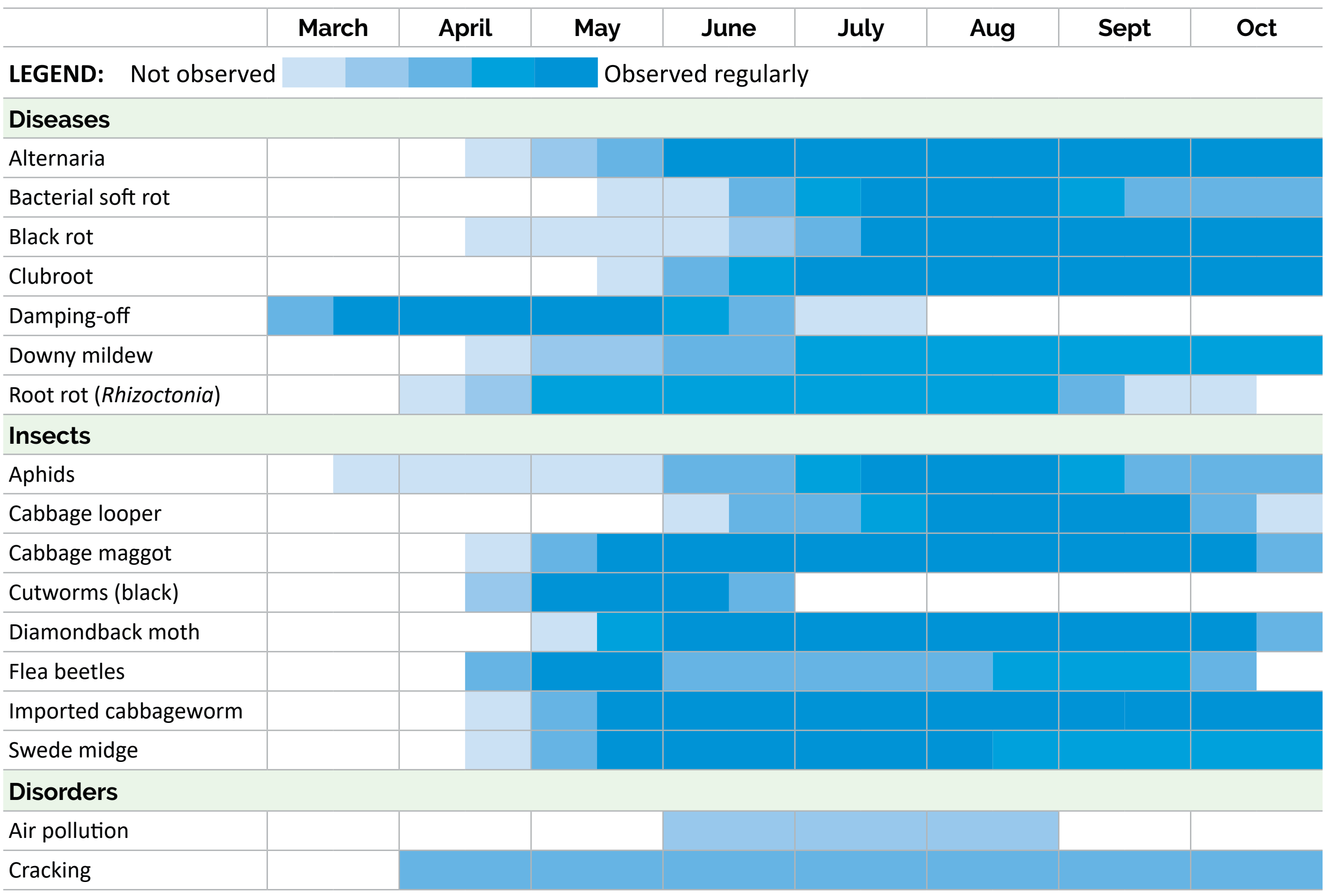


Figure 7–148. Radish stages of development and pest activity calendar. The actual period of activity for any given pest will vary significantly from year to year, depending on environmental factors.

Production Requirements

Soil types:	sandy loam and muck soil
Soil pH:	sandy loam: 6.5
	muck soil: 5.1–5.5
Recommended rotational crops:	lettuce, tomatoes, peppers, spinach
Do not rotate with:	other brassica crops, carrots, potatoes, beets
Minimum soil temperature:	4°C (38°F)
Optimum air temperature:	10°C–18°C (50°F–64°F)
Earliest planting date:	early to late April

Table 7–109. Radish Crop Spacing

Crop	Row Spacing	In-Row Spacing	Depth	Seeding Rate
Radish (hand harvest)	20–30 cm (8–12 in.)	2–2.5 cm (1 in.)	1.5 cm (½ in.)	11–17 kg/ha (10–15 lb/acre)
Radish (machine harvest)	10–15 cm (4–6 in.)	2–2.5 cm (1 in.)	1.5 cm (½ in.)	22–34 kg/ha (20–30 lb/acre)

Radish Types

There are two main categories of radish grown in Ontario: radish and Asian radish. Radish (*Raphanus sativus*) cultivars come in many shapes and sizes including red globe, candy cane, yellow and watermelon. Asian radish (*Raphanus sativus* subvar. *longipinnatus*) has many other names, including daikon radish, Chinese radish, moo radish, lo bok or luo bu radish. These radishes have a long white root and are grown similarly to carrots (Figure 7–149).

Seeding and Spacing

Radish seed can be sown as soon as the soil is workable. For radish crop spacing, see Table 7–109. The minimum soil temperature required for seed germination is 4°C–7°C (39°F–45°F). Spring frosts or even snowfalls do not seriously injure the crop after the plants have emerged. Under favourable weather conditions, radish seedlings emerge 2 or 3 days after sowing. Sowing at regular intervals in the spring will provide a continuous harvest.

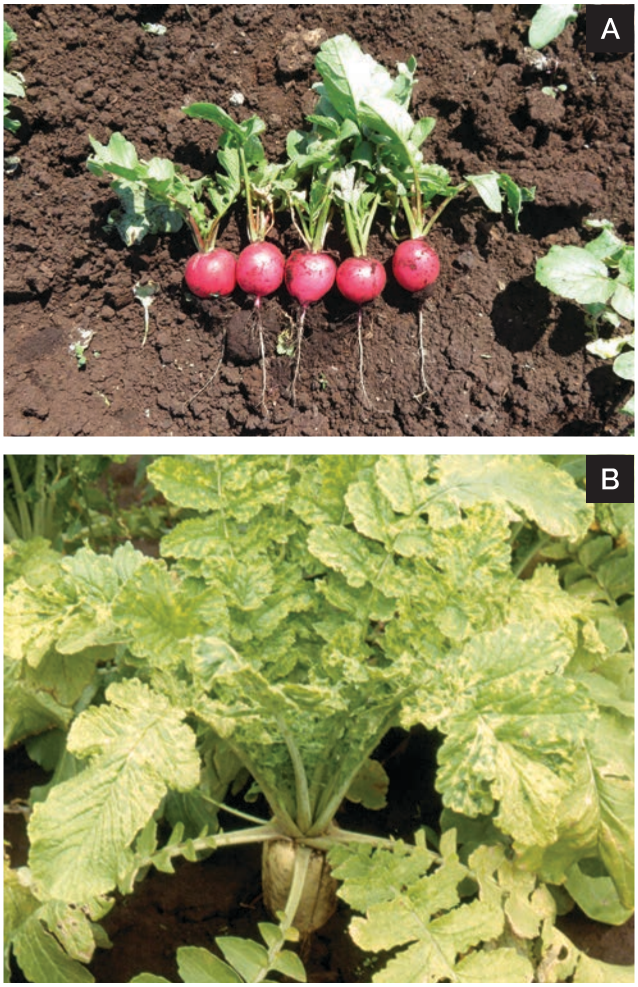


Figure 7–149. Examples of red globe radish (A) and daikon radish (B).

Fertility

Macronutrients

Nitrogen

On mineral soils, apply up to 60 kg N/ha (45 lb N/acre). On muck soils, apply 40 kg N/ha (36 lb N/acre). If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. See Table 1–12 and Table 1–13, Chapter 1, for more information.

Phosphorus and Potassium

Test the soil to determine phosphorus and potassium requirements. See Table 7–110 and Table 7–111.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. For complete information, see *Micronutrients*, Chapter 1.

Boron deficiencies on radish result in splitting and cracking of the skin. Use caution when applying boron as it can build to toxic levels quite quickly, harming rotational crops.

Calcium deficiencies cause a backward cupping of leaves and discolouration of the leaf margins.

Magnesium and manganese deficiencies appear as bronzing or yellowing of leaf tissue between the veins.

Table 7–110. Radish Phosphorus Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Sodium Bicarbonate Phosphorus Soil Test (ppm)													
	0–3	**4–5**	**6–7**	**8–9**	**10–12**	**13–15**	**16–20**	**21–25**	**26–30**	**31–40**	**41–50**	**51–60**	**61–80**	**81+**
Mineral Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	80 (71) (HR)	70 (63) (HR)	60 (53) (HR)	60 (53) (HR)	50 (45) (MR)	50 (45) (MR)	40 (36) (LR)	40 (36) (LR)	30 (27) (LR)	30 (27) (LR)	20 (18) (LR)	0 (LR)	0 (RR)	0 (NR)
Muck Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	100 (89) (HR)	100 (89) (HR)	100 (89) (HR)	100 (89) (HR)	90 (80) (MR)	90 (80) (MR)	80 (71) (MR)	70 (64) (MR)	60 (54) (MR)	50 (45) (LR)	30 (27) (LR)	20 (18) (LR)	0 (RR)	0 (NR)

Table 7–111. Radish Potassium Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Ammonium Acetate Potassium Soil Test (ppm)											
	0–15	**16–30**	**31–45**	**46–60**	**61–80**	**81–100**	**101–120**	**121–150**	**151–180**	**181–210**	**211–250**	**251+**
Mineral Soils												
Potash (K_2O) required kg/ha (lb/acre)	60 (54) (HR)	60 (54) (HR)	50 (45) (HR)	50 (45) (HR)	40 (36) (MR)	30 (27) (MR)	30 (27) (MR)	20 (18) (MR)	20 (18) (MR)	0 (LR)	0 (RR)	0 (NR)
Muck Soils												
Potash (K_2O) required kg/ha (lb/acre)	100 (89) (HR)	100 (89) (HR)	90 (80) (HR)	80 (71) (HR)	60 (54) (MR)	40 (36) (MR)	30 (27) (MR)	20 (18) (MR)	20 (18) (MR)	0 (LR)	0 (RR)	0 (NR)

Table 7–112. Radish Nutrient Ranges

LEGEND: – = no data available

Plant Part	Time of Sampling	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu	Mo
		Per Cent (%)						Parts Per Million (ppm)					
Most recently mature leaf	at harvest	3.0–4.5	0.3–0.4	1.5–3	1–2	0.3–0.5	–	30–50	20–40	30–50	15–30	3–10	0.1–2

Adapted from G Hochmuth et al. 2018. *Plant Tissue Analysis and Interpretation for Vegetable Crops in Florida*. University of Florida IFAS Extension. HS964.

Plant Tissue Analysis

When used in conjunction with soil analysis, plant tissue analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. Plant tissue analysis does not replace soil testing or a sound soil fertility program.

For more information, see Table 7–112 and *Plant Tissue Analysis*, Chapter 1.

Harvest

Radish reaches maturity within 22–30 days. Harvest radish when 1.3–2.5 cm (½–1 in.) in diameter. Harvest spring radishes before hot weather in July and winter radishes before the ground freezes. Radish quality is at its best May, June, September and October. Bunched radishes are typically hand-harvested. Topped radishes may be harvested by hand or mechanically. Radishes remain in prime condition for only a few days and must be picked frequently.

Asian radish reaches maturity within 60–90 days. Asian radish can be harvested by hand, using a top-pull harvester or a potato digger type harvester.

Storage

Remove the field heat from the crop immediately after harvest. At 0°C (32°F) and a relative humidity of 95%–100%, radishes have a shelf life of up to 3–4 weeks. For more information on storage, see Table 3–1 in Chapter 3.

Pest Management and Disorders

See Figure 7–148. *Radish stages of development and pest activity calendar*.

Diseases

Alternaria

Alternaria brassicae, A. brassicicola, A. raphani

Identification: Small, yellowish lesions develop on older leaves. As the spots expand, they resemble a "target" with concentric light and dark rings.

Biology: Alternaria is both seed-borne and spread by wind throughout the summer season. Cool, humid conditions favour black spot development.

Scouting: Inspect 10 leaves at each of 20 random locations in the field. Observe both the older and newer leaf growth. Record the percentage of leaves infected and the average number of lesions per leaf.

Management Notes: Adequate air circulation will reduce humid conditions in the canopy. Avoid overhead irrigation once the disease has been diagnosed in a field. Ensure that radishes are free of alternaria before going into storage. In storage, temperatures below 4°C (39°F) inhibit the development of new infections. If this disease is present in the field, protect the plants with a fungicide prior to harvest.

Hot-water seed treatment will eliminate both internal infection and external infestation of seed, while fungicide seed treatment will only control spores on the seed.

Rotate with less-susceptible crops (cereals or corn) and control chewing insects.

Bacterial Soft Rot

See *Brassica Crops*, in this chapter.

Black Root

Aphanomyces raphani

Identification: Infected seedlings die back. Late-season infections cause stunted plants and blackening on both the exterior and interior of the radish root. Black root infection usually begins as a dry rot. Secondary bacterial rots eventually cause the disintegration of the root (Figure 7–150).

Figure 7–150. Outer and inner root symptoms of black root.

Biology: This soil-borne disease is favoured by moist, warm soil conditions. Infection occurs between 16°C–32°C (61°F–90°F), with maximum damage at 27°C (81°F).

Management Notes: Plant into well-drained soils; follow a 4-year rotation with unrelated crops. Control all brassica weeds (wild mustard, yellow rocket, etc.). Resistant cultivars are available. Deep-plow infested residue.

Black Rot

Xanthomonas campestris pv. *campestris*

Identification: Affected crops develop blackened veins and vascular bundles. This is most noticeable when the stems or roots are cut lengthwise or crosswise. Root rots may also develop.

Biology: As little as one infected plant in 10,000 can result in a field epidemic. Black rot is spread rapidly during warm, humid weather with an optimal temperature range of 27°C–30°C (81°F–86°F) at 80%–100% humidity. Once in the soil, the bacteria spread by splashing rain and wind. Bacteria enter plants through wounds or natural openings at the leaf margins called hydathodes.

Management Notes: Use certified disease-free seed and/or hot-water-treated seed. Longer season radish cultivars are most susceptible to black rot. Never store diseased radishes. Clean out and disinfect the storage area each spring. Follow at least a 2–3-year crop rotation to non-brassica crops and control all brassica weeds.

Club Root

Plasmodiophora brassicae

See Chapter 6 and Figure 7–151.

Figure 7–151. Root galling caused by clubroot on radish roots.

Common Scab

Streptomyces scabies, *S. scabiei*

Identification: Pitted, corky, scale-like spots develop on infected roots. Lesions frequently enlarge to 1.5 cm (¾ in.) in size and have raised edges (Figure 7–152).

Figure 7–152. Symptoms of scab infection on the outside of radish roots.

Biology: The scab bacterium survives in the soil indefinitely. Warm, dry soils and a soil pH of 5.5–7.5 favour scab development. See Figure 7–137.

Scouting: To assess disease incidence, pull plants at random and examine the tubers or roots. Disease assessment can start when daughter tubers are about nickel size.

Management Notes: Do not grow radish in rotation with potato, carrot or beets. Rotations with grains are partially effective at reducing scab levels in the soil. Maintaining high soil moisture levels during root development may reduce infection.

Damping-Off — also known as Root Rots

Pythium sp., *Phytophthora* sp., *Rhizoctonia* sp., *Fusarium* sp.

See Chapter 6.

Downy Mildew

Peronospora parasitica = *Hyaloperonospora parasitica*

Identification: Symptoms appear as yellow spots on the upper leaf surface with corresponding greyish-white fungal growths on the underside. Infections on the roots cause dark, discoloured areas extending from the crown, down the root. Infected roots may split or become invaded by secondary rot organisms (Figure 7–153).

Figure 7–153. Yellow lesions with white fungal growth typical of downy mildew on the underside of radish leaves.

Biology: Infection occurs at any growth stage. Cool temperatures of 10°C–15°C (50°F–59°F) and prolonged periods of leaf wetness, dew or fog favour disease development. This fungus overwinters in seed and on infected plants. Downy mildew fungi survive for at least 1 year in the soil and 2 years in infected seed.

Management Notes: Plant into well-drained soil. Avoid excessive use of overhead irrigation. Follow a 2-year rotation with non-host crops. Tolerant radish cultivars are available.

Powdery Mildew

See Chapter 6.

Root Rot, Crown Rot, Stem Canker (Rhizoctonia)

Rhizoctonia solani

Biology: *Rhizoctonia solani* is a ubiquitous soil-borne fungus. It can survive in the soil for many years. Infections can occur throughout the season under warm and wet or very humid conditions (Figure 7–154).

Rhizoctonia solani is one of the fungal species that cause damping-off. See *Damping-Off*, Chapter 6.

Figure 7–154. Black cankers caused by rhizoctonia on red radish.

Management Notes: Avoid planting susceptible crops in previously infected areas. Rotate for several years with corn or small grains, and practise strict sanitation procedures to avoid spreading infected soil between fields.

Turnip Mosaic Virus (TuMV)

Identification: Older leaves turn yellow and drop prematurely. Leaves emerging after infection are stunted and wrinkled and show a yellow, mottled pattern. Roots become "goose-necked" and do not reach normal size.

Biology: TuMV is spread by aphids. A rapid increase in infection usually begins in early July, when large numbers of winged aphids become active. Volunteer rutabagas and winter canola are the main overwintering sources of the virus.

Management Notes: Applications of mineral oil deter the feeding of virus-spreading aphids. Aphid control does not completely prevent the spread of the virus.

White Rust
Albugo candida

Identification: Symptoms of the disease first appear as yellow spots on the upper leaf surface. White pustules form on the underside of the leaf.

Biology: The development of white rust is favoured by warm, sunny days followed by cool nights with dew. This disease can occur any time during the season.

Management Notes: Avoid planting fall crops in or adjacent to fields where an infected spring crop was grown. Practice a 3-year crop rotation.

Insects

Aphids

See Chapter 5.

Cabbage Looper
Trichoplusia ni

See Chapter 5.

Cabbage Maggot
Delia radicum

Identification: The cabbage maggot adult is a grey fly, approximately half the size of the common housefly. The female lays eggs in the soil at the base of seedlings. The small, white eggs look like tiny (1 mm (<1⁄16 in.)) grains of rice. The larvae are small (7 mm (⅓ in.)), legless and white (Figure 7–155).

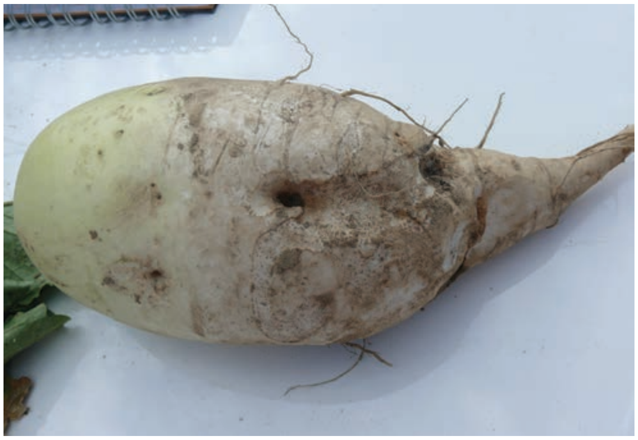


Figure 7–155. Symptoms of cabbage maggot tunneling and feeding damage on the outside of a daikon radish.

Damage: The maggots tunnel and feed along the roots of radish crops. Cabbage maggot feeding causes serious economic damage. These wounds also act as points of entry for soft rot bacteria.

Biology: Cabbage maggots overwinter as pupae in the soil. There are three periods of egg-laying throughout the season. The first generation is the most active and most damaging. It occurs from mid-May through June (flowering of yellow rocket). A second occurs in mid-July (flowering of day lilies) and a third in late August (flowering of goldenrod).

Hot, dry conditions reduce maggot survival, especially for the later generations. Damage from all three generations may be expected in cooler regions of the province. Crops receiving irrigation, root crops and most specialty brassicas are more susceptible to this pest.

Scouting and Thresholds: Sticky trap monitoring programs for cabbage maggot adults can help with spray timing. Growing degree days (base of 6°C) (GDDs) may be used to predict cabbage maggot activity. First-generation adults emerge between 314 and 398 GDDs. Second-generation adults emerge between 847 and 960 GDDs. Third-generation adults emerge between 1,446 and 1,604 GDDs. See *Growing Degree Days*, Chapter 4.

Management Notes: Cabbage root maggot management is primarily preventive. Later plantings of brassica crops are less likely to require protection. Follow a 3–4-year crop rotation. Time control of root maggots to coincide with the egg-laying activity of each generation.

Cutworms (Early-Season)

Agrotis ipsilon (black cutworm),
Euxoa messoria (dark-sided cutworm),
Crymodes devastator (glassy cutworm),
Euxoa detersa (sandhill cutworm)

See Chapter 5.

Diamondback Moth

Plutella xylostella

See Chapter 5.

Flea Beetles

Phyllotreta sp.

Identification: Flea beetles are small (2–3 mm (~⅛ in.) long), shiny black beetles. Adults are active and jump when disturbed.

Figure 7–156. Shiny, black adult flea beetles on a radish leaf causing the shotgun hole feeding damage pattern.

Damage: Feeding damage consists of numerous very small "shot-holes," 1–5 mm (<¼ in.) in diameter. Older damage may be ringed with brown, dried leaf tissue, while fresh feeding holes have green edges. At the seedling stage, flea beetle feeding can kill the plant. Flea beetles feed on radish tops, rendering them unmarketable. Larval feeding on the root may reduce marketability.

Biology: Flea beetles in Ontario generally have one generation per year. The lifecycle from egg to adult may take as little as 7 weeks, making a second generation possible in some years. Adult flea beetles overwinter in leaf litter. They emerge and begin feeding on young plants in mid-May. Adults lay eggs near the roots of host plants throughout the spring and early summer. Larvae develop on the roots. In late July, adults emerge from the soil, feed and then seek hibernation sites in the fall.

Scouting and Thresholds: Begin monitoring for flea beetles as soon as the crop is seeded in the field.

Management Notes: Early plantings may be protected with row covers. Beetles tend to prefer daikon radish over other brassica crops. If black rot is present in the field, flea beetle management is important, as the beetle can spread black rot disease as it feeds.

Imported Cabbageworm

Pieris rapae (L.)

See Chapter 5.

Swede Midge

See *Brassica Crops*, in this chapter.

Disorders

Cracking

See *Rutabagas and Turnips*, in this chapter.

Rutabagas and Turnips

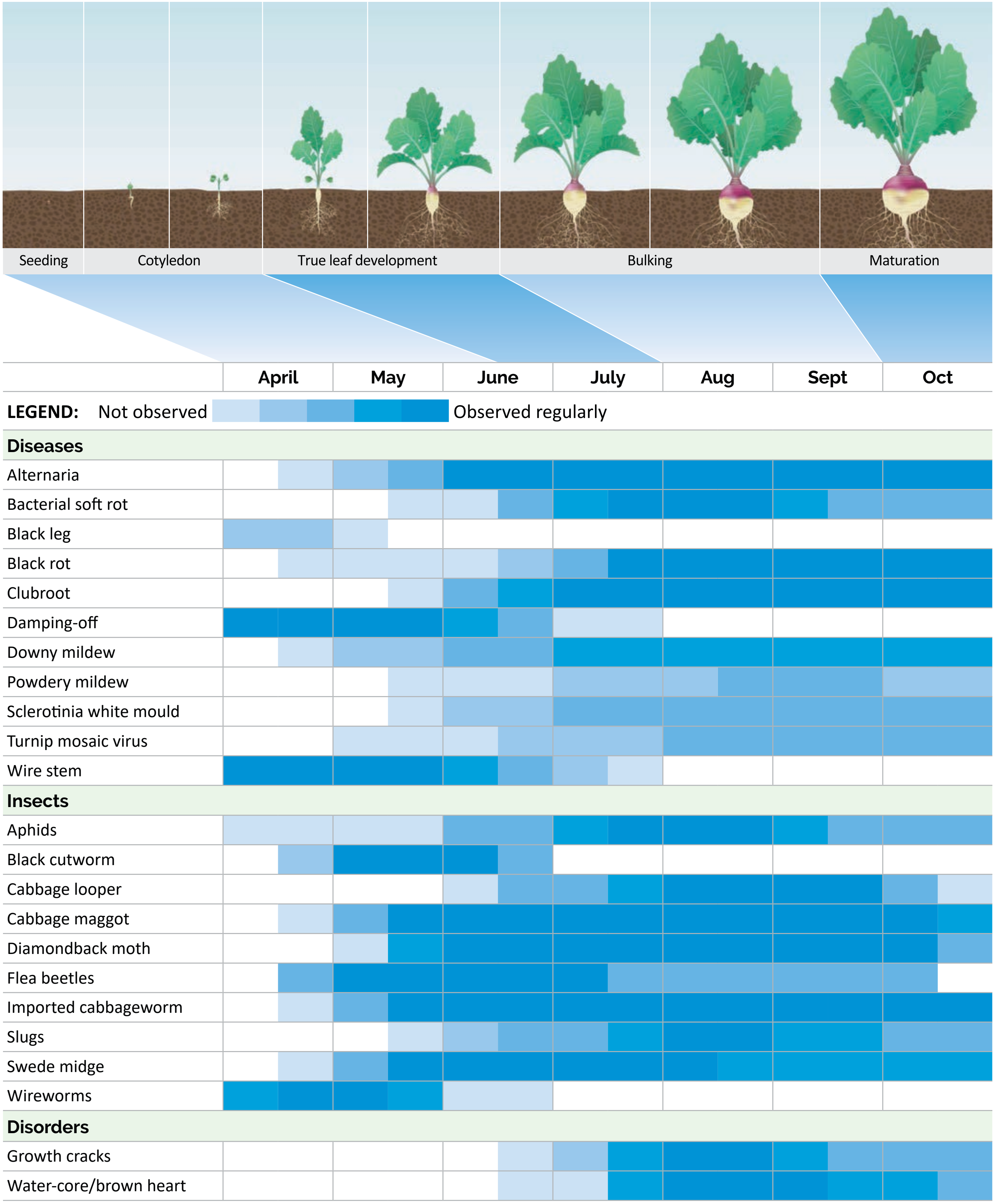


Figure 7–157. Rutabaga and turnip stages of development and pest activity calendar. The actual period of activity for any given pest will vary significantly from year to year, depending on environmental factors.

Production Requirements

Soil types:	a wide range of mineral soil types but performs best on a deep, well-drained loam or sandy loam soil
Soil pH:	6.1–6.5
Recommended rotational crops:	cereal crops, potatoes, peppers, tomatoes
Do not rotate with:	other brassica crops, including canola
Minimum soil temperature:	5°C (41°F)
Minimum air temperature:	16°C (61°F)
Earliest planting date:	April

Rutabaga vs. Turnips

The terms rutabaga and turnips are often used interchangeably but describe two different species with very different growing seasons. Rutabagas (*Brassica campestris* var. *napobrassica*) are the result of a cross between turnip and cabbage and have a large root with a purple crown and white/yellow fleshed root and long growing season. In Ontario, the main cultivar grown is Laurentian. Turnips (*Brassica rapa* var. *rapa*) are smaller than rutabaga, generally have a purple top and white/yellow flattened globe root. Although their growing seasons are different, they have very similar pests and diseases (Figure 7–158).

Figure 7–158. Large mature root of a rutabaga plant (A) compared to the smaller mature turnip (B). *Source (B):* Shutterstock.com.

Seeding and Spacing

The optimum soil temperature for germination is from 16°C–29°C (61°F–84°F). There is a limited market for early rutabaga crops, seeded in April and May. Seed the main crop, grown for winter storage, from late May to late June. Rutabagas seeded during this time can size up during the cool, fall weather, resulting in improved root quality. Crops seeded in early July can sometimes run into high temperatures and a lack of moisture for germination.

Rutabaga can also be grown from transplants for an early market. The cultivar York is usually used for transplanted crop as it grows better in a plug tray and matures a little earlier than Laurentian.

Good seed bed preparation is required to encourage quick germination and consistent emergence. Seed at a depth of 0.6–1.2 cm (¼–½ in). Vigorous, even germination is critical to ensuring good-quality roots. Not only do missing plants reduce populations but the issue is compounded by allowing more space for neighbouring plants to grow. These neighbouring plants grow excessively and produce growth cracks or grow larger than the rest of the field, leading to oversized, unmarketable roots.

To achieve the desired plant stand, use a precision seeder or thin plants after emergence. When thinning, seed at a higher rate and remove plants with hoes after 90% germination. Thinning requires significant labour investment but may be preferred if optimal germination is an issue. See Table 7–113.

Table 7–113. Rutabaga and Turnip Crop Spacing

Crop	Row Spacing	In-Row Spacing	Population	Seeding Rate
Rutabaga	60–90 cm (24–36 in.)	13–15 cm (5–6 in.)	87,722–101,217 plants/ha (35,500–40,961 plants/acre)	approx. 500 g seed/ha (approx ½ lb seed/acre)
Rutabaga (transplanted)	60–90 cm (24–36 in.)	15 cm (6 in.)	87,722 plants/ha (35,500 plants/acre)	approx. 500 g seed/ha (approx ½ lb seed/acre)
Turnips	36–76 cm (14–30 in.)	5–7 cm (2–3 in.)	1.5 million plants/ha (600,000 plants/acre)	approx. 6.7 kg seed/ha (approx 6 lb seed/acre)

Fertility

There are no established Ontario fertility recommendations for turnips. See other shorter-season root brassica crops such as radish for fertility guidelines. The following are guidelines for rutabaga.

Macronutrients

Nitrogen

Apply up to 35 kg N/ha (31 lb N/acre). If manure is used in the rotation, apply it at least 1 year before the rutabaga crop is grown. Do not over-apply nitrogen as it can cause excess growth, splits and growth cracks leading to unmarketable roots.

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. See Table 1–12 and Table 1–13, Chapter 1.

Phosphorus and Potassium

Test the soil to determine phosphorus and potassium requirements. See Table 7–114 and Table 7–115.

Magnesium

For rutabagas grown on soils with magnesium tests of less than 100 ppm, decrease the recommended potash application rate to a minimum of 50% at a magnesium test of 50 ppm. For example, a soil testing 75 ppm magnesium should receive only 75% of the usual potash recommendation for that soil. On soils testing 50 ppm magnesium or less, apply 50% of the total potash recommendation.

Table 7–114. Rutabaga and Turnip Phosphorus Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Sodium Bicarbonate Phosphorus Soil Test (ppm)													
	0–3	4–5	6–7	8–9	10–12	13–15	16–20	21–25	26–30	31–40	41–50	51–60	61–80	81+
Mineral Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	180 (161) (HR)	170 (152) (HR)	170 (152) (HR)	160 (143) (HR)	160 (143) (HR)	150 (134) (HR)	140 (125) (HR)	120 (107) (MR)	100 (89) (MR)	80 (71) (MR)	50 (45) (LR)	30 (27) (RR)	0 (RR)	0 (NR)

Table 7–115. Rutabaga and Turnip Potassium Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Ammonium Acetate Potassium Soil Test (ppm)											
	0–15	16–30	31–45	46–60	61–80	81–100	101–120	121–150	151–180	181–210	211–250	251+
Mineral Soils												
Potash (K_2O) required kg/ha (lb/acre)	340 (303) (HR)	330 (294) (HR)	310 (277) (HR)	280 (250) (HR)	250 (223) (HR)	200 (178) (HR)	150 (134) (MR)	90 (80) (MR)	50 (45) (MR)	0 (LR)	0 (RR)	0 (NR)

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. For complete information, see *Micronutrients*, Chapter 1.

Boron

Boron is a critical micronutrient needed for a quality rutabaga crop and to prevent water-core. Water-core or brown heart, caused by boron deficiency, first appears in young, growing roots as firm, brownish, water-soaked patches. Severely affected rutabagas develop a soft, brown internal discolouration during storage.

Mix boron with preplant fertilizer applications. Apply boron-enriched fertilizer as uniformly as possible. Foliar applications of Solubor are often as effective as larger amounts applied to the soil. Make the first foliar application when the roots are about 1.5–2.5 cm (approximately 1 in.) in diameter. The second and third applications can be applied at 10–14-day intervals.

Do not combine pesticides with boron sprays unless the label specifies compatibility. Use caution when applying boron. Many rotational crops are sensitive to high levels of boron in the soil.

Harvest

Rutabagas typically maturity in 90 days after planting. Roots should be 102–178 mm (4–7 in.) in diameter. Early harvest of transplant rutabagas can begin as early as July while the main crop harvest does not get under way until the month of October. Harvest is usually completed by mid-November.

Rutabaga can be harvested with a top-pull belt harvester, making top health an important priority. It is also possible to top and harvest rutabagas with a potato-type digger. Avoid excessive mechanical injury as much as possible. Bruises, cuts and scrapes affect the appearance and create an entry point for disease organisms to enter and start rots.

Storage

It is important to remove the field heat as quickly as possible and move rutabagas into storage at 0°C and a relative humidity of 90%–95%. Damaged and bruised rutabagas do not store well, and rot quickly. Rutabaga can be stored in bulk or in pallet boxes in air-cooled or refrigerated storages (Figure 7–159).

Figure 7–159. Large pile of rutabagas stored in bulk with forced air ventilation.

Disease-free rutabagas will keep up to 6 months. For long-term storage, store at 0°C (32°F) and a relative humidity (RH) of 90%–95%. Rutabagas freeze at approximately –1°C (30°F), and temperatures below –0.5°C (31°F) should be avoided in storage. A high RH is important to prevent excessive water loss and shriveling. Maintain adequate ventilation and air movement throughout the storage area. For more information, see Chapter 3.

Waxing and Trimming

Rutabagas should be trimmed before going to market. Remove secondary roots on the bottom half of the root. Rutabagas are normally hot-waxed just before being marketed. Waxing improves their appearance, keeps them clean, protects freshly trimmed surfaces from disease organisms and prevents undue moisture loss and shrinkage during the marketing period. Waxing is not recommended for rutabagas being held in storage.

Immerse clean, dry rutabagas for one second in a "rutabaga/turnip" wax at 126°C (259°F)and then pack as desired for market. Temperatures must be kept low after waxing. Waxed rutabagas can spoil within a few days at room temperature.

Pest Management and Disorders

See Figure 7–119, *Rutabaga and turnip stages of development and pest activity calendar*.

Diseases

Alternaria

See *Brassica Crops*, in this chapter.

Bacterial Soft Rot

Pectobacterium carotovorum subsp. *Carotovorum* (formerly known as *Erwinia carotovora*)

Identification: Infected leaf or head tissue often takes on a tan colour, becoming moist and mushy and developing a foul odour. Soft rot may attack the plant below the soil surface, especially when cabbage maggots are present (Figure 7–160).

Figure 7–160. Water-soaked and mushy symptoms of a rutabaga infected with soft rot bacteria.

Biology: Bacterial soft rot causes serious losses in the field, in transit and in storage. Insect damage, mechanical damage or hail predispose plants to soft-rot infection. Soft rot spreads rapidly in warm, humid conditions. It is spread by direct contact, hands, tools, soil water, insects and splashing rain or irrigation.

The soft rot bacteria overwinter in infected tissues, in the soil, and on contaminated equipment and containers. They also overwinter in insects such as the cabbage maggot.

Warm, moist weather is favourable for infection by the bacterial soft rot pathogens.

Management Notes: Plant into well-drained soils and maximize air flow through the plant canopy. Once the disease is identified in a field, avoid overhead irrigation. Rotate with less-susceptible crops (cereals or corn) and control chewing insects. Excess nitrogen may promote soft rot infections.

Storage temperatures below 4°C (39°F) inhibit the development of new infections in brassica crops and radishes. When infections appear in storage, remove and destroy infected plants. Practice good storage sanitation.

Black Leg (Brassica Crops)

Leptosphaeria maculans
(anamorph: *Phoma lingam*)

Identification: Seedlings infected with black leg may die or may simply lose their cotyledons. On leaves, circular, light brown-to-grey spots develop. The stems of infected plants develop light brown lesions with purplish or black edges. On mature rutabaga plants, cankers develop on the root. Dry, sunken spots with dark borders develop in storage. Waxed rutabaga roots rot rapidly.

Biology: Plants may be infected at any time in the field. Rutabagas are susceptible to these diseases at the seedling stage, as mature plants and in storage.

Management Notes: Follow a 4–5-year rotation away from all brassica crops. Control brassica weeds. Do not apply manure or compost containing rutabaga refuse or diseased rutabagas on land intended for rutabagas. The black leg pathogen can move with wind and water from adjacent fields. Never store diseased rutabagas. Clean out and disinfect the storage area each spring.

Black Rot

Xanthomonas campestris pv. *campestris*

Identification: Affected crops develop blackened veins and vascular bundles. This is most noticeable when the stems or roots are cut lengthwise or crosswise. On rutabaga, root rots may also develop. Seedlings infected with black rot usually die. Later infections cause stunted plants with yellow, wilting foliage.

Biology: As little as one infected plant in 10,000 can result in a field epidemic. Black rot is spread rapidly during warm, humid weather with an optimal temperature range of 27°C–30°C (81°F–86°F) at 80%–100% humidity. Once in the soil, the bacteria spread by splashing rain and wind. Bacteria enter plants through wounds or natural openings at the leaf margins called hydathodes. Rutabagas are susceptible to this disease as seedlings, mature plants and in storage.

Management Notes: Use certified disease-free seed and/or hot-water-treated seed. Do not apply manure or compost containing rutabaga refuse or diseased rutabagas on land intended for rutabagas. Never store diseased rutabagas. Clean out and disinfect the storage area each spring. Follow a 4–5-year rotation away from all brassica crops. Control brassica weeds.

Clubroot

Plasmodiophora brassicae

See Chapter 6 and Figure 7–161.

Figure 7–161. Root galling symptoms on rutabaga roots as a result of clubroot infection.

Damping-Off — also known as Root Rots

Pythium sp., *Phytophthora* sp., *Rhizoctonia* sp., *Fusarium* sp.

Identification: Seeds infected prior to emergence rot and typically fail to produce a seedling. If the seedlings do emerge, they are usually weak and lack vigour. Post-emergence infections cause the seedlings to rot at the soil line. This usually occurs within 2–4 weeks of emergence (or transplanting). Affected plants tend to curl downward or melt into the soil. Other symptoms include mouldy seeds as well as lesions or cankers on the roots, hypocotyl or lower stem (Figure 7–162).

Figure 7–162. Rutabaga with brown, stunted taproot and side roots as a result of damping-off pathogens.

Biology: Pythium and phytophthora are water moulds. They are particularly destructive in wet and cool soil conditions. Infections commonly occur on heavier soil types, or in poorly drained fields.

Fusarium is found in most agricultural soils. The overwintering spores remain in the soil for long periods of time. Infections occur under a wide-range of soil and temperature conditions, depending on the species and the crop. Many fusarium species also cause foliar or fruit infections later in the season. For more information, see Chapter 5.

Rhizoctonia solani persists in soil as a hard resting structure (sclerotia) and grows as microscopic threads through the soil. This damping-off pathogen tends to prefer slightly warmer and dryer soil than the water moulds. Often, *Rhizoctonia* will girdle the stems of susceptible crops slightly above and below the soil line. See *Rhizoctonia*, also in *Rutabagas*.

Management Notes: Plant seeds treated with a registered fungicide seed treatment that controls damping-off pathogens. Do not seed too deep. Plant only when soil and weather conditions are favourable for quick germination, emergence and vigorous crop development.

Scout fields early in the spring soon after planting to assess the plant stand and its establishment. Look for areas of patchy or poor emergence. Dig up non-emerged seedlings or plants and look for symptoms of rotting or stem girdling.

Downy Mildew

Peronospora parasitica = Hyaloperonospora parasitica

Identification: Symptoms appear as yellow spots on the upper leaf surface with corresponding greyish-white fungal growths on the underside. Infected roots may split or become invaded by secondary rot organisms. In rutabaga, the leaves often turn purple in response to infection (Figure 7–163).

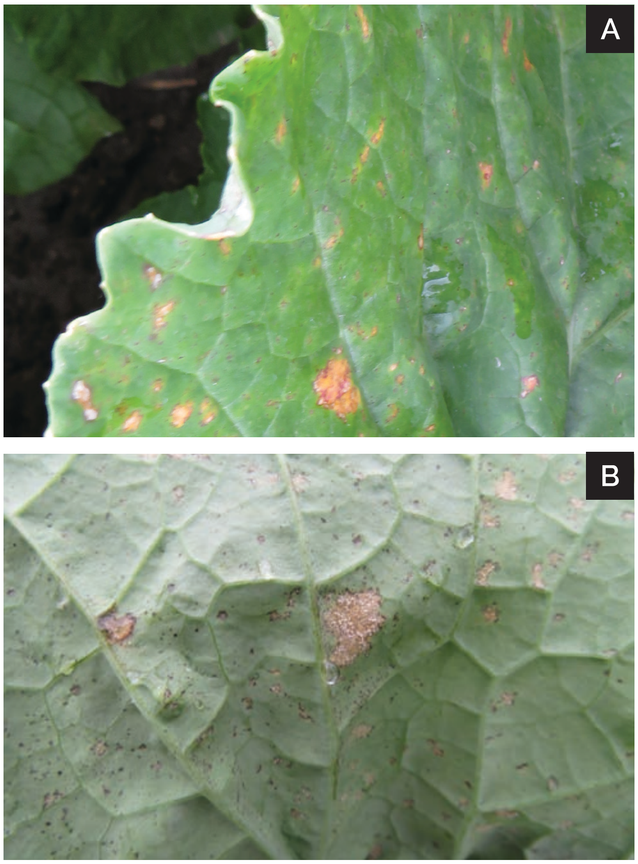


Figure 7–163. Downy mildew symptoms of yellow spots on the upper side of the leaves (A) and white fuzzy growth from the lesions on the underside of the leaves (B).

Biology: Infection occurs at any growth stage. Cool temperatures of 10°C–15°C (50°F–59°F) and prolonged periods of leaf wetness, dew or fog favour disease development. This fungus overwinters in seed and on infected plants. Downy mildew fungi survive for at least 1 year in the soil and 2 years in infected seed.

Management Notes: Plant into well-drained soil. Avoid excessive use of overhead irrigation. Follow a 2-year rotation with non-host crops.

Nematodes

See Chapter 6.

Powdery Mildew

Erysiphe polygoni

Identification: Initial symptoms usually appear on the older, shaded leaves. A dense, white fungal (powdery) growth develops on the lower leaf surface. A pale green-to-yellow discolouration may also appear on the corresponding upper leaf surface. The white, powdery growth spreads to the upper leaf surface and down the petiole. Infected leaves and stems turn yellow, wither and die prematurely. In rutabaga, the leaves often turn purple in response to infection (Figure 7–164).

Figure 7–164. White powdery fungal growth on the upper side of the rutabaga leaves.

Biology: The pathogens causing powdery mildew do not overwinter in the field in Ontario. Wind-borne spores usually arrive from the southern U.S. and Mexico in mid-summer. Peak infection periods occur when temperatures are in the range of 20°C–26°C (68°F–79°F). Disease development slows when temperatures climb above 26°C (79°F).

Infections can develop at relatively low humidity (<20%) levels, although humid weather conditions and heavy dews lead to more rapid disease development. Under these conditions, visual symptoms may appear 3–7 days after the initial infection.

Scouting and Thresholds: Powdery mildew is difficult to detect in its early stages. The underside of leaves must be checked to detect spore growth.

Once mildew and yellowing are present on the upper leaf surfaces, the disease is quite advanced and unlikely to respond to fungicide applications.

Management Notes: The Laurentian cultivar is very susceptible to powdery mildew. Fungal spores can travel long distances by wind. Initiate control tactics at the first appearance of symptoms. Fungicides are available that may offer suppression of the disease, but good coverage on both the upper and lower leaf surfaces is essential. Due to its wide host range, it can be difficult to control with cultural practices.

Rhizoctonia

Rhizoctonia solani

Biology: *Rhizoctonia solani* is a ubiquitous soil-borne fungus. It can survive in the soil for many years. Infections can occur throughout the season under warm and wet or very humid conditions. It is known by a variety of common names and causes a wide range of symptoms.

Rhizoctonia solani is one of the fungal species that causes damping-off. See *Damping-Off*, Chapter 6, and Figure 7–165.

Figure 7–165. Brown dry rot, usually around the crown of the rutabaga caused by *Rhizoctonia* species.

Management Notes: Avoid planting susceptible crops in previously infected areas. Rotate for several years with corn or small grains and practice strict sanitation procedures to avoid spreading infected soil between fields.

Sclerotinia White Mould

See *Brassica Crops*, in this chapter.

Turnip Mosaic Virus (TuMV)

Identification: Older leaves turn yellow and drop prematurely. Leaves emerging after infection are stunted and wrinkled and show a yellow, mottled pattern. Roots become "goose-necked" and do not reach normal size.

Biology: TuMV is spread by aphids. A rapid increase in infection usually begins in early July, when large numbers of winged aphids become active. Volunteer rutabagas and winter canola are the main overwintering sources of the virus.

Management Notes: Losses from turnip mosaic virus are especially heavy in plantings sown after mid-June. Applications of mineral oil deter the feeding of virus-spreading aphids. Aphid control does not completely prevent the spread of the virus. For more information, see *Aphids*, Chapter 5, and *Northern Root Knot Nematode*, Chapter 6.

Wire Stem

See *Brassica Crops*, in this chapter.

Insects

Aphids

Aphididae family

Identification: There are several aphid species affecting vegetable crops in Ontario. Aphids are small, soft-bodied, pear-shaped insects, with cornicles or "tail-pipes" near the tip of their abdomen. They have relatively long legs and prominent antennae. Colour may vary depending on the species and the host plant. A few species found in vegetable crops have a waxy or woolly appearance (Figure 7–166).

Damage: Aphids act as a primary vector of turnip mosaic virus, an economically significant virus of rutabagas and turnips.

Aphids often congregate on new growth. They pierce the leaves and suck the sap from the plant, causing leaf distortion, stunting, delayed maturity and wilting. While feeding they exude a sticky substance called "honeydew." Honeydew, and the moulds associated with it, may affect the marketability of the harvested product.

Figure 7–166. A colony of aphids on the underside of a rutabaga leaf.

Biology: Most aphids overwinter as eggs on primary hosts and migrate to vegetable crops in the summer. Aphids are present throughout most of the growing season. Populations increase rapidly under favourable conditions, including hot, dry weather. Natural predators (lady beetles, lacewings, minute pirate bugs, etc.) or parasitoids (*Aphelinus* and *Aphidius* spp.) often help keep aphid populations below threshold levels.

Scouting and Thresholds: Aphid distribution may be patchy within a field. Populations are often higher along field margins and hedgerows. Inspect the underside of leaves from the top, middle and bottom of plants. Note the presence of aphid honeydew on the foliage and fruit. Look for beneficial insects (aphid predators or parasites) as well. Look closely to distinguish live aphids from dead aphids and moulted skins.

Management Notes: When controlling other insect pests, select pest control products that are safer for beneficial insects. Broad-spectrum insecticides may also control natural enemies, resulting in higher aphid populations.

Black Cutworm

See *Brassica Crops*, in this chapter.

Cabbage Looper
Trichoplusia ni

See *Brassica Crops*, in this chapter.

Cabbage Maggot
Delia radicum

Identification: The cabbage maggot adult is a grey fly, approximately half the size of the common housefly. The female lays eggs in the soil at the base of seedlings. The small, white eggs look like tiny (1 mm (1⁄16 in.)) grains of rice. The larvae are small (7 mm (¼ in.)), legless and white. They feed and burrow In the roots and render rutabagas unmarketable (Figure 7–167).

Figure 7–167. Extensive feeding damage and cabbage maggot larvae on rutabaga roots (A)(B)(C).

Damage: The maggots tunnel and feed along the roots of rutabaga and turnip. Brassica crop seedlings are very susceptible to damage by the cabbage maggot. On root brassicas and especially rutabagas, cabbage maggot feeding causes serious economic damage. The later generations of cabbage maggot cause significant feeding to the marketable portion of the roots. These wounds also act as points of entry for soft rot bacteria.

Biology: Cabbage maggots overwinter as pupae in the soil. There are three periods of egg-laying throughout the season. The first generation is the most active and most damaging. It occurs from mid-May through June (flowering of yellow rocket). A second occurs in mid-July (flowering of day lilies) and a third in late August (flowering of goldenrod). These dates are approximate. Pest activity levels vary depending on regional temperatures and differences in soil type.

Hot, dry conditions reduce maggot survival, especially for the later generations. Damage from all three generations may be expected in cooler regions of the province. Crops receiving irrigation, root crops and most specialty brassicas are more susceptible to this pest.

Scouting and Thresholds: Sticky trap monitoring programs for cabbage maggot adults can help with spray timing. Growing degree days (base of 6°C) (GDDs) may be used to predict cabbage maggot activity. First-generation adults emerge between 314 and 398 GDDs. Second-generation adults emerge between 847 and 960 GDDs. Third-generation adults emerge between 1,446 and 1,604 GDDs. See the section, *Growing Degree Days*, Chapter 4.

Management Notes: Cabbage root maggot management is primarily preventive. Follow a 3–4-year crop rotation. Do not grow early and late rutabagas in the same field and avoid growing them near winter canola, early broccoli, cabbage or cauliflower. Time control of root maggots to coincide with the egg-laying activity of each generation.

Cutworms (Early-Season)

Agrotis ipsilon (black cutworm), *Euxoa messoria* (dark-sided cutworm), *Crymodes devastator* (glassy cutworm), *Euxoa detersa* (sandhill cutworm)

See Chapter 5.

Diamondback Moth

Plutella xylostella

See *Brassica Crops*, in this chapter.

Flea Beetles

Phyllotreta sp.

Identification: Flea beetles are small (2.5 mm (⅛ in.) long), shiny black beetles. Adults are active and jump when disturbed (Figure 7–168).

Figure 7–168. Adult flea beetle feeding damage on a recently emerged rutabaga plant.

Damage: While all crucifers are attacked by these beetles, flea beetles prefer the non-waxy, ethnic crucifers. Feeding damage consists of numerous “shot-holes,” 1–5 mm (⅛ in.) in diameter. Older damage may be ringed with brown, dried leaf tissue, while fresh feeding holes have green edges. At the seedling stage, flea beetle feeding can kill the plant. Rutabaga plants are most vulnerable at the seedling stage. Larval feeding on the root may reduce marketability.

Flea beetles and their larvae may feed on cotyledons, leaves and parts of the stem under the soil. They are unlikely to cause significant damage unless populations are very high during the seedling stage, especially if the plants are growing slowly in cool conditions.

Biology: Flea beetles in Ontario generally have one generation per year. The life cycle from egg to adult may take as little as 7 weeks, making a second generation possible in some years. Adult flea beetles overwinter in leaf litter. They emerge and begin feeding on young plants in mid-May. Adults lay eggs near the roots of host plants throughout the spring and early summer. Larvae develop on the roots. In late July, adults emerge from the soil, feed and then seek hibernation sites in the fall.

Scouting and Thresholds: For all crops, begin monitoring for flea beetles as soon as the transplants are set in the field. Inspect 25 randomly selected plants throughout the field for flea beetles and damage. Up to the 6-leaf stage, plants can tolerate no more than 1 flea beetle per plant. After this stage, feeding will not interfere with plant growth. Feeding damage at later stages may impact marketability and crop quality.

Management Notes: If black rot is present in the field, flea beetle management is important, as the beetle can spread black rot disease as it feeds. For rutabaga, target controls at the adult beetle stage. There is no control for larvae established in roots. Begin applications as soon as beetles appear in the field. Beetles may migrate into the field over several weeks, resulting in the need for multiple applications. Insecticide drenches applied for root maggot control may also control flea beetles.

Imported Cabbageworm

Pieris rapae (L.)

See *Brassica Crops*, in this chapter.

Slugs

See *Brassica Crops*, in this chapter.

Swede Midge

Contarinia nasturtii

See *Brassica Crops*, in this chapter.

Wireworms

See Chapter 5.

Disorders

Growth Cracks

Growth cracks typically present as deep, longitudinal or horizontal cracks in roots. They are typically caused by uneven growing conditions, particularly when heavy rain or irrigation follows prolonged dry periods. They can also be caused by inconsistent plant stand. Cracks render roots unmarketable and can provide pathways of infection for pathogens.

Water-Core — also known as Brown Heart

The symptoms are internal and are usually not visible from the outside. Small cracks develop in the stem and enlarge as the crop matures. These cavities may become discoloured, especially if associated with boron deficiency (Figure 7–169). In some instances, breakdown does occur. This disorder is often associated with nutrient imbalances (i.e., boron deficiency, high nitrogen or potassium fertilizer rates) and/or fluctuations in growth due to heat or moisture stress. See Table 1–8 and Table 1–9, Chapter 1.

Figure 7–169. Cross-section of a rutabaga with water-soaked areas typical of water-core or brown heart.

Specialty Vegetables

Production Requirements

Specialty vegetables grown in Ontario belong to a wide range of plant families (e.g., brassicas, cucurbits, legumes). Production and pest management strategies developed for more traditional crops may be helpful for establishing and managing related specialty vegetable species since they often have similar cultural requirements or pest complexes. The guidelines provided in this section are compiled from a combination of Ontario research and on-farm experience as well as other jurisdictions where market preferences, available equipment and climate vary widely. On-farm research may be required to adapt the guidelines to the specific growing conditions, resources and available equipment of each farm.

Marketing

Some specialty vegetable markets require specific cultivars or have unique harvest stages to meet customer demand (e.g., bitter melon, okra, leafy amaranth, eggplant, peppers, melons, yardlong beans). Some crops can be harvested at different crop stages for different market segments. Conducting background research on consumer preferences of different cultivars or crop maturity may be required for marketability. Very few specialty vegetables have established grades, and therefore quality is determined by the market.

Establishing Cool-Season Specialty Vegetable Crops

Specialty vegetables are generally classified into either cool-season or warm-season crops. Planting dates will differ between species, and some crops can be planted more than once a season.

Cool-season crops can be seeded or planted outdoors in early spring when the weather is still cool. Many, but not all, are short-season crops that require 30–70 days from establishment to harvest. Because of their short growing cycle, many cool-season vegetable crops lend themselves to multiple plantings in a single growing season. Site selection and establishment requirements for cool-season specialty vegetables are summarized in Table 7–116.

Table 7–116. Guidelines for Establishing Cool-Season Specialty Vegetables

LEGEND: **Plant type:** A = annual B = biennial P = perennial HA = harvested annually
Soil type: E = every mineral soil type S = sand L = loam C = clay M = muck
Irrigation required: Y = yes B = beneficial N = no

Crop	Type	Soil Type	Optimal pH Range	Propagation and Other Establishment Notes[1]	Row Spacing	In-row Spacing	Irrigation[2]
Brassicas							
Bok choy (*Brassica rapa* subsp. *chinensis*)	See *Brassica Crops*.						
Chinese broccoli (*Brassica alboglabra*)	See *Brassica Crops*.						
Chinese flowering cabbage/ flowering edible rape (*Brassica rapa* subsp. *chinensis* var. *oleifera*)	A	E, best in S, L	5.5–7.5 [3]	◦ Direct seed mid-April to mid-September. ◦ Transplant late April to mid-September. ◦ Harvest 50–55 days after direct seeding.	30–45 cm (12–18 in.)	5–10 cm (2–4 in.)	Y
Kohlrabi (*Brassica oleracea* var. *gongylodes*)	See *Brassica Crops*.						
Leaf and heading mustards (*Brassica juncea, Brassica rapa* subsp. *nipposinica*)	A	E, best in S, L	5.5–7.5 [3]	◦ Direct seed mid-April to mid-September. ◦ Harvest 20–65 days after seeding, depending on cultivar or species.	30–60 cm (12–24 in.)	10–20 cm (4–8 in.)	Y
Napa cabbage (*Brassica rapa* subsp. *pekinensis*)	See *Brassica Crops*						
Shanghai bok choy (*Brassica rapa* subsp. *chinensis 'Shanghai'*)	A	E, best in M	6.0–7.5 [3]	◦ Direct seed April to August. ◦ Transplant between April and August approximately 4 weeks after seeding. ◦ Harvest 45–60 days after direct seeding.	45 cm (18 in.)	15 cm (6 in.)	Y
Tah tsai (*Brassica rapa* subsp. *narinosa* var. *rosularis*)	A	E, best in S, L, M	5.5–7.5 [3]	◦ Direct seed April to September. ◦ Transplant between April and September. ◦ Harvest 25–45 days after direct seeding.	45–60 cm (18–24 in.)	20 cm (8 in.)	Y

[1] Days to harvest provided for annual crop planning purposes.
[2] Under normal Ontario conditions.
[3] Lower pH and warm temperatures may increase severity of clubroot.
[4] May be required depending on soil type and season.

SPECIALTY VEGETABLES

Table 7–116. Guidelines for Establishing Cool-Season Specialty Vegetables

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Irrigation required: Y = yes B = beneficial N = no

Crop	Type	Soil Type	Optimal pH Range	Propagation and Other Establishment Notes[1]	Row Spacing	In-row Spacing	Irrigation[2]
Leafy Vegetables							
Celtuce (*Lactuca sativa asparagina, L. sativa angustana*)	A	E, best in S, L, M	**Mineral soils:** 6.1–6.5 **Muck soils:** 5.5	◦ Seed from April to early August. ◦ Transplant in April. ◦ Harvest 70–90 days after seeding.	30–40 cm (12–16 in.)	20–30 cm (8–12 in.)	Y
Pointed leaf lettuce/ sword lettuce (*Lactuca sativa, L. sativa longifolia*)	A	S, L, M	5.5–7.8	◦ Seed from April to early August ◦ Transplant in April ◦ Harvest 85 days after seeding	30–40 cm (12–16 in.)	22–30 cm (9–12 in.)	Y
Rhubarb (*Rheum rhabarbarum*)	P	E, M	6.0–6.8	◦ Transplant dormant crowns April to May, October with buds facing up, 30–40 cm (12–16 in.) deep ◦ Limited harvest in second spring after planting	90–150 cm (35–59 in.)	60–130 cm (24–51 in.)	B
Swiss chard, specialty (e.g., coloured) (*Beta vulgaris* subsp. *cicla*)	See *Spinach and Swiss Chard*.						
Witloof chicory/endive (*Cichorium intybus*)	See *Lettuce* in this chapter.						
Root and Tubers							
Carrots, specialty (e.g., coloured) (*Daucus carota*)	See *Carrots*.						
Horseradish (*Armoracia rusticana*)	See *Brassica Crops*.						
Japanese burdock/gobo (*Arctium lappa*)	A	S, M	6.5–7.5, does not grow well in acidic soils	◦ Direct seed, late April to May. ◦ Harvest 90–120 days after seeding.	60–90 cm (24–35 in.)	15–30 cm (6–12 in.)	B
Jerusalem artichoke/ sunchoke (*Helianthus tuberosus*)	P, HA	E, well drained soils	4.5–8.2 tolerates wide range but best in slightly alkaline soils	◦ April to May ◦ Harvest 125 days after planting.	45–120 cm (18–47 in.)	30–60 cm (12–24 in.)	N
Maca (*Lepidium meyenii*)	See crop-specific notes in this chapter.						
Specialty radish (e.g., daikon) (*Raohanus sativus* subvar. *longipinnatus*)	A	S, L, M	S–L: 6.0–7.0 M: 5.1–5.5	◦ Direct seeding in early spring to mid-summer. ◦ Harvest 50–80 days after seeding, depending on cultivar.	30–40 cm (12–16 in.)	5–20 cm (2–8 in.)	B [4]

1 Days to harvest provided for annual crop planning purposes.
2 Under normal Ontario conditions.
3 Lower pH and warm temperatures may increase severity of clubroot.
4 May be required depending on soil type and season.

SPECIALTY VEGETABLES

Table 7–116. Guidelines for Establishing Cool-Season Specialty Vegetables

LEGEND: Plant type: A = annual B = biennial P = perennial HA = harvested annually
Soil type: E = every mineral soil type S = sand L = loam C = clay M = muck
Irrigation required: Y = yes B = beneficial N = no

Crop	Type	Soil Type	Optimal pH Range	Propagation and Other Establishment Notes[1]	Row Spacing	In-row Spacing	Irrigation[2]
Other Specialty Vegetables							
Florence fennel (*Foeniculum vulgare* var. *azoricum*)	A	E, well-drained soils	6.0–8.0	◦ Transplant from seed, less commonly, direct seed. ◦ Seed in April. ◦ Transplant, 4–6 weeks after seeding. ◦ Harvest 70–80 days after transplanting, 90–100 days after direct seeding.	90–120 cm (35–47 in.)	20–30 cm (8–12 in.)	B
Globe artichoke (*Cynara scolymus*)	A	E, well-drained soils	6.0–7.5	◦ Transplant April to May for un-vernalized transplants, April to June for vernalized transplants. ◦ Harvest 90–100 days after transplanting.	100–150 cm (39–59 in.)	80–100 cm (31–39 in.)	Y

1 Days to harvest provided for annual crop planning purposes.
2 Under normal Ontario conditions.
3 Lower pH and warm temperatures may increase severity of clubroot.
4 May be required depending on soil type and season.

Establishing Warm-Season Specialty Vegetable Crops

Warm-season crops must be seeded or transplanted outdoors after the soil has become warm. They are typically considered to be long-season crops and require 60+ days from establishment to harvest. A temperature of 14°C–15°C (57°F–59°F) in the top 10–12 cm (4–6 in.) of soil is a good guideline for when they can be planted in the field. Some warm-season crops can be, or must be, started indoors and transplanted when the soil is warm enough, however, not all species are suitable for transplanting.

Warm-season crops typically benefit from the use of season extension techniques, including the use of row covers (Figure 7–170), plastic mulch, low tunnels (Figure 7–171) and high tunnels. Benefits associated with season extension include earlier harvest, increased yield, a prolonged harvest period, higher-quality produce, soil moisture retention, reduced disease pressure, reduced fertilizer leaching, increased season-long nutrient availability and increased weed control. Site selection and establishment requirements for warm season specialty vegetables are summarized In Table 7–117.

Figure 7–170. Row covers used to accelerate establishment or early development of tender annual crops.

Figure 7–171. Low tunnels increase early-season temperatures to accelerate development of warm-season annual crops.

SPECIALTY VEGETABLES

Table 7–117. Guidelines for Establishing Warm-Season Specialty Vegetables

LEGEND: Plant type: A = annual B = biennial P = perennial GA = grown as an annual under Ontario conditions
Soil type: E = every mineral soil type S = sand L = loam C = clay M = muck
Irrigation required: Y = yes B = beneficial N = no

	Type	Soil Type	Optimal pH Range	Propagation and Other Establishment Notes[1]	Row Spacing	In-row Spacing	Irrigation[2]
Cucurbits							
Bitter melon (*Momordica charantia*)	A	E, well-drained soils	6.0–6.7	◦ Transplant from seed, less commonly, direct-seed. ◦ Greenhouse seeding late April to early May, direct-seed after last frost. ◦ Transplant after last frost, 3–5 weeks after seeding. ◦ First harvest 60–90 days after transplanting.	120–150 cm (47–59 in.)	40–50 cm (16–20 in.)	B
Bottle gourd (*Lagenaria sicerari* var. *clavata*)	A	E, well-drained soil	6.0–6.7	◦ Transplant from seed, less commonly, direct-seed. ◦ Greenhouse seeding in late April to early May, direct seed after last frost. ◦ Transplant after last frost, 3–5 weeks after seeding. ◦ First harvest 40–90 days after transplanting.	120–300 cm (47–118 in.) or more	**Trellised:** 60–300 cm (24–118 in.) **Ground:** 240–300 cm (94–118 in.)	B
Fuzzy melon (*Benincasa hispada* var. *chieh-gua*)	A	E, well-drained soils	5.5–6.5	◦ Transplant from seeds, less commonly, direct-seed. ◦ Greenhouse seeding in late April to early May, direct-seed after last frost. ◦ Transplant after last frost, 3–5 weeks after seeding. ◦ First harvest 60–90 days after transplanting.	120 cm (47 in.) or more	50–60 cm (20–24 in.)	B
Luffa/loofah/loofa Smooth luffa (*Luffa cylindrica/Luffa aegyptiaca*) Angled loofa (*Luffa acutangular*)	A	S, L, well-drained soils	5.5–6.8	◦ Transplant from seed, less commonly, direct-seed. ◦ Greenhouse seeding in late April to early May, direct-seed after last frost. ◦ Transplant after last frost, 4–6 weeks after seeding. ◦ First harvest 60–90 days after transplanting for culinary use, 100–140 days to harvest for industrial use.	150–200 cm (59–79 in.)	40–100 cm (16–39 in.)	B
Melons, specialty (e.g., brilliant melon) (*Cucumis melo*)	See *Cucurbit Crops*.						

[1] Days to harvest provided for annual crop planning purposes.
[2] Under normal Ontario conditions.

SPECIALTY VEGETABLES

Table 7–117. Guidelines for Establishing Warm-Season Specialty Vegetables

LEGEND: Plant type: A = annual B = biennial P = perennial GA = grown as an annual under Ontario conditions
Soil type: E = every mineral soil type S = sand L = loam C = clay M = muck
Irrigation required: Y = yes B = beneficial N = no

	Type	Soil Type	Optimal pH Range	Propagation and Other Establishment Notes[1]	Row Spacing	In-row Spacing	Irrigation[2]
Mousemelon/ cucamelon (*Melothria scabra*) (*Zehneria scabra*)	A	E, well-drained soils	6.0–6.8	◦ Transplant from seed, less commonly, direct seed. ◦ Greenhouse seeding in late April to early May, direct seed after last frost. ◦ Transplant after last frost, 3–5 weeks after seeding. ◦ 70–90 days to harvest.	120–200 cm (47–79 in.)	40–60 cm (16–24 in.)	Y
Winter gourd (*Benincasa hispada*)	A	E, well-drained soils	5.5–6.5	◦ Transplant from seed, less commonly, direct-seed. ◦ Greenhouse seeding in late April to early May, direct seed after last frost. ◦ Transplant after last frost, 3–5 weeks after seeding. ◦ 90–110 days to harvest.	120 cm (47 in.) or more	50–300 cm (20–118 in.)	B
Fruiting Vegetables							
Eggplant, specialty (*Solanum melongena*)	See *Eggplant*.						
Okra (*Abelmoschus esculentus*)	A	E, well-drained soils	6.5–7.0	◦ Transplant from seed, less commonly, direct-seed. ◦ Greenhouse seeding early April. ◦ Transplant or direct seed after last frost. ◦ Harvest begins 40–50 days after transplanting and continues until frost.	90 cm (35 in.)	25–45 cm (10–18 in.)	Y
Peppers, specialty (e.g., hot) (*Capsicum annuum, Capsicum chinense*)	See *Peppers*.						
Physalis (e.g., tomatillo, ground cherry, cape gooseberry) (*Physalis* spp.)	A	E	6.0–6.8	◦ Transplant from seed. ◦ Seeding April to early May. ◦ Transplant in late May to early June. ◦ First harvest 80–100 days after transplanting.	40–75 cm (16–30 in.)	35–60 cm (14–24 in.)	B

[1] Days to harvest provided for annual crop planning purposes.
[2] Under normal Ontario conditions.

SPECIALTY VEGETABLES

Table 7–117. Guidelines for Establishing Warm-Season Specialty Vegetables

LEGEND: Plant type: A = annual B = biennial P = perennial GA = grown as an annual under Ontario conditions
Soil type: E = every mineral soil type S = sand L = loam C = clay M = muck
Irrigation required: Y = yes B = beneficial N = no

	Type	Soil Type	Optimal pH Range	Propagation and Other Establishment Notes[1]	Row Spacing	In-row Spacing	Irrigation[2]
Leafy Vegetables							
Edible chrysanthemum (*Chrysanthemum coronarium*)	A	E, well-drained soils	5.2–7.5	◦ Transplant from seeds (early spring crops), direct-seed (later crops). ◦ Greenhouse seed February to March. ◦ Direct-seed May to early September. ◦ Transplant April to May. ◦ Harvest 35–50 days.	30–45 cm (12–18 in.)	15 cm (6 in.)	B
Leafy amaranth/ callaloo (*Amaranthus* spp.)	A	S, L	6.0	◦ Direct-seed or transplant from seeds. ◦ Greenhouse seeding in April, direct-seeding May to June. ◦ Field transplant after risk of frost. ◦ Harvest time 30–60 days.	10–50 cm (4–20 in.)	4–15 cm (2–6 in.)	B
Pea and Beans							
Edamame (*Glycine max*)	A	E, well-drained soils	6.0–7.0	◦ Direct-seed early May to June. ◦ Harvest 65–110 days after seeding.	18–75 cm (7–30 in.)	10–20 cm (4–8 in.)	B
Garbanzo bean (fresh) (*Cicer arietinum*)	A	E	5.5–8.6	◦ Direct-seed early May to June. ◦ First harvest 90 days after seeding.	25–60 cm (10–24 in.)	10 cm (4 in.)	B
Yardlong bean (*Vigna unguiculata* subp. *sesquipedalis*)	A	E, well-drained soils	6.0–7.0	◦ Direct-seed after last frost. ◦ First harvest 60–80 days after seeding.	60–150 cm (24–59 in.)	15–40 cm (6–16 in.)	B
Root and Tubers							
Sweetpotato (*Ipomoea batatas*)	See *Sweetpotatoes*.						
Tigernut/chufa (*Cyperus esculentus* var. *sativus*)	A	S, L	6.5–7.0	◦ Direct seed after last frost into either a flat seedbed or hilled row. ◦ Harvest 120–150 days after seeding.	60 cm (24 in.)	10 cm (4 in.)	N
Yacon (*Smallanthus sonchifolius*)	A	S, L	6.0–6.8	◦ Force tubers indoors starting in early April. ◦ Transplant when 15–30 cm (6–12 in.) tall after risk of frost and soil temperature is above 15°C (59°F). ◦ Harvest 90–120 days after transplanting.	100–120 cm (39–47 in.)	75 cm (30 in.)	N

[1] Days to harvest provided for annual crop planning purposes.
[2] Under normal Ontario conditions.

SPECIALTY VEGETABLES

Fertility

The requirement of a crop for supplemental nutrient application is dependent on a wide range of factors, including rainfall/irrigation, temperatures, soil type, soil organic matter, pH and cultivar. With the wide range of specialty vegetables grown in Ontario, a single fertility recommendation cannot be made. However, a balanced fertility program based on a soil test can form the basis for good crop health. Experience from related crops will also be useful. See Chapter 1 for more information on soil management and nitrogen, phosphorus, potassium and micronutrients.

No current Ontario fertility recommendations exist for most specialty vegetables. However, research and recommendations are available for many related crop species and provide a good starting point for many of the specialty vegetables listed in this resource. Research and recommendations from outside Ontario do not necessarily apply to Ontario growing conditions because of differences in climate and soil factors. Of the crops listed in this chapter, currently only rhubarb has approved Ontario fertility recommendations for nitrogen, phosphorus and potassium.

It can be difficult to determine how much fertilizer or manure to apply for adequate nitrogen, phosphorus or potassium. Under-application of nutrients can reduce yield and quality, while over-application can have similar effects, can be costly and can lead to environmental damage.

Consider the following points for your specialty vegetable fertility program:

- take a soil test
- ensure soil pH is adequate for the crop
- look at the current approved Ontario fertility recommendations for closely related crops

When looking at closely related crops, compare:

- plant family, as crops in the same plant family often have similar nutrient requirements (e.g., there is no recommendation for tomatillos in Ontario, but the recommendation for fresh market tomatoes would be a good starting point)
- harvested portion, as nutrient requirements differ depending on the portion of the plant harvested such as leaves, stems, roots or tubers
- days to maturity, as longer-season crops will generally require more nutrients than a closely related short-season crop

Additionally, crops producing a large amount of biomass will likely have higher nutrient requirements than those producing low amounts of biomass (e.g., while specialty brassica greens such as Shanghai pak choy are closely related to storage cabbage, they are unlikely to require the same amount of fertilizer because storage cabbage can take 150 days to mature and produce large amounts of biomass, while some of the specialty greens only require 30–60 days to mature and have much lower biomass).

Table 7–118 provides suggested starting points based on Ontario field trials, similar crops or from other jurisdictions. Where Ontario fertility recommendations exist for a crop, they are provided in *Crop-Specific Comments*, also in *Specialty Vegetables*, and in the following sections of Chapter 1:

- *Assessing Vegetable Crop Nutrient Needs*
- *Macronutrients*
- *Micronutrients*

Table 7–118. Fertility Guidelines for Specialty Vegetables

Crop Species	Nitrogen Guidelines	Notes	Phosphorus and Potassium Reference Crop
Brassicas			
Bok choy	See *Brassica Crops*.		*Brassica Crops*
Chinese broccoli	See *Brassica Crops*.		*Brassica Crops*
Chinese flowering cabbage/flowering edible rape	80–120 kg N/ha (71–107 lb N/acre)	For each planting through the growing season.	*Brassica Crops*
Kohlrabi	See *Brassica Crops*.		*Brassica Crops*
Leaf and heading mustards	80–120 kg N/ha (71–107 lb N/acre)	For each planting through the growing season.	*Brassica Crops*
Napa cabbage	See *Brassica Crops*.		*Brassica Crops*
Shanghai pak choy	90–120 kg N/ha (80–107 lb N/acre)	For each planting through the growing season.	*Brassica Crops*
Tah tsai	90–120 kg N/ha (80–107 lb N/acre)	For each planting through the growing season.	*Brassica Crops*
Cucurbits			
Bitter melon	110 kg N/ha (98 lb N/acre)	**Split:** 65 kg N/ha (58 lb N/acre) preplant, 45 kg N/ha (40 lb N/acre) side-dressed, before the vines start to run or climb	*Cucurbit Crops*
Bottle gourd	110 kg N/ha (98 lb N/acre)	**Split:** 65 kg N/ha (58 lb N/acre) preplant, 45 kg N/ha (40 lb N/acre) side-dressed, before the vines start to run or climb	*Cucurbit Crops*
Fuzzy melon	110 kg N/ha (98 lb N/acre)	**Split:** 65 kg N/ha (58 lb N/acre) preplant, 45 kg N/ha (40 lb N/acre) side-dressed, before the vines start to run or climb	*Cucurbit Crops*
Luffa/loofah/loofa	110 kg N/ha (98 lb N/acre)	**Split:** 65 kg N/ha (58 lb N/acre) preplant, 45 kg N/ha (40 lb N/acre) side-dressed, before the vines start to run or climb	*Cucurbit Crops*
Melons, specialty (e.g., brilliant melon)	See *Cucurbit Crops*.		*Cucurbit Crops*
Mousemelon/cucamelon	110 kg N/ha (98 lb N/acre)	**Split:** 65 kg N/ha (58 lb N/acre) preplant, 45 kg N/ha (40 lb N/acre) side-dressed, before the vines start to run or climb	*Cucurbit Crops*
Winter gourd	110 kg N/ha (98 lb N/acre)	**Split:** 65 kg N/ha (58 lb N/acre) preplant 45 kg N/ha (40 lb N/acre) side-dressed, before the vines start to run or climb	*Cucurbit Crops*

Table 7–118. Fertility Guidelines for Specialty Vegetables

Crop Species	Nitrogen Guidelines	Notes	Phosphorus and Potassium Reference Crop
Fruiting Vegetables			
Eggplant, specialty	70 kg N/ha (62 lb N/acre)	**Split:** 35 kg N/ha (31 lb N/acre) preplant 35 kg N/ha (31 lb N/acre) side-dressed, 3–4 weeks after transplanting	*Eggplant*
Okra	146 kg N/ha (130 lb/acre)	**Preplant:** 56 kg N/ha (50 lb N/acre) PLUS **side-dressed:** two 45 kg N/ha (40 lb N/acre), 3–4 weeks after seeding and 6–8 weeks after seeding	*Peppers*
Peppers, specialty (e.g., hot)	See *Peppers*.		*Peppers*
Physalis spp. (e.g., tomatillo, ground cherry)	120 kg N/ha (107 lb N/acre)		*Tomatoes*
Leafy Vegetables			
Celtuce	**Mineral soils:** 110 kg N/ha (98 lb N/acre)	**Split:** 55 kg N/ha (49 lb N/acre) preplant, 55 kg N/ha (49 lb N/acre) side-dressed, 3 weeks after transplanting or thinning	*Lettuce*
	Muck soils: 120 kg N/ha (107 lb N/acre) preplant	Reduce to 100 kg N/ha (89 lb N/acre) for mid- to late-season plantings.	
Edible chrysanthemum	100 kg N/ha (89 lb N/acre)		*Lettuce*
Leafy amaranth/callaloo	90–120 kg N/ha (80–107 lb N/acre)	For each planting through the growing season.	*Lettuce*
Pointed leaf lettuce/sword lettuce	**Mineral soils:** 110 kg N/ha (98 lb N/acre)	**Split:** 55 kg N/ha (49 lb N/acre) preplant, 55 kg N/ha (49 lb N/acre) side-dressed, 3 weeks after transplanting or thinning	*Lettuce*
	Muck soils: 120 kg N/ha (107 lb N/acre) preplant	Reduce to 100 kg N/ha (89 lb N/acre) for mid- to late-season plantings.	
Rhubarb — Field Grown	**Preplanting:** 100 kg N/ha (89 lb N/acre)		See *Rhubarb*, in *Crop-Specific Comments*.
	Annually: 200 kg N/ha (178 lb N/acre)	**Split:** 50% early spring and 50% after harvest	
Rhubarb – Crowns for Forcing	280 kg N/ha (250 lb N/acre)	**Split:** 100 kg N/ha (89 lb N/acre) early spring, 180 kg N/ha (161 lb N/acre) in July	
	As much as 100 kg N/ha (89 lb N/acre) of the nitrogen recommendation may be applied through the fertigation system after harvest or in July.		

Table 7–118. Fertility Guidelines for Specialty Vegetables

Crop Species	Nitrogen Guidelines	Notes	Phosphorus and Potassium Reference Crop
Swiss chard, specialty (e.g., coloured)	**Mineral soils:** 110 kg N/ha (98 lb N/acre)		*Spinach and Swiss Chard*
	Muck soils: 55 kg N/ha (49 lb N/acre)		
Witloof chicory/endive	See *Lettuce*.		*Lettuce*
Pea and Beans			
Edamame	30–40 kg N/ha (27–36 lb N/acre) preplant	Or banded through the planter	*Beans*
Garbanzo bean	30–40 kg N/ha (27–36 lb N/acre) preplant		*Beans*
Yardlong bean	30–40 kg N/ha (27–36 lb N/acre) preplant		*Beans*
Root and Tubers			
Carrots (coloured, specialty)	See *Carrots*.		*Carrots*
Horseradish	See *Brassica Crops*.		*Brassica Crops*
Japanese burdock/gobo	120 kg N/ha (107 lb N/acre)		*Carrots*
Jerusalem artichoke/sunchoke	25–50 kg N/ha (22–45 lb N/acre)		*Carrots*
Maca	See *Crop-Specific Comments*, also in *Specialty Vegetables*.		
Specialty radish (e.g., daikon)	**Mineral soils:** 60 kg N/ha (54 lb N/acre)		*Radish*
	Muck soils: 40 kg N/ha (36 lb N/acre)		
Sweetpotatoes	See *Sweetpotatoes*.		*Sweetpotatoes*
Tigernut/chufa	0–60 kg N/ha (0–54 lb N/acre)		*Potatoes*
Yacon	40 kg N/ha (36 lb N/acre)		*Potatoes*
Other Specialty Vegetables			
Florence fennel	**Mineral soils:** 195 kg N/ha (174 lb N/acre)	**Split:** 135 kg N/ha (120 lb N/acre) preplant, 30 kg N/ha (27 lb N/acre) side-dressed	*Celery*
	Muck soils: 160 kg N/ha (143 lb N/acre)	**Split:** 80 kg N/ha (71 lb N/acre) preplant with up to 2 x 40 kg N/ha (36 lb N/acre) side-dressed	
Globe artichoke	110–120 kg N/ha (98–107 lb N/acre)	**Split:** 25% preplant, 75% applied 6 weeks after planting	Sunflower (see OMAFRA Publication 811, *Agronomy Guide to Field Crops*)

Harvest and Storage

Harvesting at the correct stage for the target market and proper storage conditions are very important for specialty vegetable crops. Most specialty vegetables do not have established grades, and quality is determined by the market. Cultivar choice and crop uniformity at harvest can be determining factors for selling specialty vegetables.

Harvest aids used in traditional vegetable crops (e.g., cucumbers, melons) may be useful in harvesting related specialty vegetable species.

During harvest, most crops require field heat to be removed as quickly as possible to prevent wilting and prolong shelf life. Access to adequate cold storage space, between harvesting and packing, and packing and shipping, may also be needed, depending on the crop. Removal of field heat is very rapid with iced water, ice slurry or hydro-cooling followed by storage using forced-air cooling or standard cold storage.

It is impossible to generalize storage principles for all specialty vegetables because of the diversity of crops grown in Ontario. However, most specialty vegetables are marketed fresh and require high humidity to prevent wilting and prolong shelf life. Because high humidity promotes fungal growth, these crops are often stored at very low temperatures, often just above freezing, to prevent rots. However, storing certain crops at low temperatures can result in chilling injury. This is especially true of many warm-season vegetable crops that are typically crops of tropical or sub-tropical origin. Examples of this include sweetpotatoes, tomatillos and many cucurbits. Table 7–119 and Table 7–120 provide general principles of harvesting, postharvest handling for specialty vegetables. Table 7–121 and Table 7–122 describe storage conditions.

Table 7–119. Guidelines for Harvesting Cool-Season Specialty Vegetables

LEGEND: H = hand M = machine

Crop	Harvest Indicators (e.g., frequency, duration)	Harvest Method
Brassicas		
Bok choy	◦ Harvest whole plant when approximately 15 cm (6 in.) tall. ◦ Single harvest from the same planting, successive plantings possible.	H
Chinese broccoli	◦ Harvest stalks and leaves when the stalks are 12–20 cm (5–8 in.) high, just prior to flowering. ◦ Harvest during cooler parts of the day to avoid moisture loss and cooling costs. ◦ Multiple harvests from the same planting, successive plantings, multi-cropping possible.	H
Chinese flowering cabbage/ flowering edible rape	◦ Harvest when the lowest (most mature) buds are unopened, or starting to open into flowers, depending on the target market. ◦ Harvest during cooler parts of the day to reduce moisture loss and cooling costs. ◦ Successive plantings, multi-cropping possible.	H
Kohlrabi	◦ Harvest during cooler parts of the day to reduce moisture loss and cooling costs. ◦ Traditional cultivars of kohlrabi are woody when larger than 5–10 cm (2–4 in.). Larger cultivars (e.g., Kossak) remain tender at a larger size of 15–20 cm (6–8 in.). ◦ Traditional kohlrabi should be harvested when no more than 5 cm (2 in.) in diameter, especially when grown in the spring or summer. Some markets prefer leaves attached and some with leaves trimmed off. ◦ Single harvest, successive plantings, multi-cropping possible.	H
Leaf and heading mustards	◦ Harvest during cooler parts of the day to reduce moisture loss and cooling costs. ◦ Single harvest, successive plantings, multi-cropping possible.	H
Napa cabbage	◦ Harvest firm heads by cutting plant at soil level before outer leaves begin to lose their colour. ◦ Harvest during cooler parts of the day to reduce moisture loss and cooling costs. ◦ Multiple harvests from same planting, successive plantings, multi-cropping possible.	H
Shanghai pak choy	◦ Harvest during cooler parts of the day to reduce moisture loss and cooling costs. ◦ Multiple harvests from the same planting, successive plantings, multi-cropping possible.	H
Tah tsai	◦ Harvest during cooler parts of the day to reduce moisture loss and cooling cost. ◦ Multiple harvests from the same planting, successive plantings, multi-cropping possible.	H

Table 7–119. Guidelines for Harvesting Cool-Season Specialty Vegetables

LEGEND: H = hand M = machine

Crop	Harvest Indicators (e.g., frequency, duration)	Harvest Method
Leafy Vegetables		
Celtuce	◦ Harvest during cooler parts of the day to reduce moisture loss and cooling costs. ◦ Single harvest.	H
Pointed leaf lettuce/sword lettuce	◦ Harvest during cooler parts of the day to reduce moisture loss and cooling costs. ◦ Single harvest or continuous harvests possible from successive plantings.	H
Rhubarb	◦ Successive harvests of mature stalks (15–20/crown) leaving approximately 6 stalks per plant. Remove leaf blades for marketing. Leaves contain oxalic acid and are poisonous to humans.	H
Swiss chard, specialty (e.g., coloured)	◦ See *Spinach and Swiss Chard*.	
Witloof chicory/ endive	◦ See *Lettuce*.	
Root and Tubers		
Carrots, specialty (e.g., coloured)	◦ See *Carrots*.	
Horseradish	◦ See *Brassica Crops*.	
Japanese burdock/gobo	◦ Harvest in the fall or early spring before new shoots develop. ◦ Single harvest.	H, M
Jerusalem artichoke/ sunchoke	◦ Remove tops after first frost, prior to tuber harvest. ◦ Minimize handling to avoid bruising or injury. ◦ Single harvest.	H, M
Maca	◦ See *Crop-Specific Comments*, also in *Specialty Vegetables*.	
Specialty radish (e.g., daikon)	◦ Single harvest, continuous harvests are possible from successive plantings for many cultivars, but some do poorly in mid-summer heat.	H, M
Other Specialty Vegetables		
Florence fennel	◦ Harvest the enlarged leaf base before bolting begins when the base of stem is 6–8 cm (2–3 in.) wide. ◦ Bolting causes the bulbs to become woody. Bulbs should be round and pale in colour. Much of the leaf and stem material is cut off at harvest, leaving several centimetres of stem and some leaves on the bulb. ◦ Harvest during the cooler parts of the day to reduce moisture loss and cooling costs. ◦ Single harvest, successive plantings.	H
Globe artichoke	◦ Artichoke buds should be collected when they stop enlarging and lower bracts begin to separate. ◦ Flowers can also be harvested as a cut flower when the flowers are fully open. ◦ Multiple harvests from the same planting.	H

Table 7–120. Guidelines for Harvesting Warm-Season Specialty Vegetables

LEGEND: H = hand M = machine

Crop Species	Harvest Indicators (e.g., frequency, duration)	Harvest Method
Cucurbits		
Bitter melon	◦ Harvest firm, young fruits, light green in colour with soft white flesh. ◦ Multiple harvests from the same planting.	H
Bottle gourd	◦ Use harvest guidelines for cucumber as a guide for fruit harvested for consumption. Gentle handling is required to avoid fruit injury. ◦ Harvest during cooler parts of the day to reduce moisture loss and cooling costs. ◦ Multiple harvests from the same planting.	H
Fuzzy melon	◦ Begin picking fruits when still covered in silky hairs. Use harvest guidelines for cucumber as a guide for fruit harvested for consumption. Gentle handling is required to avoid fruit injury. ◦ Harvest during cooler parts of the day to reduce moisture loss and cooling costs. ◦ Multiple harvests from the same planting.	H
Luffa/loofah/loofa	◦ Use harvest guidelines for cucumber as a guide for fruit harvested for consumption. Gentle handling is required to avoid fruit injury. ◦ For industrial use (e.g., sponge production, etc.), fruits should be allowed to fully mature on the vine and then can be dried on or off the vine. Fruit skin, pulp and seeds can be removed and the sponge can be bleached to lighten colour. ◦ Multiple harvests of fruits for consumption from the same planting (immature fruits). Single harvest of fruits for industrial use (mature fruits).	H
Melons, specialty (e.g., brilliant melon)	◦ See *Cucurbit Crops*.	
Mousemelon/cucamelon	◦ Use harvest guidelines for cucumber as a guide for fruit harvested for consumption. ◦ Remove field heat as soon as possible after harvest. ◦ Multiple harvests from the same planting.	H
Winter gourd	◦ Winter gourd is the mature fruit of fuzzy melon. Harvest when fruit reach full size and vines begin to dry down. ◦ Harvest during cooler parts of the day to reduce moisture loss and cooling costs. Remove field heat as soon as possible. ◦ Multiple harvests from the same planting.	H
Fruiting Vegetables		
Eggplant, specialty	◦ See *Eggplant*.	
Okra	◦ Harvest fruits when 7–12 cm (3–5 in.) in length depending on cultivar and market, before fruits become fibrous and more difficult to slice through with a knife. ◦ Harvest by cutting the stalk just below the fruit. Remove over-ripe fruits from the plant to ensure continued fruit production. ◦ Harvest required every 1–2 days to ensure proper fruit maturity and size. ◦ Multiple harvests from the same planting.	H
Peppers, Specialty (e.g., hot)		
Physalis spp. (e.g., tomatillo, ground cherry)	◦ Tomatillos are often ripe when the husks split, the husk turns tan or dry, and the fruit is still green. Some fruit fill the husk but do not cause splitting. ◦ Some experience with harvest will be necessary to assess ripeness. ◦ Fruits are sensitive to chilling below 10°C (50°F). ◦ Harvest every 2–3 days. ◦ Multiple harvests from same planting.	H

Table 7–120. Guidelines for Harvesting Warm-Season Specialty Vegetables

LEGEND: H = hand M = machine

Crop Species	Harvest Indicators (e.g., frequency, duration)	Harvest Method
Leafy Vegetables		
Edible chrysanthemum	◦ Harvest leaves before the plant begins to flower. Remove flower buds to promote new leaf growth. Older plants result in poor leaf quality. ◦ Harvest during cooler parts of the day to reduce moisture loss and cooling costs. ◦ Multiple harvests from the same planting (leaf harvest) or single harvest (whole crown harvest), successive plantings or multi-cropping possible.	H
Leafy amaranth/callaloo	◦ Harvest leaves, shoots or branches before the plant begins to flower. ◦ Harvest during cooler parts of the day to reduce moisture loss and cooling costs. ◦ Multiple harvests from the same planting, continuous harvests are possible with successive plantings.	H
Pea and Beans		
Edamame	◦ Harvest at the R6 stage when pods are still green, immature and tight with fully developed green seeds. ◦ Harvest during cooler parts of the day to reduce moisture loss and cooling costs. ◦ Single harvest, successive plantings.	H, M (edamame can be harvested using green pea combines)
Garbanzo bean	◦ Harvest green when pods have filled. ◦ Multiple harvests from the same planting, successive plantings.	H
Yardlong bean	◦ Harvest pods when 45–75 cm (18–30 in.) long, every 1–3 days. Crop maturity depends on the market. ◦ Pods are usually sold in bundles tied at the stem end. ◦ Multiple harvests from the same planting.	H
Roots and Tubers		
Sweetpotatoes	◦ See *Sweetpotatoes*.	
Tigernut/chufa	◦ Dig tubers at the end of the season when majority of tubers are 1.5–2 cm (½–¾ in.) in diameter. ◦ Mow top growth prior to digging. ◦ Single harvest.	H, M (modified digger for small tubers)
Yacon	◦ Dig tubers after flowering to first frost. ◦ Remove stalks prior to digging. ◦ Single harvest.	H, M

Table 7–121. Guidelines for Storing Cool-Season Specialty Vegetables

LEGEND: RH = relative humidity

Crop	Storage Conditions
Brassicas	
Bok choy	0°C (32°F) at 95%–100% RH for 3–4 weeks
Chinese broccoli	0°C (32°F) at 95%–100% RH for 10–14 days
Chinese flowering cabbage/ flowering edible rape	0°C (32°F) at 95%–100% RH for 10–14 days
Kohlrabi	0°C (32°F) at 98%–100% RH for 14 days (with leaves) or 2–3 months (leaves removed)
Leaf and heading mustards	0°C (32°F) at 95%–100% RH for 10–14 days
Napa cabbage	0°C (32°F) at 95%–100% RH for 2–3 months Do not store cabbage with produce that releases ethylene gas.
Shanghai pak choy	0°C (32°F) at 95%–100% RH for 2–3 weeks
Tah tsai	0°C–1°C (32°F–34°F) at 95%–100% RH for 10–14 days
Leafy Vegetables	
Celtuce	0°C (32°F) at 95%–100% RH for 10–14 days
Pointed leaf lettuce/ sword lettuce	Temperature 0°C (32°F) at 85%–100% RH for 15–20 days
Rhubarb	0°C (32°F) at 95% RH for 2–4 weeks
Swiss chard, specialty (e.g., coloured)	See *Spinach and Swiss Chard*.
Witloof chicory/endive	See *Lettuce*.
Root and Tubers	
Carrots, specialty (e.g., coloured)	See *Carrots*.
Horseradish	See *Brassica Crops*.
Japanese burdock/gobo	0°C (32°F) at 90%–95% RH for 20–35 days
Jerusalem artichoke/ sunchoke	0°C–2°C (32°F–36°F) at 95% RH for 4–5 months
Maca	See *Crop-Specific Comments*, also in *Specialty Vegetables*.
Specialty radish (e.g., daikon)	0°C (32°F) at 95%–100% for 3–4 weeks
Other Specialty Vegetables	
Florence fennel	0°C–2°C (32°F–36°F) at 90%–95% RH for 14–21 days
Globe artichoke	0°C (32°F) at 90%–95% RH for 2–4 weeks

Table 7–122. Guidelines for Storing Warm-Season Specialty Vegetables

LEGEND: RH = relative humidity

Crop Species	Storage Conditions
Cucurbits	
Bitter melon	12°C–13°C (54°F–55°F) at 85%–90% RH for 2–3 weeks
Bottle gourd	10°C–13°C (50°F–55°F) at 85%–90% RH for 7–14 days
Fuzzy melon	10°C–13°C (50°F–55°F) at 85%–90% RH for 7–14 days
Luffa/loofah/loofa	10°C–12°C (50°F–54°F) at 85%–90% for 7–21 days **Note:** Chilling injury can occur in luffa used for consumption in temperatures below 10°C (50°F).
Melons, specialty (e.g., brilliant melon)	See *Cucurbit Crops*.
Mousemelon/cucamelon	7°C–13°C (45°F–55°F) at 95% RH for 10–14 weeks
Winter gourd	13°C–15°C (55°F–59°F) at 70%–75% RH for 6 months
Fruiting Vegetables	
Eggplant, specialty	See *Eggplant*.
Okra	8°C–10°C (46°F–50°F) at 90%–100% RH for 5–10 days
Peppers, Specialty (e.g., hot)	
Physalis spp. (e.g., tomatillo, ground cherry)	10°C–15°C (50°F–59°F) at 90%–95% RH for 1–3 weeks
Leafy Vegetables	
Edible chrysanthemum	0°C (32°F) greater than 95% RH for 2–3 weeks
Leafy amaranth/callaloo	0°C–2°C (32°F–36°F) at 95%–100% RH for 10–14 days
Pea and Beans	
Edamame	0°C–2°C (32°F–36°F) at 90%–95% RH for ≤1 week
Garbanzo bean	0°C–2°C (32°F–36°F) at 90%–95% RH for ≤1 week
Yardlong bean	4°C–7°C (39°F–45°F) (lower temperatures can cause fruity injury) at 90%–95% RH for 7–14 days
Roots and Tubers	
Sweetpotatoes	See *Sweetpotatoes*.
Tigernut/chufa	7°C–10°C (45°F–50°F) at 85%–90% RH for 4–6 months
Yacon	Curing tubers at 20°C–25°C (68°F–77°F) for 6 days may be required to increase sweetness for the market. Store at 10°C–15°C (50°C–59°F) at 70%–85% RH for 2 months.

Integrated Pest Management

Pest management presents unique challenges for specialty crops, including dealing with unfamiliar pests, a lack of registered control products and the need to rely on preventive and/or labour-intensive cultural controls. In specialty vegetable crops, pests are often overlooked until they are damaging the crop, at which time it is often too late. It is important to consider the following points when managing pests in a new crop:

- Prepare for pests even if you don't see them at first. Pests are often not a problem for the first few years of production. Pest populations usually build up to damaging levels over time. Be proactive and use preventive strategies to avoid pests, scout regularly and be prepared to deal with arriving pests early.

- Look up the major pests of the crop in the areas where it is traditionally produced. If these pests are also present in Ontario or have close relatives that are present here, it is a potential pest of your specialty vegetable crop. If the crop you want to grow is closely related to a crop already being grown in Ontario, you'll need to prepare for the possibility that pests of the traditional crop will also attack the new one.
- Determine how much damage you can tolerate. Some specialty vegetable crops can tolerate more pest pressure than the traditional crops you may be used to.
- It is important to determine what pest control products are registered on the crop of interest before you plant it. Many specialty vegetables have very few registered products. For crops with few pesticides but serious pests, consider whether you are willing to take the risk of losing your entire acreage to pest damage. Crops are put into groups for the purpose of pesticide registrations, and in some cases a product will be registered on an entire crop group. However, determining what products are registered on a given specialty vegetable species can be very confusing to growers.
- Non-chemical controls often require advance planning. These techniques can effectively reduce pest populations in many situations; however, they can be labour-intensive and costly. You will need to consider how much you are willing to spend on these techniques, ideally prior to planting. Additionally, many of these techniques are preventive, which means they will not be effective after you have found the pest in the crop.
- Cultivars can vary greatly in susceptibility to pests. Consider pest resistance as a factor when selecting cultivars.
- Weed management is often one of the biggest production challenges associated with growing a specialty crop. Since there are often few herbicides registered, growers must rely on non-chemical methods of control, which can be time-consuming and costly.
- Scout regularly. Pest problems typically develop over time and it is important to regularly monitor your crop, even if you do not see or even anticipate any pest problems. Pest problems are more easily dealt with in the early stages. This is particularly true with specialty vegetables, when you cannot be sure of all the pests that are likely to attack it or whether chemical controls will be available.

Management of pests in specialty crops requires planning and relies on methods that are often preventive and can be costly. It is generally not a good idea to simply plant the crop and plan on dealing with pest problems when they appear. Instead, consider pest management in advance as part of the decision-making process when determining whether to grow a specialty crop. Table 7–123 provides a brief guide to pests that have been significant in specialty vegetable crops grown in Ontario so far. It Is important to note that the pests mentioned here may not be comprehensive as there has been limited acreage of many of these crops in Ontario, so important pests may simply not have been observed so far. The pest complex of closely related conventional crops (if grown in Ontario) should serve as a starting point for your specialty crop scouting program. Reference crops for each specialty crop are given in Table 7–118, where applicable.

Table 7–123. Major Diseases, Insects and Disorders of Specialty Vegetables in Ontario as of 2022

Crop Species	Diseases , Insects and Disorders
Brassicas	
Bok choy	**Diseases:** Clubroot (*Plasmidiophora brassicae*), downy mildew (*Hyaloperonospora parasitica* syn. *Peronospora parasitica*) **Insects:** Flea beetles (*Phyllotreta* spp.)
Chinese broccoli	**Diseases:** Clubroot (*Plasmodiophora brassicae*), downy mildew (*Hyaloperonospora parasitica*) **Insects:** Flea beetles (*Phyllotreta* spp.), leafminers (*Liriomyza* spp.), Swede midge (*Contarinia nasturtii*)
Chinese flowering cabbage/ flowering edible rape	**Diseases:** Clubroot (*Plasmidiophora brassicae*), downy mildew (*Peronospora parasitica*) **Insects:** Flea beetles (*Phyllotreta* spp.)
Kohlrabi	For more information on pests of kohlrabi, see *Brassica Crops*.
Leaf and heading mustards	**Diseases:** Clubroot (*Plasmidiophora brassicae*) **Insects:** Flea beetles (*Phyllotreta* spp.)
Napa cabbage	**Diseases:** Clubroot (*Plasmidiophora brassicae*), downy mildew (*Peronospora parasitica*) **Insects:** Flea beetles (*Phyllotreta* spp.), Swede midge (*Contarinia nasturtii*)
Shanghai pak choy	**Diseases:** Downy mildew (*Hyaloperonospora parasitica*) **Insects:** Flea beetles (*Phyllotreta* spp.)
Tah tsai	**Insects:** Flea beetles (*Phyllotreta* spp.)
Cucurbits	
Bitter melon	**Diseases:** Alternaria blight (*Alternaria cucumerina*) **Insects:** Cucumber beetle (*Acalymma vittata*)
Bottle gourd	**Diseases:** Powdery mildew (*Sphaerotheca fuliginea, Erysiphe cichoracearum*) **Insects:** Cucumber beetle (*Acalymma vittata*)
Fuzzy melon	**Diseases:** Powdery mildew (*Sphaerotheca fuliginea, Erysiphe cichoracearum*) **Insects:** Aphids (e.g., *Myzus persicae, Brevicoryne brassicae, Lypaphis erysimi, Aphis gossypii*), cucumber beetle (*Acalymma vittata*)
Luffa/loofah/loofa	**Diseases:** Alternaria blight (*Alternaria cucumerina*), powdery mildew (*Sphaerotheca fuliginea, Erysiphe cichoracearum*) **Insects:** Aphids (e.g., *Myzus persicae, Brevicoryne brassicae, Lypaphis erysimi, Aphis gossypii*), cucumber beetle (*Acalymma vittata*)
Melons, specialty (e.g., brilliant melon)	For more information on pests of melons, see *Cucurbit Crops*.
Mousemelon/ cucamelon	**Diseases:** Powdery mildew (*Sphaerotheca fuliginea, Erysiphe cichoracearum*)
Specialty cucumber (e.g., Korean cucumber, Japanese cucumber, Suyo cucumber)	**Diseases:** Angular leaf spot (*Pseudomonas syringae*), anthracnose (*Colletotrichum obriculare*), downy mildew (*Pseudoperonospora cubensis*), powdery mildew (*Sphaerotheca fuliginea, Erysiphe cichoracearum*) **Insects:** Aphids (e.g., *Myzus persicae, Brevicoryne brassicae, Lypaphis erysimi, Aphis gossypii*), cucumber beetle (*Acalymma vittata*)
Winter gourd	**Diseases:** Powdery mildew (*Sphaerotheca fuliginea, Erysiphe cichoracearum*) **Insects:** Aphids (e.g., *Myzus persicae, Brevicoryne brassicae, Lypaphis erysimi, Aphis gossypii*), cucumber beetle (*Acalymma vittata*) See *Cucurbit Crops*.

Table 7–123. Major Diseases, Insects and Disorders of Specialty Vegetables in Ontario as of 2022

Crop Species	Diseases , Insects and Disorders
Fruiting Vegetables	
Eggplant, specialty	This crop is closely related to conventional eggplant and will have a similar pest complex. See *Eggplant*, for more information.
Okra	**Diseases:** Powdery mildew (*Erysiphe* spp.), botrytis (*Botrytis* spp.), cercospora leaf spot (*Cercospora* spp.), verticillium wilt (*Verticillium* spp.), white mould (*Sclerotinia* spp.) **Insects:** Aphids (e.g., *Aphis gossypii, Myzus persicae*), cabbage looper (*Trichoplusia ni*), European corn borer (*Ostrinia nubilalis*), flea beetle (various species), Japanese beetle (*Popillia japonica*), leafminer (various species), leafhopper (*Empoasca fabae*), spotted cucumber beetle (*Diabrotica undecimpunctata*), striped cucumber beetle (*Acalymma vittata*), tarnished plant bug (*Lygus lineolaris*), thrips (*Frankliniella occidentalis*), two-spotted spider mite (*Tetranychus urticae*) See Chapters 5 and 6.
Peppers, specialty (e.g., hot)	This crop is closely related to conventional peppers and will have a similar pest complex. For more information, see *Peppers*.
Physalis spp. (e.g., tomatillo, ground cherry)	Diseases have not yet been noted in *Physalis* in Ontario. **Insects:** Three-lined potato beetle (*Lema daturaphila*), two-spotted spider mites (*Tetranychus urticae*), subflexus straw moth (*Chloridea (Heliothis) subflexa*)
Leafy Vegetables	
Celtuce	This crop is closely related to conventional lettuce and will have a similar pest complex. See *Lettuce*.
Edible chrysanthemum	See Chapter 5 for more information on this pest. Diseases have not yet been noted on edible chrysanthemum in Ontario. **Insects:** Japanese beetle (*Popillia japonica*)
Leafy amaranth/ callaloo	**Diseases:** Leaf and stem blight (*Phomopsis amaranthicola*), pythium stem rot (*Pythium aphanidermatum*) **Insects:** Aphids (*Myzus persicae*, others), striped flea beetle (*Phyllotreta striolata*), three-spotted flea beetle (*Disonycha triangularis*) See *Lettuce*.
Pointed leaf lettuce/sword lettuce	This crop is closely related to conventional lettuce and will have a similar pest complex. See *Lettuce*.
Rhubarb	**Diseases:** Crown rot (*Phytophthora* spp.), nematodes (various species), turnip mosaic virus **Insects:** Aphids (various species), cabbage looper (*Trichoplusia ni*), potato stem borer (*Hydraecia micacea*), rhubarb curculio (*Lixus concavus*), slugs (*Arion* spp., *Droceras* spp., *Helix* spp., *Limax* spp.) **Disorders:** Air pollution injury, walnut wilt See *Crop-Specific Comments* for rhubarb, *Specialty Vegetables*, for more information on these pests.
Swiss chard, specialty (e.g., coloured)	This crop is closely related to conventional Swiss chard and will have a similar pest complex. See *Spinach and Swiss Chard*.
Witloof chicory	For more information on pests of whitloof chicory, see *Lettuce*.

SPECIALTY VEGETABLES

Table 7–123. Major Diseases, Insects and Disorders of Specialty Vegetables in Ontario as of 2022

Crop Species	Diseases , Insects and Disorders
Pea and Beans	
Edamame	**Diseases:** Septoria leaf spot (*Septoria cucurbitacearum*), white mould (*Sclerotinia sclerotiorum*), viruses (various) **Insects:** Aphids (*Aphis gossypii*), Japanese beetle (*Popillia japonica*) Edamame is the same species as conventional soybean and will have a similar pest complex. See OMAFRA Publication 811, *Agronomy Guide for Field Crops,* for a complete list of pests.
Garbanzo bean	No pest information available for Ontario. In other areas, the following pests that are also present in Ontario have been reported on garbanzo bean: cutworms, grasshoppers, wireworms, lygus bugs and aphids, fusarium wilt, white mould, botrytis. See Chapters 5 and 6 for general information on these pests.
Yardlong Bean	**Insects:** Leafhoppers (*Empoasca fabae*), stink bugs (various species). In other areas, the following pests that are present in Ontario have been reported: bacterial blight (*Pseudomonas syringae*), root rots (*Fusarium* spp., *Rhizoctonia* spp.), white mould (*Sclerotinia* spp.), powdery mildew (various species), aphids (various species), two-spotted spider mites (*Tetranychus urticae*). See Chapters 5 and 6 for general information on these pests.
Root and Tubers	
Carrots, specialty (e.g., coloured)	This crop is the same species as conventional carrots and will have a similar pest complex. For more information on pests of specialty carrots, see *Carrots*.
Horseradish	For more information on pests of horseradish, see *Brassica Crops*.
Japanese burdock/ gobo	**Diseases:** Viruses (various species) **Insects:** Aphids (various species), leafhoppers (various species) Although not yet observed in Ontario, it is likely that other root-feeding insects such as white grubs, millipedes and wireworms could be pests of this crop. Four-lined plant bug is a serious pest of this crop in other areas and also occurs in Ontario. See Chapters 5 and 6 for general information on these pests.
Jerusalem artichoke/ sunchoke	**Diseases:** Powdery mildew (*Erysiphe cichoracearum*), sclerotinia wilt, stalk and tuber rot (*Sclerotinia sclerotiorum*) **Insects:** Slugs (*Arion* spp., *Droceras* spp., *Helix* spp, *Limax* spp.) See Chapters 5 and 6 for general information on these pests. There is limited additional information on diseases of this crop.
Maca	Unknown for Ontario
Specialty radish (e.g., daikon)	**Insects:** Cabbage maggot (*Delia radicum*), flea beetle (*Phyllotreta* spp.) See *Brassica Crops* (especially radish).
Sweetpotatoes	See *Sweetpotatoes* for a list of pests.
Tigernut	**Insects:** White grubs (*Rhizotrogus majalis, Popillia japonica, Phyllophaga* spp.), wireworm (various *Coleoptera* species) See Chapters 5 and 6 for general information on these pests. There is limited additional information on diseases of this crop.
Yacon	Unknown for Ontario
Other Specialty Vegetables	
Florence fennel	**Diseases:** Bacterial leaf spot (*Pseudomonas syringae*), itersonilia blight (*Itersonilia perplexens*), phoma blight (*Phoma anethi*) **Insects:** Aphids (*Aphis gossypi, Myzus persicae*, others), leafhopper (various species), parsleyworm (*Papilio polyxenes*) See *Herbs*.
Globe artichoke	**Diseases:** Fungal leaf blights (e.g., *Alternaria* spp.) **Insects:** Aphids (*Aphis gossypi*, others), slugs (*Arion* spp., *Droceras* spp., *Helix* spp, *Limax* spp.) See Chapter 5 for more information on these pests.

SPECIALTY VEGETABLES

Crop Group Comments

Brassicas

Many brassica crops are sensitive to day length and will bolt if exposed to long-day photoperiods. Increased temperatures or sustained dry periods may result in undesirable spicy or pungent flavours in the leaves, stems or roots. Many of these species can also be grown in winter greenhouses with temperatures of 12°C–14°C (54°F–57°F).

Cucurbits

Some cucurbit crops may require a trellis structure to preserve fruit quality (e.g., bitter melon, fuzzy melon, bottle gourd, mousemelon), while others can be grown on the ground like traditional vine crops (e.g., winter melon). Most specialty cucurbits benefit from season extension practices.

Fruiting Vegetables

Most fruiting vegetables are field transplanted from seed and benefit from season extension practices and supplemental irrigation. They can be grown in either the greenhouse or in the field. Some crops, like okra, are very labour-intensive, requiring daily harvest intervals.

Crop-Specific Comments

Edamame

Edamame can fix its own nitrogen but should be inoculated with *Bradyrhizobium* if it has not been grown on a site before. Experience with edamame in Ontario indicates that some cultivars do not nodulate as well as conventional soybean and therefore additional nitrogen fertilizer may be beneficial.

Garbanzo Bean (fresh)

Garbanzo bean is the same species as chickpea but harvested at the green stage. Garbanzo beans can fix their own nitrogen but should be inoculated with *Bradyrhizobium* if they have not been grown on a site before and additional nitrogen fertilizer may be beneficial.

Globe Artichoke

Globe artichoke requires a vernalization (cold) period as a young transplant in order to develop flower buds. The required length of vernalization depends on the cultivar, with Green Globe and Imperial Star requiring the shortest vernalization period (80% vernalization after 200 hours at or below 10°C (50°F)). Production of some cultivars is not commercially feasible in Ontario due to extended vernalization requirements. Transplants are typically grown for 4 weeks in the greenhouse, placed in a cooler at 10°C (50°F) for 10–14 days under artificial lights and then transplanted into the field. Direct transplanting into the field in early spring can result in natural vernalization, but only if weather conditions are cool enough during this period.

Japanese Burdock/Gobo

Traditional root crop harvesters may not dig deep enough to harvest roots of Japanese burdock unless the crop is grown on tall, raised beds. Gobo roots can exceed 1 m (39 in.) in length in loose soil. Equipment modifications may be required.

Maca

Maca requires a long growing season in the range of 250–280 days with cool-to-moderate growing temperatures. Initial experience with maca in Ontario field trials has shown that it does not produce a marketable crop.

Physalis spp.

While many pests of specialty vegetables are shared with at least some traditional vegetable crops, there are some pests that appear to be problematic only on *Physalis* species. In Ontario, this includes the subflexus straw moth and the three-lined potato beetle.

Insects

Subflexus Straw Moth
Chloridea (Heliothis) subflexa

Identification: Larvae are orangish-brown, with white and brown lines and dark spots running along the sides. Adults have pale green forewings with 3 dark lines, edged in white, running across them, and white hind wings. Adults are not commonly observed in the field.

Damage: Larvae feed on the fruit within the calyx. Husks may be completely or partially devoid of fruit, filled with insect excrement, and larvae may be present in the husk at harvest.

Biology: Larvae of the moth species *Chloridea subflexa* (formerly *Heliothis subflexa*) feed only on the fruits of *Physalis* species and can be quite problematic in ground cherry in Ontario. It has also been reported in tomatillo in other areas. There is limited information on the life cycle of this pest. Newly hatched caterpillars cut small holes in the calyx or husk that surrounds the fruit, climbs inside and bores into the fruit. Fruit are consumed from the inside out, leaving insect excrement within the husk. The larvae then spend the majority of their life protected by the husk and may still be present at harvest. This means that fruit may be contaminated when sold, if it is sold in the husk.

Scouting and Thresholds: Scouting for this pest is challenging because eggs are difficult to find. Randomly opening the husks of developing fruit during the growing season can help check for larvae. Husks infested with larvae may seem lighter and the fruit inside are often more rubbery. No thresholds have been established.

Management Notes: There is limited information on management of this pest. No insecticides are registered for control in Ontario at this time.

Three-Lined Potato Beetle
Lema daturaphila

Identification: Adults are approximately 8 mm (⅓ in.) long, orangish-yellow with an orange head and three black stripes running along the back. The oval eggs are orange and laid in clusters under leaves. Larvae are dark grey and slug-like, with three pairs of legs and a round black head and may cover themselves in excrement as they feed to defend themselves from predation.

Damage: The three-lined potato beetle feeds on solanaceous plants, but while it is rare on potatoes and tomatoes, it can be quite devastating to tomatillo and ground cherries. Both adults and larvae feed extensively on the foliage of *Physalis* plants.

Biology: Three-lined potato beetles overwinter as adults or pupa in the soil, becoming active in May, after which they lay eggs on the underside of host crop leaves. The eggs hatch in June to July, and larvae feed in groups until mid-to-late summer, then pupate. There are 1–2 generations/year, depending on location.

Scouting and Thresholds: There are no thresholds established for this pest, but it can cause very severe damage to ground cherry, cape gooseberry and tomatillo.

Management Notes: Row covers or netting can be used to exclude beetles, if they are put in place before beetles occur on the crop. Removing nearby weeds in the *Solanaceae* family will reduce alternate hosts. Handpicking may be helpful if the plants are not heavily infested.

Rhubarb

In the spring, growth begins when soil temperatures reach 7°C (45°F). Temperatures above 26°C (79°F) cause leaf decline and seed stalk development during the months of July and August. Flower stalk development reduces plant vigour and depletes valuable resources from the crown. Remove stalks while they are still small and before the flowers open. Rhubarb can be grown in the winters as a “forced” crop. Two-year-old crowns are moved inside for the winter. They require a dormancy period where temperatures are held below 5°C (41°F) for 7–9 weeks. Temperatures of 13°C–18°C (55°F–64°F) will initiate growth. Force rhubarb crowns in the dark to prevent chlorophyll development. The use of gibberellic acid (Activol GA) is recommended to decrease the required dormancy period. Consult the label for details. Average yield range for fresh market and processing is 27–33 tonnes/ha (12–15 tons/acre) at 15–20 stalks/crown. Red stalks are preferred by most markets. Colour is often cultivar dependent but is also affected by temperature. The red colour is more pronounced in stalks grown in relatively cool weather conditions. As temperatures increase, the green colour predominates. As crowns age, the bud development moves from the centre of the plant to the edges. If crowns are left undivided, the centre portion will become unproductive. Eventually It will rot and die, reducing overall productivity of the field.

The best productivity occurs in the first 8–10 years after planting.

Diseases

Crown Rot

Phytophthora spp.

Identification: Crown rot infections of rhubarb cause sunken, brown lesions on the base of the stalks. The leaves wilt and die, and stalks may collapse. Infected crowns are very susceptible to secondary bacterial soft rots.

Biology: Appearance of the disease is favoured by cool, wet weather.

Management Notes: Allow for at least 2–3 years between growing vegetables and establishing rhubarb. Plant in well-drained soils.

Nematodes

Identification: A number of different nematode species affect a wide range of vegetable crops in Ontario. The symptoms and thresholds vary, depending on both the causal nematode and the host crop. In some cases, several types of nematodes may be present and causing damage in the crop.

Biology and Management Notes: The presence of nematodes may also exacerbate the impact of certain soil-borne fungal diseases, such as verticillium. For more information on nematodes in vegetable crops, see Chapter 6.

Turnip Mosaic Virus (TuMV)

Identification: Older leaves turn yellow and drop prematurely. Leaves emerging after infection are stunted and wrinkled and show a yellow, mottled pattern. Roots become "goosenecked" and do not reach normal size.

Biology: TuMV is spread by aphids. A rapid increase in infection usually begins in early July, when large numbers of winged aphids become active. Volunteer rutabagas and winter canola are the main overwintering sources of the virus.

Management Notes: Applications of insecticides, where registered, deter the feeding of virus-spreading aphids. Aphid control does not completely prevent the spread of the virus. Mark the plants with vigorous growth in June. Use these crowns as planting stock the following spring. Remove and discard all unhealthy crowns.

Insects

Aphids

Aphididae family

Identification: Aphids are small, soft-bodied, pear-shaped insects, with cornicles or "tail-pipes" near the tip of their abdomen.

Damage: They pierce the leaves and suck the sap from the plant, causing leaf distortion, stunting, delayed maturity and wilting. In rhubarb, aphids also act as a primary vector of virus diseases.

Biology, Scouting and Thresholds and Management Notes: There are several aphid species affecting vegetable crops, including rhubarb, in Ontario. For more information, see Chapter 6.

Cabbage Looper

Identification: Cabbage loopers are smooth and pale green, with a thin white line along each side and two faint lines down the middle of the back. They are up to 4 cm (1½ in.) long. They move in a very distinctive "looping" manner. The pupa is initially light green in a loose cocoon, darkening in colour as it matures. Adult moths are a mottled greyish-brown with a wingspan of 4 cm. They have a distinctive silvery figure eight pattern on their forewings and a slight tuft of hair behind the head. Eggs are small, rounded and greenish-white. They appear in small groups on the underside margins of leaves.

Damage: Small larvae feed on the underside of leaves, while more mature larvae chew large, irregular holes throughout the plant. Large amounts of dark, brown-green frass can also be observed. Cabbage loopers presence is unpredictable, and it may show up in one field and not in the adjacent field. Although this is a rare problem in rhubarb crops, it can cause sporadic damage.

Biology, Scouting and Thresholds, and Management Notes: For more information on biology, scouting and management of cabbage looper, see *Brassica Crops*, in this chapter.

Potato Stem Borer

Hydraecia micacea

Identification: Potato stem borer larvae are pink-purple with a pale brown head. The adult moths have light brown forewings with olive green markings. The eggs are laid in parallel lines on the leaves of grassy weeds.

Damage: Young larvae feed on the leaves of host plants. As they mature, they enter the protective environment of the stalk. They feed on the plant's vascular tissue, causing the plant to wilt and eventually die.

Biology: The potato stem borer overwinters as an egg. The larvae hatch in mid-May and feed until mid-summer, at which time they pupate. In early fall, the adult moths lay the overwintering eggs on host plants and on grassy weeds.

Scouting and Thresholds: There are no established thresholds for this pest in Ontario. The potato stem borer is an occasional pest in most crops in Ontario.

Management Notes: Control grassy weeds in and around rhubarb plantings. Chemical controls are most effective on small larvae. Control of the potato stem borer must occur before they bore into the plant.

Rhubarb Curculio

Identification: The rhubarb curculio (rhubarb weevil) is about 1.3 cm (½ in.) long with a pronounced, downward-curving snout. It is dark coloured, with a yellow dust on its back that rubs off when the insect is touched. Larvae are white, legless grubs with brown heads that reach about 1.9 cm (¾ in.).

Damage: The rhubarb curculio feeds on stalks, crowns and roots. Feeding injury looks like notches in the stem and leaf edges. Injured stalks may leak sap and partially decay, due to feeding and egg laying punctures of adults. Eggs laid in rhubarb do not hatch, so most damage to rhubarb comes from adult feeding and egg laying.

Biology: Insects are present from late May through early summer. Adults appear in mid-May and lay eggs in cavities along the stalks of host plants (weeds and rhubarb). Eggs hatch about 7–10 days later, except in rhubarb, where they are killed by the growing tissue. In weedy hosts, larvae burrow down the stalk of host plants, reaching maturity in 8–9 weeks. Adults emerge, feed and lay eggs on weeds and nearby rhubarb and seek sheltered locations to overwinter.

Scouting and Thresholds: No thresholds have been established for this pest.

Management Notes: This insect breeds on weeds (curl dock, thistle and sunflower) growing near rhubarb plantings in July, so destruction of these weeds can help reduce populations. Beetles are large and can be relatively easily hand-picked from plants when they appear.

Slugs

Identification: Slugs are soft-bodied, legless, grey mollusks that have variations in colour from dark brown and black to light grey.

Damage: They have rasping mouthparts and will create ragged holes on the lower leaves, sometimes leaving a "window-pane" of waxy cuticle behind. Severely affected plants may become skeletonized. Under high populations, slugs also attack seeds and emerging seedlings.

Biology, Scouting and Thresholds, and Management Notes: For more information on biology and management of slugs, see Chapter 5.

Disorders

Air Pollution Injury

Air pollution injury may be confused with symptoms of disease, insect feeding, nutrient deficiencies or toxicities, herbicide injury or damage caused by weather extremes. Plant damage caused by air pollution is usually most severe during warm, clear, calm, humid weather, when barometric pressure is high, as these conditions can cause an air inversion. During an air inversion, warm air above the earth's surface traps cooler air at ground level, allowing pollutants to accumulate. Injury may also be more severe during foggy conditions, heavy dews or in fields near very busy highways.

Sulfur Dioxide Injury

Different plant species, cultivars and even individual plants may vary considerably in their sensitivity to sulfur dioxide. Variations occur because of the differences in location, climate, stage of growth and maturation. Symptoms of acute injury appear as necrotic lesions between the veins and occasionally along the margins of the leaves. The colour can vary from a light tan or near white to an orange-red or brown depending on the time of year, the plant species affected and weather conditions. Recently expanded leaves usually are the most sensitive to acute sulfur dioxide injury, the very youngest and oldest being somewhat more resistant. Chronic injury is caused by long-term absorption of sulfur dioxide at sub-lethal concentrations. The symptoms appear as a yellowing or chlorosis of the leaf, and occasionally as a bronzing on the under surface of the leaves.

Walnut Wilt

Walnut wilt can occur if a crop is planted within 12–15 m (39–49 ft) of walnut trees or in soil from which walnut trees have been removed within the last several years. The plants wilt and die; other susceptible plants in the immediate area may be affected.

Tigernut/Chufa

Tigernut is related to a common weedy species in Ontario known as yellow nutsedge (*Cyprus esculentus*), however, experience from Ontario field trials suggests that tigernut varieties are cold sensitive and do not overwinter in the field. To date, no volunteer tigernut plants have been found in the following year where they have been grown in Ontario. Tigernut tubers are small and have many crevasses where soil can collect. Tubers marketed as a whole "nut" require extensive washing for marketability.

Yardlong Bean

Yardlong bean can fix its own nitrogen but should be inoculated with *Bradyrhizobium* if it has not been grown on a site before and additional nitrogen fertilizer may be beneficial.

Spinach and Swiss Chard

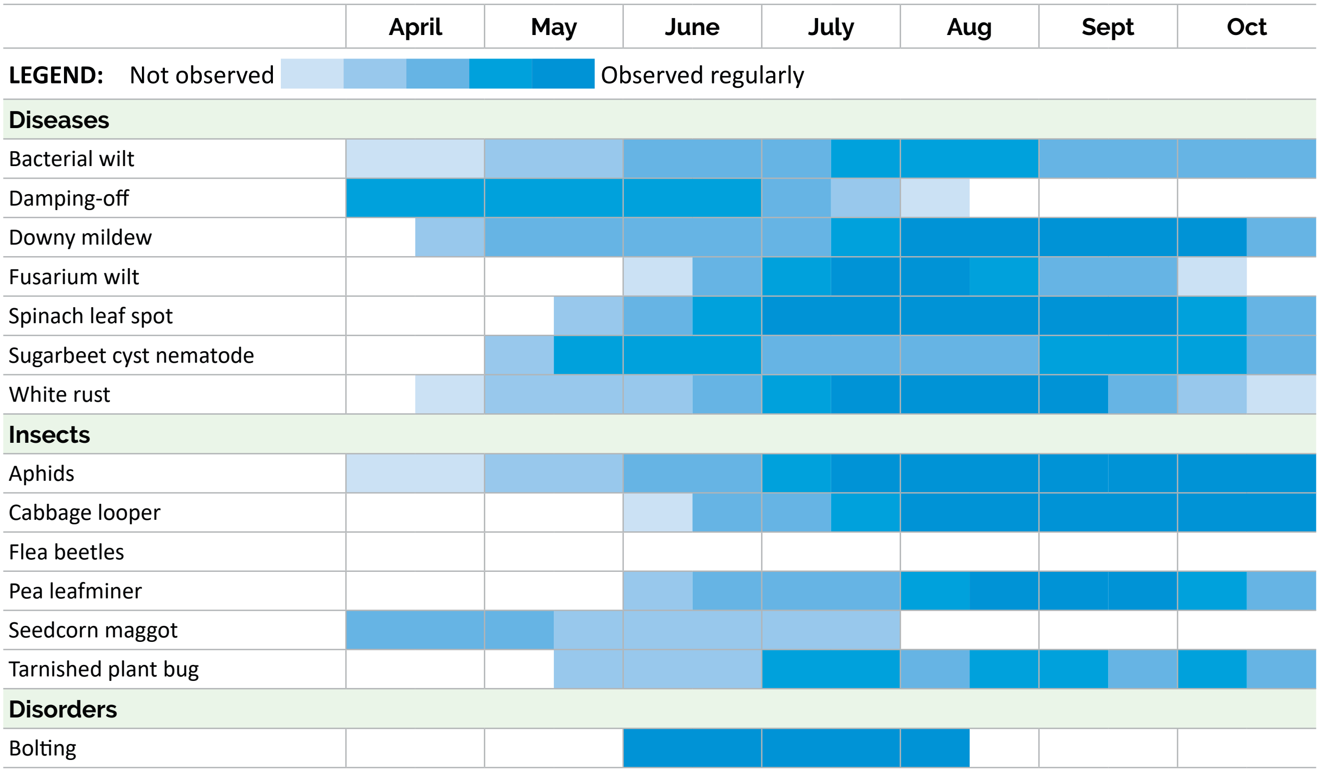


Figure 7–172. Spinach and Swiss chard pest activity calendar. The actual period of activity for any given pest will vary significantly from year to year, depending on environmental factors.

Production Requirements

Soil types:	mineral and muck soil
Soil pH:	mineral: 6.5–7.5
	muck: 5.1–5.5
Recommended rotational crops:	brassica crops, cucurbits, lettuce
Do not rotate with:	beets, spinach, rhubarb
Minimum soil temperature:	2°C (36°F)
Minimum air temperature:	–3°C (27°F)
Earliest planting date:	early to late April

Seeding and Spacing

Sow outside as soon as the soil is workable, in early spring through to early May. Choose cultivars that are resistant to bolting for seedings from mid-June to mid-July. Seed will germinate readily at soil temperatures as low as 3°C–4°C (37°F–39°F). Optimum germination occurs at 10°C–16°C (50°F–61°F). At higher temperatures, there is a more rapid emergence but decreased percentage germination. See Table 7–124.

Table 7–124. Spinach and Swiss Chard Crop Spacing

Crop	Row Spacing	In-Row Spacing	Depth	Seeding Rate
Spinach, baby leaf	15 cm (6 in.)	1–2.5 cm (½–1 in.)	1.3 cm (½ in.)	12 kg/ha (11 lb/acre)
Spinach, bunched	30 cm (12 in.)	2.5 cm (1 in.)	1.3 cm (½ in.)	12 kg/ha (11 lb/acre)
Swiss chard	40–60 cm (16–24 in.)	10–20 cm (4–8 in.)	1.3–1.9 cm (½–¾ in.)	6 kg/ha (5½ lb/acre)

Fertility

Macronutrients

Nitrogen

Broadcast and incorporate the recommended preplant nitrogen with all the required phosphate and potash. For early-sown crops, apply the total nitrogen recommendation as a preplant application. See Table 7–125.

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. See Table 1–12 and Table 1–13.

Table 7–125. Spinach and Swiss Chard Nitrogen Recommendations

Soil Type	Actual N
Mineral Soils	
Preplant	55 kg/ha (49 lb/acre)
Side-dress	55 kg/ha (49 lb/acre)
Total	**110 kg/ha (98 lb/acre)**
Muck Soils	
Preplant[1]	75 kg/ha (67 lb/acre)

[1] On muck soils, if rainfall has been excessive, an additional 55 kg/ha (49 lb/acre) may be side-dressed.

Phosphorus and Potassium

Test the soil to determine phosphorus and potassium requirements. See Table 7–126 and Table 7–127.

Table 7–126. Spinach and Swiss Chard Phosphorus Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Sodium Bicarbonate Phosphorus Soil Test (ppm)													
Crop	**0–3**	**4–5**	**6–7**	**8–9**	**10–12**	**13–15**	**16–20**	**21–25**	**26–30**	**31–40**	**41–50**	**51–60**	**61–80**	**81+**
Mineral Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	180 (161) (HR)	170 (152) (HR)	170 (152) (HR)	160 (143) (HR)	160 (143) (HR)	150 (134) (HR)	140 (125) (HR)	120 (107) (MR)	100 (89) (MR)	80 (71) (MR)	50 (45) (LR)	30 (27) (RR)	0 (RR)	0 (NR)
Muck Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	100 (89) (HR)	100 (89) (HR)	100 (89) (HR)	100 (89) (HR)	90 (80) (MR)	90 (80) (MR)	80 (71) (MR)	70 (62) (MR)	60 (53) (MR)	50 (45) (LR)	30 (27) (LR)	20 (18) (LR)	0 (RR)	0 (NR)

Table 7–127. Spinach and Swiss Chard Potassium Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Ammonium Acetate Potassium Soil Test (ppm)											
	0–15	**16–30**	**31–45**	**46–60**	**61–80**	**81–100**	**101–120**	**121–150**	**151–180**	**181–210**	**211–250**	**251+**
Mineral Soils												
Potash (K_2O) required kg/ha (lb/acre)	230 (205) (HR)	220 (196) (HR)	210 (187) (HR)	190 (170) (HR)	160 (143) (HR)	130 (116) (HR)	100 (89) (MR)	80 (71) (MR)	50 (45) (MR)	0 (LR)	0 (RR)	0 (NR)
Muck Soils												
Potash (K_2O) required kg/ha (lb/acre)	100 (89) (HR)	100 (89) (HR)	90 (80) (HR)	80 (71) (HR)	60 (54) (MR)	40 (36) (MR)	30 (27) (MR)	20 (18) (MR)	20 (18) (MR)	0 (LR)	0 (RR)	0 (NR)

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. For complete information, see *Micronutrients*, Chapter 1.

Boron

Boron deficiencies on spinach and Swiss chard are not common but can occur during periods of hot, dry weather. Leaves become twisted with light spots developing on the petioles. Internal breakdown may occur in the roots. External cankers may also develop on the root surface.

See Table 1–8, Chapter 1. Use caution when applying boron. Many rotational crops are sensitive to high levels of boron in the soil.

Magnesium

A magnesium deficiency may occur on spinach. The usual symptoms are yellowing of older leaves, while the veins remain dark green. See Table 1–8, Chapter 1.

Plant Tissue Analysis

When used in conjunction with soil analysis, plant tissue analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. Plant tissue analysis does not replace soil testing or a sound soil fertility program. For more information, see Table 7–128 and *Plant Tissue Analysis*, Chapter 1.

Harvest

Baby/processed spinach: Usually the smooth leaved or semi-savoy type. Typically, ready for harvest 21–30 days after planting when plants have greater than six leaves in ideal conditions. Early spring and fall crops may take 40–70 days after planting. Higher yields result when plants have 10–12 leaves. Most Ontario baby spinach is machine harvested.

Bunched/fresh spinach: Upright habit of leaves that can be smoothed, savoy (wrinkled) or crumpled. Typically harvested by hand in bunches 30–70 days after planting when plants are over 15 cm (6 in.) high. Plants that have reached 20–25 cm (8–10 in.) are ideal for bunched spinach. Higher yields result when plants have 10–12 leaves.

Swiss Chard: Typically harvested by hand 45–70 days after planting once plants are over 35–40 cm (14–18 in.) high, however, younger plants can be harvested earlier while leaves are young and tender or later when they are larger and have tougher stems.

Table 7–128. Spinach and Swiss Chard Nutrient Ranges

LEGEND: – = no data available

		N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu	Mo
Plant Part	**Time of Sampling**	**Per Cent (%)**						**Parts Per Million (ppm)**					
Most recently mature leaf	30 days after seeding	3–4.5	0.3–0.5	3–4	0.6–1	1–1.6	–	–	50–100	50–70	20–40	5–7	0.1–1
	harvest	3–4	0.3–0.5	2.5–3.5	0.6–1	1–1.6	–	–	30–50	50–70	20–40	5–7	0.1–1

Adapted from G. Hochmuth, et al. 2018. *Plant Tissue Analysis and Interpretation for Vegetable Crops in Florida*. University of Florida IFAS Extension. HS964.

Storage

Remove the field heat from spinach as soon as possible after harvest. Stored product may last for 10–14 days under good conditions. Store at 0°C (32°F) and a relative humidity of 95%–100%.

For more information, see Chapter 3 and Table 3–1.

Pest Management and Disorders

See Figure 7–172, *Spinach and Swiss chard pest activity calendar.*

Diseases

Bacterial Leaf Spot

Pseudomonas syringae pv. *aptata*

Identification: Water-soaked, tan lesions that begin as 3-mm (⅛-in.) oval spots with brown to black borders on Swiss chard leaves.

Biology: The bacterial cells are seed-borne and require a wound to enter the plant. Bacterial cells are spread to new plants by irrigation and rain splash, wind or equipment.

Management Notes: Obtain pathogen-free seed. Irrigate in the morning to avoid prolonged periods of leaf wetness. Bury crop residue immediately after harvest.

Bacterial Wilt

Pseudomonas syringae pv. *spinaciae*

Identification: Water-soaked, wedge-shaped spots form along the leaf margins of spinach. Spots may become olive-coloured.

Biology: Bacterial wilt is a seed-borne pathogen. It requires a wound, such as frost injury, sandblasting or mechanical damage, to infect healthy plants. Bacterial cells are spread by overhead irrigation.

Management Notes: Excessive nitrogen or overhead irrigation may increase disease levels. Follow good sanitation practices in all greenhouse areas used for transplant production.

Cercospora Leaf Spot

Cercospora beticola

Identification: Small, tan, circular spots 3–5 mm (⅛–¼ in.) in diameter develop on the stem and leaves of Swiss chard. Spots often have an off-white centre with a red margin around the lesion. Black dots can be seen with a hand lens, forming in the centre of the lesions.

Biology: The pathogen survives on crop residues, weed hosts and on seeds. Temperatures of 24°C–29°C (75°F–85°F) with high relative humidity favour disease development. Spores enter the plant through stomates, create lesions and produce conidia that are able to spread by wind, insects, irrigation or equipment.

Management Notes: Obtain pathogen-free seed. Observe a 3-year crop rotation with non-host crops. Avoid planting cultivars with later seeding dates next to one another. Irrigate in the morning to avoid prolonged periods of leaf wetness. Bury crop residue immediately after harvest.

Damping-Off

See Chapter 6.

Downy Mildew

Peronospora effusa

Identification: Infection usually begins on the mature, lower leaves and spreads inward. Yellowish or pale-green areas appear on the upper surface of the leaves (Figure 7–173). Greyish-purple mould spores develop on the underside of the leaf (Figure 7–174).

Figure 7–173. Yellow spots caused by spinach downy mildew.

Figure 7–174. The underside of a leaf showing greyish-purple mould development by spinach downy mildew.

Biology: Infection can occur at any growth stage. Cool temperatures of 10°C–15°C (50°F–59°F) and prolonged periods of leaf wetness, dew or fog support development. Downy mildew fungi survive for at least 1 year in the soil and 2 years in infected seed.

Management Notes: Resistant cultivars are available. Follow a 3-year rotation with non-host crops and plant into well-drained soils. Do not grow fall spinach crops in, or adjacent to, fields where an infected spring crop was grown. Apply preventive fungicides when field conditions are conducive for downy mildew infection.

Fusarium Wilt

Fusarium oxysporum f. sp. *spinaciae*

Identification: Fusarium wilt causes the outer leaves to wilt and turn yellow. Severe infections may progress to younger leaves. Light brown-to-black lesions develop on the roots, and the water-conducting xylem vessels turn black.

Biology: Moist soil conditions are required for initial root infection. Once established, the disease will progress quickly, especially if the soil becomes dry and the plants become stressed. Fusarium wilt is most severe at soil temperatures of 27°C (81°F).

Management Notes: In soils where this is a problem, do not seed spinach from May 31 to August 15. Some spinach cultivars may be more tolerant to the disease. Maintain a high soil pH; acidic soils favour disease development.

Spinach Blight, Cucumber Mosaic Virus, Beet Mosaic Virus

Identification: Infected plants become stunted with progressive yellowing and mottling. Beet mosaic virus produces small spotting early in the infection period without the distortion of the leaves common to other viruses.

Biology: Cucumber mosaic virus is usually transmitted by aphids.

Management Notes: Rogue out infected plants. Virus-resistant cultivars are available. Control weeds in adjacent fence rows. Milkweed, ground cherry, pokeweed, chickweed and mother-wort are alternative hosts to the cucumber mosaic virus. Avoid growing spinach near other mosaic-susceptible vegetable crops.

Spinach Leaf Spot

Colletotrichum spinaciae, *Stemphyliumn botryosum* f. sp. *spinacia*

Identification: Small circular to oval spots 0.3–0.6 mm (⅛–¼ in.) in diameter and green/grey, turning tan as the pathogen develops. Lesions in older leaves coalesce and become papery. (Figure 7–175).

Biology: The pathogen is seed-borne and, once established in the field, is spread by splashing water. It may overwinter on crop debris or on perennial weeds.

Management Notes: Hot water treatment of the seed by the seed supplier may help reduce the incidence but is unlikely to eradicate the pathogen from the seed. No cultivars have shown complete resistance to the pathogen. Incorporate crop debris immediately after harvest.

Figure 7–175. Colletotrichum lesions on spinach leaves.

Sugarbeet Cyst Nematode

Heterodera schachtii

Identification: Oval or elongated patches of plants appear stunted, yellow or lighter green, unthrifty with delayed maturity or flowering. Small white to cream or yellow coloured immature lemon-shaped cysts attached to roots. Cyst turns brown at maturity. Shows no visible foliar symptoms in fields with relatively low population levels. High levels in the field may produce patches of areas of stunted plants that will wilt during hot and dry weather.

Biology: Nematodes feed on roots after hatching from eggs. Males leave the root after feeding for a few days. Females attach to the root, lose the ability to move, and swell into small, lemon-shaped white cysts.

Scouting and Thresholds: Established threshold is 2,000 nematodes or eggs/kg soil, or >250 cysts/kg soil. When scouting, use a shovel to carefully dig roots and look for cysts on root hairs. If found, dig in multiple areas and record the percentage of the field infected.

Management Notes: Before deciding upon a management strategy for nematodes, complete a nematode soil test to determine the levels of nematodes present. In Ontario, nematode populations in soil and roots are usually at their highest in May to June and again in September to October. The fall months are a good time to soil sample for nematodes, as the populations are high and controls can be taken well in advance of planting the crop. Plant tolerant cultivars, and rotate with non-host crops, including grains, corn, soybeans or alfalfa. Plant cover crops to prevent wind blowing infected soil to non-infected fields. Plant early in the season in infected fields to avoid favourable environments for nematodes. To avoid damage from sugarbeet cyst nematode, do not plant spinach following rhubarb, beets or spinach.

Turnip Mosaic Virus (TuMV)

Identification: Infected leaves exhibit mottling (yellow or light green areas surrounded by normal green colour), and wrinkling or puckering of the leaf tissue between the veins. TuMV can also cause necrotic ring spots.

Biology: TuMV overwinters in volunteer rutabagas and winter canola. It can be vectored by aphids or transmitted mechanically with equipment.

Scouting and Thresholds: When scouting, document the location of infected plants within the field, and rogue infected plants if possible.

Management Notes: Avoid planting within 5 km of fields that were planted in rutabaga or winter canola in the previous year. Volunteer rutabagas growing in fields of wheat, barley or other crops can allow for severe outbreaks. Ensure infected plants are removed. Manage aphid populations to reduce rate of virus.

White Rust

Albugo candida

Identification: Symptoms of the disease first appear as yellow spots on the upper leaf surface. White pustules form on the underside of the leaf (Figure 7–176).

Biology: The development of white rust is favoured by warm, sunny days followed by cool nights with dew. This disease can occur any time during the season.

Management Notes: Tolerant cultivars are available. Avoid planting fall crops in or adjacent to fields where an infected spring crop was grown. Practise a 3-year crop rotation.

Figure 7–176. White rust on spinach leaf.

Insects

Aphids

See Chapter 5.

Cabbage Looper

Trichoplusia ni

Identification: Cabbage looper larvae are smooth and pale green, with a thin white line along each side and two faint lines down the middle of the back. They are up to 4 cm (2 in.) long. They move in a very distinctive "looping" manner. The pupa is initially light green in a loose cocoon, darkening in colour as it matures. Adult moths are a mottled, greyish-brown with a wingspan of 4 cm (2 in.). They have a distinctive silvery figure-eight pattern on their forewings and a slight tuft of hair behind the head. Eggs are small, rounded and greenish-white. They appear in small groups on the underside margins of leaves.

Damage: Small larvae feed on the underside of leaves, while more mature larvae chew large, irregular holes throughout the plant. Large amounts of dark, brown-green frass can also be found. Its presence is virtually unpredictable and it may show up in one field and not in the adjacent field.

Biology: Cabbage looper do not overwinter in Ontario. The adults travel on weather patterns from the South in midsummer to early fall.

Scouting and Thresholds: Count the number of cabbage loopers on 25 randomly selected plants in the field. The suggested threshold for leafy greens is 5%.

Management Notes: Insecticides are most effective against small larvae. Begin application of insecticides when young larvae are found. Continue on a 5–10-day schedule, or as determined by scouting.

Flea Beetles

See *Brassica Crops*, in this chapter.

Pea Leafminer

Liriomyza huidobrensis

Identification: The pea leafminer is a fly with a yellow and black body and red eyes. It mines the leaves of spinach, rendering the crop unmarketable.

Biology: Optimal temperatures for leafminer development range from 21°C–32°C (7°F–9°F). Egg-laying is reduced at temperatures below 10°C (50°F). Leafminers can be a problem throughout the season, however, the pea leafminer is typically a late-season pest with populations peaking from the end of August through the middle of September.

Scouting and Thresholds: None have been established. Scout for mines and larvae or for eggs on the underside of leaves. Yellow sticky traps placed in the crop can be used to monitor adult flies.

Management Notes: Lamb's-quarters is an alternate host for leafminers. Good weed control can reduce infestations. Crop rotation is an effective pest management tool. The pea leafminer requires protected areas such as hoop houses or heated greenhouses to overwinter. Management of pea leafminers in protected areas throughout the winter will lower the incidence the following summer.

Seedcorn Maggot

Delia Platura

Identification: The adult seedcorn maggot is a small (4-mm (⅛ in.)), black fly whose females lay eggs in the soil often around the base of seedlings. Several days later, those larvae, often referred to as maggots, immediately start feeding on the host plant's roots or newly germinated spinach seed. Small amounts of feeding at the initial crop development stages can lead to severe reductions in yield.

Damage: Larvae tunnel into the roots and basal plate of the plant. Newly planted crops may have low emergence. The type of damage is related to crop development at the time of attack.

Biology: The seedcorn maggot overwinters as pupa in the top 15 cm (6 in.) of the soil.

Scouting and Thresholds: A degree day (DD) model has been developed to predict emergence of seedcorn maggot flies. Using a base of 4°C (39°F), seedcorn maggot adults emerge at 200, 600 and 1000 DDs for first, second and third generations, respectively. For more information, see *Growing Degree Days*, Chapter 4.

Management Notes: Implement a 3-year crop rotation and avoid planting spinach in fields with undecomposed plant materIal from the previous crop. Avoid planting into fields with crop residue or recently incorporated cover crop. Floating row covers/exclusion nets will significantly reduce damage but are hard to implement. Treatments against adult flies have shown to not be effective.

Tarnished Plant Bug

See *Lettuce*, in this chapter.

For more information on spinach and Swiss chard IPM, see the following OMAFRA Factsheets:

- *Leafminers Attacking Field Vegetables and Greenhouse Crops*
- *Caterpillar Pests of Crucifer Crops*
- *Aphids Infesting Lettuce and Celery in Ontario*

Sugarbeets

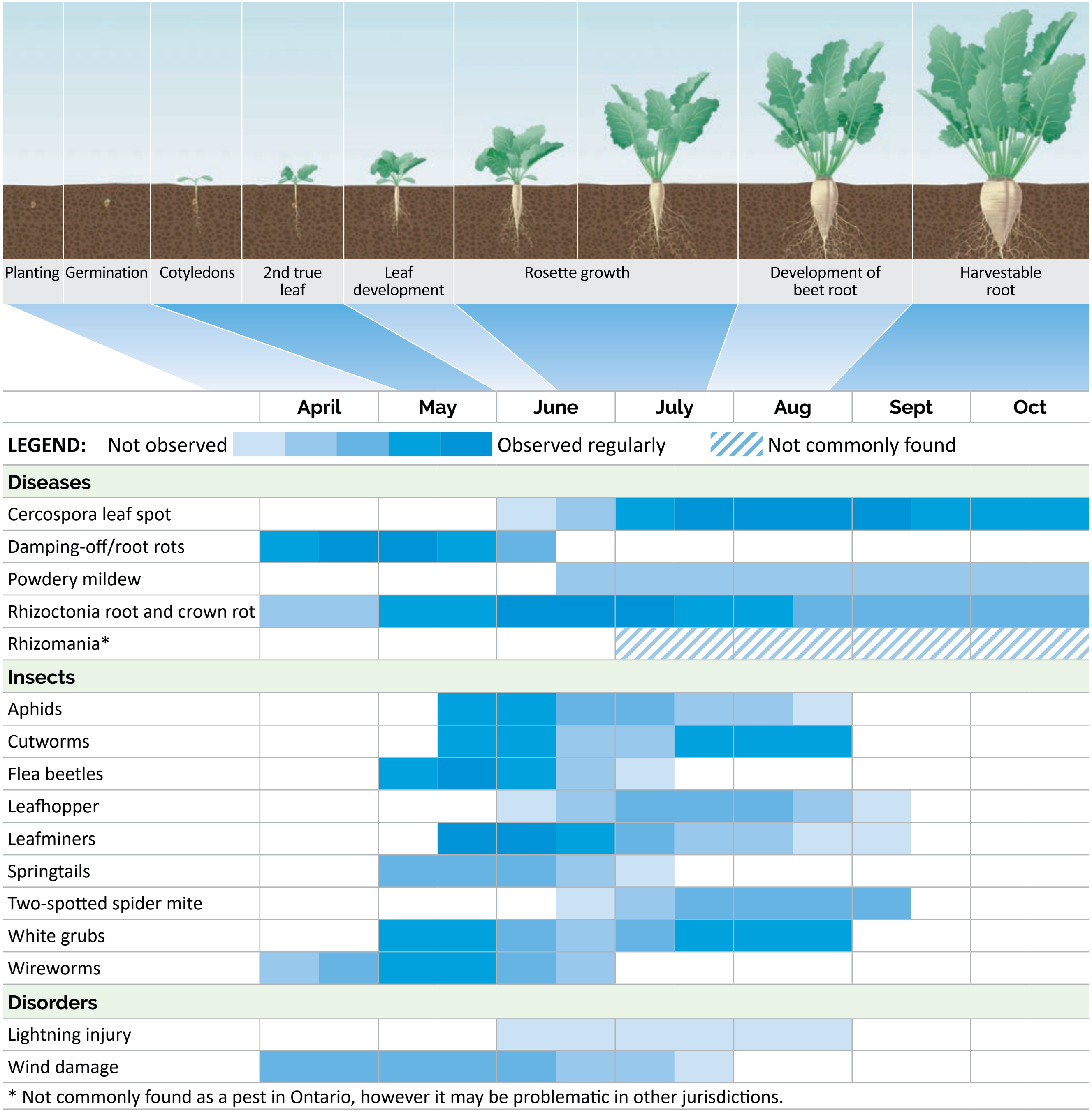


Figure 7–177. Sugarbeet stages of development and pest activity calendar. The actual period of activity for any given pest will vary significantly from year to year, depending on environmental factors.

Sugarbeet Crop Growth

Sugarbeet is a biennial plant, which means it has a 2-year growth cycle. When it is grown as an agricultural crop for sugar production, we are mainly concerned with the first year of this cycle. Sugar reserves are stored in the sugarbeet root during the first growing season as an energy source for overwintering, which is when the beet is harvested for processing.

Sugarbeets are direct seeded, usually in late March and April. Approximately 8–10 days later, the seedlings emerge with a pair of cotyledons. Successive leaves develop in pairs throughout the growing season. Leaves usually last from 45–65 days before dying off. Leaf development continues until the leaf canopy completely covers the soil around the root. The plant will then start to develop the tap root system, which can utilize water and soil nutrients to depths of 2–3 m (6–10 ft). Sugarbeets are harvested from late August through early November.

Production Requirements

Soil types:	wide range of soil types. Well-drained.
Soil pH:	6.5–7.2
Recommended rotational crops:	beans, cereal crops, corn, cucurbits, eggplant, peas, peppers, potatoes, soybeans, tomatoes
Do not rotate with:	table beets, brassica crops, Swiss chard
Minimum soil temperature:	4.0°C (39°F)
Earliest planting date:	late March to mid-April

Soil pH

Soil pH can have a significant impact on the breakdown of several commonly used field crop herbicides. Carryover of these herbicides will severely injure sugarbeets. While pH can be increased with the application of lime, it takes time after the application for the pH to fully adjust. Adjusting the pH may improve herbicide breakdown, but it is still necessary to allow for sufficient time for herbicide breakdown to occur. Even where the average pH of a field is suitable, areas of low or high pH may still exist.

Carryover herbicides of concern for sugarbeets:

imazethapyr (Pursuit, Clean Sweep, Conquest, Valor): degrades very slowly at pH less than 6.0–6.5

flumetsulam (Broadstrike Dual Magnum)
cloransulam (First Rate): breaks down very slowly below a pH of 6, increased activity above a pH of 7.8

chlorimuron-ethyl (Classic): degradation stops at a pH greater than 7

Soil pH can also have an effect on the availability of certain nutrients to the plant. For example, aluminum and manganese may become more available to plants in low pH or acidic soils. Meanwhile calcium, phosphorus and magnesium are less available to plants in soils with a low pH. In basic or high pH soils, phosphorus and many micronutrients can be less available to the plants. Nutrient applications may need to be adjusted based on the soil pH to optimize plant health.

Seeding and Spacing

The Michigan Sugarbeet Research and Education Advisory Council (REACh) recommends planting enough seed to give a final emerged stand of 175–225 sugarbeets per 30 m (100 ft) of row, regardless of row spacing. Adjust the seeding rate according to field conditions, emergence characteristics of the cultivar and row width. Aim for the lower end of the range in 71–76-cm (28–30-in.) rows and the high end of the range for 56-cm (22-in.) rows. See Table 7–129. These spacings will consistently produce more recoverable sugar per hectare than lower stands.

Table 7–129. Sugarbeet In-Row Spacing

	Seed Spacing	
Expected Emergence	**180 sugarbeets per 30 m (100 ft) of row**	**150 sugarbeets per 30 m (100 ft) of row**
40%	6.8 cm (2¾ in.)	8.1 cm (3⅛ in.)
50%	8.4 cm (3⅓ in.)	10.2 cm (4 in.)
60%	10.2 cm (4 in.)	12.2 cm (4¾ in.)
70%	11.9 cm (4¾ in.)	14.2 cm (5⅔ in.)
80%	13.5 cm (5⅓ in.)	16.3 cm (6½ in.)

Proper planter set-up and maintenance are extremely important for successful establishment of the sugarbeet stand. Good seedbed preparation is also important for achieving early seeding dates, rapid seedling emergence and a uniformly spaced stand. Deep or excessive spring tillage reduces soil moisture and increases crusting, impacting sugarbeet emergence. Planting depth will vary with soil types and moisture conditions. A depth of 2.5 cm (1 in.) is generally satisfactory.

Fertility

Macronutrients

Nitrogen

After field corn and small grains, use 157–180 kg/ha (147–160 lb/acre). Reduce nitrogen application to 112–135 kg/ha (100–120 lb/acre) when following other crops. Excess nitrogen will not increase sugarbeet yield but will decrease sugar content and clear juice purity.

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. See Table 1–12 and Table 1–13, Chapter 1

Phosphorus and Potassium

Test the soil to determine phosphorus and potassium requirements. See Table 7–130 and Table 7–131.

Table 7–130. Sugarbeet Phosphorus Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Sodium Bicarbonate Phosphorus Soil Test (ppm)													
	0–3	**4–5**	**6–7**	**8–9**	**10–12**	**13–15**	**16–20**	**21–25**	**26–30**	**31–40**	**41–50**	**51–60**	**61–80**	**81+**
Mineral Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	150 (134) (HR)	140 (125) (HR)	140 (125) (HR)	130 (116) (HR)	130 (116) (MR)	120 (107) (MR)	100 (89) (LR)	90 (80) (LR)	70 (62) (RR)	50 (45) (RR)	30 (27) (RR)	0 (RR)	0 (RR)	0 (NR)

Table 7–131. Sugarbeet Potassium Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Ammonium Acetate Potassium Soil Test (ppm)											
	0–15	**16–30**	**31–45**	**46–60**	**61–80**	**81–100**	**101–120**	**121–150**	**151–180**	**181–210**	**211–250**	**251+**
Mineral Soils												
Potash (K_2O) required kg/ha (lb/acre)	180 (161) (HR)	170 (152) (HR)	160 (143) (HR)	140 (125) (HR)	120 (107) (HR)	90 (80) (MR)	70 (62) (MR)	20 (18) (MR)	0 (LR)	0 (LR)	0 (RR)	0 (NR)

Starter Fertilizer

Sugarbeet plants require a source of early-season nitrogen, which can be applied broadcast at planting or with a starter fertilizer. If nitrogen is applied broadcast in fields with high soil-test levels of phosphorus and potassium, starter fertilizer is less beneficial. In fields where nitrogen is applied after planting (side-dressing), starter fertilizer should be used to supply the crop's early-season nitrogen needs. Sugarbeets following corn are often more responsive to starter nitrogen. Where starter is required, place it in a band at least 5 cm (2 in.) to the side and 5 cm (2 in.) below the seed to avoid seedling injury. See *Starter Fertilizers for Vegetable Crops*, Chapter 1, for more information.

Boron

Boron deficiencies are more commonly observed on sandy or fine-textured soils and soils with high organic matter, as boron leaches quite easily. Symptoms of boron deficiency most often develop during drought periods and start as a white netted chapping of the upper blade surfaces or wilting of the plants. If the deficiency is severe, crosswise cracking of the petioles develops, and new leaves may turn black at the growing point.

Boron deficiency can be corrected using two foliar applications before mid-June. To prevent deficiency, boron can be applied in the starter fertilizer. See *Starter Fertilizers for Vegetable Crops*, Chapter 1, for more information.

Manganese

Manganese deficiencies are more common on heavier-textured soils with high pH and high soil organic matter levels. Deficient plants show marked yellowing between the leaf veins; the veins themselves remain green. If soybeans regularly exhibit manganese deficiencies in the field, then manganese deficiency may also occur in sugarbeets. To correct a deficiency, spray with manganese sulfate. See Table 1–9 and Table 1–10, Chapter 1.

Plant Tissue Analysis

When used in conjunction with soil analysis, plant tissue analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. Plant tissue analysis does not replace soil testing or a sound soil fertility program. For more information, see Table 7–132 and *Plant Tissue Analysis*, Chapter 1.

Table 7–132. Sugarbeet Nutrient Ranges

Sample taken from centre of fully developed leaf blade.

Time of Sampling	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu	Mo
	Per Cent (%)						Parts per Million (ppm)					
Mid-season	3.01–4.50	0.26–0.50	2.01–6.00	0.36–1.20	0.36–1.00	0.21–0.50	51–200	21–150	19–60	26–80	11–40	0.15–5.0

Adapted from M.L. Vitosh, et al. 1994. *Secondary and Micronutrients for Vegetables and Field Crops.* Michigan State University Extension. E-486.

Harvest

Harvest Process

Handle sugarbeets as gently as possible to minimize breakage and bruising. Adjust flails or knives to remove all leaf and petiole material from the crowns. Knives should be set to scalp only the very top of the root, which contains most of the petiole area (silver dollar size). Throughout the day, the temperature of topped beets will increase at a faster rate than beets with the leaves still attached. Attempt to harvest beets as soon as possible after defoliation. Top only what can be harvested the same day.

Topped beets will freeze in the field much more quickly than beets with tops. When sugarbeet crowns are frosted or frozen in the field, delay harvest until the tissue has had a chance to thaw and stabilize. Damaged, poorly topped or freeze-damaged beets cause storage problems in the piles.

Harvest Frequency

Sugarbeets are machine harvested once-over. Defoliators and harvesters must be operated to minimize damage to the beet and to adequately remove soil and trash.

Harvest Duration

Early harvest can begin in late summer, whenever the factory is ready to accept beets. Harvest for permanent piling typically begins in mid-October and can continue into early November or until hard freezes start to damage the beets and freeze the soil. Sugarbeets will continue to grow and increase in yield until they are harvested, provided disease control is adequate and hard freezes have not occurred. Growers typically harvest fields with low yield potential first, allowing the best fields to continue to grow. It is especially beneficial to harvest heavily diseased fields before permanent piling, as many diseases can reduce yield potential throughout the fall and increase storage losses.

Average Yields:	67–78 tonnes/ha (30–35 tons/acre)

Storage

Sugarbeets are delivered by trucks directly from the field to piling stations or the factory for storage and processing. Storage is primarily on flat, unpaved piling grounds provided by the processing company in the factory yard or at outside piling stations. Some storage also may be over forced air ventilation/aeration systems or in climate-controlled storage buildings. These specialized piling grounds or buildings minimize the loss of sugar caused by storage rots and root respiration.

Pest Management and Disorders

See Figure 7–177, *Sugarbeet stages of development and pest activity calendar*.

Diseases

Cercospora Leaf Spot

Cercospora beticola

Identification: Numerous small (3–5 mm (⅛–³⁄₁₆ in.)), circular lesions develop on the leaves. Lesion centres are tan to ash grey in colour, while borders are often reddish-purple to dark brown. Small black dots (fungal structures) in the centre of the lesions can be seen with a hand lens. Cercospora leaf spot leads to defoliation and reductions in both yield and sugar content. Symptoms do not generally appear until 10–14 days after infection (Figure 7–178).

Figure 7–178. Cercospora leaf spot lesions on sugarbeet leaves.

Biology: Cercospora leaf spot is most active from mid-July through September. Daytime air temperatures between 24°C (75°F) and 32°C (90°F) with night temperatures of at least 15°C (59°F) and extended periods of leaf wetness due to rain, dew or fog are favourable for disease development.

Management Notes: Use BEETcast to determine optimum fungicide timing. If BEETcast is unavailable, begin the fungicide program as soon as leaf symptoms appear. See *Disease Prediction Models*, Chapter 4.

Sugarbeet cultivars have varying levels of leaf spot tolerance.

The currently registered cercospora fungicides must be managed responsibly to maintain their efficacy and to avoid the development of resistance to multiple fungicides. Scout fields regularly to ensure the fungicide program is controlling the disease.

The systemic fungicide families must be rotated; never apply systemic products from the same family in sequential applications. Tank-mix the systemic fungicides with contact fungicides that have multiple sites of action. Follow a shorter disease severity value (DSV) spray interval when using contact fungicides alone. Use water rates of at least 187–281 L/ha (20–30 gal/acre).

BEETcast

The BEETcast program uses temperature and leaf wetness measurements to schedule preventive fungicide applications, before the damaging disease symptoms are visible. BEETcast calculates a daily disease severity value (DSV) for each location. A zero means conditions were not favourable for disease development, due to cool temperatures or dry leaves. Favourable conditions, due to warm temperatures and periods of leaf wetness, are given a rating of 1 to 4. Spray applications are made when the accumulated daily DSVs reach a target number. BEETcast DSVs are available from Weather INnovations Consulting LP, with support from the Michigan Sugar Company. For more information, contact Weather Innovations Incorporated at 519-352-5334 or visit their website at www.weatherinnovations.com.

Damping-Off — also known as Root Rots

Aphanomyces cochlioides, *Pythium* sp., *Rhizoctonia solani*, *Phoma betae*

Identification: Plants infected prior to emergence rot and typically fail to produce a seedling. If the seedlings do emerge, they are usually weak and lack vigour. Post-emergence infections cause the seedlings to rot at soil line. This usually occurs within 2–4 weeks of emergence. Affected plants tend to curl downward or melt into the soil. See Chapter 6 for more information.

Powdery Mildew

Erysiphe polygoni (syn. *E. betae*)

Identification: Initial symptoms usually appear on the older, shaded leaves. A dense, white fungal (powdery) growth develops primarily on the upper leaf surface, though it can also occur on the lower leaf surface. A pale green-to-yellow discolouration may also appear on the corresponding upper leaf surface. The white, powdery growth spreads to the upper leaf surface and down the petiole. Infected leaves and stems turn yellow, wither and die prematurely.

In sugarbeets, infected plants are more susceptible to frost than healthy leaves.

Biology: The pathogens causing powdery mildew do not overwinter in the field in Ontario. Wind-borne spores usually arrive from the southern U.S. and Mexico in mid-summer. Peak infection periods occur when temperatures are in the range of 20°C–26°C (68°F–79°F). Disease development slows when temperatures climb above 26°C (79°F).

Infections can develop at relatively low humidity (<20%) levels, although humid weather conditions and heavy dews lead to more rapid disease development. Under these conditions, visual symptoms may appear 3–7 days after the initial infection.

Management Notes: There are varying levels of tolerance among sugarbeet cutivars. Fungicides are available that may offer suppression of the disease, but good coverage on both the upper and lower leaf surfaces is essential. In this region, the fungicides used for cercospora leaf spot management generally offer acceptable control of powdery mildew.

Powdery mildew is difficult to detect in its early stages. Both the upper and lower leaf surfaces must be checked to detect spore growth. Once mildew and yellowing are present on the upper leaf surfaces, the disease is quite advanced and unlikely to respond to fungicide applications.

Due to its wide host range, it can be difficult to control with cultural practices.

Rhizoctonia Root and Crown Rot
Rhizoctonia solani

Identification: Symptoms include wilting of the leaves and the eventual death of the foliage. Infections occur on the crown, sides or tips. In some cases, tip infections begin before foliar symptoms. Roots may develop large cracks. Infection often spreads down the row (Figure 7–179).

Figure 7–179. Rhizoctonia crown and root rot damage on sugarbeets.

Biology: *Rhizoctonia solani* is a ubiquitous soil-borne fungus. It can survive in the soil for many years. Infections can occur throughout the season under warm and wet or very humid conditions.

Rhizoctonia root and crown rot is a warm weather disease. It becomes active at temperatures of 12°C–35°C (54°F–95°F) but is most active at 25°C–33°C (77°F–91°F). Fields considered at high risk for *Rhizoctonia solani* infection include those with a history of the disease or fields in which a host crop was grown the previous year. Stressful growing conditions such as soil compaction or poor soil drainage will also make plants more susceptible to infections.

Rhizoctonia solani is one of the fungal species that cause damping-off. See *Damping-Off*, Chapter 6, for more information.

Management Notes:

- Azoxystrobin fungicides should be applied in furrow, at the 6–8-leaf stage or both, to effectively aid in managing the disease.
- *Rhizoctonia*-resistant sugarbeet cultivars are available and should be used in fields with a history of the disease.
- Make sure fields are well drained.
- Take measures to reduce soil compaction.
- Avoid planting susceptible crops in previously infected areas.
- Rotate for several years with corn or small grains and practice strict sanitation procedures to avoid spreading infected soil between fields.
- Avoid throwing soil onto beet crowns during cultivation.
- Do not dump sugarbeet tare dirt onto fields scheduled for sugarbeets the following year.

Rhizomania
Beet Necrotic Yellow Vein Virus (BNYVV), vectored by the soil fungus *Polymyxa betae Keskin*

Identification: Symptoms include stunted roots with a proliferation of lateral roots. The taproot is often constricted, giving the root a wineglass shape. Root vascular tissue becomes discoloured. Leaves become a bright, highlighter yellow colour and develop an erect growth habit. Symptoms may be patchy within a field (Figure 7–180).

Figure 7–180. Prolific growth of lateral beet roots caused by rhizomania.

Biology: The disease is widespread in other sugarbeet growing areas but has not yet been confirmed in Southwestern Ontario. Rhizomania is regarded as one of the most destructive of sugarbeet diseases. It can severely reduce tonnage and sucrose levels. A very small amount of contaminated soil can start an infection that will eventually spread throughout a field.

Management Notes: Once present, the disease cannot be eradicated, however, management practices can be used to slow its spread and reduce the impact. Any activity that moves soil has the potential to spread the disease (e.g., field work, tare dirt). Resistant cultivars are available.

Sugarbeet Cyst Nematode
Heterodera schachtii

Sugarbeet cyst nematode (SBCN) is an expanding problem in Michigan but has not yet been found in Ontario.

Identification: Oval or elongated patches of plants appear stunted, yellow or lighter green, and unhealthy. Small white to cream or yellow-coloured immature lemon-shaped cysts attached to roots. Cyst turns brown at maturity.

If ever identified in Ontario, resistant cultivars, an extended crop rotation and planting trap crops prior to beets are effective strategies to manage SBCN. Prior to deciding upon a management strategy, confirm the identification by contacting the Agricultural Information Contact Centre at 1-877-424-1300 or ag.info.omafra@ontario.ca.

See Chapter 6, for more information.

Insects

Aphids
Aphididae family

Identification: There are several aphid species affecting vegetable crops in Ontario. Aphids are small, soft-bodied, pear-shaped insects, with cornicles or "tail-pipes" near the tip of their abdomen.

To scout for sugarbeet root aphids, dig up and inspect the roots of wilted plants. The aphids may also be found on the roots of weed hosts such as lamb's-quarters and pigweed.

Sugarbeet cultivars with resistance to root aphids are available. The level of resistance varies between cultivars.

No threshold is established, but less than 10% infestation may result in reduced yield. See Chapter 5, for more information.

Cutworms
Agrotis ipsilon (black cutworm),
Euxoa messoria (dark-sided cutworm),
Crymodes devastator (glassy cutworm),
Euxoa detersa (sandhill cutworm)

Cutworms are primarily an early-season pest that can severely affect seedlings. Seedlings appear as if they were cut off at the soil surface with scissors. See Chapter 5, for more information.

Flea Beetles
Phyllotreta sp.

Identification: Flea beetles are small (2–3 mm (1⁄8 in.) long), shiny black beetles. Adults are active and jump when disturbed.

Damage: Feeding damage consists of numerous small "shot-holes," 1–5 mm (<¼ in.) in diameter. Older damage may be ringed with brown, dried leaf tissue, while fresh feeding holes have green edges. At the seedling stage, flea beetle feeding can kill the plant.

Flea beetles and their larvae may feed on cotyledons, leaves and underground parts of beets. They are unlikely to cause significant damage unless populations are very high during the seedling stage, especially if the plants are growing slowly in cool conditions.

Other flea beetle species including potato flea beetle (*Epitrix cucumeris*) and possibly palestriped flea beetle (*Systena blanda*) and spinach flea beetle (*Disonycha xanthomelas*) occasionally damage sugarbeets. Small plants in less-than-ideal growing conditions are more likely to be affected by flea beetle feeding. Most plants are able to outgrow the damage.

Biology: Flea beetles in Ontario generally have one generation per year. The lifecycle from egg to adult may take as little as 7 weeks, making a second generation possible in some years. Adult flea beetles overwinter in leaf litter. They emerge and begin feeding on young plants in mid-May. Adults lay eggs near the roots of host plants throughout the spring and early summer. Larvae develop on the roots. In late July, adults emerge from the soil, feed and then seek hibernation sites in the fall.

Scouting and Thresholds: Begin monitoring for flea beetles as soon as the seedlings are through the soil surface. For sugarbeets, treatment may be necessary if 25% of seedlings show damage or if damage is contributing to stand loss.

Leafhopper
Empoasca spp.

Identification: Adults are small, pale green, about 3 mm (⅛ in.) long and wedge-shaped, with a broad head and thorax. The body tapers along the wings. Leafhoppers are very active and quick to fly. Nymphs are similar to adults but lack fully developed wings. When disturbed, nymphs run sideways like crabs over the edge of the leaflet to the underside. Do not confuse leafhopper nymphs with aphids. Leafhopper nymphs move fast and walk sideways. Aphids walk very slowly.

Damage: Adults and nymphs feed by sucking sap from the leaves and stems. Initially, the feeding damage causes yellowing and browning of the tips and margins of the leaves. Later, the leaf margins pucker and roll inward, resulting in the typical hopperburn damage. Hopperburn is usually noticeable 4–5 days after leafhopper feeding. To avoid yield losses, leafhoppers must be controlled before hopperburn is visible.

Leafhoppers are often present in a variety of vegetable crops, including sugarbeets. Consider treatment only if populations build to high levels and leaf curling becomes evident.

Biology: The potato leafhopper does not overwinter in Ontario. It is carried by upper-level winds from the U.S. and can arrive in Ontario as early as May. Females lay eggs on alfalfa. The nymphs hatch in about 10 days. There are 5 nymphal instars, which reach maturity in 10–25 days. Depending on weather conditions, 2–4 generations can develop during the season.

Management Notes: Leafhopper populations can increase rapidly in warm weather. Thus, field scouting is the first line of defence against this insect.

Leafminers
Pegomya betae, *P. hyoscyami*

Identification: The primary species of leafminers that attack beets include the beet leafminer (*Pegomya betae*) and the spinach leafminer (*Pegomya hyoscyami*). Other species from the genera include *Liriomyza* and *Psilopa*. Generally, leafminers are small (7-mm (¼-in.)), greyish-green to greyish-brown flies that lay their eggs in leaves. The larvae of leafminers are small, translucent, whitish to pale green maggots (Figure 7–181).

Damage: Female leafminers lay their white, cigar-shaped eggs in clusters of 2–10 on the underside of leaves. Females pierce the leaves to feed on plant sap. Larvae feed between the upper and lower surface of the leaves. Depending on the species, mines can be straight (pea leafminer) or serpentine (other leafminers). Leafminer feeding reduces the plant's photosynthetic capacity. The mines also provide an entrance for disease organisms.

For sugarbeets, leafminer damage occurs in Ontario but has not been known to cause economic losses. The leafminer adults that emerge in early spring are more damaging than later generations, as the beets are at a smaller, more susceptible stage of growth.

Figure 7–181. Mines created by serpentine leafminers in beet leaves.

Biology: Optimal temperatures for leafminer development range from 21°C–32°C (70°F –90°F). Egg-laying is reduced at temperatures below 10°C (50°F). Leafminers can be a problem throughout the season.

Scouting and Thresholds: In sugarbeets, if 50% of plants have eggs or larvae, treatment may be required.

Scout for mines and larvae or for eggs on the underside of leaves. Yellow sticky traps placed in the crop can be used to monitor adult flies.

Management Notes: Lamb's-quarters is an alternate host for leafminers. Good weed control can reduce infestations. Crop rotation is an effective pest management tool. Alternating leafminer-susceptible crops with leafminer-resistant crops reduces the population.

Springtails

Collembola spp., *Bourletiella hortensis*

Springtail damage to sugarbeets has been seen in Ontario. They are generally considered beneficial insects but may feed on crops. Damage to seedlings can be significant under the right conditions.

Identification: At first glance, globular springtails may be confused with flea beetles. They are dark in colour and range in length from 0.8–3.0 mm (up to ⅛ in.). They can be found above ground and tend to jump when disturbed. Subterranean springtail species are whitish and elongated, ranging from 0.8–2.4 mm (up to ⅛ in.) long. They live in the soil and do not have the ability to jump like other springtails. Subterranean springtail species are rare in this region.

Damage: Springtails are generally not a concern except when extended cool, wet conditions occur during the seedling stage. Globular springtails feed on sugarbeet cotyledons, stems and roots. Subterranean springtails feed on roots. Damage may show up as small round holes in cotyledons or leaves, or as pitting or scraping of plant tissue below or above ground. Stands can be reduced when springtail populations are high and sugarbeet seedlings are small and growing slowly.

Biology: Springtails usually feed on organic material in the soil, helping to break down crop residue and improve soil structure. In extended moist conditions, populations can become very high and seedling damage may become noticeable.

Scouting and Thresholds: The crop is only vulnerable in the seedling stage. There is no established threshold or treatment, but where damage is seen, populations are probably in the thousands per square foot.

Management Notes: Sugarbeets generally outgrow the damage, and yield impacts have not been measured. Springtails are unlikely to cause significant damage in cases where a soil- or seed-applied insecticide has been used to target other seed or seedling insect pests.

Two-Spotted Spider Mite

Tetranychus urticae

Identification: The adult mite is approximately 0.5–1 mm (<1⁄16 in.) in length, barely visible to the naked eye. It is a translucent yellowish colour with two dark spots on the sides of its abdomen.

Damage: Spider mites feed through sucking mouth parts. Injury first appears as a bronzed, stippled effect. Severe feeding causes curling and drying of the leaves. Symptoms are often confused with drought stress.

Biology: Spider mites overwinter as female adults in crop residue or sheltered areas. In early spring, they lay eggs on grassy weeds, in fence rows and in wheat fields. Spider mites often move into sugarbeet crops as the wheat fields and other grasses begin to dry down. Under hot, dry conditions, spider mites may complete a generation in as little as 6 days, resulting in numerous generations each year.

Scouting and Thresholds: No thresholds have been established. Look for "bronzed" leaves and for signs of webbing, eggs or mites on the lower leaf surface. If spider mites are present, re-visit the field over a 3–5-day period to determine if the mite population is increasing.

Management Notes: Heavy rain often reduces mite populations to tolerable levels. Sugarbeets are most susceptible to mite damage in the period leading up to harvest as the crop is sizing.

White Grubs

See Chapter 5.

Wireworm
Limonius spp.

See Chapter 5.

Disorders

Lightning Injury

A circular patch of affected plants (generally 3–20 m (10–66 ft) in diameter) suddenly appears in the field. Plants toward the outer edge may show less damage.

Leaves will begin to droop, followed by wilting and, in severe cases, death of the plant.

Wind Damage — also known as Sandblasting, Wind Whipping, Dessication

Wind damage occurs in several different forms, including sandblasting, wind whipping and dessication.

Sandblasting (sand abrasion) occurs when light, sandy or exposed soils are eroded by high winds. Stems and leaves on the windward side of the plant develop light, tan-coloured, roughened areas. If severe, sandblasting can stunt or kill plants and significantly reduce yield.

Wind whipping occurs on any type of soil. The whipping and twisting of young plants by strong winds can severely damage or kill the plants. Sugarbeet seedlings are very suceptible to wind whipping.

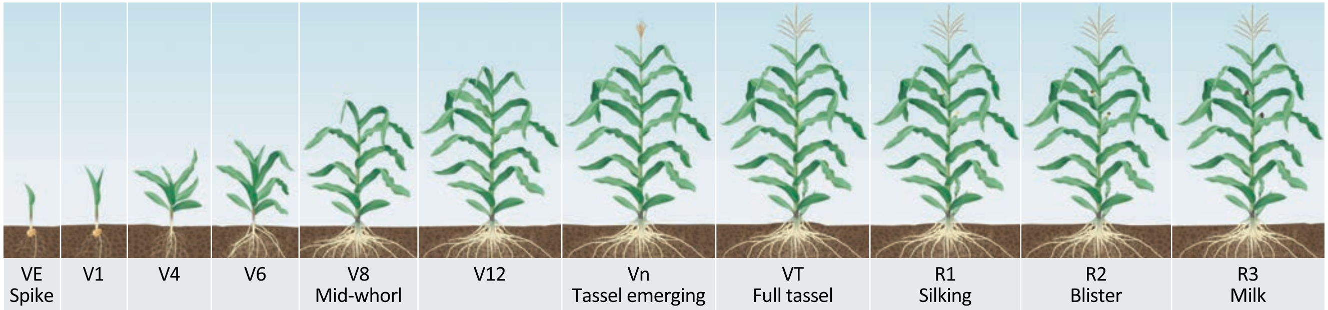
Dessication is most common on tender, young seedlings during strong wind conditions and extreme temperatures.

All types of wind damage can predispose plants to foliar diseases. Wind-strips, cover crops and windbreaks will minimize problems due to wind and sand movement. See *Soil Health*, Chapter 2, for more information.

Vertebrate Pests

Pests such as birds, deer, raccoons, etc., are common in horticulture crops. For more information, see *Vertebrate Pests*, *Sweetpotatoes*.

Sweet Corn



Planting to harvest: 69-80 days

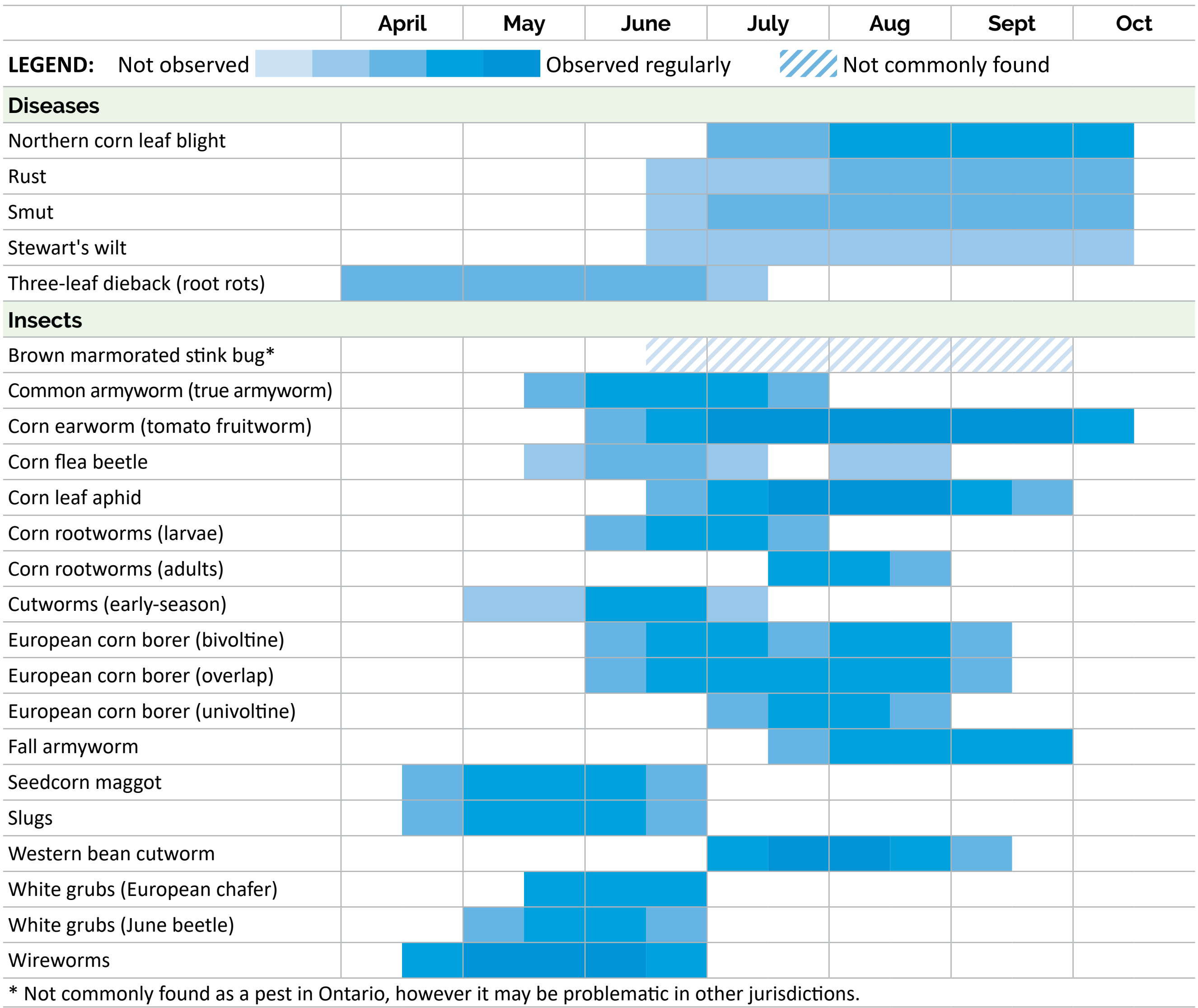


Figure 7–182. Sweet corn stages of development and pest activity calendar. The actual period of activity for any given pest will vary significantly from year to year, depending on environmental factors.

Production Requirements

Soil types:	Early-season production is suited to sandy-loam soils. Later plantings benefit from the higher moisture-holding capacity of silt-loam and clay-loam soils.
Soil pH:	5.6–6.0
Recommended rotational crops:	beans, peas, cucurbits, tomatoes, peppers, brassicas
Do not rotate with:	corn (sweet, seed or field)
Minimum soil temperature:	normal (su): 13°C (55°F) sugar-enhanced (se): 16°C (61°F) supersweet (sh2): 18°C (64°F)
Minimum/maximum air temperature:	10°C/32°C (50°F/90°F)
Earliest planting date:	early April (plasticulture)

Corn Development

Corn is a deep-rooted grass. It thrives in warm growing conditions and can tolerate a wide variety of soil textures. Although it is less vigorous than field corn, in a vegetable crop rotation, it can provide a dense root structure to help loosen compacted soils. With a larger selection of herbicides, it also offers an opportunity to clean up certain problem weeds.

The critical period of weed control extends from emergence to the 8-leaf stage. Correct leaf-staging is important for many post-emergence herbicides (Figure 7–182).

Several recessive genes confer the sweetness in sweet corn. Depending on the gene, it either increases the sugar content and/or delays the conversion of sugar into starch. Due to the higher sugar content of sweet corn, the seeds are not as vigorous as field corn. They are more prone to germination problems due to cold, wet soils, fungal diseases or seed predation by soil insects.

Sweet corn breeding programs select for three main genes:

Sugary (su) cultivars have a higher sugar content than field corn. They have good cool soil germination, but the sugar content of the kernels quickly convert to starch once harvested. They can be stored for 1–3 days, under good storage conditions.

Sugary enhanced (se) have elevated levels of sugar. While not as hardy as the su cultivars, they have some tolerance of cool soil conditions at planting. The sugars still convert to starch quickly, but due to the higher sugar content, they can retain eating quality for 3–5 days under good storage conditions.

Supersweet (sh2) cultivars have the highest sugar content combined with a delayed conversion to starch after harvest, providing 5–10 days of storage under ideal conditions. Improved Supersweet cultivars have been selected for a thinner pericarp, resulting in more tender kernels.

Synergistic cultivars offer a combination of su and sh2, which helps to improve early-season vigour, while maintaining longer storage and eating quality.

Isolation

Corn kernels develop when the fresh silks receive pollen from neighbouring tassels. Cross-pollination between different types of corn can affect the sweetness and texture, or colour of the resulting kernels. Isolating the different types will prevent the development of undesired characteristics. See Table 7–133. Separate incompatible cultivars by at least 100 m (330 ft), or schedule the plantings so that pollen-shed is at least 2–3 weeks apart.

Table 7–133. Sweet Corn Compatibility

	Pollen Source		
Sweet Corn Type	Supersweet (sh2)	Sugary Enhanced (se)	Sugary (su)
Supersweet (sh2)	yes	no	no
Sugary enhanced (se)	yes	yes	no
Sugary (su)	yes	yes	yes

Yellow is the dominant colour gene. Isolation of white cultivars is necessary to avoid colour contamination. Bicolour cobs pollinated with pollen for yellow cultivars have a lower proportion of white kernels. Isolate specialty (coloured) corn from all types of sweet corn. Cross-pollination between these two types causes black kernels to appear in the sweet corn cobs.

Seeding and Spacing

See Table 7–134. Always plant into moisture. For early-season and fresh market cultivars, target 40,000–45,000 plants/ha (16,000–18,000 plants/acre). For main season and processing cultivars, aim for 45,000–55,000 plants/ha (18,000–22,000 plants/acre).

Table 7–134. Sweet Corn Crop Spacing

Crop	Row Spacing	In-Row Spacing	Depth	Seeding Rate
Sweet corn	75–90 cm (30–36 in.)	20–25 cm (8–10 in.)	4–7.5 cm (1½–3 in.)	11–17 kg/ha (10–15 lb/acre)

Fertility

Macronutrients

Nitrogen

On all soils, 90 kg N/ha (80 lb N/acre) is recommended. Nitrogen response in sweet corn is often determined by the planting date and soil organic matter levels. Earlier-planted fields with low organic matter levels (below 3% organic matter) are more likely to respond to higher rates of nitrogen. Later-planted fields can access natural soil nitrogen as the soils warm up and begin to release mineralized N. These fields often have very limited response to nitrogen levels above the provincial recommendation of 90 kg N/ha (80 lb N/acre), especially if the soil organic matter level is above 3%.

Side-dress applications are an effective method of delivering nitrogen to sweet corn. The pre-side dress nitrogen test (PSNT) can be a valuable tool to help determine the most economical rate of nitrogen to apply. Studies done in Ontario from 2003–2010 suggest that soil testing above 30 ppm soil nitrate ($N0_3$) are unlikely to require additional nitrogen applications.

Early plantings benefit from the use of a starter fertilizer. Apply the starter-fertilizer in a band 5 cm (2 in.) to the side and 5 cm (2 in.) below the seed. To avoid fertilizer injury, do not exceed the maximum banded application rates listed in Table 7–135.

Table 7–135. Maximum Banded Application Rates for Sweet Corn

Fertilizer	Maximum Banded Application Rates[1]
Nitrogen	75 kg/ha (67 lb/acre)
Nitrogen + potash	75 kg/ha + 45 kg/ha (67 lb/acre + 40 lb/acre)
Urea	40 kg/ha (36 lb/acre)
Urea + potash	40 kg/ha + 40 kg/ha (36 lb/acre + 36 lb/acre)

[1] Based on 75-cm (30 in.) rows.

Alternately, pop-up fertilizer may be applied in the furrow directly with the seed:

- Do not use more than 9 kg nitrogen-plus-potash/ha (8 lb/acre).
- Do not place urea with the seed.

Avoid "pop-up" starter fertilizers that use urea as the nitrogen source. If the N component is more than half as much as the P component, the starter may contain urea.

Side-dress the remainder of the nitrogen before the corn is 30 cm (12 in.) high.

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. See Table 1–12, and Table 1–13, for more information.

Phosphorus and Potassium

Test the soil to determine phosphorus and potassium requirements. See Table 7–136 and Table 7–137.

Magnesium

Additional magnesium will be required at soil test levels below 20 ppm Mg. The older leaves of deficient crops become yellowed between the green leaf veins. Sandy soils or areas of low pH are more prone to magnesium deficiency. High rates of potassium may also induce deficiency in rotational crops. See *Macronutrients* and Table 1–7, Chapter 1, for more information.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. See *Micronutrients*, Chapter 1, for more information.

Manganese

Manganese deficiency first appears on younger leaves. The tissue turns yellow, while the veins remain dark green. It often occurs on sandy, high pH soils or on eroded knolls. See Table 1–10, Chapter 1, for more information.

Zinc

Zinc deficiencies occasionally occur on coarse, sandy-loam soils with low organic matter and high soil pH. Plants develop pale yellow bands between the leaf veins, particularly near the leaf axils of the new growth. Soil tests are useful for identifying potential deficiencies. Apply zinc mixed in the fertilizer or as a banded application. See Table 1–11, Chapter 1, for more information.

Plant Tissue Analysis

When used in conjunction with soil analysis, plant tissue analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. Plant tissue analysis does not replace soil testing or a sound soil fertility program. For more information, see Table 7–138 and *Plant Tissue Analysis*, Chapter 1.

Table 7–136. Sweet Corn Phosphorus Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Sodium Bicarbonate Phosphorus Soil Test (ppm)													
	0–3	4–5	6–7	8–9	10–12	13–15	16–20	21–25	26–30	31–40	41–50	51–60	61–80	81+
Mineral Soils														
Phosphate (P_2O_5) required kg/ha (lb/acre)	110 (98) (HR)	100 (89) (HR)	90 (80) (HR)	70 (63) (HR)	50 (45) (HR)	20 (18) (MR)	20 (18) (MR)	20 (18) (LR)	20 (18) (LR)	0 (RR)	0 (RR)	0 (RR)	0 (NR)	0 (NR)

Table 7–137. Sweet Corn Potassium Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Ammonium Acetate Potassium Soil Test (ppm)											
	0–15	16–30	31–45	46–60	61–80	81–100	101–120	121–150	151–180	181–210	211–250	251+
Mineral Soils												
Potash (K_2O) required kg/ha (lb/acre)	170 (152) (HR)	160 (143) (HR)	140 (125) (HR)	110 (98) (HR)	80 (71) (HR)	50 (45) (MR)	30 (27) (MR)	0 (LR)	0 (RR)	0 (RR)	0 (RR)	0 (NR)

Table 7–138. Sweet Corn Nutrient Ranges

Time of Sampling	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu	Mo
	Per Cent (%)						Parts Per Million (ppm)					
Whole seedlings												
3-leaf stage	3–4	0.4–0.5	2.5–4	0.6–0.8	0.25–0.5	0.4–0.6	50–100	40–100	30–40	10–30	5–10	0.1–0.2
6-leaf stage	3–4	0.3–0.5	2.5–4	0.5–0.8	0.25–0.5	0.4–0.6						
Most recently mature leaf												
76 cm (30 in.) tall	2.5–4	0.2–0.4	2.5–4	0.5–0.8	0.20–0.4	0.2–0.4	40–100	40–100	25–40	10–30	4–10	0.1–0.2
Just prior to tassel	2.5–4	0.2–0.4	2–3.5	0.3–0.6	0.15–0.4	0.2–0.4	30–100	30–100	20–40	10–20	4–10	0.1–0.2
Tasselling	1.5–2.5	0.2–0.4	1.2–2	0.3–0.6	0.15–0.4	0.2–0.4	30–100	20–100	20–40	10–20	4–10	0.1–0.2

Adapted from G Hochmuth, et al. 2018. *Plant Tissue Analysis and Interpretation for Vegetable Crops in Florida*. University of Florida IFAS Extension. HS964.

Harvest and Storage

Sweet corn is harvested while the kernels are at the early milk stage. This occurs approximately 3 weeks after first silk. Quality declines quickly if cobs are left in the field past this stage. For average yields, see Table 7–139.

Table 7–139. Average Yields of Sweet Corn

Type	Average Yield
Fresh market	2,400–3,600 dozen ears/ha (1,000–1,500 dozen ears/acre)
Processing	17 tonnes/ha (7.6 tons/acre)

Processing sweet corn is processed as soon after harvest as possible.

For the fresh market, remove the field heat from harvested cobs as soon as possible. With all cultivars, the sugar content quickly converts to starch unless they are promptly cooled or processed. Where possible, harvest in the early morning before temperatures begin to rise. By harvesting at a lower temperature, there will be less "field heat" to remove from the product, improving overall quality. Suitable cooling methods include hydrocooling, forced air and vacuum cooling.

Store at temperatures close to 0°C (32°F) with a relative humidity of 95%–98%. Under good storage conditions, supersweet cultivars may last for up to 1 week. Normal (su) and sugar-enhanced (se) cultivars lose quality after 2–3 days.

Pest Management and Disorders

See Figure 7–182, *Sweet corn stages of development and pest activity calendar*.

Diseases

Northern Corn Leaf Blight

Setosphaeria turcica

Identification: Long, elliptical greyish-green or tan streaks (approximately 2–15 cm (¾–6 in.) in length) develop on the lower leaves. As the disease progresses, the lesions spread to the upper leaves, forming large blighted or "burned" areas. It often first appears at the time of silking or later (Figure 7–183).

Northern corn leaf blight is more common on field corn cultivars. Due to the shorter growing season, sweet corn fields are less likely to suffer serious losses due to this disease.

Figure 7–183. Northern corn leaf blight lesion.

Biology: Northern corn leaf blight survives in corn residue as either spores or fungal strands (mycelium). Wind or splashing rain spreads the spores from the ground onto the developing corn plant.

Infected plants act as a secondary source of infection, producing spores that may spread to other fields. Disease development is favoured by moderate temperatures of 18°C–27°C (61°F–81°F) with prolonged periods of humid or rainy weather.

Scouting and Thresholds: None have been established. Fungicides are most effective when applied at the first signs of the disease.

Management Notes: Tillage helps to reduce the levels of inoculum in surface residues. In reduced tillage systems, follow a good crop rotation and select resistant cultivars. Losses due to northern leaf blight are most severe when the leaves above the ear are infected at, or slightly after, pollination.

Rust
Puccinia sorghi

Identification: Reddish-brown (rusty) pustules develop on the upper leaf surface. The size of each lesion ranges from 1–3 mm (<⅛ in.). Older pustules turn blackish-brown (Figure 7–184).

Figure 7–184. Rust pustules on the upper surface of a corn leaf.

Biology: Rust infection requires cool weather — 16°C–23°C (61°F–73°F) — and 3–6 hours of leaf wetness. Heavy overnight dews favour development. The rust fungi do not overwinter in Ontario. Epidemics arise from spores blown in from the southern U.S. and Mexico.

Corn infected prior to tassel is at highest risk of yield loss. Sweet corn yield is reduced by 6% for each 10% of the leaf area infected at harvest. Corn infected after pollen shed will not usually suffer yield loss.

Scouting and Thresholds: Inspect all cultivars of sweet corn, including resistant ones, for signs of rust from the mid-whorl stage onwards. Look for symptoms on the lower leaves and in the whorl. Prior to silking, plants with more than 6 pustules per leaf will benefit from a fungicide application.

Management Notes: Many sweet corn cultivars are resistant to common rust. These cultivars provide good protection against rust infections; however, even resistant cultivars may become infected under heavy rust pressure or changing rust pathotypes.

Smut
Ustilago maydis

Identification: Smut-infected plants develop greyish galls up to 10 cm (4 in.) in diameter on the stalks, ears or tassels. Smaller galls often appear on the leaves. The galls initially have a white membrane cover that eventually breaks and releases dark-brown or black powdery spores.

Biology: Smut spores survive in soil and crop residues for many years. Disease development is favoured by rain showers, high humidity and warm temperatures. Spores are spread by wind and rain through splashing. All above-ground plant tissue is susceptible, but infection occurs most often in areas of actively growing tissue.

Common smut incidence increases in fields where the plants have been wounded by hail, frost, drought, mechanical injury, detasselling, herbicide injury, insects, poor pollination or sandblasting. High levels of nitrogen and manure promote this disease.

Management Notes: Most corn hybrids have enough resistance to smut to prevent serious outbreaks, however, low levels of smut are present in most fields. Reduce the risk of infection by minimizing mechanical and herbicide injury and maintaining a balanced fertility program.

Stewart's Wilt
Erwinia stewartii

Identification: Plants infected before the 5-leaf stage become stunted, wilt and die. Later infections cause pale green or yellow stripes, running parallel to the leaf veins. Late damage is easily confused with magnesium deficiency. Wilt-infected plants exhibit brown, mushy tissue inside the stem.

Biology: Stewart's wilt is transmitted by the corn flea beetle. Yield losses are most significant when susceptible cultivars are infected before the 7-leaf stage. On susceptible cultivars, losses at this stage may range from 40%–100%.

Management Notes: Mild winters favour flea beetle survival and increase the risk of problems the following season. There is no control for this disease. Many cultivars have excellent resistance to Stewart's wilt. Corn flea beetle control may help prevent the spread of this disease. See *Corn Flea Beetle (Flea Beetles)*, also in *Sweet Corn*, for more information.

Three-Leaf Dieback (Root Rots)
Penicillium, *Pythium*, *Rhizoctonia*, *Fusarium*

See *Damping-Off*, Chapter 6.

Insects

Brown Marmorated Stink Bug
Halyomorpha halys

See Chapter 5.

Common Armyworm (True Armyworm)
Mythimna unipuncta

Identification: Larval stages are dull-green to brown with white-bordered stripes running laterally along the body. There is a dark, diagonal band at the top of each proleg. They are as large as 5 cm (2 in.) in length at maturity.

Damage: Armyworms attack young corn plants, often eating everything but the stalk and the leaf mid-vein. Damaged leaves are very ragged and beat up. Plants outgrow moderate leaf-feeding as long as the growing point is not damaged. Damage often first occurs when neighbouring cereal crops begin to dry down and the larvae look for a new food source. They are often attracted to fields with large amounts of residue or grassy weeds.

Biology: Armyworm do not overwinter in Ontario. The moths travel on early spring weather fronts and lay their eggs in cereal crops or grassy vegetation. Larvae hatch from the eggs and feed at night or on overcast days for approximately 1 month. New adults are also blown in from the south on weather patterns, potentially increasing the populations.

Scouting and Thresholds: Scout carefully along the edges of fields bordering cereal crops. If possible, scout in the early morning or late evening. During the day, larvae often hide in the leaf whorl, in crop debris or under soil clods. Look for feeding damage, frass and larvae on the young seedlings throughout June and early July.

In seedling corn, an insecticide may be warranted if more than 10% of the plants show feeding damage. Once the plants reach the mid-whorl stage, they are more tolerant of feeding injury and the threshold increases to 50% of the plants with damage. Larvae that have reached 3.5 cm (1¼ in.) in size are ready to pupate and have finished feeding on the crop.

Management Notes: Naturally occurring beneficial organisms and parasites often keep armyworm populations from building to damaging levels. Border sprays may provide sufficient control for infestations that are entering the field from neighbouring cereal crops. Maintain good grassy weed control both in and around the field.

Corn Earworm (CEW) (Tomato Fruitworm)
Helicoverpa zea

Identification: Larvae range in colour from yellowish, to green or brown. They have a fine double stripe running down the length of their backs. They grow up to 4 cm (1½ in.) long (slightly larger than the European corn borer). The larvae are usually found in the top third of the ear. Earworm are cannibalistic and there will often only be one surviving larva per ear (Figure 7–185).

Figure 7–185. Corn earworm larvae.

The adult is a buff or tan-coloured moth with a wingspan of 3.5–4 cm (1¼–1½ in.). The forewing may have several darker markings and always has a central brown dot, clearly visible on the underside of the wing and faintly visible from the top.

Earworm eggs are laid individually on corn silks. Each egg is perfectly round and about the same colour and diameter as a corn silk.

Damage: In sweet corn, the earworm normally feed only on the kernels, beginning by feeding at the tip of the ear and moving down the ear as they grow. Feeding is almost always confined to the top third of the ear. Frass (insect fecal matter) is found as large moist pellets in the silk channel and at the ear tip. The damage is often not apparent until the ear is husked.

Biology: Corn earworm do not overwinter in Ontario. They move from the U.S. and Mexico on trade winds. In Southwestern Ontario, adult moths usually appear in mid-to-late July, or earlier, depending on the season. In eastern and northern areas, arrival occurs in mid-to-late August. In cooler years, these areas may not experience corn earworm at all.

Earworm activity is highest in hot weather conditions. Peak flights often occur immediately after severe thunderstorms.

Scouting and Thresholds: Use pheromone traps to monitor corn earworm populations. Make insecticide applications according to the number of moths caught per week and the daytime temperatures. Trapping thresholds will vary based on the type of trap used. See Table 7–140 and Table 7–141.

Table 7–140. Corn Earworm Insecticide Spray Intervals (Heliothis Traps)

Average Number of CEW Moths per Trap		Spray Interval (Adjusted for Maximum Daily Air Temperature)	
Moths per Day	Moths per Week	Less than 27°C (80°F)	Greater than 27°C (80°F)
<0.2	<1.4	0	0
0.2–0.5	1.4–3.5	6 days	6 days
0.5–1	3.5–7	5 days	4 days
1–13	7–91	4 days	3 days
>13	>91	3 days	2 days

Table 7–141. Corn Earworm Insecticide Spray Intervals (Hartstack Traps)

For the Hartstack style of trap, also consider the stage of neighbouring field corn fields. If the field corn is silking, greater than 10 moths per night in the traps will trigger a spray threshold. If field corn is not silking, use a threshold of >1 moth per night and the following spray intervals.

Moths per Night	Moths per Week	Spray Interval
< 5	<35	5 days
50–100	350–700	2–3 days

Management Notes: Sweet corn is susceptible to corn earworm damage while the silks are green. Good spray coverage of the rapidly growing silks is important. Pyrethroid resistance has been identified in earworm populations arriving from cotton-growing regions of the southern U.S.

Transgenic cultivars (Bt sweet corn) have complete resistance to corn borers and partial resistance to earworms and fall armyworms. Insecticides may be needed for other pests if pressure is high. Check with your seed company representative for availability and planting restrictions.

Corn Flea Beetle (Flea Beetles)
Chaetocnema pulicaria

Identification: Corn flea beetles are small (2 mm (⅛ in.)), shiny black beetles that move very quickly when disturbed.

Damage: Adult beetles feed on corn plants, causing small circular holes or elongated scratch marks on the leaves. Feeding injury rarely causes economic losses; however, corn flea beetles are the primary vector of the bacterial disease, Stewart's wilt. Only certain cultivars are susceptible to this disease. See *Stewart's Wilt*, also in *Sweet Corn*. Beetle feeding is not a direct cause of yield loss.

Biology: Beetles overwinter in the top 5 cm (2 in.) of the soil/residue. They emerge when soil temperatures reach 18°C (64°F). The first peak of activity is usually in late June. Mild winters favour beetle survival and increases the risk of Stewart's wilt transmission.

Scouting and Thresholds: Susceptible cultivars may require foliar control if more than 10% of the plants have severe feeding injury or there are more than 2 beetles per plant.

Management Notes: Insecticide seed treatments and varietal tolerance provide the best flea beetle control. Susceptibility to Stewart's wilt varies greatly between cultivars. Many early hybrids are particularly vulnerable. The highly mobile nature of the beetle makes them very difficult to control with foliar insecticides.

Corn Leaf Aphids
Rhopalosiphum maidis

Identification: The corn leaf aphid is the most common aphid found in corn. It is blue-green in colour and less than 2 mm (~$\frac{1}{16}$ in.) in length. It has a pear-shaped body with two cornicles at the tip of the abdomen.

Damage: Corn leaf aphids have piercing, sucking mouthparts. They feed on the tassels, cobs and upper leaves of corn plants. Aphids rarely cause actual yield losses in sweet corn, however their presence on the husk often results in an unmarketable ear. Extremely high populations during pollen shed and silking may result in reduced pollination or poor kernel fill, especially if the silks and tassels become covered with honeydew and sooty mould as a result of the feeding.

Figure 7–186. Asparagus aphids, casings and predatory lady bird beetle larvae on a sweet corn cob.

Biology: Corn leaf aphids do not overwinter in Canada. They migrate northwards on wind currents throughout the summer. Populations tend to increase over the course of the growing season and are often highest during hot, dry periods. Female aphids are able to reproduce without mating, giving live birth to wingless nymphs. There are several generations per year. There is a large difference in the attractiveness of different sweet corn cultivars to corn leaf aphids. In general, Sh2 cultivars (supersweet) are likely to experience more damage than Su (normal) or Se (sugar enhanced) cultivars.

Scouting and Thresholds: Examine 10 sets of 10 plants per field. Look for developing colonies on the ears and tassels. Note whether population levels are increasing from week to week. Use a threshold of 10% of ears infested (ears with more than 20 aphids are considered infested).

Management Notes: Aphids are attacked by several types of predators and parasites and these can have a significant impact on aphid populations (Figure 7–186). Predators include ladybird beetle adults and larvae, lacewing adults and nymphs, syrphid fly larvae and cecidomyiid fly larvae. Several fungal pathogens will also help keep populations under control.

The continuous use of broad-spectrum insecticides may disrupt beneficial insect populations, resulting in aphid resurgence. In the early stages (pre-tassel) of corn development, aphid control is not usually necessary. On fresh market cultivars, control is warranted if high numbers of aphids are present on the tassels or silks prior to pollination or if populations on the ears begin to increase.

Corn Rootworm
Diabrotica virgifera (western),
Diabrotica barberi (northern)

Identification: Corn rootworm larvae are cylindrical worms with a white body, brown head and 6 small legs behind the head. They are 3 mm–1.5 cm (⅛–½ in.) long when fully grown.

Adults have hard shells and are approximately 6 mm (¼ in.) long. The western corn rootworm is yellow with black stripes on the wing pad. The northern corn rootworm is pale green-yellow. The less common southern corn rootworm (also known as the spotted cucumber beetle) is yellow with black spots.

Damage: Both the adults and the larvae attack sweet corn. Larvae feed on root hairs and tunnel into the roots, resulting in a compromised root system. This affects water and nutrient uptake as well as structural support. Indications of infested fields include poor root formation, plants with curved stalks (goose necking) or a high proportion of lodged plants. Corn rootworm damage affects both yield and harvestability.

Later in the season, adult rootworm feed on fresh corn silks. If the silks are clipped prior to seed set, the subsequent lack of pollination may result in a barren cob. Severe feeding may result in poor kernel set.

Biology: The corn rootworm over-winters in the soil as an egg. Adults lay their eggs in the fall in corn fields. In the spring, the eggs hatch and development begins once the soil temperatures reach 10°C (50°F). The larvae feed on corn roots for 3–4 weeks. Corn rootworm complete only one generation per year. After emerging, adults will look for corn fields on which to feed and lay the overwintering eggs.

Scouting and Thresholds: None established.

Management Notes: Late-planted sweet corn fields are less likely to sustain injury from rootworm larvae. Crop rotation will almost always control corn rootworm populations; however, a new variant of the corn rootworm is present in Ontario. This variant lays its eggs in soybean crops. Additional control may be necessary if this variant is present in fields rotated solely with soybeans. Populations are usually kept under control by corn borer and earworm sprays.

Cutworms (Early-Season)
Agrotis ipsilon (black cutworm),
Euxoa messoria (dark-sided cutworm),
Crymodes devastator (glassy cutworm),
Euxoa detersa (sandhill cutworm)

See Chapter 5.

European Corn Borer
Ostrinia nubilalis

In the past, European corn borer was the major insect pest of sweet corn. However, due to the widespread adoption of transgenic (Bt) field corn, ECB populations have declined across the landscape and they are no longer as prevalent as they once were. However, changing population dynamics along with the threat of Bt resistance within the ECB population means that it is still important to scout, identify and manage this pest when necessary (Figure 7–187). See Chapter 5, for more information.

Figure 7–187. European corn borer feeding and frass. Note the black head capsule.

SWEET CORN

Fall Armyworm

Spodoptera frugiperda

Identification: Fall armyworm larvae are pale green to tan (sometimes darker) with a solid dorsal stripe. The head is dark brown with a distinct white inverted "Y" marking. Adults have mottled grey forewings and grey/white hindwings. The eggs are laid in masses of 150 and are covered in hair.

Damage: Larvae create large, rough holes in the leaves and the cob.

Biology: Fall armyworm are migratory pests. They usually arrive in Ontario slightly later than the corn earworm. The moths are nocturnal, and egg-laying occurs at night. After hatching, the larvae feed on corn for approximately 20 days. In Ontario, fall armyworm complete only one generation per year.

Scouting and Thresholds: Consider using pheromone traps to monitor for incoming summer populations. The yellow, white and green bucket trap is typically the most effective at catching this pest. The spray threshold is 5% feeding injury.

Management Notes: Sprays used for corn borer and corn earworm usually control the armyworm as well.

Seedcorn Maggot

Delia platura

See *Seedcorn Maggot*, *Peas.*

Slugs

Arion, *Deroceras*, *Helix* and *Limax* species

See Chapter 5.

Western Bean Cutworm

Striacosta albicosta

Identification: Adult moths have a white band running along the edge or margin of the wing, a spot or "moon" and boomerang-like mark. The larvae are tan-to-pink in colour with two distinct brown stripes on the pronotum (shield-like structure just behind the head). The eggs are laid in clusters on the upper surface of the top 3–4 corn leaves. The round eggs are initially white, turning purple as they near hatching (Figure 7–188).

Figure 7–188. Western bean cutworm eggs.

Damage: In corn, young larvae feed on the tassels and silks until they are large enough to tunnel into the ear and feed extensively on the kernels

Biology: Western bean cutworm overwinter as mature larvae. They pupate in late May and the adults emerge in July. Adult populations typically peak in late July to early August. Eggs hatch in 5–7 days. During egg laying, the adults are most attracted to pre-tassel corn. After corn has tasseled, adults may move to sweet corn crops to complete their generation. While they can be found in sweet corn, populations are generally lower than in field corn crops.

Scouting and Thresholds: Monitor for western bean cutworm populations using green bucket pheromone traps. Begin scouting corn fields as soon as the first adult moths are caught in an area.

Management Notes: Western bean cutworm larvae will typically be controlled by corn earworm sprays. While there are no specific thresholds, a spray may be required if there is substantial egg laying in the field prior to tasselling.

White Grubs

Rhizotrogus majalis (European chafer),
Phyllophaga anxia (June beetle),
Popillia japonica (Japanese beetle)

See Chapter 5.

Wireworm

Limonius spp.

See Chapter 5.

Disorders

Blank Cobs

Poor pollination can also cause missing kernels or uneven kernel development. Pollination problems can be caused by environmental conditions (overly wet, dry, hot or windy) during pollen shed and silking. Insects feeding on silks may also cause blank cobs.

Curved Ears

Incomplete pollination on one side of the ear can cause it to curve inwards. It is also called banana ear or zipper ear. While this is also believed to be a pollination issue, the causes are not well understood.

Poor Tip Fill

Kernels at the tip of the ear are either absent or fail to fill. A total absence of kernels at the tip indicates poor conditions during silking, especially at the end of the silking period, as the cob pollinates from the base to the tip. Causes include drought stress, insect feeding on the silks or poor pollen viability. Unfilled kernels indicate dry soil conditions during the cob development phase.

Birds

Red-Winged Blackbirds and Crows

Agelaius phoeniceus, *Corvus brachyrhynchos*

Birds feed on the tips of the ears, rendering them unmarketable. Cultivars with ears well-covered by husks are somewhat resistant to bird damage. Birds are often attracted to cobs that have already been damaged by insect pests such as the corn earworm. In high numbers, birds can cause significant yield and marketability losses in both crops. Bird pressure is often higher near marshy and wooded areas.

Generally, a landowner in protection of property may capture, kill or harass wildlife protected under the *Fish and Wildlife Conservation Act*, including birds such as crows, cowbirds, starlings, grackles and blackbirds. However, growers require a permit to use a firearm to scare or shoot gulls, other migratory birds or songbirds. For a permit, call the Enforcement Coordinator, Canadian Wildlife Service, Environment Canada (905) 336-4464.

Noisemakers, such as propane cannons and digital distress calls, are often used to scare birds away from sweet corn crops. For full effectiveness, begin operating noisemakers such as propane cannons and digital distress calls at least 10 days before kernel fill and ripening. In some cases, utilizing the noisemakers during early spring may help deter the birds from nesting in the vicinity of sweet corn fields.

The randomness of the acoustic device is more important than the frequency or level of the noise. They should also be moved around frequently. Visual deterrents may be used in combination with acoustic devices, or alone, in situations where noisemakers cannot be used. “Scare-eye” balloons, flashing tape, mirrors and predator-shaped kites are available but are generally not as effective as noisemakers.

Sweetpotatoes

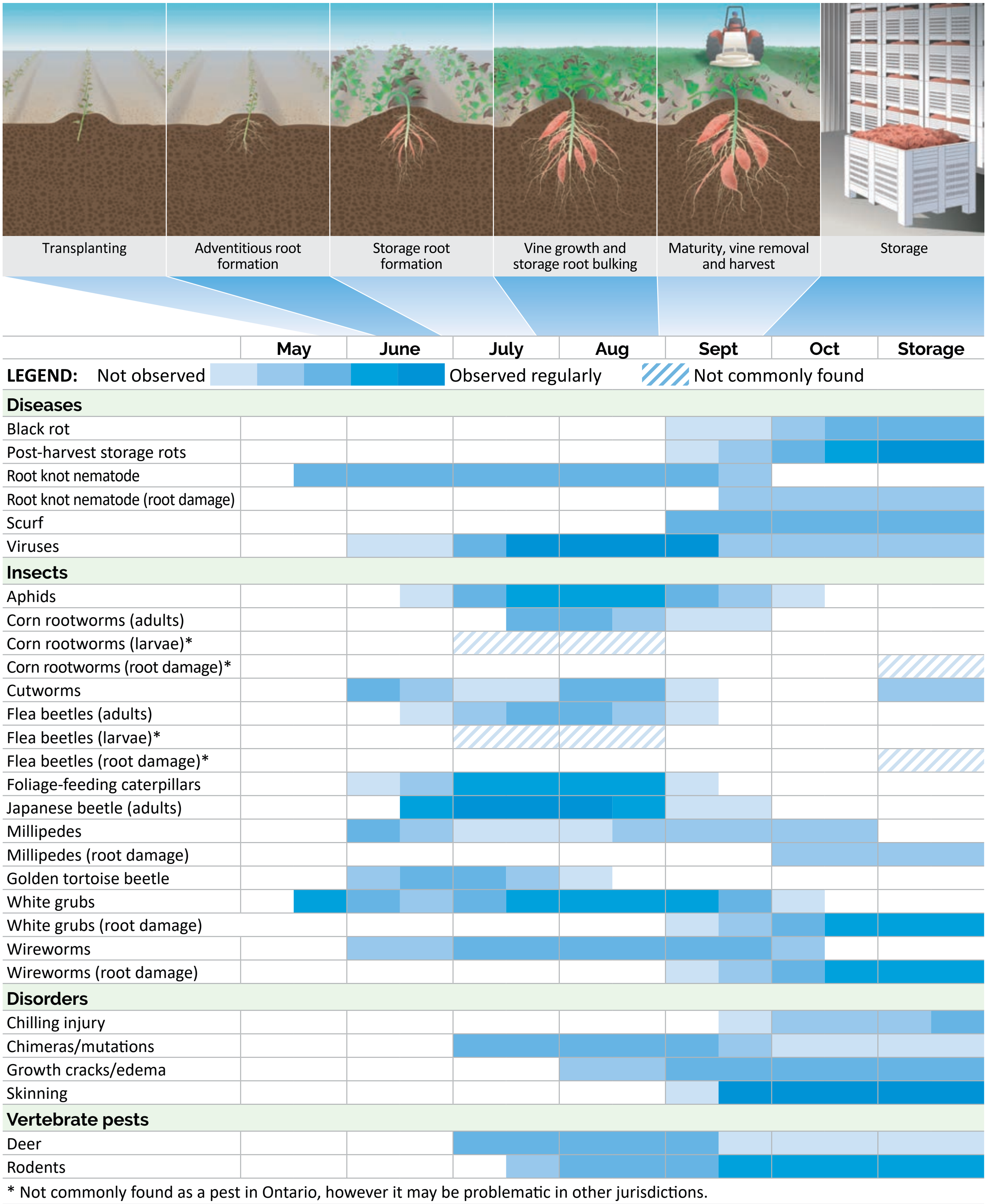


Figure 7–189. Sweetpotato stages of development and pest activity calendar. The actual period of activity for any given pest will vary significantly from year to year, depending on environmental factors.

Production Requirements

Soil types:	sandy to sandy-loam soils low in organic matter. Sweetpotatoes can grow in clay loam soils but in the spring they may not warm up quickly enough under Ontario growing conditions.
Soil pH:	5.0–7.5, optimal growth at 5.8–6.2
Do not rotate with:	crops that increase nematode or wireworm populations in the soil (e.g., other root vegetables, grasses, turf). Fields with a history of weed pressure (especially bindweed and other morning glory relatives). Rotate away from sweetpotatoes for 3–4 years.
Minimum soil temperature:	>18°C (64°F) at planting
Optimum air temperature:	25°C–28°C (77°F–82°F), cold sensitive below 10°C (50°F)
Earliest planting date:	late May to early June, after all danger of frost has passed

Sweetpotato Crop Growth

The sweetpotato is a tropical, perennial, vining plant native to South America that is grown as an annual in temperate climates. Sweetpotato plants cannot tolerate freezing temperatures, and most commercial production occurs in warm regions with very long, frost-free periods. In Ontario, large-scale commercial production is best suited to areas with ≥3,000 crop heat units and deep, fine sandy soils that warm rapidly in the spring. Most current production of sweetpotatoes in Ontario is concentrated along the northern shore of Lake Erie. The sweetpotato is part of the morning glory family (*Convulvulaceae*) and consequently is not related to white potatoes, with very different production practices and pests.

For the stages of sweetpotato development, see Figure 7–189. Sweetpotato plants are vegetatively propagated and commercial fields are started from slips (unrooted vine cuttings or sprouts) (Figure 7–190). Slips are produced in seedbeds (hotbeds) where mother, or seed, roots (small roots saved from the previous year's crop) are planted under a thin layer of soil and allowed to produce vines, which are cut by hand or mechanically 2.5 cm (1 in.) above the soil line approximately 8 weeks later. Slips may be cuttings of portions of the vine, or they may consist of the entire plant (sprouts). Because they must be started by early March, field seedbed production for slips grown in Ontario occurs only in the southern U.S. In Ontario, slips can only be produced in the greenhouse, however, this is less common than sourcing slips from the U.S.

Figure 7–190. Boxes of sweetpotato slips (A and B).

SWEETPOTATOES

Slips are typically planted into raised beds, or hills, which help warm the soil and improve drainage. In Ontario, newly planted sweetpotatoes often lose many of their leaves due to stresses associated with transplanting and/or transport from the southern U.S. (Figure 7–191). If slips are healthy and soil conditions are ideal, they will soon form new roots and leaves. Shortly after transplanting, white adventitious roots are formed from underground nodes on slips, as well as from the tissue at the cut end. During this establishment period, slips may form some leaves, but above-ground growth is slow.

Figure 7–191. Sweetpotato field shortly after planting.

Storage root initiation, the phase in which adventitious roots differentiate into storage roots, begins within a few weeks of transplanting. Adventitious roots form one of three root types, depending on growing conditions:

- storage roots, which are fleshy, bulky lateral roots that are >2 cm diameter (⅘ in.) at harvest, form under ideal growing conditions and comprise the marketable part of the plant.
- fibrous roots, which are thin, non-thickened, white roots that absorb nutrients and water
- pencil roots, which are slightly thickened, elongated, lignified roots that are less than 2 cm (⅘ in.) wide at maturity.

Research has shown that 90% of adventitious roots have the potential to develop into storage roots, and this occurs quite soon after transplanting. However, if unfavourable environmental conditions occur during this period, and/or nodes or adventitious roots are damaged at or before planting, this can result in the development of pencil roots or a proliferation of fibrous roots.

Maximal storage root production by adventitious roots, and therefore yield, is highly dependent on environmental and biotic conditions (soil moisture, temperature, fertility rate and timing, use of good quality slips) occurring within the first 30–40 days after transplanting. Agronomic decisions and prevailing temperatures during this period can have an important effect on final yields. Research from the southern U.S. indicates that yearly variability in sweetpotato yield can often be attributed to variability during early transplant establishment and development.

By late June or early July, above-ground growth also begins to increase, and plants begin to form vines that grow rapidly. By mid-summer, vines typically cover most of the field (Figure 7–192). During the last third of the growing season, above-ground vine growth slows and eventually stops.

Figure 7–192. Sweetpotato rows become covered in vines by mid- to late summer (A). Vines from a single sweetpotato plant, about 9–10 weeks after transplanting (B).

This period is characterized by rapid bulking of the storage roots. In Ontario, sweetpotatoes are typically ready for harvest within 95–150 days of transplanting, depending on environmental conditions during the growing season.

Seeding and Spacing

Most sweetpotato slips planted in Ontario are purchased from slip suppliers/propagators in the southeastern U.S., especially North Carolina, although recently there has been some commercial production of certain cultivars in Canadian greenhouses. Consult the Canadian Food Inspection Agency for import requirements associated with bringing planting material into Canada.

Slips should be planted within 1–3 days (maximum 7 days) after they have been cut from seed beds, to avoid negative effects on storage root initiation and yield. Use of mail or courier services to bring slips from the southern U.S. to Ontario is not advisable, as it may lead to unexpected delays at the border, which would reduce viability of slips. In Ontario, many commercial growers contract climate-controlled trucks to ensure more prompt delivery of slips from southern U.S. propagators to their farms.

Sweetpotatoes are prone to mutation and virus accumulation over time, which can reduce yield and quality. To avoid this, select certified, virus-free plants ("seed") from reputable propagators. Avoid growing sweetpotatoes from the same stock for more than 3 seasons.

A finger-type vegetable transplanter (1–8 row) is suitable for setting out slips (Figure 7–193).

Figure 7–193. Sweetpotato planting.

Consistent spacing is important for root size and any gaps inadvertently missed by the transplanter are usually manually planted. Water is typically applied at or after transplanting. Ideal spacing of sweetpotatoes varies considerably with the cultivar selected. See Table 7–142 for overall ranges.

Ensure several nodes are placed under the soil surface to maximize storage root set. Larger slips (>20 cm (8 in.) from cut to growing point) have higher yields and better survival after planting. Plant slips in raised beds, or hills, approximately 15 cm (6 in.) high and 40–45 cm (15–17 in.) wide.

Fields are mechanically cultivated several times to warm the soil, control weeds and enhance hill formation to ease digging. This is typically done before extensive vine growth in early to mid-summer. Use of black plastic on the rows can help increase soil temperature at planting in areas with lower heat units but will also increase the cost of production and complicate irrigation and harvest.

Table 7–142. Sweetpotato Crop Spacing

Crop	Row Spacing	In-Row Spacing	Depth	Seeding Rate
Sweetpotatoes	102–122 cm (40–48 in.)	30–40 cm (12–16 in.)	7–13 cm (3–5 in.)	20,218–32,348 plants/ha (8,168–13,069 plants/acre)

Fertility

Sweetpotato fertility programs often vary with cultivar. The recommended rate of nitrogen for the variety Beauregard in Ontario is 50 kg/ha (44 lb/acre). However, other cultivars (e.g., Covington) have a higher demand for nitrogen.

Research from the southern U.S. suggests that sweetpotatoes benefit from split nitrogen applications, with some applied preplant and the remainder (or all) applied about 3–4 weeks after transplanting. This is thought to be related to the fact that high levels of nitrogen are not required during initial root formation, with maximum uptake by the storage roots occurring 23–40 days after transplanting. Applications of other nutrients, such as potash, are also split on some U.S. farms. Fertility requirements have not yet been established for other nutrients on sweetpotatoes in Ontario. However, a balanced fertility program based on a soil test can form the basis for good crop health. See Chapter 1 for more information.

Some general guidelines can serve as a basis when initiating a sweetpotato fertility program. Phosphorus and potassium should be applied based on the results of soil testing. With soil test values of 60 ppm P_2O_5 or greater, there is not likely to be a response to additional phosphorus. If a soil test shows a lesser amount of phosphorus, consider applying additional amounts at transplanting. Potassium is removed by the crop in relatively large amounts as the roots contain about 1.5% K on a dry weight basis, however, the exact potassium requirements of sweetpotatoes have not been established for Ontario.

Plant Tissue Analysis

When used in conjunction with soil analysis, plant tissue analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. Plant tissue analysis does not replace soil testing or a sound soil fertility program. For more information, see Table 7–143, and *Plant Tissue Analysis*, Chapter 1.

Irrigation

While sweetpotatoes are often thought to be a drought-tolerant crop, reductions in yield and quality may result if the crop receives too little, too much or irregular watering. Adequate soil moisture during the first 40 days after transplanting is particularly important for ensuring maximum storage root formation. If the available soil moisture level in the root zone drops below 50% from planting through August, supplemental irrigation can help maintain crop yield and quality. It is important to keep water availability consistent throughout the growing season, as uneven water can cause growth cracks in storage roots. Irrigation generally stops 2–4 weeks before harvest.

For more information on irrigation scheduling, see the *Irrigation Management* BMP (order number BMP08E) and the OMAFRA factsheet, *Monitoring Soil Moisture to Improve Irrigation Decisions*.

Table 7–143. Sweetpotato Nutrient Ranges

Plant Part	Time of Sampling	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu
		Per Cent (%)						Parts Per Million (ppm)				
Most recently mature leaf	Early vining	4–5	0.3–0.5	2.5–4	0.8–1.6	0.4–0.8	0.2–0.6	40–100	40–100	25–50	20–50	5–10
	Mid-season: before root enlargement	3–4	0.2–0.3	2–4	0.8–1.8	0.25–0.5	0.2–0.4	40–100	40–100	25–40	25–40	5–10
	Root enlargement	3–4	0.2–0.3	2–4	0.8–1.6	0.25–0.5	0.2–0.6	40–100	40–100	25–50	20–50	5–10
	Just before harvest	2.8–3.5	0.2–0.3	2–4	0.8–1.6	0.25–0.5	0.2–0.6	40–100	40–100	25–50	20–50	5–10

Adapted from G Hochmuth et al. 2018. Plant Tissue Analysis and Interpretation for Vegetable Crops in Florida. University of Florida IFAS Extension. HS964.

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Harvest

Sweetpotatoes reach maturity within 95–150 days after planting, depending on the cultivar. Sweetpotatoes can be dug as soon as the roots are edible size. Test digs in late August or early September are typically done, and the crop is harvested when there is a maximum number of premium grade roots per plant (see below for more information on sweetpotato grades). Sweetpotato harvest should be completed before soil temperatures consistently drop below 10°C (50°F), to avoid chilling injury to roots. See *Chilling Injury*, also in *Sweetpotatoes,* for more information.

In Ontario, sweetpotato harvest generally starts in early to mid-September and continues through October. Sweetpotato roots have very thin, delicate skin that is easily torn from the underlying root tissue (called "skinning"). This wounding can lead to post-harvest losses due to water and weight loss and can provide an entry way for decay pathogens. Extreme care must be taken throughout the harvest process to avoid damaging sweetpotato roots.

Skinning can be reduced by removing surface vine growth by mowing about 3–7 days (no longer) before the scheduled harvest (Figure 7–194).

Figure 7–194. Mowing of sweetpotato field prior to harvesting.

In Ontario, sweetpotatoes are harvested mechanically, using a modified potato digger that can harvest 2–8 rows at a time (Figure 7–195). Sweetpotatoes are generally field-graded during harvest, when off-size or misshapen roots are removed, then roots are gently moved into wooden or plastic vented storage bins.

Figure 7–195. Sweetpotato harvest.

It is not uncommon to cull 30%–40% of roots in the field for being undersized, wounded or misshapen.

Marketable Yield (all grades):	13,450–20,175 kg/ha (12,000–18,000 lb/acre)
Standard Container:	40-lb box or 50-lb box (1 bushel)

Sweetpotatoes are highly variable and are usually sold based on grades to satisfy market requirements for consistency in root size, shape and quality. There are no established Canadian grades for sweetpotatoes, however the U.S. Department of Agriculture's (USDA) Agricultural Marketing Service has developed standards for U.S. markets. The premium grade of sweetpotatoes is typically referred to as a "Number 1" or "U.S. No. 1," however several other grades of marketable roots also exist (e.g., Jumbo, Canner). While U.S. grading standards may provide a general guide for new growers, Canadian retailers vary in their size requirements for sweetpotatoes. It is important to check with buyers for specific grading requirements prior to packing.

Curing and Storage

Move the sweetpotatoes into the curing facility immediately after digging to reduce the risk of chilling or sunscald. Curing is essential for sweetpotatoes to heal wounds (which reduces losses to shrinkage and disease), set the skin to reduce skinning during packing and enhance flavour by converting starches to sugars. During curing, maintain a temperature of 29°C (85°F) and relative humidity of 85%–90% for 3–5 days. Adequate ventilation and air circulation in the curing facility is critical. Curing should stop once sprouts begin to form. While tobacco kilns and other buildings are sometimes used in the initial years of production, specialized curing and storage facilities are generally required for large-scale production and long-term (more than a few months) storage of sweetpotatoes (Figure 7–196).

Figure 7–196. Sweetpotato curing and storage facility.

After curing, store roots at 13°C (55°F) and 85%–90% relative humidity, with sufficient ventilation. Properly cured roots that are free of disease can be stored for up to 13 months under these conditions.

Pest Management and Disorders

See Figure 7–189, *Sweetpotato stages of development and pest activity calendar*.

Diseases

Black Rot
Ceratocystis fimbriata

Identification: Black rot symptoms may be present at harvest, but more commonly appear after curing or storage. Affected roots have sunken, dark, rounded lesions (Figure 7–197) that are dry and firm and do not typically extend past the outer tissue into the core of the root (Figure 7–198).

Figure 7–197. Black rot lesion on surface of sweetpotato root.
Source: Dr. Lina Quesada, NC State University.

Figure 7–198. Black rot is generally limited to the outer tissues of the root and does not extend into the inner cortex.
Source: Dr. Lina Quesada, NC State University.

White fungal growth and black reproductive structures, called perithecia, may be present upon examination with a hand lens. Lesions may initially be small but can expand over time and may spread to other healthy roots in storage. Affected roots taste bitter and may have a fruity aroma. Lesions can occur on slips in the field, which can cause stunting, wilting and death of young transplants, however this is not common in Ontario.

Biology: Black rot can spread in seed beds from infected mother ("seed") roots to the below-ground portion of nearby shoots that may be cut for slip production. If affected slips are transplanted to the field, the fungus can continue to develop on the lower stem and then onto the new storage roots. The fungus produces large quantities of spores (conidia) on infected roots, which can spread the disease in storage and contaminate equipment, dump tanks and packing lines, which can lead to an increase in disease levels even after roots leave the farm. The black rot fungus also produces overwintering spores that allow it to survive in the soil for several years, or persist on the roots of weeds in the morning glory family.

Management Notes: Fungicides are not effective against established infections, and black rot is mainly controlled through cultural practices. Ensure slip suppliers have protocols in place for controlling disease spread, including use of disease-free mother roots that are treated with a registered fungicide and frequent sanitation of tools when harvesting slips. It is critical that slip suppliers cut vines at least 2–4 cm (¾–1½ in.) above the soil line, as this is where the black rot fungus is typically located. Plant only in fields that have not had sweetpotatoes for 3–4 years. Avoid fields known to have high levels of black rot, and remove morning glory weeds, which can serve as an alternative host. Do not dispose of sweetpotato culls in fields where sweetpotatoes will be planted. Wounds can serve as entry points for secondary infections in storage, so ensure roots are cured properly and quickly after harvest to allow injuries to heal. Remove visibly infected roots prior to washing. Remove debris from storage crates prior to harvest, and sanitize harvest equipment, storage crates, dump tanks and packing lines frequently.

Plastic storage crates are much more easily sanitized than wooden ones. If possible, rinse roots prior to placing in a dump tank because soil and organic matter can render sanitizers ineffective.

Post-Harvest Storage Rots

Erwinia* spp., *Rhizopus stolonifer*, *Fusarium solani*, *Fusarium oxysporum

Sweetpotatoes are susceptible to a variety of post-harvest storage rots. While several bacterial and fungal pathogens can cause storage rots in sweetpotatoes, over the last several years fungal pathogens in the genus *Rhizopus* and *Fusarium* have been the most common causes of post-harvest storage losses in Ontario sweetpotatoes.

Identification: Rhizopus soft rot is the most common post-harvest rot of sweetpotatoes. It initially appears as a white, hairy fungal growth, eventually developing large quantities of dusty black spores on root surfaces (Figure 7–199). A soft, wet decay develops that can rapidly spread over large areas of the root. A ring rot can also occur when the fungus infects the middle portion of the root. Infected tissue often has a pronounced, sweet odour, which can attract fruit flies.

Figure 7–199. Rhizopus soft rot on sweetpotato roots.

Fusarium root rot, caused by the fungus *Fusarium solani*, causes light and dark brown circular concentric lesions on the skin of sweetpotatoes, which may coalesce and overlap over time (Figure 7–200). Fusarium root rot is generally dry, and infected roots remain firm. Symptoms often originate from the end of the root. Lesions extend into the flesh of the root, causing light to dark brown lens-shaped cavities that often have white fungal mycelium growing inside (Figure 7–200). If infected sweetpotatoes are stored in a humid environment, a white fungal growth can develop on the exterior of the roots near the infection site.

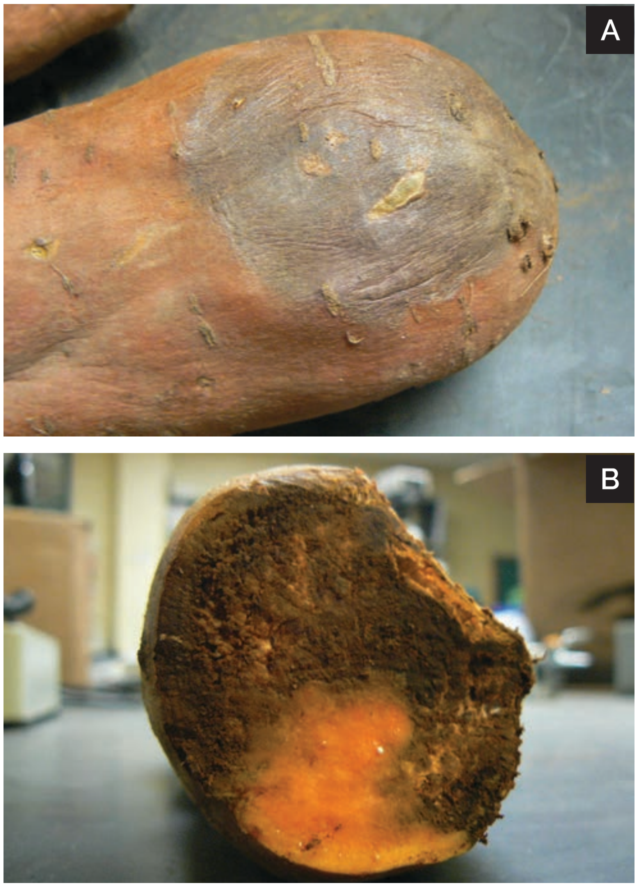

Figure 7–200. Fusarium root rot lesion on root surface (A). Lesion extending into the root cortex (B).

Fusarium surface rot is caused by the fungus *Fusarium oxysporum* and by some strains of *F. solani,* and leads to circular, light brown, firm dry lesions on the root surface. Lesions generally do not extend into the flesh of the root and often occur at points of injury to the root. Early symptoms of root rot can be easily confused with surface rot, as external symptoms are very similar. The differentiating feature is that surface rot does not colonize the inner tissue of the root, and symptoms are restricted to the outer layers of tissue. Both *F. oxysporum* and *F. solani* infections develop slowly, and consequently do not typically occur after packing (Figure 7–201).

Figure 7–201. Fusarium surface rot on sweetpotato root. *Source:* Gerald Holmes, Strawberry Center, Cal Poly San Luis Obispo, Bugwood.org.

Bacterial infections caused by *Erwinia* sp. generally result in external or internal, extremely moist, soft rots. They typically develop under warm, humid conditions. Other storage diseases have been reported from other areas but have not yet been confirmed in Ontario (Figure 7–202).

Figure 7–202. Bacterial soft rot on sweetpotato root. *Source:* Charles Averre, North Carolina State University, Bugwood.org.

Biology: *Rhizopus*, *Fusarium*, *Erwinia* and other fungal and bacterial pathogens are common in soil and the atmosphere. They can enter sweetpotato roots through wounds inflicted during harvesting and handling. Less commonly, bacteria and *Fusarium* enter roots in the field through rootlets or growth cracks. Once established in the root,

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these pathogens can cause rots in storage, during transport or at retail outlets.

Wet, cool soil at harvest can make roots more susceptible to rhizopus soft rot. White-fleshed cultivars are more susceptible to *Rhizopus* spp. than orange-fleshed ones, although all roots can suffer losses to *Rhizopus* spp. under the right conditions (cool, wet weather at harvest and injury to roots during harvest or packing). Both species of *Fusarium* are persistent soil-borne pathogens and require wounds in the fleshy roots of sweetpotatoes for infection to occur. These wounds are most often caused by mechanical harvesting, leading to the more common storage rots. However, rots can occasionally occur in the field through wounds caused by insects, nematodes or rodents, and through growth cracks. This pathogen will not spread between roots in storage unless new wounds occur. However, *F. solani* can spread from seed roots to sprouts, leading to fusarium stem canker in the resulting slips. Sweetpotatoes with minor *F. solani* infection can appear healthy but if used as parent material, the pathogen can be transferred to the sprouts.

Chilling injury, heat damage, excessive skinning (e.g., when soil is extremely dry prior to harvest) and high relative humidity during storage or transport can increase levels of infection of all post-harvest pathogens.

Management Notes: All sweetpotato post-harvest pathogens are widespread in the environment and are likely present in all sweetpotato fields. However, since they can only enter sweetpotatoes through wounds in the skin, the best way to manage these diseases is through sanitation and proper handling of roots to minimize entry points for these pathogens.

Handle roots carefully at harvest to minimize injuries to the skin. Complete harvest early to avoid chilling temperatures (prolonged exposure to 10°C–12°C (50°F–54°F) or less), which can predispose roots to storage rot pathogens. If possible, avoid harvesting from very wet soil or under extremely dry conditions that increase skinning, thus creating more sites for infection. Properly cure roots as soon as possible after harvest to heal any wounds that do occur during harvest. Ensure the entire storage facility has adequate air flow to maintain appropriate temperatures (13°C–16°C (55°F–61°F)) and humidity levels throughout. In some cases, the storage rots have been reported to be more severe at the bottom of solid containers or along outer walls, where there is inadequate heating or air flow.

Wounding of roots at the packing stage can also lead to development of rhizopus soft rot after sweetpotatoes have left the storage facility. Gentle handling during packing and minimizing/cushioning any drops along the packing line can help reduce incidence of the disease. Apply post-harvest fungicides, where registered, if infections are severe or spreading rapidly. Use clean water on packing lines. Some cultivars are more resistant to fusarium root rots.

Root Knot Nematodes
Meloidogyne hapla

Various species of nematodes are significant pests of sweetpotatoes in the southern U.S. and other growing regions, however the main species causing issues there, the southern root knot nematode (*Meloidogyne incognita*) and the reniform nematode (*Rotylenchulus reniformis*), do not occur in northern growing regions such as Ontario.

Identification: On sweetpotatoes, root knot nematodes can cause generalized yellowing and stunting of plants that may be mistaken for nutrient deficiencies, however this is not commonly seen in Ontario. Sweetpotato roots attacked by root knot nematodes may be distorted and/or cracked, with a rough texture, and galls may be present on the roots (Figure 7–203).

Figure 7–203. Cracking of sweetpotato roots due to southern root knot nematode damage.
Source: Hunter Collins and Dr. Lina Quesada, NC State University Vegetable Pathology Lab.

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In some cases, the female nematodes themselves may be visible with a magnifying lens, by looking under the raised bumps they form on the roots.

Biology: The main nematode species likely to cause problems for sweetpotatoes in Ontario is the northern root knot nematode, *Meloidogyne hapla*. However, damage from this species appears to be more sporadic and less consistently significant than that caused by nematodes present in more southern growing regions. Research from the U.S. has also shown that penetration of sweetpotatoes by root knot nematodes increases with higher soil temperatures, so the cooler soil temperatures present in Ontario sweetpotato fields may also help reduce damage from this pest. Lesion nematodes (*Pratylenchus* spp.) have been reported to cause minor damage to sweetpotatoes, however damage has never been reported for the species present in Ontario, *P. penetrans*. For more information on the biology of *M. hapla* and *P. penetrans*, see *Nematodes*, Chapter 6.

In the early 2000s, a new species of invasive nematode, the guava root knot nematode (*M. enterolobii*) was reported in Florida and has since been found in Louisiana and North and South Carolina. The guava root knot nematode is a concern in the southern U.S. because populations can increase very quickly, and it can damage cultivars that are resistant to other species of root knot nematode. *M. enterolobii* has not been reported in Canada, and it is not known if this species can survive northern winters. However, Ontario growers should be watching for symptoms, which include higher than normal numbers of galls on roots, as *M. enterolobii* cannot be distinguished visually from other root knot nematodes.

Management Notes: Always purchase plants grown according to the guidelines of an accredited plant propagation program. Crop rotation to a non-preferred crop (such as grasses, cereals and corn) can help reduce root knot nematode populations in the soil prior to planting. For southern root knot nematode, some sweetpotato cultivars are more resistant (e.g., Evangeline, Burgundy and Covington) than others (e.g., Orleans, Beauregard), however it is not known whether this resistance extends to the root knot nematode species present in Ontario. Where root knot nematode populations are very high, biofumigants, fumigants or nematode-suppressing cover crops can be considered before planting, to reduce nematode numbers. In other Ontario root crops, a threshold of 500 root knot nematodes/kg soil is used, however it is not known whether this applies to sweetpotatoes.

Scurf

Monilochaetes infuscans

Identification: Sweetpotato roots with scurf have superficial, greyish- or purplish brown to black lesions on the skin (Figure 7–204). These lesions slowly enlarge and can affect large portions of the root surface, but do not penetrate the inner portions of the root. They do not affect eating quality; however, the cosmetic damage can reduce marketability. They also increase water loss during storage, leading to shrinkage.

Figure 7–204. Scurf lesion on sweetpotato root.

Biology: Scurf is spread primarily through infected planting material. If a scurf-infected root is used to produce slips, the fungus spreads from the root to the lower, below-ground portion of the sprouts. If this infected portion is pulled with the slip, the fungus can be transferred to the field, where it then spreads from the infected stems back down to the daughter roots after the slip is transplanted. Lesions usually begin to develop on the roots in the field, and continue to enlarge in storage, particularly when relative humidity in the storage facility is high. Spread of the pathogen from infected to healthy roots in storage is generally limited. The fungus can persist in the soil for 1–2 years. Heavier soils, or soils with high levels of organic matter have higher levels of survival. The scurf pathogen is different from that causing scurf of white potatoes. It infects only sweetpotatoes and close relatives in the morning glory family.

Management Notes: Use scurf-free planting material and avoid fields with a history of scurf. Since the pathogen is restricted to the below-ground portion of the sprouts, the most important control measure is to ensure that slip suppliers are cutting vines at least 2.5 cm (1 in.) above the soil surface without allowing the knife to contact the soil. Practise a 2–3-year rotation away from sweetpotatoes for lighter soils, or a 3–4-year rotation in heavier soils or in fields with a history of scurf. Do not dispose of sweetpotato culls in fields where sweetpotatoes will be planted.

Viruses

A variety of viruses have been isolated from sweetpotato plants, and they are extremely common where virus-free plants are not used.

Identification: Sweetpotato feathery mottle virus (SPFMV) is the most ubiquitous virus in sweetpotatoes worldwide and has been found in all Ontario sweetpotato fields surveyed. Symptoms vary with cultivar and environment but include irregular chlorotic patterns ("feathering") and chlorotic spots that often have purple borders (Figure 7–205) and mild stunting of plants. In certain cultivars and with certain SFPMV strains, roots may also exhibit symptoms, including "russet crack," which causes necrotic lesions that may girdle roots (Figure 7–206).

Figure 7–205. Sweetpotato feathery mottle virus symptoms on leaves.

Figure 7–206. Russet crack symptoms on sweetpotato root.

Many sweetpotato cultivars infected with only SPFMV show only mild symptoms, however if plants are infected together with another virus — the sweetpotato chlorotic stunt virus (SPCSV) — the interaction of the two viruses causes sweetpotato virus disease, which has led to yield losses of up to 80% in some countries. SPSCV has not yet been detected in Ontario but is present in many countries worldwide.

More than 28 other viruses have been reported from sweetpotatoes to date worldwide. Most of these have not been confirmed in Ontario, however, there has not been significant testing for sweetpotato viruses in Ontario to date.

Biology: SFPMV is transmitted by aphids, including green peach and melon aphids, in a non-persistent fashion. When an aphid lands on an infected plant, it can acquire a non-persistent virus on its stylet (mouthparts) within less than 1 minute of feeding. If the aphid then moves on to sample a new plant, the virus is spread from the infected plant to a healthy plant. As an aphid feeds, it clears the virus from its mouthparts and is no longer able to transmit the disease to additional plants. Once the problem is identified, the aphids have already moved on, making insecticide applications inefficient for the control of non-persistent virus diseases.

Viruses can spready rapidly through a field within a season, however the main source of sweetpotato viruses each year is through infected planting material, especially when slips are cut from roots saved from the previous year's crop.

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Management Notes: The main method for controlling viruses in sweetpotatoes is planting virus-free slips. Virus-free certification programs are in place in many U.S. states where slips are sourced. Purchase only from propagators certified by these programs. Viruses can be re-introduced to a field planted with clean slips by aphids. Within-season impacts of the re-introduction of viruses are likely to be minor, however, do not save roots from one season to start slips for the next. Many sweetpotato breeding programs have also produced virus-resistant or tolerant cultivars, which are less affected by viruses.

See *Viruses*, Chapter 6.

Insects

While numerous insects will feed on sweetpotato foliage, the large amount of biomass produced by the plant allows it to tolerate considerable damage without a significant impact on yield. In Ontario, most economic damage to sweetpotatoes is caused by soil-dwelling insects that feed on the roots, in particular, various species of wireworms and white grubs.

Aphids

Myzus persicae*, *Aphis gossypii

Aphids are small, soft-bodied insects that are often found in colonies on the underside of leaves. They have sucking mouthparts that they use to pierce plant parts and suck out fluids. The melon aphid and the green peach aphid are common species on sweetpotatoes. Both are sporadic pests of sweetpotato in Ontario, and feeding typically has negligible effects on root yield. However, aphids are vectors of a number of sweetpotato viruses. In the southern U.S., melon aphid is a primary vector of the sweetpotato feathery mottle virus. See *Viruses*, also in *Sweetpotatoes*.

For more information on aphid identification and management, see Chapter 5.

Corn Rootworm (Spotted Cucumber Beetle)

Diabrotica undecimpunctata

Identification: Adult spotted cucumber beetles are about 6 mm (¼ in.) long, with a yellow-green body, 12 black spots on the wings, and black heads, antennae and legs (Figure 7–207). The larval form of this insect is known as the southern corn rootworm, which is a different species than the more common western corn rootworm (*Diabrotica virgifera*) and northern corn rootworm (*Diabrotica barberi*). The larvae are difficult to distinguish from other species of rootworms, with a yellow-white, wrinkled body up to 12 mm (½ in.) long when fully grown, and three pairs of short, brownish legs near a grey-brown head (Figure 7–207).

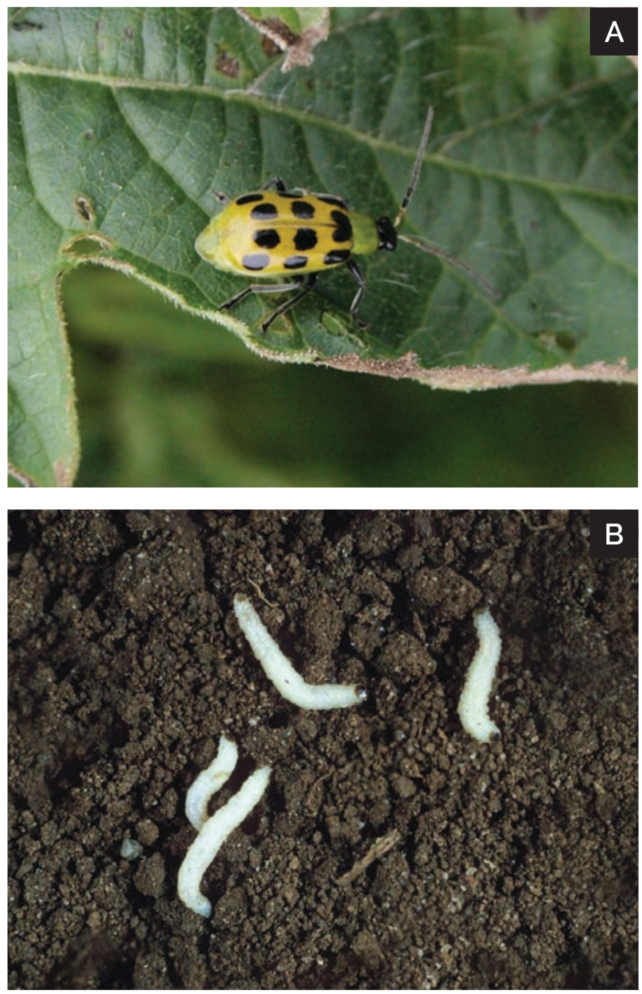


Figure 7–207. Spotted cucumber beetle: Adult (A). *Source:* Jim Jasinski, Ohio State University Extension, Bugwood.org.
Larvae (also called the southern corn rootworm) (B). *Source:* John C. French Sr., Retired, Universities: Auburn, GA, Clemson and U of MO, Bugwood.org.

Damage: Adults chew irregular-shaped holes in sweetpotato foliage, but damage to foliage is not typically sufficient to impact yields. However, in the southern U.S., rootworm larvae can bore into the outer skin of maturing sweetpotato roots, eating small holes in the skin and causing scars 1–3 mm (<⅛ in.) wide, with shallow cavities under the skin. Holes are generally smaller than that caused by wireworms, and cavities shallower. Damage can occur throughout the season but appears to increase as the season progresses. Root damage from this pest is not typically observed in Ontario sweetpotatoes.

Biology: While some spotted cucumber beetles overwinter as adults in Ontario, most are thought to migrate into the province from southern regions in late spring. Eggs are laid in the soil at the base of host plants, and hatching larvae feed on roots for about 2–6 weeks, depending on temperature, before the pupa form. Adult beetles emerge about 1–2 weeks later, feeding on the foliage of various plants. There is likely only 1 generation per year in northern regions, with most individuals moving southwards at the end of the season to overwinter. While the geographic range of the spotted cucumber beetle includes most of North America, it is typically far more damaging in southern regions, where it can survive the winter and go through multiple generations.

Scouting and Thresholds: There are no established thresholds for this insect in Ontario. Damage to foliage is rarely an issue, however if large numbers of adults are present, check developing roots for signs of damage.

Management Notes: Control of this insect is not normally required, as adult feeding on foliage does not typically affect yield, and damage to sweetpotato roots is rare. Cultural management methods for this insect on other crops include use of row covers and/or growing nearby cucurbits as a trap crop, but it is not known whether this would be effective for managing this pest in sweetpotatoes. Some sweetpotato cultivars are less susceptible to spotted cucumber beetles than older cultivars such as Beauregard.

Cutworms
Agrotis ipsilon (black cutworm)
Peridroma saucia (variegated cutworm)

Identification: Cutworm larvae are soft and fat, and they roll up when disturbed. Mature larvae can be as large as 3–4 cm (1⅛–1⅝ in.) in length. Black cutworms are grey to black with no striping on the body, whereas most other cutworms have stripes along their back or sides. Variegated cutworms appear later in the season and are larger than other cutworm species. They are grey to brown in colour, with longitudinal stripes and diamond-shaped, pale-yellow markings along the back and sides of the body.

Damage: Sweetpotatoes in Ontario escape much of the early-season damage from cutworms because they are planted in June, as activity of the first generation is ending. Damage to new sweetpotato transplants, by cutting petioles or stems, is rare. Later in the season, subsequent generations of cutworms feed on foliage at night, leaving large irregular holes. In white potatoes, cutworms may chew holes in tubers in the soil, however it is not known if this occurs in sweetpotatoes. In some areas, cutworm moths have laid eggs on or near sweetpotato roots at harvest, and hatching larvae have gone on to damage roots in storage.

Biology: Most species of cutworm do not overwinter in Ontario. In the early spring, adult moths are transported on the trade winds from more southerly areas. Females are attracted to dense, green cover to lay their eggs. Often, when they arrive in Ontario in early spring, the main source of habitat for the females are winter annual or perennial weeds. Cutworms are therefore more frequent in fields with green cover early in the spring before primary tillage. Egg-hatching and larval feeding often coincide with planting and crop emergence.

Scouting and Thresholds: Most species of cutworms feed at night, hiding during the day under loose stones or in the soil near the base of the plant. Scouting is best done in the middle of the day, when the water demand of plants is high. Check for cutworm damage to plants. If any is found, dig around in the soil at the base of the plant. The cutworm, if present, will be found 2.5 cm (1 in.) deep and within 10 cm (4 in.) of the damaged plant(s). There is no threshold for cutworms in sweetpotatoes.

Management Notes: Cutworm control is most effective on small (<2.5 cm (<1 in.)) larvae. Larger larvae are difficult to control with insecticides. At more mature stages (>2.5 cm (>1 in.) in length), they cease feeding as they prepare to pupate, and control becomes unnecessary. Apply insecticides, where registered, in the early evening, as the cutworms come to the surface to feed at night. Insecticides are more effective on moist soils. Moths are often attracted to weedy spots in low areas of the field for egg laying. Control weeds, especially in these areas.

Flea Beetles

Systena blanda, *Systena frontalis*, *Chaetocnema confinis*

Identification: Flea beetles are small, often dark beetles with characteristically enlarged hind legs that give them the ability to jump very quickly when disturbed. Various species have been reported to feed on sweetpotato foliage, including the pale-striped flea beetle (*Systena blanda*), the red-headed flea beetle (*S. frontalis*) and sweetpotato flea beetle (*Chaetocnema confinis*). Red-headed flea beetle adults are black, approximately 4 mm long, with a dark-red spot on the head. Pale-striped flea beetle adults are 3–4 mm long, pale to dark black, with two yellow stripes running down the back. Sweetpotato flea beetle adults are much smaller (<2 mm long), black with a bronze tinge, with reddish-yellow legs and deep ridges on its wing covers. Flea beetle larvae are delicate, thread-like and white with brown heads and three pairs of small legs.

Damage: Pale-striped and red-headed flea beetle adults chew small, irregular holes in sweetpotato foliage, which may give a “shot-gun” appearance of holes in the leaves. Sweetpotato flea beetles chew long narrow channels in the upper surface of leaves that often run parallel to the leaf veins. Flea beetle feeding on sweetpotato foliage is rarely economically damaging. In the southern U.S., sweetpotato flea beetle larvae are an occasional problem, feeding primarily on the fibrous roots, but sometimes leaving narrow, shallow, winding tunnels on sweetpotato roots. Flea beetle damage to sweetpotato roots has only rarely been reported in Ontario.

Biology: Flea beetles overwinter as adults in the soil or in protected places, becoming active as temperatures warm in the spring, where they feed on weeds and early planted crops and lay eggs in the soil at the base of host plants. Flea beetle larvae feed on roots in the soil for several weeks before pupating. There may be one to three generations per year, depending on the species.

Scouting & Thresholds: None established for Ontario. Flea beetles are highly mobile, making it difficult to count insects on the plant. Look for jumping beetles as plants are approached, or note signs of feeding injury. Beetles can also be captured in sweep nets.

Management Notes: Sweetpotato foliage can tolerate a considerable amount of damage from flea beetles, and control is generally only required if there is significant feeding on very young plants. Damage to roots is rare.

Foliage-Feeding Insects — Sweetpotato Hornworm, Golden Tortoise Beetle, Japanese Beetle, Loopers, Armyworm

Many insect species will feed on sweetpotato leaves, however, because mature vines produce so much foliage, plants can tolerate considerable feeding damage before there is an effect on yield.

Identification and Damage:
Sweetpotato hornworms (*Agrius convolvuli*) are a different species than the more common tomato hornworm, and feed mainly on sweetpotato and other members of the morning glory family. Larvae vary in colour from green to brown and can be distinguished by slanted, dark lines running along the side of their bodies, dark horns at the end of the abdomen and three dark stripes along the side of their heads (Figure 7–208). Larvae are large, with mature caterpillars reaching more than 90 mm (3½ in.) long at maturity. Larvae cause large irregular holes in the leaf, or caterpillars can eat the leaf starting at the edge, eventually leaving only the petiole. Sweetpotato hornworms are much less numerous in Ontario than in southern or tropical regions. In the southern U.S., there are several generations from June through September, but the life cycle is not as well known in northern regions.

SWEETPOTATOES

Figure 7–208. Sweetpotato hornworm.

Golden tortoise beetle (*Charidotella sexpunctata* bicolour) adults and larvae feed exclusively on the foliage of sweetpotatoes and their relatives, leaving large round holes all over the leaf. Young larvae initially eat only the outer layers of the leaf, but as they grow, they begin to eat their way through. Adult tortoise beetles are oval and slightly flattened, with the edge of the body very extended, covering most of the head and legs and looking somewhat turtle-shaped (Figure 7–209).

Figure 7–209. Tortoise beetle on sweetpotato.

The adult is a brilliant metallic golden colour but becomes orange with black spots when disturbed. The larvae are broad and flattened, about 9 mm (⅓ in.) long, with spiny sides and a hook along the abdomen that they use to cover themselves in feces, which helps hide them from predators. Tortoise beetle adults emerge from May to June to feed on morning glory weeds and move to crops when they are planted, laying eggs on the undersides of sweetpotato leaves. Larvae hatch in 7–10 days and feed for 3–4 weeks before pupating and emerging as adults in early August. These beetles can have multiple generations per year in southerly regions but may have only one in cooler climates.

Japanese beetle (*Popillia japonica*) adults feed voraciously on the foliage of a wide variety of vegetable, fruit and ornamental species. The beetles are large (10–13 mm (½ in.) long), metallic green to greenish bronze with coppery red wings and small white tufts on the sides of their abdomen. Adult beetles appear in late June and remain on crops through the summer, feeding and mating in large numbers on plant foliage. They chew leaf tissue between the veins, leaving leaves with a skeletonized appearance. Japanese beetles will feed on sweetpotatoes in some areas of Ontario, but rarely cause significant damage to mature vines. However, larvae feed on roots in the soil and are part of the complex of white grub species that can be damaging to a number of crops. For more information on this stage, see *White Grubs*, also in *Sweetpotatoes*.

Loopers, specifically the cabbage looper (*Trichoplusia ni*) will occasionally feed on sweetpotatoes. Caterpillars are light green with a white strip along each side of the body and two faint lines down the middle of the back, reaching about 4 cm (1⅝ in.) long at maturity. The legs are confined to the front and rear of the body, resulting in a very distinctive "looping" manner of movement. They chew irregular holes in leaves, giving them a ragged appearance. Larvae generally appear around mid-July.

Several species of **armyworm caterpillars** have been reported as occasional pests of sweetpotatoes. These insects eat the leaves and stems of a wide variety of host plants, which includes a number of vegetable and field crops.

The common armyworm (*Mythimna unipuncta*) is dull green to brown with white-bordered stripes running laterally along the body, and a dark, diagonal band at the top of each proleg. It is up to 5 cm (2 in.) long at maturity. Larvae are present for 3–4 weeks from late May to early July, depending on the year.

Fall armyworm (*Spodoptera frugiperda*) caterpillars are pale green to tan, with a solid dorsal stripe and a dark brown head with a distinct white inverted "Y" marking. In Ontario, peak numbers generally occur in late August through September.

Scouting and Thresholds: Mature sweetpotato vines can tolerate a considerable amount of damage to the leaves. In the southern U.S., yield reductions are not generally expected unless defoliation exceeds 30%. Foliar-feeding insects will have more of an impact on yield during earlier growth stages than after vines have begun to elongate rapidly.

Management Notes: Control of foliar feeding insects is not often required in Ontario sweetpotatoes. Naturally occurring beneficial predators and parasites often keep pest populations from building to levels that can cause yield reductions. When selecting insecticides for other pests, opt for products that minimize impacts on these natural enemies. Maintaining good control of grassy and morning glory family weeds in and around fields will help reduce alternate hosts for some of these pests.

Millipedes

Cylindroiulus caeruleocinctus, *Blaniulus guttulatus*, *Pseudopolydesmus* spp.

Millipedes are occasional pests of sweetpotatoes, with damage observed only rarely. Millipede damage to sweetpotato roots typically presents as fine tunnelling into the flesh or shallow cavities with ragged edges, that may be mistaken for wireworm damage (Figure 7–210). See *Millipedes*, Chapter 5.

Figure 7–210. Millipede feeding on sweetpotato root.

White Grubs

Amphimallon majale, *Phyllophaga* spp., *Popillia japonica*

Identification: White grubs are the larvae of the June beetle (*Phyllophaga* spp.), the European chafer (*Amphimallon majale*), and (in some areas) the Japanese beetle (*Popillia japonica*). All three species may feed on Ontario sweetpotatoes, but the European chafer is the most prevalent. Grubs have six well-developed legs with a C-shaped white body and darker head. The tail end of the grub often appears dark due to soil it ingests during feeding. Identification to species may be important from a management standpoint and is possible by examination of the pattern of hairs (raster pattern) at the end of the abdomen:

European chafer:	Y-shaped raster
June beetle:	oval-shaped raster, with two parallel rows
Japanese beetle:	V-shaped raster

Damage: Wireworms and white grubs are the most economically damaging insects affecting sweetpotatoes in Ontario. White grub larvae feeding gouges out broad, shallow channels across the root surface that may extend over a considerable area and can expand as the root enlarges (Figure 7–211). This damage can greatly reduce the marketability of roots.

Figure 7–211. White grub damage to sweetpotato root.

Biology: Adults of all three species feed above ground on foliage, blossoms and fruit, while larvae feed underground on plant roots. June beetle adults can feed on tree species and ornamentals, but not crops. European chafer adults do little if no feeding. Japanese beetle adults are highly polyphagous and will feed on the foliage of many crops and ornamentals, including sweetpotatoes, although adult damage to foliage is minimal.

SWEETPOTATOES

European chafers (an annual grub) overwinter as early instar larvae. Peak feeding occurs in April to mid-May. Larvae pupate in the late spring, adults emerge and in June lay eggs that hatch in August. Young larvae will feed on roots until the ground freezes.

Japanese beetles (an annual grub) overwinter as third instar larvae, which resume feeding from late spring through mid-June. Although Japanese beetle larvae prefer the roots of grasses, they will also feed on the roots of vegetables and other crops. Japanese beetles emerge in late June and are active through August, feeding on a wide variety of crop and ornamental foliage. Vegetable crops are not preferred for oviposition, so damage usually occurs because crops are planted at sites that previously hosted grass cultivars, and larvae are still present in the soil. Eggs are laid through the summer, and hatching larvae will feed on roots until the beginning of October.

June beetle larvae are present in the soil for 3 years. Feeding is most noticeable in the late spring. However, damage may occur throughout the growing season on root crops.

For European chafer and Japanese beetles, it is the new generation of larvae hatching in the summer that are damaging to sweetpotatoes, as the overwintering grubs that feed in the spring have pupated by the time sweetpotato storage roots are formed. June beetle larvae are present in the soil season-long and may damage young and older sweetpotato roots.

Scouting and Thresholds: None have been established. Look for grubs in the crop row, approximately 5 cm (2 in.) below the soil surface. Older larvae of the June beetle may feed on deeper roots, down to 25 cm (10 in.).

Management Notes: There are limited insecticide options registered for control of white grubs on sweetpotatoes in Ontario, making management of this insect a challenge. For insecticides to be effective, their efficacy would have to extend to mid-late summer, when most feeding damage occurs in sweetpotatoes. To avoid injury by white grubs, wait 2 or more years before planting on land that had been planted with grass sod. Where white grubs have been identified prior to planting (or in replant situations), consider planting to a non-host crop, such as beans. Because sweetpotatoes continue to be fed on into the early fall, consider an earlier harvest (if possible) if heavy grub damage is suspected. See *White Grubs/European Chafer*, Chapter 5, for more information.

Wireworms

Limonius spp., *Agriotes* spp., others

Identification: Wireworms, the larvae of click beetles, attack the roots, seeds and stems of a wide variety of crops and weeds in Ontario. Wireworms are copper-coloured, cylindrical and hard-bodied, with three pairs of short legs near a brown, flattened head, and reach 2–3 cm (¾–1¼ in.) in length when fully grown. Adults are reddish-brown to black, elongate beetles that are generally active at night.

Damage: Wireworms and white grubs are the most economically damaging insects affecting sweetpotatoes in Ontario. In sweetpotatoes, wireworm feeding results in small, round feeding holes on the root surface (Figure 7–212).

Figure 7–212. Wireworm damage to sweetpotato root.

Wireworms are present in the field all season, but feeding damage to sweetpotatoes generally starts around root elongation and continues through harvest. While initial feeding holes are generally shallow (6 mm (<¼ in.) deep), holes may further deepen as the root grows. Damage is often scattered randomly across the field. By fall, wireworm feeding may render sweetpotatoes unmarketable.

Biology: Wireworms take up to 5 years to complete development from egg to adult, depending on species. Most of this time is spent as larvae in the soil. Adult beetles are active in the spring, laying eggs in the soil or near the roots of grasses. Eggs hatch 2–4 weeks later, and larvae burrow into the soil in search of food, where they remain until they are ready to pupate, 3–5 years later. Wireworm larvae are therefore present in fields all season but move up and down in the soil in response to changes in temperature, moisture and the presence of a food source/carbon dioxide. Larvae pupate near the soil surface, and new adults overwinter in the soil and emerge the following spring to lay eggs and continue the cycle.

Wireworms are most likely to be present in fields that have recently had sod crops or following years of high grassy-weed pressure. Populations are often patchy within a field, and consequently damaged roots at harvest are not uniformly distributed. Sandy or silty areas of fields, especially knolls or areas with high levels of grassy weeds, are more likely to have wireworms.

Scouting and Thresholds: The patchy distribution of wireworms in sweetpotato fields, together with their habit of moving up and down in the soil in response to moisture, makes them difficult to find during the growing season, and they can go undetected while causing significant damage. Wireworms may be monitored in the fall or in the early spring prior to planting, using bait stations. Baits can consist of whole carrots, cut potatoes, corn or corn-wheat mixtures buried about 7.5 cm (3 in.) deep, at 5–10 marked stations across the field. Check the stations in 5–10 days. An average count of 0.5–1 wireworm per station indicates a potential problem.

Management Notes: There are limited insecticide options registered for control of wireworms in sweetpotatoes in Ontario, making management of this insect a challenge. For insecticides to be effective, their efficacy would have to extend to mid- to late summer, when most feeding damage occurs in sweetpotatoes. The best way to manage wireworms in sweetpotatoes is to avoid planting in fields known to be infested, either based on bait counts or a history of wireworm damage to the field. Do not plant sweetpotatoes immediately after pasture, sod or a wireworm-susceptible crop (e.g., grains, grasses, carrots and potatoes). Control grassy weeds in and around fields, to remove alternate food sources for wireworms. Cultivation of fields before planting or after harvest can help remove alternate food sources and expose wireworms to predators. Because sweetpotatoes continue to be fed on into the early fall, consider an earlier harvest (if possible) if heavy wireworm damage is suspected. See *Wireworm*, Chapter 5 for more information.

Disorders

Chilling Injury

Chilling injury is damage to fruits and vegetables exposed to temperatures above their freezing point but below some minimum temperature. Sweetpotatoes are highly susceptible to chilling injury when roots are exposed to temperatures of 12°C (54°F) or less, either at harvest or in storage. Chilled roots may appear fine at harvest, but decay quickly during curing, or symptoms may not become evident until several weeks after roots are placed into storage. Symptoms of chilling injury in sweetpotatoes can be difficult to diagnose and include surface pitting, loss of dry matter, internal breakdown and discolouration of tissue when exposed to air (Figure 7–213). Chilling greatly increases the susceptibility of roots to decay in storage due to a variety of fungi. Chilling can also negatively affect the colour, texture, taste and smell of sweetpotatoes, and the core of the root may stay hard after cooking (a condition known as hardcore).

Figure 7–213. Surface pitting and growth of decay fungi on chilled sweetpotato root.

Chilling injury is a function of both the temperature and the length of exposure, so exposure to 1 or 2 hours at 4°C (39°F) may cause the same amount of damage as several hours at 8°C (46°F). The effects are also cumulative: one brief period of exposure to soil temperatures below 10°C (50°F) may not result in any damage, while several days where soil temperatures dip below 10°C (50°F) for short periods could cause extensive injury.

To avoid chilling injury, aim to finish sweetpotato harvest before soil temperatures consistently drop below 10°C (50°F). If you are forced to harvest later in the season, consider separating these roots from earlier harvested roots, as these will be more likely to develop fungal rots in storage. Ensure harvested roots are moved out of the field as quickly as possible if air temperatures during harvesting operations are dropping below 12°C (54°F), and never leave harvested roots in the field overnight. After curing, ensure storage facility temperatures do not drop below 13°C (55°F), and that air flow throughout the facility is enough that temperatures are consistent throughout.

Chimeras/Mutations

Chimeras are random genetic abnormalities in plants that result in variegated colours in leaves or roots, e.g., patterns of white or yellow intermixed with the normal colour (Figure 7–214 and Figure 7–215). These are sometimes confused with other diseases or disorders. Sweetpotatoes have an unusually high rate of mutations, and flesh colour mutations in sweetpotato roots are common.

Figure 7–214. Chimera of sweetpotato leaf.

Figure 7–215. Chimera of sweetpotato root.

Chimeras are sometimes confused with other diseases (e.g., viruses) or disorders (e.g., nutritional deficiency or herbicide injury). In general, chimeras would only occur on individual plants, while disease or disorders would affect more than one.

Edema

Prolonged periods of rain during cool, cloudy periods, especially in the fall prior to harvest, can also lead to edema (also spelled oedema) in storage roots and leaves. This occurs when roots take up water faster than it can be transpired by the leaves, causing a build-up of water pressure in leaf and root cells, causing them to burst. The resulting dead cells look like blisters or bumps on the surface of roots or underside of leaves (Figure 7–216).

Figure 7–216. Burst cells and blisters are characteristic of edema.

Growth Cracks

Sweetpotato roots can develop fissures or cracks during root elongation, when uneven growing conditions cause inner root tissue to expand more rapidly than the outer tissue and skin. These cracks often run longitudinally along larger storage roots and can be quite deep (Figure 7–217). The skin covering the crack may or may not be partially healed or may be necrotic, depending on how long before harvest the crack occurred.

Figure 7–217. Growth crack in sweetpotato root at harvest (A, B).

Cracks can serve as openings for invasion by secondary pathogens before they heal. Cracking is most commonly attributed to fluctuations in soil moisture, particularly when periods of extremely dry soil are followed by prolonged heavy rain or irrigation, leading to rapid and uneven uptake of water by the root. Cracking has also been linked to low soil temperatures (12°C–16°C or 54°F–61°F) during the period where roots are being set and, less commonly, excess nitrogen or boron deficiency.

Cracking can also be caused by certain species of nematodes but has not been linked to nematode species present in Ontario.

Skinning

Skinning, or surface abrasions, occurs when the root epidermis, or outer layer of skin, tears loose from the underlying root tissue either at harvest or, less commonly, during packing and shipping (Figure 7–218). Sweetpotato skin is extremely fragile, and roots are much more prone to skinning than most other vegetables. Freshly harvested sweetpotatoes, which have very thin skin, are highly susceptible to skinning at harvest, and this susceptibility can increase for several days after harvest.

Figure 7–218. Skinning on sweetpotato root.

If skinned roots are not properly cured right after harvest, the damage may become dark and sunken, and may be mistaken for post-harvest storage rots. The resulting wound is not only a cosmetic problem but can also lead to loss of water and weight by roots in storage and provide an entryway for decay pathogens. Skinning can also occur when roots are handled during packing and shipping, although the problem decreases once roots have been properly cured and stored for several weeks. Skinning in sweetpotatoes is not well understood and has been linked to numerous factors, including cultivar and environment, with some cultivars more prone to skinning than others.

To avoid skinning, sweetpotatoes should be handled gently, ideally with gloves, during harvest. Sweetpotato harvest equipment is often modified to minimize jostling of roots, and roots should be placed, not thrown into storage containers. Very dry soil at harvest can increase the likelihood of skinning. Avoid harvest when the soil is dry or consider irrigating. Prompt and proper curing of sweetpotatoes after harvest helps to “set” or toughen the skin. The removal of sweetpotato vines by mowing 3–7 days prior to harvest has been shown to reduce skinning, however intervals between mowing and harvest should not be too long, or roots may be damaged by soil pathogens entering wounds or by cold temperatures.

Vertebrate Pests

Deer

Vertebrates are common problems in many horticultural crops. Sweetpotato leaves and vines are quite attractive to white-tailed deer, and individuals or groups will move into fields to feed, particularly at night. Extensive feeding on foliage will affect root growth, and movement of deer through fields can also destroy hills. Occasionally, deer will dig into hills for roots. While there have been several reports of limited deer damage to sweetpotatoes, particularly on field edges, economic damage to large sections of fields is less common in Ontario, and tends to occur mainly in fields that are surrounded by forest or other deer habitat (Figure 7–219).

Figure 7–219. Sweetpotato field damaged by deer.

Rodents

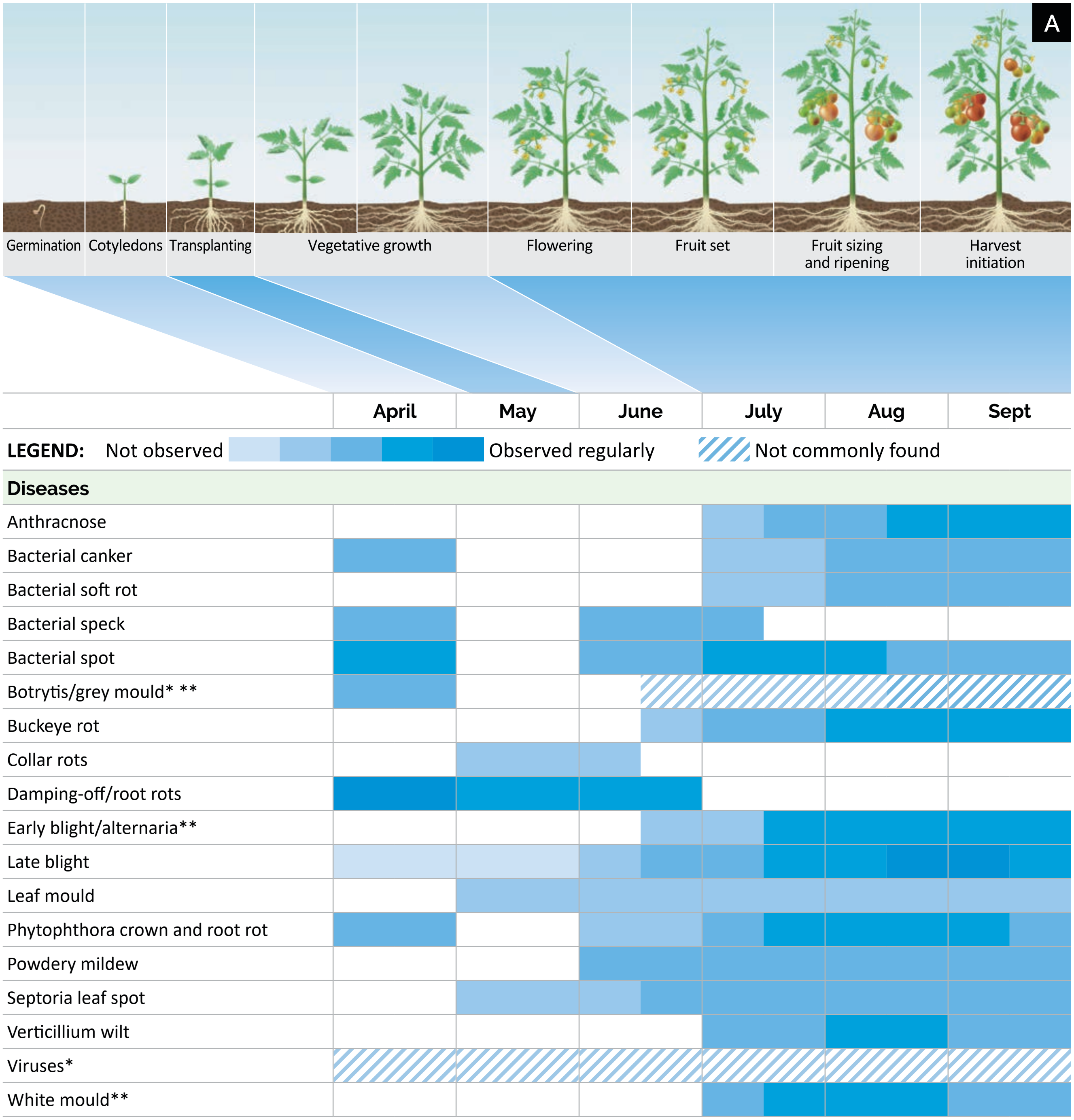
Rodents, particularly mice and voles, will feed on sweetpotato roots later in the season. Voles prefer areas with natural cover and are attracted to the dense foliage in mature sweetpotato fields. They tend to feed on portions of roots that protrude above the soil or are close to the top of the soil profile, gnawing out large chunks from these roots. Damage from mice or voles can typically be distinguished from that of soil insects by the presence of gnaw marks, and the large sections of root removed. Vole burrows may expose roots to sunscald or cold temperatures, and damage can also occur by predators digging into sweetpotato hills for voles, although typically this type of damage is not widespread across the field. Since direct damage tends to be restricted to upper roots that protrude above the soil, economic damage from rodents to sweetpotatoes is uncommon in Ontario (Figure 7–220).

Figure 7–220. Vole damage to sweetpotato.

For more information on vertebrates in horticultural crops, search for “vertebrate” or “vole” at www.ontario.ca. Note that some management techniques suggested for vertebrates in tree crops may not be applicable to vegetables. Rodenticides, baits or repellants mentioned in these resources must be registered for use on or around sweetpotato fields in order to legally use them.

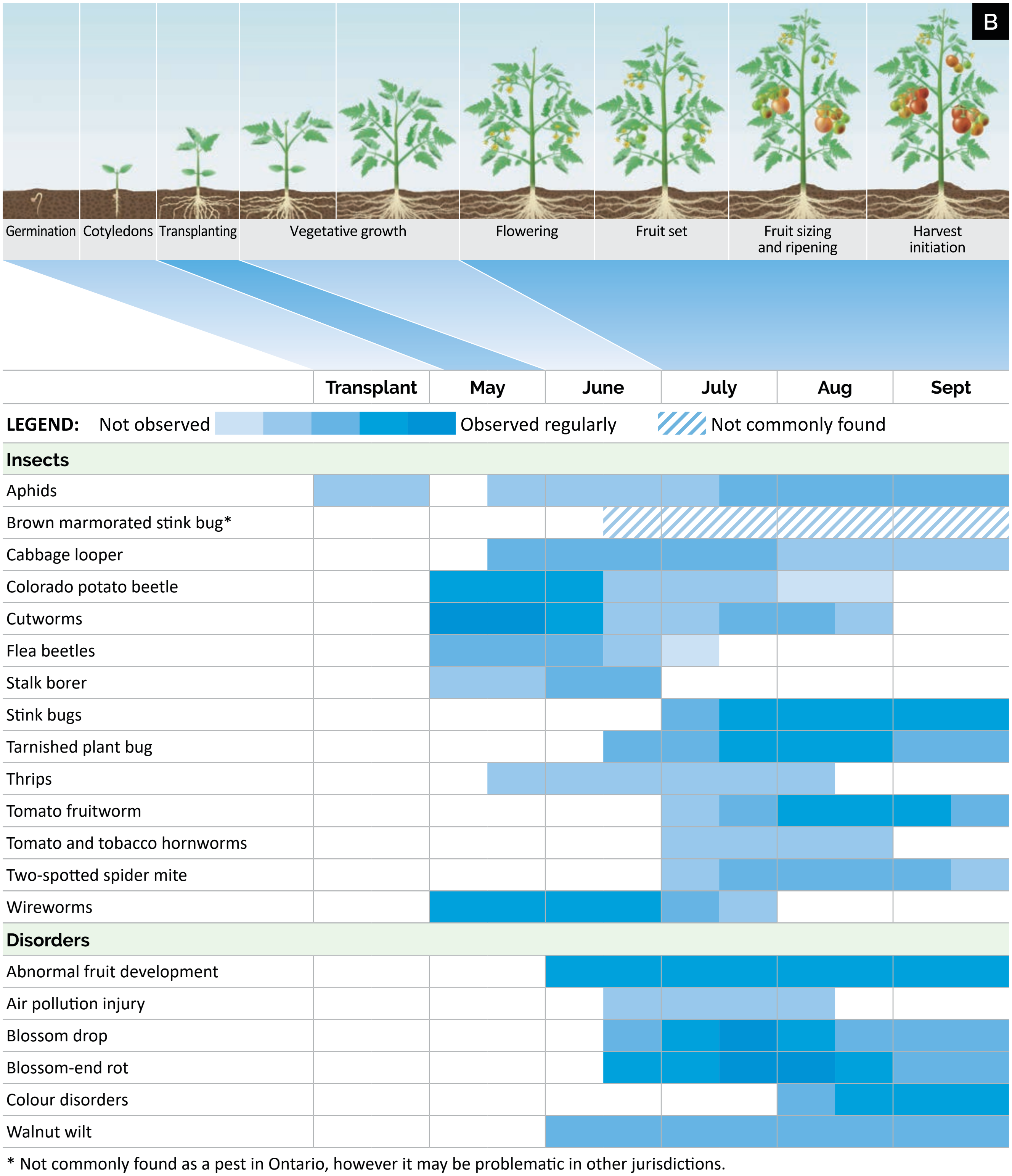
SWEETPOTATOES

Tomatoes



* Not commonly found as a pest in Ontario, however it may be problematic in other jurisdictions.
** Can also cause a collar rot in seedlings and young plants. See *Collar Rot*.

TOMATOES



* Not commonly found as a pest in Ontario, however it may be problematic in other jurisdictions.

Figure 7–221. Tomato stages of development and pest activity calendar. The actual period of activity for any given pest will vary significantly from year to year, depending on environmental factors.

Tomato Crop Growth

Tomatoes in Ontario are planted in the field as transplants. Transplants are grown in greenhouses for approximately 6–8 weeks. Seeds germinate 8–10 days after seeding and sprout two initial leaves called cotyledons, which have an elongated oval shape. The next two leaves to grow are the first true leaves. Processing tomato transplants are usually 5–10 cm (2–4 in.) tall and generally have 4 or more true leaves when they are planted in the field. Fresh market transplants are slightly larger, around 10–20 cm (4–8 in.) tall, and usually have 6 or more true leaves.

Once transplanted, the tomato plants continue in the establishment of root system and vegetative growth, or growth of leaf tissue. Once the first flowers are visible, the plants have entered the flowering stage. Flowers are pollinated primarily by wind, and small green fruit begin to form. This is the flowering and fruit set stage. The next stage is sizing. The fruit are still green but are growing in size. Once the fruit are full size, they are known as mature green fruit. It is at this stage that the fruit become sensitive to Ethrel, which is a ripening agent used by processing tomato growers. Once the bottom of the fruit starts to show a slight orange colour, it is known as a breaker fruit, and the fruit has begun to ripen. Harvest is initiated for processing tomatoes once the majority of the fruit is fully ripe and red. For fresh market tomatoes, colour and ripeness will depend on the end market and could be anywhere from mature green to fully red and ripe (Figure 7–222). Fruit are harvested once or twice a week until temperatures drop and the crop is no longer productive.

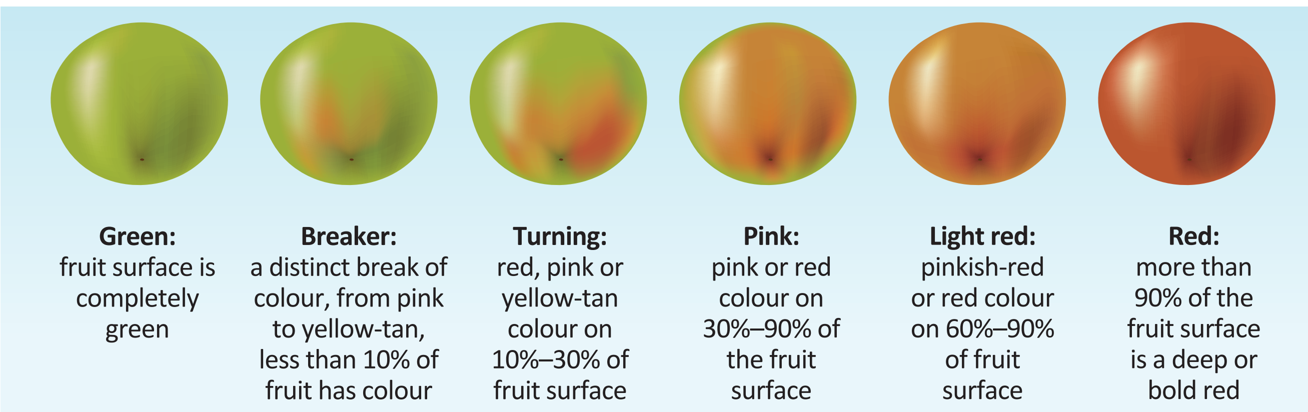


Figure 7–222. Tomato ripening stages.

Production Requirements

Soil types:	wide range of mineral soil types, but good drainage is essential
Soil pH:	6.0–6.8
Recommended rotational crops:	beans, brassica crops, cereal crops, corn, peas, soybean
Do not rotate with:	eggplant, peppers, potatoes, tobacco
Minimum soil temperature:	10°C (50°F)
Minimum air temperature:	10.5°C (51°F)
Earliest planting date:	early to late May

Transplanting and Spacing

In Ontario, tomatoes are grown from transplants. Sow approximately 85 g (3 oz) of seed to get 10,000 transplants. Table 7–144 shows spacing for both fresh-market and processing types of tomatoes. Machine harvest cultivars may be grown in twin or single rows, with or without raised beds, depending on the harvest equipment. The improved air circulation associated with single rows and staking plants in fresh-market production may help reduce foliage and fruit disease.

Table 7–144. Tomato Plant Spacing

	Row Spacing	In-Row Spacing
Fresh Market		
Large-vined (indeterminate)	1.5–1.8 m (5–6 ft)	50–70 cm (20–27 in.)
Small-vined (determinate and semi-determinate)	0.9–1.5 m (3–5 ft)	30–60 cm (12–24 in.)
Processing (Machine Harvest)		
Twin-row system[1]	45 cm (18 in.)	38–45 cm[2] (15–18 in.)
Single-row system	75 cm (30 in.)	38–45 cm[2] (15–18 in.)

[1] Plant on 1.5–1.65-m (5–5½-ft) bed centres.
[2] For small-vined, early-season processing cultivars, in-row spacing can be reduced to 33–38 cm (13–15 in.).

Fertility

Macronutrients

Nitrogen

Fresh-Market Tomatoes

For non-fertigated and fertigated fresh-market tomatoes, apply nitrogen according to Table 7–145. Avoid late side-dress applications, as they may prune the roots and trigger blossom-end rot.

Processing Tomatoes

The nitrogen rate will vary greatly, according to cultivar, soil type, crop rotation, organic matter and soil management. For tomatoes that are not fertigated, apply nitrogen as a preplant broadcast application according to the recommendations in Table 7–145.

For fertigated tomatoes, broadcast and incorporate the recommended preplant nitrogen. Apply the remainder of the nitrogen according to Table 7–145.

Table 7–145. Tomato Nitrogen Recommendations

Timing	Actual N
NON-FERTIGATED TOMATOES	
Fresh-Market Tomatoes	
Preplant	35–50 kg/ha 31–44 lb/acre
Side-dress (applied after the first fruit are set)	35–50 kg/ha 31–44 lb/acre
Total	**70–100 kg/ha (62–88 lb/acre)**
Processing Tomatoes – Hybrid	
Coarse sand and sandy loams: <2% organic matter	160–180 kg/ha (142–160 lb/acre)
Loams, silt loams and sandy loams: >2% organic matter	90–120 kg/ha (80–107 lb/acre)
Processing Tomatoes – Open-Pollinated	
Coarse sand and sandy loams: <2% organic matter	100–120 kg/ha (89–107 lb/acre)
Loams, silt loams and sandy loams: >2% organic matter	70–90 kg/ha (62–80 lb/acre)
FERTIGATED TOMATOES Do not exceed 300 kg/ha (267½ lb/acre) total nitrogen applied during the season.	
Fresh Market Tomatoes – on all soils **Processing Tomatoes – on all soils (except coarse-textured soils containing less than 3.2% organic matter)**	
Preplant (broadcast)	35–50 kg/ha (31–44 lb/acre)
Transplanting to fruit set	2.5 kg/ha/week (2 lb/acre/week)
Fruit sizing to harvest	5 kg/ha/week (4 lb/acre/week)
Harvest	2.5 kg/ha/week (2 lb/acre/week)
Processing Tomatoes – on coarse-textured soils containing less than 3.2% organic matter only	
Preplant (broadcast)	85–120 kg/ha (76–107 lb/acre)
Week 1–3 (transplant to first bloom)	no fertigation
Week 4 (beginning of fruit set)	20–25 kg/ha/week (18–22 lb/acre/week)
Week 5–7 (beginning of fruit sizing)	25–35 kg/ha/week (22–31 lb/acre/week)
Week 8–9	20–25 kg/ha/week (18–22 lb/acre/week)
Week 10	continue irrigation, no fertigation
Week 11 to harvest	no irrigation/ fertigation

Table 7–146. Tomato (Paste, Whole Pack and Fresh Market) Phosphorus Requirements

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Sodium Bicarbonate Phosphorus Soil Test (ppm)													
	0–3	4–5	6–7	8–9	10–12	13–15	16–20	21–25	26–30	31–40	41–50	51–60	61–80	81+
Phosphate (P_2O_5) required kg/ha (lb/acre)	230 (205) (HR)	230 (205) (HR)	220 (196) (HR)	220 (196) (HR)	210 (187) (HR)	190 (170) (HR)	170 (152) (HR)	140 (125) (MR)	110 (98) (MR)	80 (71) (MR)	50 (45) (MR)	30 (27) (LR)	0 (RR)	0 (NR)

Table 7–147. Tomato Potassium Requirements

For tomatoes grown on soils with magnesium tests of less than 100 ppm, decrease the recommended potash application rate to a minimum of 50% at a magnesium test of 50 ppm. For example, a soil testing 75 ppm magnesium should receive only 75% of the usual potash recommendation for that soil. On soils testing 50 ppm magnesium or less, apply 50% of the total potash recommendation.

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

	Ammonium Acetate Potassium Soil Test (ppm)											
	0–15	16–30	31–45	46–60	61–80	81–100	101–120	121–150	151–180	181–210	211–250	251+
Paste												
Potash (K_2O) required kg/ha (lb/acre)	230 (205) (HR)	220 (196) (HR)	200 (178) (HR)	180 (161) (HR)	140 (125) (HR)	100 (89) (HR)	70 (62) (MR)	50 (45) (MR)	40 (36) (MR)	0 (LR)	0 (RR)	0 (NR)
Fresh Market												
Potash (K_2O) required kg/ha (lb/acre)	660 (589) (HR)	640 (571) (HR)	600 (535) (HR)	560 (500) (HR)	480 (428) (HR)	400 (357) (HR)	340 (303) (MR)	300 (268) (MR)	280 (250) (MR)	140 (125) (MR)	70 (62) (MR)	0 (LR)

The nitrogen rate for fertigated processing tomatoes on coarse-textured soils with organic matter levels of 2.5%–3.2% is very specific to these soils. The supporting research was conducted near Harrow, on Granby sandy loam and Granby loamy sand soils. There is no research showing a benefit of this higher fertigation rate on other soil types. All other soils should use the alternative fertigation recommendation.

Cover crops planted immediately following the harvest of vegetable crops help manage residual soil nitrogen and nitrogen release from plant residue.

Phosphorus and Potassium

Test the soil to determine phosphorus and potassium requirements. See Table 7–146, Table 7–147 and Table 7–148.

Table 7–148. Fertigated Tomato Potassium Recommendations

Alternately, potassium can be applied 100% preplant, according to Table 7–147.

Timing	Actual K_20
Preplant	35–50 kg/ha (31–45 lb/acre)
Transplanting to fruit set	2.5 kg/ha/week (2 lb/acre/week)
Fruit sizing to harvest	5 kg/ha/week (4½ lb/acre/week)
Harvest (fresh market)	2.5 kg/ha/week (2 lb/acre/ week)

Table 7–149. Tomato Starter Solution Recommendations

Soil Temperature	Starter Concentration[1]
Below 18°C (64°F)	Use full label rate as recommended.
18°C–27°C (64°F–81°F)	Use half of recommended rate.
Above 27°C (81°F)	Starter not normally required.

[1] Under dry conditions or in sandy soils with less than 2% organic matter, use half the recommended rates.

Starter Solution (All Tomatoes)

Apply a high-phosphorus starter fertilizer in the transplant water when transplanting tomatoes. Starter fertilizer is especially important when planting in cool soils. Starter fertilizers are available in several forms, including liquids (e.g., 10-34-0 or 6-24-6), soluble or granular materials (e.g., 10-30-20 or 10-52-10). Apply according to the recommendations in Table 7–149.

Micronutrients

Magnesium

A magnesium deficiency may occur on tomatoes. The usual symptoms are yellowing of older leaves while the veins remain dark green. Excessive potash applications may induce a magnesium deficiency. Reduce potassium fertilizer rates on soils testing less than 100 ppm magnesium. Adjust the potassium rate proportionally to a minimum of 50% at 50 ppm Mg. See *Micronutrients*, Chapter 1, for more information.

Plant Tissue Analysis

When used in conjunction with soil analysis, plant tissue analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. Plant tissue analysis does not replace soil testing or a sound soil fertility program. For more information, see Table 7–150.

Table 7–150. Tomato Nutrient Ranges
Sample taken from most recently mature leaf.

Time of Sampling	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu	Mo
	Per Cent (%)						Parts per Million (ppm)					
5-leaf stage	3–5	0.3–0.6	3–5	1–2	0.3–0.5	0.3–0.8	40–100	30–100	25–40	20–40	5–15	0.2–0.6
First flower	2.8–4	0.2–0.4	2.5–4	1–2	0.3–0.5	0.3–0.8	40–100	30–100	25–40	20–40	5–15	0.2–0.6
Early fruit set	2.5–4	0.2–0.4	2.5–4	1–2	0.25–0.5	0.3–0.6	40–100	30–100	20–40	20–40	5–10	0.2–0.6
First ripe fruit	2–3.5	0.2–0.4	2–4	1–2	0.25–0.5	0.3–0.6	40–100	30–100	20–40	20–40	5–10	0.2–0.6
During harvest period	2–3	0.2–0.4	1.5–2.5	1–2	0.25–0.5	0.3–0.6	40–100	30–100	20–40	20–40	5–10	0.2–0.6

Adapted from G. Hochmuth, et al. 2018. *Plant Tissue Analysis and Interpretation for Vegetable Crops in Florida.* University of Florida IFASExtension. HS964.

Irrigation

Note: You must have a Permit to Take Water issued by the Ministry of the Environment to use more than 50,000 L (13,209 gal) of water in a day from either surface or groundwater sources.

Most vegetable crops require a uniform supply of moisture throughout the growing season. The average rainfall in Ontario is 70 mm/month (2¾ in./month) during the growing season. For most vegetable crops, this provides only 65% of the water needed for optimum yield. Historically, moisture levels are often at their lowest in July and August when the crop water demand is at its highest.

Common defects caused by moisture stress in tomato crops include blossom end rot, growth cracks and fruit deformities.

For tomatoes, the most critical period for irrigation is during flowering, fruit set and sizing. There are a number of types of irrigation systems that have been adapted for use in vegetable crops. They include hand-moved sprinklers, travelling gun systems, centre-pivot and lateral systems, and drip (trickle) irrigation. Whichever type of irrigation system is used, it is important to schedule irrigation to avoid drought stress and provide water when it is most needed. Timely application of water will reduce the potential for nutrient loss or disease pressure due to excess water. There are two basic methods of scheduling irrigation: the water budget method and measuring soil moisture.

For more detailed information on irrigation, see:

- *Best Management Practices — Water Management*
- *Best Management Practices — Irrigation Management*
- OMAFRA Factsheet, *Irrigation Scheduling for Tomatoes — Water Budget Approach*
- OMAFRA Factsheet, *Monitoring Soil Moisture to Improve Irrigation Decisions*
- OMAFRA Factsheet, *How to Prepare for Irrigation During Water Shortages*

Fertigation

Fertigation is a method of applying water and nutrients through a drip irrigation system. It can be used to increase the yield and quality of many vegetable crops.

Dissolve a stock solution of soluble fertilizer in a tank and introduce it through a valve into the irrigation system either by suction or pressure. Feed the fertilizer solution through the system slowly. After the fertilizer has passed through the system, continue to irrigate to flush the lines. Do not apply phosphorus through the drip tape. Certain forms of phosphorus will clog the drip emitters. Phosphorous fertilizers encourage the growth of algae in the drip lines. Algae may also cause emitters to plug.

Fertigation applications are usually made weekly. However, depending on the design of the irrigation system, the soil type and time constraints, applications may be made more or less frequently. It is important that the irrigation cycle is run for ample time to adequately flush the system after each fertigation. Avoid over-watering after fertigation. Excess water has the potential to leach the fertilizer below the crop rooting zone.

Harvest

Harvest Indicators

Tomatoes reach maturity within 60–90 days after transplant.

Tomatoes are a climacteric plant. Mature fruit are able to produce ethylene and ripen fully off the plant. To determine if a tomato has reached the mature green stage, cut the fruit with a sharp knife. In mature fruit, the contents of the locules turn to a gel and the seeds are not cut, but shift out of the way of the knife. In immature fruit, the gel has not formed, and the seeds will be cut. Ripeness at harvest will depend on the market needs at the time. Expected yields for processing and fresh market tomatoes can be found in Table 7–151.

Table 7–151. Average Yields for Ontario Field Tomatoes

Crop	Yield	Standard Container
Tomatoes (cherry)	5.5–8 tonnes/ha (2½–3½ tons/acre) 8,600–9,800 boxes/ha (3,500–4,000 boxes/acre)	quart box
Tomatoes (fresh market)	22–31 tonnes/ha (10–14 tons/acre) 2,800 boxes/ha (1,100 boxes/acre)	20-lb box
Tomatoes (processing)	89–112 tonnes/ha 40–50 tons/acre)	n/a

Harvest Duration

Tomato harvest typically starts around the beginning of August and runs through to late September or the first frost, depending on the planting dates, season, market and cultivars grown. Growers using season extension techniques may be able to advance harvest and extend harvest beyond these dates. Fresh market harvest is multi-pick, while processing crops are harvested once-over by machine.

After harvest is completed, seed a cover crop to protect soil and reduce erosion. In addition, the cover crop will absorb and tie up left-over nitrogen fertilizer, reducing leaching.

Post-Harvest

Some packing lines use a wet-dump to unload tomatoes from the field bins. When tomatoes are immersed in water, it is critical that a labelled sanitizing agent is used and maintained at the effective concentration. For some sanitizers, such as chlorine, water pH must be maintained within a certain range. The water must also be kept at a temperature about 5°C (41°F) warmer than the fruit internal temperature to avoid infiltration of water — and potentially microorganisms — into the stem scar. For the same reason, tomato fruit should never be immersed for more than 2 minutes or immersed too deeply in the water. Tomatoes should not accumulate to more than a layer deep in the tank or flume. As soil, crop debris and microorganisms accumulate in the water, it will be necessary to drain and clean the tank regularly, and refill with potable water. Organic matter in the water can also deactivate the sanitizer. After sanitizer use, equipment needs to be rinsed to prevent corrosion or reaction with incompatible chemicals (e.g., chlorine and quaternary ammonium).

Ensure that sanitizers remain at effective levels throughout the day. When using chlorine, maintain the dump tank water at 150–200 ppm free chlorine at a pH of 6.5–7.5. Continual monitoring is necessary. Follow label instructions for all sanitizers to ensure effectiveness.

Storage

Rapid and efficient cooling is the most effective management practice for maintaining the quality and shelf-life of fresh tomatoes. It is essential that only good quality produce is placed in cold storage. Room cooling and forced-air cooling are the most common methods used for tomato fruit.

Room Cooling

Containers of produce are placed into a refrigerated room and cold air from the evaporator coils slowly cools the product. It takes considerable time to cool produce to acceptable storage temperatures. The cold air does not always penetrate deep within the container. Highly perishable produce may suffer significant quality loss and hence shelf life.

Forced-Air Cooling

Vegetables are placed in a refrigerated room, and cold air is pulled through the containers using high-capacity fans. An effectively designed system allows good contact between the cold air and the produce. Forced-air cooling is not as rapid as hydro-cooling. However, it is adaptable to more types of produce and more flexible for smaller-scale operations. Forced-air cooling should be done quickly so produce does not lose too much moisture.

Mature-green fresh-market tomatoes may be stored for 1–3 weeks at 13°C (55°F) but kept at 18°C–21°C (64°F–70°F) for ripening. Store firm, ripe tomatoes at 8°C–10°C (46°F–50°F) for no more than 4–7 days. Maintain storage at a relative humidity of 90%–95%.

Pest Management and Disorders

See Figure 7–221. *Tomato stages of development and pest activity calendar.*

Diseases

Anthracnose

Colletotrichum coccodes*, *C. gloeosporioides*, *C. dematium

Identification: Leaf lesions are inconspicuous. Fruit symptoms on tomato appear as small, sunken, water-soaked, circular spots. Lesions gradually expand to 20 mm (¾ in.) in diameter, developing a pattern of concentric rings. The lesions darken, and small black fungal structures appear in the centre. Salmon-coloured mucus-containing spores may be visible on the lesion surface when conditions are humid.

Biology: *Colletotrichum* spp. overwinter in infected plant debris. It can also survive in the soil for a short time. Many common weeds and some crops are symptomless hosts. Anthracnose is also seed-borne. Once leaf or fruit lesions are present, they act as inoculum for more infections.

Infections take place under a wide range of temperatures from 10°C–30°C (50°F–86°F). Rapid development occurs during periods of prolonged leaf wetness. On tomato, while symptoms appear only on ripe fruit, infection can be initiated on green fruit.

Management Notes: Follow a minimum 3-year rotation with non-solanaceous crops. Control weeds that act as hosts. Use disease-free or treated seed.

Fungicide programs must begin before fruit infection occurs — well before the onset of symptoms. Where available, use the TOMcast program for scheduling fungicide applications (see *Disease Prediction Models*, Chapter 4). Properly timed fungicide sprays are effective at reducing losses to this disease. If unavailable, begin a preventive spray program when the first fruits are about walnut size.

There is little tolerance for anthracnose in processing tomato crops, where fruit must be held in the field and the taste of the product can be affected.

Bacterial Canker

Clavibacter michiganensis* subsp. *michiganensis

Identification: Early (systemic) infections from infected seed or seedlings are most severe, though they do not commonly occur in Ontario. They cause the plant to wilt, often on only one side. Streaking or open cankers may appear on the stems, accompanied by a light reddish-brown discolouration in the vascular tissue, just above the soil line.

Secondary infections (not involving the vascular system) are more common and less severe. They show up later in the season. Leaves develop brown-to-black margins with a thin, yellow border. Leaflet edges usually curl upwards. Infected fruit may develop "bird's-eye" spots: small lesions with a light brown centre and a greasy white halo (Figure 7–223).

Figure 7–223. Secondary bacterial canker lesions on tomato fruit.

Biology: Infected seed is probably the major source for systemic infections. Pruning or transplant clipping operations can also introduce the bacteria directly into the vascular system, producing a systemic infection.

The canker bacteria enter the plant through natural openings and wounds, including root wounds. Infected crop debris, weeds, volunteer tomatoes and contaminated equipment also act as sources of infection. Infections spread through splashing water, especially during storms. In the field, machinery or worker transmission is probably not as significant as in the transplant greenhouse where plant density is high and conditions for the bacterium are optimal.

TOMATOES

Infections occur from plant emergence through to harvest. Warm, wet weather conditions with temperatures of 24°C–32°C (75°F–89°F) favour the spread of this disease.

Management Notes: Use disease-free or disinfected seed and disease-free transplants. Copper fungicides may slow development of the disease; start applications during transplant production. Experience has shown that if a bacterial disease outbreak can be delayed until after the main fruit set, the crop will be minimally affected.

Bacterial Soft Rot

Pectobacterium carotovorum subsp. *carotovorum* (formerly known as *Erwinia carotovora*)

Identification: Sunken water-soaked lesions develop around damaged areas on the tomato fruit. The water-soaked areas expand rapidly. Bacterial ooze may develop, and secondary organisms may invade. The entire fruit may deteriorate to a watery soft slimy mass that is kept intact by the thin outer skin.

Biology: Bacterial soft rot causes serious losses in the field, in transit and in storage. Insect damage, mechanical damage or hail predispose plants to soft-rot infection. Soft rot spreads rapidly in warm, humid conditions. It is spread by direct contact, hands, tools, soil, water, insects and splashing rain or irrigation.

The soft-rot bacteria overwinter in infected tissues, in the soil and on contaminated equipment and containers.

Warm, moist weather is favourable for infection by the bacterial soft-rot pathogens.

Management Notes: Plant into well-drained soils and maximize air flow through the plant canopy. Once the disease is identified in a field, avoid overhead irrigation. Rotate with less-susceptible crops (cereals or corn) and control chewing insects. Excess nitrogen may promote soft-rot infections.

Post-harvest infections may occur if water used during post-harvest operations is not treated to kill pathogens, especially if the fruit imbibe the water. In dump-tanks, maintain water temperature at 5°C (41°F) above fruit temperature and do not immerse fruit for more than 3 minutes, to reduce the risk of water entering the fruit. Dry stem scars are more resistant to water imbibation post-harvest. Fruit harvested in wet conditions have a higher risk of post-harvest infection.

Bacterial Speck

Pseudomonas syringae pv. *tomato*

Identification: On leaves, symptoms appear as small dark brown to black specks, less than 2 mm (⅛ in.) in diameter, sometimes surrounded by a yellow halo. Lesions are also typically observed on leaf tips where moisture accumulates (Figure 7–224).

Figure 7–224. Bacterial speck lesions on tomato foliage.

These lesions sometimes cause distortion of the leaf. Severely infected seedlings may become stunted.

Only green fruit less than 3 cm (1⅛ in.) in diameter are susceptible to infection by the bacterial speck pathogen. Small (<1–3 mm (<⅛ in.)), slightly raised, black specks develop. Lesions on the fruit are usually superficial and can be scraped off with some effort. Lesions also occur on stems and flower buds. Severe infections may cause defoliation.

Biology: Major sources of infection for these bacteria are thought to be seed and infected crop debris. Bacteria enter the plant through natural openings or wounds caused by insect feeding, wind-driven soil, handling, pruning, wind whipping, high pressure sprayers and cultivators.

The primary mode of spread is probably by splashing water, especially during storms. In the field, spread by equipment or workers is of lesser importance than it is in the transplant greenhouse, unless wounding is occurring.

TOMATOES

The bacterial speck pathogen is favoured by temperatures in the range of 18°C–24°C (64°F–75°F). Abundant rainfall and high humidity aid infection. The organism is inhibited when average daily temperatures exceed 21°C (70°F).

Management Notes: All tomato seed should be disinfected by the supplier, using acid or chlorine treatment. Do not plant diseased transplants. Bacterial speck populations in Ontario show resistance to copper.

Fruit lesions, which have a major impact on marketable yield, can only be initiated on young green fruit, so control measures initiated prior to fruiting are most beneficial.

Clean and sanitize machinery after working in affected fields. If possible, schedule overhead irrigation early in the day to allow the foliage time to dry before nightfall or consider a drip irrigation system. Avoid working in the fields when the foliage is wet.

Bacterial Spot

Xanthomonas gardneri, X. perforans

Identification: The bacterial spot pathogen may produce lesions on all above-ground parts of the plant: leaves, stems, flowers and fruit. Initial leaf symptoms are small, circular, dark lesions that may be surrounded by a yellow halo. The lesions often concentrate on the leaf edges and tips, where moisture accumulates. They may increase in size to a diameter of 3–5 mm (⅛–¼ in.). Foliar symptoms cannot easily be distinguished from bacterial speck. When severe, foliage turns yellow and eventually dies, leading to defoliation of the lower portion of the plant. Lesions on pedicels may cause flower abortion, resulting in lost yield and split fruit sets.

Fruit lesions are initiated only on green fruit. The first symptoms are small, dark, raised spots. The lesions also may have a white halo, initially similar to bacterial canker fruit lesions. As the fruit ages, the white halos disappear. Bacterial spot lesions may increase in size to 4–6 mm (approximately ¼ in.) in diameter and become greasy-looking and sometimes scabby and cracked (Figure 7–225).

Figure 7–225. Bacterial spot lesions on tomato fruit.

Biology: *Xanthomonas* spp. are not known to overwinter in Ontario. Other sources of infection and methods of spread are similar to bacterial speck (see *Bacterial Speck*, also in *Tomatoes*).

Bacterial spot thrives under warm temperatures of 24°C–30°C (75°F–86°F). Abundant rainfall and high humidity aid infection. The time for concern is from transplanting through to early flowering and fruit set.

Management Notes: Management is similar to that for bacterial speck. Bacterial spot populations in Ontario show resistance to copper.

Botrytis Grey Mould

Botrytis cinerea

Identification: Main symptoms of grey mould are ghost spots on the fruit. Ghost spots show a pale halo or ring with a brown-to-black pinpoint spot in the centre. Fruit rotting occasionally occurs. A grey, velvety covering of spores may also appear on leaves, stems, dying flowers or fruit. Infection appears first on leaves in contact with soil, damaged leaves or flowers. Infection on stems may girdle the plant.

This pathogen also affects transplants (see *Damping-Off*, Chapter 6, for more information).

Biology: The pathogen responsible for grey mould has a wide host range. It is spread by wind and also grows on organic matter in or on the soil. It generally needs a wound or dead tissue to begin an infection into live tissue. Also, more tender tissues, such as blossoms, are more susceptible to grey mould infections.

Periods of prolonged high humidity and cool weather (18°C–24°C (64°F–75°F)) promote grey mould activity.

Management Notes: In most vegetable crops, this disease is sporadic, and control measures are rarely required. Some registered fungicides have activity on this pathogen, but it can be difficult to get adequate coverage of the lower leaves, where infection first occurs.

Buckeye Rot (Phytophthora Blight)
Phytophthora spp. (excluding *P. infestans*)

Identification: Buckeye rot occurs primarily on immature green fruit that are in contact with the soil. It produces grey-to-dark brown concentric rings, but the surface of the fruit remains smooth. Under wet conditions, sporulation may occur on the fruit as well (Figure 7–226).

Figure 7–226. Grey-brown buckeye rot lesion with concentric rings on tomato fruit.

Leaf and stem lesions can occur but are not as common as fruit symptoms. Lesions are nondescript, dark brown and usually accompanied by fruit lesions. See *Phytophthora Crown and Root Rot*, also in *Tomatoes*.

Biology: Phytophthora survives between crops as a thick-walled oospore in the soil or as mycelium on crop residue. The oospores can survive in the soil for 5–10 years. Under intensive solanaceous and cucurbit production systems with short crop rotations, the levels of inoculum build up over time, potentially becoming a significant production problem.

Spores are spread long distances by air and splashing water. Under saturated conditions, zoospores are released. They are mobile and can move on the plant surface and in the soil water. They are also attracted towards the root exudates of host crops. Irrigation water may also be a source of zoospores.

Management Notes: *Phytophthora capsici* is becoming more common in certain areas of Ontario. Once established in a field, *P. capsici* is extremely difficult to control. Prevention is critically important.

Rotate fields for a minimum of 3 years away from all host crops. Do not plant tomatoes, peppers or cucurbits in a field that has a history of *P. capsici* infections. Some beans can also host *P. capsici*. Select well-drained fields. Where drainage problems do exist, use a grassed waterway to divert surface water away from the crop.

Minimize soil compaction and avoid excessive irrigation, especially in overhead systems. Always clean and sanitize farm equipment if travelling between infected and non-infected fields to prevent the movement of contaminated soil. Irrigation water can also be a source of infection, especially surface water, and should be tested to determine if it contains *P. capsici*.

Raised beds and the use of plastic mulch significantly reduce *P. capsici* infections. Beds must be dome-shaped, to prevent water collecting at the base of the plant. Ensure that the planter does not leave a depression at the base of the plants.

Collar Rots

See Chapter 6.

Damping Off and Root Rots

See Chapter 6.

Early Blight (Alternaria, Black Mould)
Alternaria solani, *Alternaria tomatophila*

Identification: The first signs of disease often appear on older foliage, deep in the canopy where the leaves stay wet. Lesions often start small and can be confused with bacterial spot or speck. Foliar lesions first appear as dark spots, 8–13 mm (¼–½ in.) in size. The lesions are circular to angular with dark concentric rings (target spot) and enlarge over time. They are usually limited by large veins and surrounded by a narrow light green-to-yellow halo (Figure 7–227).

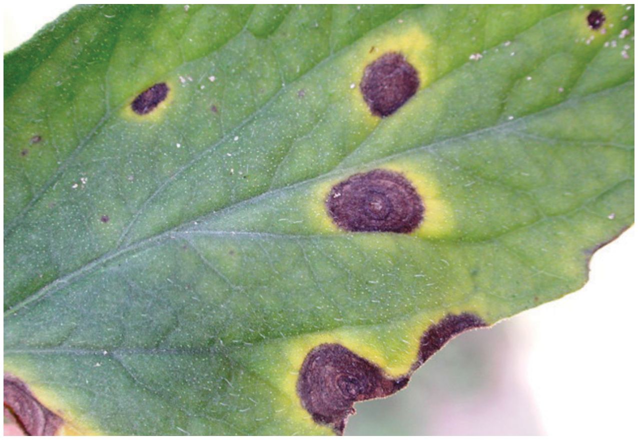


Figure 7–227. Early blight lesions with concentric rings on tomato foliage.

In severe infections, the foliage is completely covered by lesions and dries up. Lesions may also appear on stems and blossoms (a cause of blossom drop in tomatoes).

Tomato fruit infection is uncommon, showing up as a leathery or blackened area, similar in appearance to blossom-end rot, but at the stem end of the fruit. Fruit symptoms are most common late in the season, especially when extended wet periods occur at harvest. Overripe tomato fruit may develop black mould, caused by another species, *Alternaria alternata*. Symptoms can range from small, dark blotches to large sunken areas. In hot, humid weather, the lesions develop the soft, velvety, black fungal growth that gives the disease its name.

Biology: Fungal structures overwinter in the field in crop residue, on infected seed and on weed hosts such as hairy nightshade.

Infections occur under warm temperature conditions (20°C–30°C (68°F–86°F)) and periods of prolonged leaf wetness due to wet weather or heavy dewfall. Spores are spread primarily by wind and splashing water. As a result, the disease progresses rapidly during periods of alternating wet and dry weather.

Management Notes: Management of early blight requires an integrated program of cultural and chemical practices to minimize sources of inoculum and crop stress.

Reduce early blight inoculum by following a 3–4-year crop rotation. Ensure transplants are healthy and free of disease. Tomato cultivars vary in tolerance to early blight. Overhead irrigation can promote foliar fungal disease due to longer periods of leaf wetness.

The TOMcast program is available in some growing areas to help field tomato growers determine the optimum time to apply foliar fungicides for the control of early blight, septoria leaf spot and anthracnose. See the section, *Disease Prediction Models*, Chapter 4. If unavailable, begin a preventive spray program when the first fruits are about walnut size.

For processing tomatoes, harvest scheduling to avoid holding overripe fruit in the field will reduce fruit problems with black mould. A high incidence of blossom-end rot provides an increased opportunity for mould growth.

Late Blight
Phytophthora infestans

Late blight is one of the most devastating diseases of tomatoes. If left uncontrolled and weather conditions favour disease development, it can devastate a field in 7 days.

Identification: Initial leaf symptoms are pale green-to-brown water-soaked spots that enlarge rapidly and become brown-to-purplish-black with a greasy appearance. A pale yellow or green halo may surround the leaf lesions. Under conditions of high humidity, a grey-to-white mouldy growth develops on the underside of the leaf lesion (Figure 7–228).

Figure 7–228. Greasy, grey-brown late blight lesions on tomato foliage.

Grey-brown lesions may appear on leaf petioles and stems. The stem lesions may quickly girdle the stem and kill it. Under favourable conditions, the pathogen can blight the foliage so quickly, that it appears the plants were hit by frost. Fruit lesions appear as firm greyish-green-to-brown, rough, irregular-shaped blotches, which rapidly enlarge. The texture of the lesions is comparable to that of an orange peel (Figure 7–229).

Figure 7–229. Grey-brown, bumpy lesions on tomato fruit caused by late blight.

Biology: Late blight is caused by the oomycete, *Phytophthora infestans*. Spores are produced from 10°C–27°C (50°F–81°F). It grows most actively from 18°C–21°C (64°F–70°F) and a relative humidity of 90%. A minimum of 8 hours of leaf wetness is required for the spores to germinate and penetrate the plant tissue. After infection takes place, late blight symptoms develop in 3–5 days.

Late blight survives only on living plant material (e.g., cull piles after harvest). The pathogen produces spores on the lesions of infected plants at any time during the growing season. The spores are splashed by rain to neighbouring healthy plants or by wind to other areas of the field. Spores can travel great distances by wind.

Late blight has two mating types (A1 and A2). If both become established in an area, they can mate and produce thick-walled spores (oospores) that can overwinter in the soil without a living host. In Ontario, oospores have not been detected. Numerous late blight strains exist, and new strains emerge over time. Different strains of *P. infestans* are sensitive to different fungicides and can also vary in how virulent they are on tomato. See Table 7–152.

Table 7–152. Late Blight Strains and Host Ranges

Strain	Mating Type	Optimum Temperature for Growth	Host Range
US-8	A2	18°C–24°C (64°F–75°F)	More virulent on potato.
US-22	A2	24°C (75°F)	Can infect tomato and potato; could not infect foliage of single cultivar of tomatillo, eggplant, pepper, ground cherry; could infect foliage of hairy, black and bittersweet nightshade (limited sporulation).
US-23	A1	18°C (64°F)	Virulent on tomato and potato (most common strain in Ontario in recent years).
US-24	A1	20°C (68°F)	More virulent on potato.

Scouting: There is no tolerance for this disease, as it is easily spread by wind and can rapidly destroy the crop. Begin scouting for late blight in mid-to-late June. Monitor fields closely, at least twice a week, to detect late blight at its early stages. Pay special attention to low pockets and other areas that may experience prolonged periods of high humidity. Be sure to look for late blight in the lower portions of the plant, where the foliage stays wet longer and the disease is most likely to begin. Scouting for late blight symptoms is best on foggy mornings with heavy dew.

Management Notes: Some preventive fungicide sprays for early blight, septoria and anthracnose also offer some protection against late blight in tomatoes. If the disease is present in the area, follow a 5–7-day fungicide schedule, using fungicides recommended specifically for late blight control in tomatoes. For in-season updates on late blight in tomatoes in Ontario and neighbouring regions, visit ONvegetables.com.

Immediately remove affected plant tissue as soon as it is identified in a field. If possible, wait until leaves are dry so there will be fewer spores dispersed. Dispose of infected plant tissue either in plastic garbage bags, tillage, burial, or pile the residue and cover it with a tarp (heat will build up under tarp to kill the plant tissue and pathogen).

Hose down all farm equipment after leaving an infected field. Farm equipment carrying contaminated plant material can spread the pathogen to healthy fields. Continue intensive scouting and remove any plants that develop symptoms.

Solanaceous weeds such as hairy, black and bittersweet nightshade are also attacked by late blight. Mild infections of eggplant, pepper and ornamental hybrid petunia have been reported.

It is important to monitor the strains that might occur in Ontario. Please report late blight occurrences to OMAFRA so that samples can be collected and disease progress tracked.

Leaf Mould

Passalora fulva

Identification: Leaf mould is rarely seen in field tomatoes but is fairly common when the crop is grown under tunnels. Starting with older leaves, pale green-to-yellowish spots develop on the upper leaf surface. On the underside of the leaves, an olive-green-to-grey mould develops. These symptoms eventually cover most of the leaf. Leaves wither, curl and eventually drop. The pathogen also infects stems, blossoms and fruit.

Biology: The fungal structures of this pathogen survive for at least a year without a living host. The fungus also survives on crop residue and in infected seed.

Management Notes: High humidity and long periods of leaf wetness promote disease development under a wide range of temperatures. Maintain good air circulation in tunnels. Remove and destroy crop residue after harvest.

Nematodes

See Chapter 6.

Phytophthora Crown and Root Rot

Phytophthora capsici

Identification: Primary infections of *Phythophthora capsici* are characterized by dark brown stem lesions at the soil surface that can extend up the tomato stem. When the stem is cut lengthwise, dark brown vascular tissue starting at the root ball and extended up can be seen. Plants often wilt, and leaves may turn a pale-green-to-yellow before the plant completely collapses. These infections are usually accompanied by fruit lesions as well (see *Buckeye Rot (Phytophthora Blight)*, also in *Tomatoes*).

Biology: See *Buckeye Rot (Phytophthora Blight)* for more information on the biology of *Phythophthora capsici*.

Management Notes: See *Buckeye Rot (Phytophthora Blight)* for management and control strategies.

Powdery Mildew

Leveillula taurica, *Oidium neolycopersici*

Powdery mildew is usually found on the upper surface of tomatoes leaves. Symptoms are usually found on lower, older leaves first. See Chapter 6, for more information.

Septoria Leaf Spot

Septoria lycopersici

Identification: Small, water-soaked, circular spots first occur on the underside of older leaves. They develop into small, dark, circular lesions that may eventually expand to 5–6 mm (¼ in.) in diameter. Spots are generally grey or tan with a dark brown margin and a narrow yellow halo. Within the lesions, small, black, pinhead-sized fungal structures appear. These structures (pycnidia) help to distinguish the lesions from early blight and are visible with a dissecting microscope or hand lens.

The disease spreads from the lower leaves and stems to the younger leaves. The first signs of disease are often seen deep in the canopy where leaves stay wet for long periods. Septoria leaf spot causes less yellowing of the foliage than early blight. It can quickly defoliate the plant in severe cases.

Biology: The fungus survives in infected residue of crop and weed hosts. Splashing water moves the spores from the crop debris to the foliage or from existing lesions to new infection sites.

Septoria is common and can occur at any stage of plant development; however, plants are most susceptible after fruit set. Infection can occur from 15°C–27°C (59°F–81°F), but temperatures of 20°C–25°C (68°F–77°F) and extended periods of leaf wetness caused by overhead irrigation, rain or heavy dews are optimal conditions.

Management Notes: Ensure disease-free seed and transplants. Rotate crops and control solanaceous weeds, such as nightshade.

The TOMcast program is available in some growing areas to help field tomato growers determine the optimum time to apply foliar fungicides for the control of early blight, septoria leaf spot and anthracnose. See *Disease Prediction Models*, Chapter 4. If this is unavailable, begin a preventive spray program when the first fruits are about walnut size.

Verticillium Wilt

Verticillium albo-atrum, V. dahliae

Identification: The first symptom of verticillium wilt in tomatoes is yellowing of the leaves, possibly followed by wilting (especially during the heat of the day, with recovery at night). Yellow leaf lesions, extending between veins out to the leaf edge, develop initially on the lower leaves. The lesions often have a characteristic V-shape (Figure 7–230).

Tissue within the lesions may die, but this is typically surrounded by an irregular yellow area.

Figure 7–230. Typical V-shaped lesion of verticillium wilt on tomato.

Surrounding leaves may show yellowing, initially without the browning. This helps distinguish the disease from early blight. Symptoms often appear on one side of the plant or one side of the leaf. When sliced lengthwise, the vascular tissue of the main stem will be brown, especially at the soil line.

Biology: The fungal inoculum survives in the soil and on debris from host plants. Many crop species are hosts, including potatoes, peppers, eggplant, strawberries, raspberries, beets, cucurbits, some crucifers and alfalfa. Weed species such as ragweed, lamb's-quarters, pigweed, velvetleaf and solanaceous weeds are also hosts.

Symptoms are often more severe after fruit set or during dry periods. The presence of plant parasitic nematodes increases the severity of the disease.

Management Notes: Follow a 4–6-year crop rotation. Do not rotate with other host crops. Cereals and grasses are non-hosts. Keep fields clean of host weeds, such as nightshades.

Tomato cultivars with resistance to verticillium wilt are available. Take soil samples to test for verticillium and nematodes. Soil fumigation may be required if verticillium and nematode counts are high. The best times to sample are in May to June and September to October. Try to sample at the same time of year each time, using the same laboratory, so that you can compare the counts from year to year. Counts will be lower in the spring than in the fall. The established thresholds are based on spring sampling.

Table 7–153. Most Common Viruses Found on Tomato

Virus	Host(s)	Mode of Transmission
Pepino mosaic virus (PepMV)	Primarily solanaceous plants (tomato, pepper, eggplant, potato).	Seed-borne. Virus can remain in crop debris. Infected plants serve as reservoirs for the virus. Mechanically transmitted.
Tobacco mosaic virus (TMV)	Over 150 host plants, including most vegetables.	Seed-borne. Virus can remain in crop debris. Infected plants serve as reservoirs for the virus. Mechanically transmitted.
Tobacco ring spot virus (TRSV)	Over 20 plant families, including most fruiting vegetable.	Seed-borne and pollen-borne. Transmitted by aphids, mites and the dagger nematode.
Tomato brown rugose fruit virus (ToBRFV)	Tomato, pepper, eggplant, some weed species (rapidly growing list of host plants).	Seed-borne. Virus can remain in crop debris. Infected plants serve as reservoirs for the virus. Mechanically transmitted. Can survive on surfaces for up to 1 month.
Tomato mosaic virus (ToMV)	Over 150 host plants, including most vegetables.	Seed-borne. Virus can remain in crop debris. Infected plants serve as reservoirs for the virus. Mechanically transmitted.
Tomato spotted wilt virus (TSWV)	Over 900 host plants. Most vegetable crops and many weeds.	Transmitted by thrips.

Viruses

Viruses are not commonly observed in field-grown tomatoes. Common symptoms include leaf distortion, leaf mottling and stunted growth. It is important to be aware of viruses and to get affected plants tested quickly. Quick and easy test strips are available for some viruses and can be conducted on farm. See Table 7–153 and Chapter 6 for more information.

White Mould
Sclerotinia sclerotiorum

Identification: In tomatoes, water-soaking or “melt-out” of the foliage is the first symptom of white mould, followed by bleached stems. When the stem is cut lengthwise, white fungal growth can be seen inside along with hard, black sclerotia. Fluffy, white fungal growth can be seen in the advanced stages on the outside of the stem.

Biology: *S. sclerotiorum* overwinters in the soil as small, black sclerotia. Temperatures ranging from 20°C–25°C (68°F–77°F) and continuous leaf wetness (high humidity and/or heavy dews) favour sclerotinia white mould development. Overwintering sclerotia may survive for several years in the soil.

Management Notes: Practice a 3–4-year crop rotation away from host crops (solanaceous species, brassica crops, cucurbits, edible beans, soybeans, carrots and lettuce). Avoid applying high rates of nitrogen fertilizer. Excess nitrogen promotes an exceptionally dense crop canopy, resulting in restricted air movement and more favourable disease development conditions.

Insects

Aphids
Aphididae family

Aphids are a common pest in many crops and are often found feeding on young leaves, though they seldom cause economic damage. Feeding damage can cause leaf distortion and the production of sticky honeydew promotes the growth of sooty mould on leaves. See Chapter 5 for more information.

Brown Marmorated Stink Bug (BMSB)
Halyomorpha halys

Brown marmorated stink bug (BMSB) is a new pest to Ontario. It has the potential to damage a wide variety of agricultural crops but has not yet caused economic damage to tomatoes. See Chapter 5 for more information.

Cabbage Looper

See *Brassica Crops*, in this chapter.

Colorado Potato Beetle (CPB)
Leptinotarsa decemlineata

Identification: Adult beetles are somewhat rounded. They are approximately 10 mm (⅜ in) long and 7 mm (¼ in.) wide. The wing covers are yellow-cream with 10 black, lengthwise stripes.

Figure 7–231. Colorado potato beetle larva feeding on tomato leaf.

Eggs are yellow-to-orange, elongated and cylindrical. Egg masses contain 25–40 individual eggs. They are usually laid on the underside of the leaves. Recently laid eggs are bright yellow, turning dark orange close to hatching time.

Larvae are orange-red with a distinct black head and a humped back. They have two rows of black spots on both sides of their bodies. Larvae range in size from 2–12 mm (1⁄16–½ in.) long (Figure 7–231).

Damage: Beetles and larvae feed primarily on the foliage. They chew irregular holes in and along leaf margins. When no leaves are left, beetles eat pieces of stems or tomato fruit. Crops are most susceptible to yield losses during the transplant stage.

Biology: Adult potato beetles overwinter in the soil of the previous year's host crops or in protected areas surrounding these fields. The first generation of adult beetles start emerging in early May. Emergence occurs over a period of 4–6 weeks. The specific timing of the beetle emergence depends on the area and weather conditions.

Immediately after emergence, most beetles walk to the crop. A few are able to fly longer distances to a host field. Signs of infestation and feeding damage first appear along the edges of fields close to the overwintering sites.

Mating and egg-laying occur shortly after emergence. Females may lay as many as 400 eggs over 4–5 weeks. Eggs hatch into larvae in 4–9 days. The larvae pass through 4 stages (instars), reaching maturity in 10–20 days. The second generation of adults usually emerges in July. In very hot summers, a partial third generation may develop.

Scouting and Thresholds: In tomatoes, the threshold 0.5 adults or larvae per plant in the first 2 weeks after transplanting, or 1 adult or larvae per plant later in the season.

Management Notes: Crop rotation away from host crops, such as potato and eggplant, is very effective in reducing the first generation of CPB. If high populations are expected, apply an in-furrow insecticide at planting. Scout the field for CPB even if a systemic insecticide was used at planting.

This insect has developed resistance to most of the insecticides registered for its control. To determine the efficacy of an insecticide, flag any potential hot spots and assess these areas for beetle mortality as soon as the field re-entry interval has passed. Consider using spray tests or dip tests to determine the most effective insecticides against a population of beetles. For more information on dip tests, visit the OMAFRA website at www.ontario.ca/crops.

Non-chemical control options: Plastic-lined ditches may be used to trap emerging adults as they walk between the overwintering sites and the new host crop.

Cutworms
Agrostis ipsilon (black cutworm)

Black cutworms are the most common cutworm observed in tomatoes and are an early-season pest that can severely affect transplants. Transplants appear as if they were cut off at the soil surface with scissors. See Chapter 5 for more information.

Flea Beetles

See *Brassica Crops*, in this chapter.

Stalk Borer
Papaipema nebris

Identification: Young larvae are brownish-purple with three white stripes running down the body. A large purplish "saddle" is present on the front half of the body. Older larvae are uniformly grey. They move in a looping manner when disturbed. They are often referred to as "common stalk borer."

Damage: The stalk borer attacks over 100 species of plants. In Ontario, damage has been seen in tomato. Damage is most likely to be seen near field edges. Larvae tunnel into the stems of host plants, leading to wilting or breakage of stem.

Biology: The pest overwinters in the egg stage, with larvae emerging in May and June. The larval stage lasts about 9–12 weeks.

Scouting and Thresholds: Inspect the stem of wilted or broken plants for entry holes. Cut open the stem to look for evidence of tunneling or to find the larvae, if they are still present.

Management Notes: Damage is usually confined to field edges near grassy borders or grassy weed patches and is unlikely to warrant treatment. Insecticides are not effective once larvae have entered the stem.

Stink Bug (Native)
Euchistus servus (brown stink bug),
Euchistus variolarius (one-spotted stink bug),
Chinavia hilaris (green stink bug)

Identification: Green stink bugs are bright green with a narrow yellow-to-orange border at the edge of the "shield." Adults reach 12–19 mm (½–¾ in.) long. Brown stink bugs are brownish with a pale underside and reach about 12 mm (½ in.) in length. One-spotted stink bugs resemble the brown stink bug, but males have a single dark spot on the underside. Stink bug nymphs are smaller and more rounded than adults and are wingless. Depending on species, they may be a different colour than the adult.

Some stink bugs feed on insect pests and are beneficial. Plant-feeding (pest) stink bugs can be distinguished from predatory (beneficial) stink bugs by the proboscis (beak). Predatory stink bugs have a wide proboscis for attacking other insects, while plant-feeding species have a narrow, needle-like proboscis for probing plants.

Damage: Stink bug adults and nymphs feed on tomato fruit, causing cloudy yellow blotches just under the skin of the fruit.

Biology: These stink bugs overwinter as adults, emerging early in the spring. They may have one or two generations per year, depending on species and location. Stink bugs often move into tomatoes after wheat harvest or from weedy areas as they dry out in mid-summer.

Scouting and Thresholds: Inspect tomato fruit for damage. Search for the pest (adult and nymphs) in the lower parts of the plant and on the soil under the plant. Shake the foliage onto a tray or sheet. Damage often occurs along field edges.

Management Notes: For fresh market and processing tomatoes destined for peeling, insecticide treatment may be required to maintain fruit marketability. Stink bug damage is not a concern for processing tomatoes destined for paste or juice. Trap crops have been used in some areas to reduce damage, but this method has not been tested in Ontario.

Tarnished Plant Bug
Lygus lineolaris

Identification: Nymphs are greenish in colour with well-developed legs and moderately long antennae. Late instars have wing pads and four black spots on the thorax, behind the head, as well as one on the abdomen. Adults are pale green or yellow-to-dark brown, with dark markings and have a small triangle shape on their back.

Damage: TPB have sucking mouthparts that they use to pierce into plant tissue and inject saliva that helps break down plant tissue. In many cases, damage from the TPB is seen before the insect itself, thus recognition of the damage symptoms is very important. TPB cause stings and blemishes on tomato fruit with corky tissue underneath, similar to stink bug damage.

Biology: TPBs overwinter as adults in plant debris and leaf litter in protected areas such as woodlots, fence rows and ditches. Emerging adults feed and oviposit on broadleaf weeds in the spring, before moving into crops. TPB is a sporadic pest, present in Ontario throughout the growing season. Two generations occur per year, with a partial third in parts of Southern Ontario. First generation adults emerge in July and second in August and September.

Scouting and Thresholds: Check the growing points of tomatoes plants and ripening fruit for feeding damage. The threshold for TPB on tomatoes is 1 nymph or adult per 30 plants (after fruit set).

Management Notes: TPBs breed on many common weed species, including pigweed, chickweed, dandelion, lamb's-quarters, ragweed and fleabane. Weed control in and around vegetable plantings will help reduce potential infestations. Alfalfa is also a very attractive host. After the alfalfa is cut, TPB adults may disperse and invade nearby vegetable crops.

Tomato Fruitworm (Corn Earworm)
Helicoverpa zea

Identification: Larvae range in colour from yellowish, to green or brown. They have a fine double stripe running down the length of their backs. They grow up to 4 cm (1½ in.) long.

The adult is a buff or tan-coloured moth with a wingspan of 3.5–4 cm (1¼–1½ in.). The forewing may have several darker markings and always has a central brown dot, clearly visible on the underside of the wing and faintly visible from the top.

Fruitworm eggs are laid on the underside of leaves near flowers or fruit. Each egg is perfectly round and about the same colour and diameter as a corn silk. Tomatoes are attractive egg-laying sites during flowering and fruiting, especially if surrounding corn is not in an attractive stage for egg-laying.

Damage: In tomatoes, damage consists of deep holes or burrows, typically in green fruit. The larvae are often found inside the fruit. Rotting of the fruit soon follows.

Biology: Tomato fruitworm do not overwinter in Ontario. They move from the U.S. and Mexico on trade winds. Adult moths usually appear in mid-to-late July, or earlier, depending on the season. In cooler years, Northern and Eastern Ontario growing areas may not experience fruitworm at all.

Fruitworm activity is highest in hot weather conditions. Peak flights often occur immediately after severe thunderstorms.

Scouting and Thresholds: Use pheromone traps to monitor tomato fruitworm populations. Make insecticide applications according to the number of moths caught per week and the daytime temperatures. The pest is not usually found at economically damaging levels in tomato. However, a threshold of 7 moths/trap/week is a trigger for intensive scouting.

Management Notes: In tomatoes, treatment is only necessary during flowering, as the females will not lay eggs in tomatoes after this stage. If trap counts reach threshold and scouting indicates high numbers of eggs or larvae, insecticide treatment may be needed. Note that insecticide treatments in tomatoes are most effective if applied prior to egg hatch and before larvae enter the fruit.

Tomato and Tobacco Hornworm
Manduca sexta (tobacco hornworm),
Manduca quinquemaculata (tomato hornworm)

Identification: These hornworms are large, smooth, green caterpillars. Mature larvae measure 8 cm (3 in.) in length. The hornworm has seven white diagonal markings (tobacco hornworm) or eight white V-shaped markings (tomato hornworm) down each side and a prominent spike (horn) on its rear end.

Damage: The hornworm feeds on the leaves, stems and fruit of tomato plants.

Biology: The pest overwinters as pupae in the soil.

Scouting and Thresholds: Look for feeding damage – entire leaves consumed, leaving petioles and stems bare – or heavy fruit feeding. In contrast, cabbage loopers eat relatively small holes in the leaves, while variegated cutworm damage includes holes in leaves and gouges or holes in the fruit.

With experience, these pests can also be distinguished by their frass when the actual caterpillar cannot be found. Treatment threshold is one larva per 30 plants.

Management Notes: Control measures are rarely needed for this pest in tomatoes.

Two-Spotted Spider Mite
Tetranychus urticae

Two-spotted spider mites are a common pest to many agricultural crops. They feed on leaves and can create webs that cover leaves, stems and growing points. See Chapter 5 for more information.

Variegated Cutworm
Peridroma saucia

Identification: Mature larvae reach 3.5–5.0 cm (1½–2 in.) in length, but newly hatched larvae are much smaller. They are typically brownish-grey and mottled, with a line of orange-to-yellow dots along the back, and orange lines along its sides. Colouring varies from light to very dark. They curl up when disturbed (Figure 7–232).

Figure 7–232. Variegated cutworm larva and feeding damage on tomato leaf and fruit.

Damage: They produce scattered leaf feeding on tomato, particularly along leaf edges. Tomato fruit damage ranges from light surface feeding to deep holes. Damaged fruit may be invaded by secondary micro-organisms.

Biology: The variegated cutworm appears later in the season and is larger than the other cutworm species. Although it can occasionally survive the winter in our growing area, a large proportion of the population is thought to migrate into Ontario each season. Ontario studies have detected three population peaks in Essex County (July, August and September) and two in Norfolk County (July and August). Timing and number of peaks could vary from year to year, depending on when southern populations arrive in Ontario and on summer and fall temperatures. A small moth catch could also occur in June, from the local overwintering population.

Scouting and Thresholds: Adults can be monitored using black-light traps or pheromone traps, starting early in the season. Once moths are present, field scouting can determine the level of larval infestation. Early morning or evening, when temperatures are cooler, are good times to scout for these pests.

If field scouting detects 1 larva per 30 tomato plants, control measures may be necessary. For trapping, a threshold of seven moths per trap per week is suggested for tomatoes. This threshold was developed using delta or wing style pheromone traps, although bucket traps have been shown to be more effective in a trapping program.

Management Notes: Small larvae (2nd instar or less) are much more susceptible to insecticides than older larvae. Once larvae reach 3.5–5.0 cm (1½–2 in.), not only are they difficult to kill, but they have probably finished feeding on the crop and are preparing to pupate. Southern populations that arrive in Ontario may have been exposed to intensive insecticide programs on cotton and other crops. Ontario studies have shown that low levels of resistance exist to some insecticides. Inspect fields after treatment to assess insecticide effectiveness and the need for follow-up treatments.

Good coverage (adequate water volume) into the plant canopy is essential when applying insecticide for variegated cutworm. Control failures due to inadequate coverage are likely much more common than control failures due to insecticide resistance. Insecticide treatments may be more effective when soils are moist and when applied in late evening or early morning.

Western Flower Thrips
Frankliniella occidentalis

Identification: Thrips are small (<3 mm (⅛ in.) long), soft-bodied insects. Adult thrips have straw-brown bodies and four wings fringed with hairs. Nymphs are smaller, wingless and pale white in colour.

Damage: Thrips have sucking-rasping mouth parts and cause tissue damage when they feed on the leaves. Thrips feeding on tomato is not generally a concern, but they can transmit tomato spotted wilt virus.

Biology: In Ontario, both adults and nymphs overwinter on winter grains, clover and alfalfa. They migrate into tomato fields as the weedy roadsides dry down and the winter wheat and alfalfa are harvested. Females insert white, bean-shaped eggs into the leaf tissue. Development from egg to adult requires from 10–30 days, depending on temperature. Once mature, females begin to lay eggs. The females reproduce asexually (without mating). Consequently, increases in the thrips population can occur very rapidly, especially during periods of hot, dry weather. There are several overlapping generations per year.

Scouting and Thresholds: Plantings near greenhouse tomato, ornamental or bedding plant production are at highest risk of virus transmission. No thresholds are established.

Management Notes: There are no good management options for thrips or tomato spotted wilt virus in tomatoes.

Wireworm
Limonius spp.

Wireworms are an early-season pest that can affect tomato transplants by feeding on stems at the soil line and/or burrowing into the stem. Larvae are smooth and copper coloured. See Chapter 5 for more information.

Disorders

Abnormal Fruit Development

Catfacing is most common on the earliest fruit of large fruited tomato cultivars. Catfaced fruit show scars and openings on the blossom-end of the fruit. Temperatures below 15°C (59°F) during flower development (even weeks before bloom) tend to increase the incidence of catfaced fruit. Other factors that interfere with flower development, such as hormonal herbicide injury, can also cause catfacing. High soil nitrogen levels and excessive pruning may contribute to the problem. There is a wide variation in susceptibility to this disorder among fresh-market tomato cultivars (Figure 7–233).

Figure 7–233. Catfacing on tomato fruit.

Zippering is the appearance of thin, linear scars that extend from the stem-end of the tomato fruit all or part way to the blossom-end. Openings in the fruit wall may occur along the scar. Zippering is associated with pollination problems, often attributed to low or high temperatures or high humidity during pollination.

Puffiness occurs when the fruit is light in weight with flattened sides. Locules are enlarged and may lack gel. The disorder is associated with poor pollination and can be caused by temperature extremes during fruit set, improper nutrition, extreme variations in soil moisture and genetic factors.

The development of red colour in tomato fruit is inhibited when the fruit reaches temperatures above 30°C (86°F).

Air Pollution Injury

Air pollution injury may be confused with symptoms of disease, insect feeding, nutrient deficiencies or toxicities, herbicide injury or damage caused by weather extremes. Plant damage caused by air pollution is usually most severe during warm, clear, calm, humid weather, when barometric pressure is high, as these conditions can cause an air inversion. During an air inversion, warm air above the earth's surface traps cooler air at ground level, allowing pollutants to accumulate. Injury may also be more severe during foggy conditions, heavy dews or in fields near very busy highways. Causes of air pollution injury include: ozone, sulfur dioxide, peroxyacetyl nitrate (PAN) and ethylene.

Ozone: Ozone is the main pollutant in the oxidant smog complex. Levels vary significantly throughout the growing season, as evidenced by alerts of smog days in Ontario. Tomatoes are sensitive to ozone.

Ozone symptoms tend to occur on the upper surface of affected leaves, appearing as a flecking, bronzing or bleaching of the leaf tissues. Yield reductions are not always associated with injury symptoms. Susceptibility to ozone injury is influenced by many environmental and plant growth factors. High relative humidity, optimum soil-nitrogen levels and water availability increase susceptibility. Typically, young leaves are resistant to ozone injury. During expansion, they become successively susceptible at the middle and the base of the leaf. With age, leaves become resistant again.

Sulfur dioxide: Different plant species, cultivars, and even individual plants may vary considerably in their sensitivity to sulfur dioxide. Variations occur because of the differences in location, climate, stage of growth and maturation. Tomatoes are not usually sensitive to sulfur dioxide.

Peroxyacetyl nitrate (PAN): Tomatoes are commonly affected. This pollutant typically causes a gradual glazing or silvering effect in bands or blotches, which may advance to bronzing within 2–3 days. Small plants and recently matured leaves (about 5 days after leaf emergence) are most susceptible to PAN injury.

Ethylene: Ethylene is present in exhaust gases from furnaces or heaters that burn fossil fuel or wood, used to heat transplant greenhouses or high tunnels. Ethylene influences plant tissue growth and development. Exhaust gases in a greenhouse or tunnel structure can cause damage to sensitive crops, such as tomatoes. Plants exposed to ethylene may exhibit twisting and curling, deformed foliage, defoliation and blossom drop.

Blossom Drop

Tomato fruit set is reduced with day temperatures over 32°C (90°F) and night temperatures over 21°C (70°F), or by temperatures below 10°C (50°F). Abnormal flower development can occur after several days of cool temperatures (below 17°C (63°F)) day and 10°C (50°F) night), up to 35 days before the flowers open.

Blossom-End Rot

A small water-soaked or light brown area appears around the blossom-end of immature or maturing fruit. Lesions darken and enlarge rapidly, becoming sunken and black. It may affect over half of the fruit. Fungal or bacterial pathogens may invade the lesion, causing it to look diseased. Atypical presentations of blossom end rot can occur and include internal blossom end rot, which may not be apparent from the outside of the fruit.

Blossom-end rot is thought to be triggered by a localized calcium deficiency in the blossom end of the fruit, generally associated with interruptions in water supply to the fruit, not by a deficiency of calcium in the soil. Research has shown, however, that other factors may be involved, including:

- high temperatures and intense sunlight, especially following cooler, overcast weather
- high ammonium-nitrogen levels in the soil
- susceptible cultivars
- stress occurring during periods of rapid fruit growth
- potassium/calcium ratios in the fruit
- high nitrogen fertilization
- fluctuations in levels of various growth hormones in the plant

Side-dressing with calcium nitrate or foliar sprays of calcium have not proven to be effective. Avoid deep cultivation, which can prune roots and cause plant stress. Choose less susceptible cultivars and properly schedule irrigation, ensuring steady movement of water and calcium into the plant.

Colour Disorders

Blotchy Ripening: The tomato fruit appears mottled green, yellow and red. The flesh develops large patches of hard, grey-to-yellowish tissue that do not ripen. When the fruit is cut open, brown strands of vascular tissue may be seen. These symptoms may also be called grey wall. Similar symptoms may be caused by virus infection. Blotchy ripening is linked to boron or potassium deficiency, excessive nitrogen, high humidity, temperature fluctuations, high soil moisture levels and soil compaction.

Internal White Tissue: Although the exterior of the tomato may appear red, fruit with this disorder exhibit areas of hard, white tissue on the shoulders and/or in the core. This is believed to be one variation of the yellow shoulder disorders.

Sunscald: Colour problems can also occur due to sunscald. High temperatures at the fruit surface can interfere with the development of red colour, even without obvious tissue damage. Some viruses may also cause uneven colour development.

Yellow Shoulder: The stem end of the fruit does not ripen properly. The flesh on the fruit shoulders remains green (green shoulder) or turns yellow. Yellow-eye is used to describe this disorder when only a ring of tissue around the stem scar is affected. Cultivars vary in susceptibility to these disorders; soil potassium and magnesium levels may be involved. The disorder is initiated well before ripening and the areas will not ripen even if harvest is delayed.

Cracking and Check

Fruit cracking appears as cracks at the stem end that spread out in a radial or concentric pattern. Depending on the cultivar, the cracks can appear from the mature green to the ripe stage of maturity. Cultivars vary in susceptibility. Fruit cracking may be caused by alterations in growth rate or fluctuations in moisture or temperature.

Rain check appears as tiny concentric cracks or russetting on the upper shoulder of the fruit. These may coalesce into larger cracks. The affected area feels rough, can become leathery and will not ripen properly. Rain check is less of a problem in cultivars with good canopy cover, protecting the fruit from rain and dews. Where the plant is covered, as in a high tunnel, rain check is greatly reduced.

Leaf Roll

Leaf roll tends to occur in hot, dry growing conditions or when soils become waterlogged. Injury to the roots may also trigger leaf roll. The edges of the leaves roll up and inward, and the leaf may develop a leathery texture. Some cultivars are predisposed to leaf roll. Leaf roll appears to be a moisture conservation measure and is often permanent. It does not seem to affect the productivity of the tomato plant. It may be confused with herbicide injury or virus disease.

Lightning Injury

A circular patch of affected plants (generally 3–20 m (10–66 ft) in diameter) suddenly appears in the field. Plants toward the outer edge may show less damage.

Leaves at the ends of branches will begin to droop, followed by wilting, and in severe cases, death of the plant. One side of the stem may be caved in, like a furrow, down its length. If the stem is cut, it will appear hollow, or have a ladder-like arrangement of tissue.

Sunscald

For tomatoes, sunscald may affect leaves, stems and fruit. Fruit that is suddenly exposed to the sun, due to defoliation, especially under high temperatures and humidity, can develop sunscald. Affected areas are sunken and light brown to white. The fruit can then be invaded by secondary organisms, causing fruit rot.

Early in the season, tender young leaf and stem tissue may show injury. In tomato, exposure to intense sunlight can also cause the fruit to heat up to the point at which red colour will not develop. This is characterized by yellow areas where the fruit is exposed to the sun.

Production practices that ensure adequate foliage cover over the fruit (irrigation, choice of cultivar, appropriate fertilization) will help reduce fruit damage due to sunscald. Prevent defoliation, which may occur due to disease, excessive heat, insect feeding or (in processing tomatoes) Ethrel use.

Walnut Wilt

Walnut wilt can occur if a crop is planted within 12–15 m (39–49 ft) of walnut trees or in soil from which walnut trees have been removed within the last several years. The plants wilt and die; other susceptible plants in the immediate area may be affected.

Wind Damage — also known as Sandblasting, Wind Whipping, Dessication

Wind damage occurs in several different forms, including sandblasting, wind whipping and dessication.

Sandblasting (sand abrasion) occurs when light, sandy or exposed soils are eroded by high winds. Stems and leaves on the windward side of the plant develop light, tan-coloured, roughened areas. If severe, sandblasting can stunt or kill plants and significantly reduce yield.

Wind whipping occurs on any type of soil. The whipping and twisting of young plants by strong winds can severely damage or kill the plants. Overly tall tomato transplants are very susceptible to wind whipping.

Dessication is most common on tender, young transplants during strong wind conditions and extreme temperatures. Proper hardening-off of the transplants before field setting helps minimize these effects.

All types of wind damage can predispose plants to foliar diseases. Wind-strips, cover crops and windbreaks will minimize problems due to wind and sand movement.

Vertebrate Pests

Pests such as birds, deer, raccoons, etc., are common in horticulture crops. For more information, see *Vertebrate Pests*, *Sweet Corn*.

Appendices

Appendix A. Ontario Ministry of Agriculture, Food and Rural Affairs Vegetable Crop Advisory Staff (as of September 2023)

A complete list of OMAFRA advisory staff is available on the OMAFRA website at www.ontario.ca/crops.

Specialty	Staff as of September 2023	Tel/Fax	E-mail
Guelph OMAFRA 1 Stone Rd. W., Guelph, ON N1G 4Y2			
Crop Protection Specialist	Denise Beaton	Tel: 519-400-3636	denise.beaton@ontario.ca
Minor Use Coordinator	Joshua Mosiondz	Tel: 226-971-3407	joshua.mosiondz@ontario.ca
Vegetable Crop Specialist — potatoes, carrots, parsnips, radish, horseradish, rutabaga & turnip	Dennis Van Dyk	Tel: 519-766-5337	dennis.vandyk@ontario.ca
Vegetable Crop Specialist — onions, garlic, broccoli, cauliflower, Brussels sprouts, cabbage, kale, spinach, celery & leafy greens	Travis Cranmer	Tel: 519-835-3382	travis.cranmer@ontario.ca
Harrow Research and Development Centre 2585 County Rd. 20, RR#2 Harrow, ON N0R 1G0			
Weed Management Specialist — Horticulture	Kristen Obeid	Tel: 519-965-0107	kristen.obeid@ontario.ca
Ridgetown Resource Centre Agronomy Building, Ridgetown College, Box 400, Main St. E., Ridgetown, ON N0P 2C0			
Soil Management Specialist — Horticulture Crops	Danny Jefferies	Tel: 519-359-6707	danny.jefferies@ontario.ca
Vegetable Crop Specialist — tomatoes, peppers, eggplants, sugarbeets & red beets	Amanda Tracey	Tel: 519-350-7134	amanda.tracey@ontario.ca
Vegetable Crop Specialist — sweet corn, cucurbits, beans, peas & asparagus	Elaine Roddy	Tel: 519-401-5890	elaine.roddy@ontario.ca
Simcoe Resource Centre P.O. Box 587, Blueline Rd. & Hwy #3, Simcoe, ON N3Y 4N5		Tel: 519-426-7120	
Application Technology Specialist	Jason Deveau	Tel: 519-209-1883	jason.deveau@ontario.ca
Fresh Market Quality Specialist – Horticulture Crops	Jennifer DeEll	Tel: 519-410-1806	jennifer.deell@ontario.ca
Ginseng and Herbs Specialist	Sean Westerveld	Tel: 519-420-7440	sean.westerveld@ontario.ca
Horticulture IPM Specialist	Melanie Filotas	Tel: 519-428-4340	melanie.filotas@ontario.ca
New Crop Development Specialist	Evan Elford	Tel: 519-420-9343	evan.elford@ontario.ca
Vineland Resource Centre Adv. Serv. Building, Box 8000, 4890 Victoria Ave. N., Vineland Station, ON L0R 2E0		Tel: 905-562-4147	
Horticulture Sustainability Specialist	Stephanie Vickers	Tel: 519-852-5627	stephanie.vickers@ontario.ca
University of Guelph 50 Stone Rd. E., Guelph, ON N1G 2W1		Tel: 519-824-4120	
Entomologist — Horticulture Edmund Bovey Building	Hannah Fraser	Tel: 905-708-8014	hannah.fraser@ontario.ca
Nutrition — Horticulture School of Environmental Sciences, Alexander Hall	Tejendra Chapagain	Tel: 519-835-5794	tejendra.chapagain@ontario.ca
Pathologist — Horticulture Edmund Bovey Building	Katie Goldenhar	Tel: 519-835-5792	katie.goldenhar@ontario.ca

Agricultural Information Contact Centre

Provides province-wide, toll-free technical and business information to commercial farms, agri-businesses and rural businesses.

Tel: 1-877-424-1300
E-mail: ag.info.omafra@ontario.ca

The Ontario Crop Protection Hub is our digital tool for providing an easy-to-use, customizable solution to dynamically search and select crop protection products based on your business needs. This tool has replaced our annual crop protection publications.

Visit the Ontario Crop Protection Hub at Ontario.ca/cropprotection.

Appendix B. Ontario Ministry of Environment, Conservation and Parks — Regional Contact Information (as of August 2022)

Region/County	Address	Telephone/fax
Central Region Barrie, Halton-Peel, Toronto, York-Durham	5775 Yonge St., 8th Floor Toronto, ON M2M 4J1	Tel: 416-326-6700 Toll-free: 1-800-810-8048 Fax: 416-325-6345
West-Central Region Guelph, Hamilton, Niagara	Ellen Fairclough Building 119 King St. W., 12th Floor Hamilton, ON L8P 4Y7	Tel: 905-521-7640 Toll-free: 1-800-668-4557 Fax: 905-521-7820
Eastern Region	1259 Gardiners Rd., Unit 3 PO Box 22032 Kingston, ON K7M 8S5	Tel: 613-549-4000 Toll-free: 1-800-267-0974 Fax: 613-548-6908
Southwestern Region London, Owen Sound, Sarnia	733 Exeter Rd. London, ON N6E 1L3	Tel: 519-873-5000 Toll-free: 1-800-265-7672 Fax: 519-873-5020
Northern Region Sudbury, Thunder Bay, Timmins	435 James St. S., Suite. 331 Thunder Bay, ON P7E 6S7	Tel: 807-475-1205 Toll-free: 1-800-875-7772 Fax: 807-475-1745
Pesticide Licensing — Client Services Permissions Branch	135 St. Clair Ave. W. 1st Floor Toronto, ON M4V 1L5	Tel: 416-314-8001 Toll-free: 1-800-461-6290 Fax: 416-314-8452

Appendix C. Accredited Soil-Testing Laboratories in Ontario

The following labs are accredited to perform soil tests for pH, buffer pH, P, K, Mg, Mn index, Zn index and Nitrate-N on Ontario soils.

Laboratory Name	Address	Telephone/Fax/E-mail	Contact as of August 2022
A & L Canada Laboratories Inc. www.alcanada.com	2136 Jetstream Rd. London, ON N5V 3P5	Tel: 519-457-2575 Fax: 519-457-2664 E-mail: aginfo@alcanada.com	Greg Patterson Dave Stallard
Agriculture & Food Laboratories, University of Guelph https://afl.uoguelph.ca	University of Guelph P.O. Box 3650, 95 Stone Rd. W. Guelph, ON N1H 8J7	Tel: 519-767-6299 1-877-863-4235 Fax: 519-767-6240 E-mail: aflinfo@uoguelph.ca	Nick Schrier
Activation Laboratories Ltd.	41 Bittern St. Ancaster, ON L9G 4V5	Tel: 905-648-9611 1-888-228-5227 Fax: 905-648-9613	Carolyn Fraser
Brookside Laboratories, Inc. www.blinc.com	200 White Mountain Dr. New Bremen, OH US 45871	Tel: 419-977-2766 Fax: 419-977-2767 E-mail: info@blinc.com	Jackie Brackman
Eurofins Environment Testing Canada Inc.	8-146 Colonnade Rd. Ottawa, ON K2E 7Y1	Tel: 613-727-5692 Fax: 613-727-5222 E-mail: infocanada@eurofins.com	Amy Walpole-James Addrine Thomas
Honeyland Ag Services	3918 West Corner Dr. Ailsa Craig, ON N0M 1A0	Tel: 226-377-8485 E-mail: croelands@honeylandag.com	Chris Roelands
SGS Agri-Food Laboratories www.agtest.com	503 Imperial Rd. Unit #1 Guelph, ON N1H 6T9	Tel: 519-837-1600 1-800-265-7175 Fax: 519-837-1242 E-mail: ca.agri.guelph.lab@sgs.com	Jack Legg Dr. David Boyle
Stratford Agri Analysis www.stratfordagri.ca	1131 Erie St. Box 760 Stratford, ON N5A 6W1	Tel: 519-273-4411 1-800-323-9089 Fax: 519-273-2163 E-mail: info@stratfordagri.ca	Nelmy Narvaez Barbara Spanjers

There is no official accreditation in Ontario for tissue analysis, but all the accredited soil-testing labs are monitored for proficiency on tissue analyses.

Appendix D. Production Insurance

Production insurance (PI) is a production-based insurance program that protects farmers against yield reductions and crop losses due to adverse weather and other insured perils such as excessive rain, hail, drought and plant diseases. In Ontario, Agricorp administers PI on behalf of the Government of Ontario and Agriculture and Agri-Food Canada. More than 16,000 producers and 2 million ha (5 million acres) of Ontario farmland are insured each year.

The federal and provincial governments pay up to 60% of the required PI premiums and 100% of the administration cost of delivering PI. Premium payments from all producers are pooled together into one fund, which is then used to pay claims. In this manner, the claims of a small number of producers are spread over all producers in the program. Claim payments are limited to the producer's guaranteed yield at the insured price.

PI is available to all Ontario farmers, landlords and sharecroppers who grow an eligible crop. Coverage is available on 100 commercially grown crops in Ontario in the following sectors:

- forage
- tree fruit and grapes
- strawberries
- honey and bees
- grains and oilseeds
- vegetables
- seed corn, sugarbeets, hemp and tobacco

For more information, please call Agricorp weekdays, 7 am to 5 pm at 1-888-247-4999 or visit www.agricorp.com.

Agricorp
1 Stone Rd. W., Box 3660, Stn. Central
Guelph, ON N1H 8M4

Tel: 1-888-247-4999
Fax: 519-826-4118
E-mail: contact@agricorp.com

Ontario Crops Covered by Production Insurance

Fresh Market Vegetables – Acreage Loss

- **Root Vegetables** (red beets, carrots, celeriac, French shallots, garlic, green onions, leeks, onions, parsnips, radishes, rutabagas, turnips, sweet potatoes)
- **Leafy Vegetables** (bok choy. broccoli, Brussels sprouts, cauliflower, celery, Chinese cabbages, gai lan, kale, lettuce, mesclun, mustard greens, spinach summer & winter cabbage, yu choy)
- **Fruit Vegetables** (cucumbers, eggplant, melons, peppers, pumpkins, squash, tomatoes, watermelon, zucchinis)
- **Other Vegetables** (broad beans, green and wax beans, green peas, sweet corn)

Fruit Crops

- apples and apple trees
- cherries and cherry trees, sweet and sour
- grapes and grapevines
- peaches/nectarines and peach/nectarine trees
- pears and pear trees
- plums and plum trees
- strawberries

General Crops

- barley (spring, winter)
- canola (spring, winter)
- edible beans (adzuki, black, cranberry, kidney, Japanese/ other, white)
- corn (grain, silage, organic)
- forage (forage rainfall program)
- honey and bee health
- industrial hemp
- mustard
- new forage seeding (standard and premium)
- peanuts
- popping corn
- soybeans (soybean pedigreed seed, tofu, natto, organic)
- spring grain, oats
- seed corn
- spring wheat, spring wheat pedigreed seed
- sugarbeets
- sunflower
- winter spelt, organic
- winter wheat, hard red
- winter wheat, organic
- winter wheat, soft red
- winter wheat, soft white
- winter wheat pedigreed seed

Vegetable Crops – Average Farm Yield or Total Production

- asparagus
- banana peppers
- bell peppers
- green beans and wax beans (processing)
- butternut squash (processing)
- carrots (fresh)
- carrots (processing)
- cucumbers (processing)
- lima beans (processing)
- peas (processing)
- potatoes (fresh)
- potatoes (processing)
- red beets (processing)
- rutabagas
- seed onions
- set onions
- Spanish onions
- sweet corn (processing)
- tomatoes (processing)

Tobacco

- black
- burley
- flue-cured

Appendix E. Other Contacts

AGRICULTURE & AGRI-FOOD CANADA RESEARCH CENTRES

www.agriculture.canada.ca/en/agricultural-science-and-innovation/agriculture-and-agri-food-research-centres-and-collections

Ottawa Research and Development Centre
960 Carling Ave.
Ottawa, ON K1A 0C6
Tel: 613-759-1858

Guelph Research and Development Centre
93 Stone Rd. W.
Guelph, ON N1G 5C9
Tel: 226-217-8200

Harrow Research and Development Centre
2585 County Road 20
Harrow, ON N0R 1G0
Tel: 519-738-2251

London Research and Development Centre
1391 Sandford St.
London, ON N5V 4T3
Tel: 519-457-1470

Vineland Research Farm
4902 Victoria Ave. N.
Vineland, ON L0R 2E0
Tel: 905-562-4113

Delhi Research Farm
Box 186 Schafer Rd.
Delhi, ON N4B 2W9
Tel: 519-582-1950

CANADIAN FOOD INSPECTION AGENCY REGIONAL OFFICES (PLANT PROTECTION)

www.inspection.gc.ca/english/toce.shtml

Barrie
500 Huronia Rd #103
Barrie, ON L4N 8X3
Tel: 705-739-0008

Belleville
345 College St. E.
Belleville, ON K8N 5S7
Tel: 613-969-3320

Brantford
625 Park Rd. N., Ste. 6
Brantford, ON N3T 5L8
Tel: 519-753-3478

Guelph
259 Woodlawn Rd. W., Suite A
Guelph, ON N1H 8J1
Tel: 519-217-1200

Hamilton
709 Main St. W., Ste. 101
Hamilton, ON L8S 1A2
Tel: 905-572-2201

Kingsville
106 Wigle Ave #1
Kingsville, ON N9Y 2J8
Tel: 519-733-5013

London
19-100 Commissioners Rd. E.
London, ON N5Z 4R3
Tel: 519-691-1300

North Bay
107 Sherreff Ave.
North Bay, ON P1B 7K8
Tel: 705-495-5995

Ottawa
38 Auriga Dr., Unit 8
Ottawa, ON K2E 8A5
Tel: 613-773-8660

Peterborough
163 Simcoe St.
Peterborough, ON K9H 2H6
Tel: 705-742-6917

St. Catharines
350 Ontario St.,
St. Catharines, ON L2R 5L8
Tel: 905-937-7434

Thunder Bay
977 Alloy Dr.
Thunder Bay, ON P7B 5Z8
Tel: 807-683-4370

Toronto
1122 Finch Ave. W., Unit 22
North York, ON M3J 3J5
Tel: 647-790-1100

Walkerton
19 Ontario Rd.
Walkerton, ON N0G 2V0
Tel: 519-881-2431

UNIVERSITY OF GUELPH

www.plant.uoguelph.ca

Main Campus
50 Stone Rd E
Guelph, ON N1G 2W1
Tel: 519-824-4120
www.uoguelph.ca

Ridgetown Campus
120 Main St. E.
Ridgetown , ON N0P 2C0
Tel: 519-674-1500
www.ridgetownc.com

Department of Plant Agriculture, Guelph
50 Stone Rd. E.
Guelph, ON N1G 2W1
Tel: 519-824-4120, ext. 56083

Department of Plant Agriculture, Simcoe
1283 Blueline Rd., Box 587
Simcoe, ON N3Y 4N5
Tel: 519-426-7127

Department of Plant Agriculture, Vineland
Box 7000, 4890 Victoria Ave. N.
Vineland Station, ON L0R 2E0
Tel: 905-562-4141

Lab Services Division
www.uoguelph.ca/labserv/
P.O. Box 3650, 95 Stone Rd. W.
Guelph, ON N1H 8J7
Tel: 519-767-6299

Appendix F. Diagnostic Services

Samples for disease diagnosis, insect or weed identification, nematode counts and verticillium testing can be sent to:

Plant Disease Clinic
Laboratory Services Division University of Guelph

95 Stone Rd. W.
Guelph Ontario, N1H 8J7
Tel: 519-823-1268, ext. 57256
Fax: 519-767-6240
E-mail: aflinfo@uoguelph.ca

Payment must accompany samples at the time of submission. Submission forms are available at www.afl.uoguelph.ca/submitting-samples.

Fee Schedule

To obtain information on the fee schedule, visit www.afl.uoguelph.ca or phone the Plant Disease Clinic.

How to Sample for Nematodes

Soil

When to Sample

Soil and root samples can be taken at any time of the year that the soil is not frozen. In Ontario, nematode soil population levels are generally at their highest in May and June and again in September and October.

How to Sample Soil

Use a soil sampling tube, trowel or narrow-bladed shovel to take samples. Sample soil to a depth of 20–25 cm (8–10 in.). If the soil is bare, remove the top 2 cm (1 in.) prior to sampling. A sample should consist of 10 or more subsamples combined. Mix well. Then take a sample of 0.5–1 L from this. No one sample should represent more than 2.5 ha (6¼ acres). Mix subsamples in a clean pail or plastic bag.

Sampling Pattern

If living crop plants are present in the sample area, take samples within the row and from the area of the feeder root zone (with trees, this is the drip line).

Number of Subsamples

Based on the total area sampled:

500 m^2	10 subsamples
500 m^2–0.5 ha	25 subsamples
0.5 ha–2.5 ha	50 subsamples

Roots

From small plants, sample the entire root system plus adhering soil. For large plants, 10–20 g, dig fresh weight from the feeder root zone and submit.

Problem Areas

Take soil and root samples from the margins of the problem area where the plants are still living. If possible, also take samples from healthy areas in the same field. If possible, take both soil and root samples from problem and healthy areas in the same field.

Sample Handling

Soil Samples

Place in plastic bags as soon as possible after collecting.

Root Samples

Place in plastic bags and cover with moist soil from the sample area.

Storage

Store samples at 5°C–10°C (41°F–50°F) and do not expose them to direct sunlight or extreme heat or cold (freezing). Only living nematodes can be counted. Accurate counts depend on proper handling of samples.

Submitting Plant for Disease Diagnosis or Identification

Sample Submission Forms

Forms can be obtained from your local Ontario Ministry of Agriculture, Food and Rural Affairs office. Carefully fill in all of the categories on the form. In the space provided, draw the most obvious symptom and the pattern of the disease in the field. It is important to include the cropping history of the area for the past 3 years and this year's pesticide use records.

Choose a complete, representative sample showing early symptoms. Submit as much of the plant as is practical, including the root system, or several plants showing a range of symptoms. If symptoms are general, collect the sample from an area where they are of intermediate severity. Completely dead material is usually inadequate for diagnosis.

With plant specimens submitted for identification, include at least a 20–25-cm (8–10-in.) sample of the top portion of the stem with lateral buds, leaves, flowers or fruits in identifiable condition. Wrap plants in newspaper and put in a plastic bag. Tie the root system off in a separate plastic bag to avoid drying out and contamination of the leaves by soil. Do NOT add moisture, as this encourages decay in transit. Cushion specimens and pack in a sturdy box to avoid damage during shipping.

Avoid leaving specimens to bake or freeze in a vehicle or in a location where they could deteriorate.

Delivery

Deliver to the Pest Diagnostic Clinic as soon as possible by first class mail or by courier at the beginning of the week.

Submitting Insect Specimens for Identification

Collecting Samples

Place dead, hard-bodied insects in vials or boxes and cushion with tissues or cotton. Place soft-bodied insects and caterpillars in vials containing alcohol. Do not use water, as this results in rot. Do not tape insects to paper or send them loose in an envelope.

Place live insects in a container with enough plant "food" to support them during transit. Be sure to write "live" on the outside of the container.

UNIVERSITY of GUELPH LABORATORY SERVICES | AFL AGRICULTURE & FOOD LABORATORY

Plant Disease Clinic Sample Submission Form

95 Stone Road West
Guelph, ON
Mail parcels: N1H 8J7
Courier parcels: N1G 2Z4
Tel: (519) 767-6299
Web: www.AFLuoguelph.ca

LABORATORY USE ONLY:
Rec'd By:______________ **Date Received:** ________________
Delivered By: ☐ **Mail** ☐ **Courier** ☐ **In-Person**
LS Sample No: __________________ **to** __________________
Payment Rec'd: $_____________ **Receipt #:**_____________

Submitted By:			Owner (if different from submitter):		
Business Name (if applicable):			Business Name (if applicable):		
Street:			Street:		
City:	Prov:	Postal Code:	City:	Prov:	Postal Code:
Tel: ( ) -	Fax: ( ) -		Tel: ( ) -	Fax: ( ) -	
Email:			Email:		

Unless otherwise indicated, report and invoice will be sent to submitter
Report to: ☐ Submitter ☐ Owner Required Report Format: ☐ Fax ☐ E-Mail ☐ Mail

Invoice to: ☐ Submitter ☐ Owner Quotation #: PO# / U of G G/L Code:

Services Required: Please select a test from below. If unsure of which test to select, please check Plant Disease Diagnosis and our diagnostician will choose the most appropriate testing based on symptoms.

☐ **Plant Disease Diagnosis** ☐ **Plant Virus Test** ☐ **Insect Identification**
☐ **Nematodes:** ☐ Count from Soil ☐ Cyst & Egg Count from Soil ☐ Count From Roots ☐ Bulb & Stem

DNA Scan*: Water† ☐ Basic ☐ Diagnostic Soil ☐ Basic ☐ Diagnostic Plant ☐ Basic ☐ Diagnostic ☐ Turf
*For pathogens detected by DNA scans see our website for more detailed information.

PCR: ☐ Agrobacterium (Ri & Ti plasmids) ☐ Fire Blight ☐ Phytoplasmas ☐ Tomato Bacterial Canker

☐ **Other** (please specify test required and/or pathogen suspected):

Important: Please read

By submitting samples to the Plant Disease Clinic (PDC), the submitter acknowledges and agrees that summarized plant disease results, without any link to client or location, can be published yearly in the Canadian Plant Disease Survey. The submitter also agrees that PDC may share results and contact information with government regulators to be in compliance with relevant government legislation regarding regulated or reportable plant diseases.

†If submitting WATER SAMPLES, you must complete this section:

Is the purpose of the water test request to assess the quality of water for human consumption? ☐ **YES** ☐ **NO**

Date: **Signature:**

Plant or Host Affected: **Grower's sample ID:**

Size of Planting:	% of Plants Affected:	Symptoms First Appeared in Past:	Degree of Injury:
		☐ Days ☐ Weeks ☐ Months ☐ Years	☐ Severe ☐ Moderate ☐ Light

Describe the problem in detail (i.e. symptoms, plant parts affected, distribution of symptoms, cropping history):

____

____

____

Were chemicals applied? Please specify type of product(s) used and date(s) of application. Provide additional comments and specific requests.

____

Appendix G. The Metric System and Abbreviations

Metric units		
Linear measures (length)		
10 millimetres (mm)	=	1 centimetre (cm)
100 centimetres (cm)	=	1 metre (m)
1,000 metres	=	1 kilometre (km)
Square measures (area)		
100 m × 100 m = 10,000 m^2	=	1 hectare (ha)
100 ha	=	1 square kilometre (km^2)
Cubic measures (volume)		
Dry measure		
1,000 cubic millimetres (mm^3)	=	1 cubic centimetre (cm^3)
1,000,000 cm^3	=	1 cubic metre (m^3)
Liquid measure		
1,000 millilitres (mL)	=	1 litre (L)
100 L	=	1 hectolitre (hL)
Weight-volume equivalents (for water)		
(1.00 kg) 1,000 grams	=	1 litre (1.00 L)
(0.50 kg) 500 g	=	500 mL (0.50 L)
(0.10 kg) 100 g	=	100 mL (0.10 L)
(0.01 kg) 10 g	=	10 mL (0.01 L)
(0.001 kg) 1 g	=	1 mL (0.001 L)
Weight measures		
1,000 milligrams (mg)	=	1 gram (g)
1,000 g	=	1 kilogram (kg)
1,000 kg	=	1 tonne (t)
1 mg/kg	=	1 part per million (ppm)
Dry–liquid equivalents		
1 cm^3	=	1 mL
1 m^3	=	1,000 L
Metric conversions		
5 mL	=	1 tsp
15 mL	=	1 tbsp
28.5 mL	=	1 imp. fl. oz.

Handy metric conversion factor (approximate)		
litres per hectare × 0.4	=	litres per acre
kilograms per hectare × 0.4	=	kilograms per acre

Application rate conversions		
Metric to imperial or U.S. (approximate)		
litres per hectare × 0.09	=	Imp. gallons per acre
litres per hectare × 0.11	=	U.S. gallons per acre
litres per hectare × 0.36	=	Imp. quarts per acre
litres per hectare × 0.43	=	U.S. quarts per acre
litres per hectare × 0.71	=	Imp. pints per acre
litres per hectare × 0.86	=	U.S. pints per acre
millilitres per hectare × 0.014	=	U.S. fluid ounces per acre
grams per hectare × 0.014	=	ounces per acre
kilograms per hectare × 0.89	=	pounds per acre
tonnes per hectare × 0.45	=	tons per acre
Imperial or U.S. to metric (approximate)		
Imp. gallons per acre × 11.23	=	litres per hectare (L/ha)
U.S. gallons per acre × 9.35	=	litres per hectare (L/ha)
Imp. quarts per acre × 2.8	=	litres per hectare (L/ha)
U.S. quarts per acre × 2.34	=	litres per hectare (L/ha)
Imp. pints per acre × 1.4	=	litres per hectare (L/ha)
U.S. pints per acre × 1.17	=	litres per hectare (L/ha)
Imp. fluid ounces per acre × 70	=	millilitres per hectare (mL/ha)
U.S. fluid ounces per acre × 73	=	millilitres per hectare (mL/ha)
tons per acre × 2.24	=	tonnes per hectare (t/ha)
pounds per acre × 1.12	=	kilograms per hectare (kg/ha)
pounds per acre × 0.45	=	kilograms per acre (kg/acre)
ounces per acre × 70	=	grams per hectare (g/ha)

Dry weight conversions (approximate)		
Metric		**Imperial**
grams or kilograms/hectare		**ounces or pounds/acre**
100 g/ha	=	1½ oz/acre
200 g/ha	=	3 oz/acre
300 g/ha	=	4¼ oz/acre
500 g/ha	=	7 oz/acre
700 g/ha	=	10 oz/acre
1.10 kg/ha	=	1 lb/acre
1.50 kg/ha	=	1¼ lb/acre
2.00 kg/ha	=	1¾ lb/acre
2.50 kg/ha	=	2¼ lb/acre
3.25 kg/ha	=	3 lb/acre
4.00 kg/ha	=	3½ lb/acre
5.00 kg/ha	=	4½ lb/acre
6.00 kg/ha	=	5¼ lb/acre
7.50 kg/ha	=	6¾ lb/acre
9.00 kg/ha	=	8 lb/acre
11.00 kg/ha	=	10 lb/acre
13.00 kg/ha	=	11½ lb/acre
15.00 kg/ha	=	13½ lb/acre

Conversion tables – metric to imperial (approximate)

Length		
1 millimetre (mm)	=	0.04 inches
1 centimetre (cm)	=	0.40 inches
1 metre (m)	=	39.40 inches
1 metre (m)	=	3.28 feet
1 metre (m)	=	1.09 yards
1 kilometre (km)	=	0.62 miles
Area		
1 square centimetre (cm2)	=	0.16 square inches
1 square metre (m^2)	=	10.77 square feet
1 square metre (m^2)	=	1.20 square yards
1 square kilometre (km^2)	=	0.39 square miles
1 hectare (ha)	=	107,636 square feet
1 hectare (ha)	=	2.5 acres
Volume (dry)		
1 cubic centimetre (cm^3)	=	0.061 cubic inches
1 cubic metre (m^3)	=	1.31 cubic yards
1 cubic metre (m^3)	=	35.31 cubic feet
1,000 cubic metres (m^3)	=	0.81 acre-feet
1 hectolitre (hL)	=	2.8 bushels
Volume (liquid)		
1 millilitre (mL)	=	0.035 fluid ounces (Imp.)
1 litre (L)	=	1.76 pints (Imp.)
1 litre (L)	=	0.88 quarts (Imp.)
1 litre (L)	=	0.22 gallons (Imp.)
1 litre (L)	=	0.26 gallons (U.S.)
Weight		
1 gram (g)	=	0.035 ounces
1 kilogram (kg)	=	2.21 pounds
1 tonne (t)	=	1.10 short tons
1 tonne (t)	=	2,205 pounds
Pressure		
1 kilopascal (kPa)	=	0.15 pounds/in.^{2}
Speed		
1 metre per second	=	3.28 feet per second
1 metre per second	=	2.24 miles per hour
1 kilometre per hour	=	0.62 miles per hour
Temperature		
°F	=	(°C × 1.8) + 32

Conversion tables – imperial to metric (approximate)

Length		
1 inch	=	2.54 cm
1 foot	=	0.30 m
1 yard	=	0.91 m
1 mile	=	1.61 km
Area		
1 square foot	=	0.09 m^2
1 square yard	=	0.84 m^2
1 acre	=	0.40 ha
Volume (dry)		
1 cubic yard	=	0.76 m^3
1 bushel	=	36.37 L
Volume (liquid)		
1 fluid ounce (imp.)	=	28.41 mL
1 pint (imp.)	=	0.57 L
1 gallon (imp.)	=	4.55 L
1 gallon (U.S.)	=	3.79 L
Weight		
1 ounce	=	28.35 g
1 pound	=	453.6 g
1 ton	=	0.91 tonne
Pressure		
1 pound per square inch	=	6.90 kPa
Temperature		
°C	=	(°F – 32) × .5556

Abbreviations

%	=	per cent
ai	=	active ingredient
AP	=	agricultural powder
cm	=	centimetre
cm^2	=	square centimetre
CS	=	capsule suspension
DF	=	dry flowable
DG	=	dispersible granular
DP	=	dispersible powder
E	=	emulsifiable
EC	=	electrical conductivity
e.g.	=	for example
F	=	flowable
g	=	gram
Gr	=	granules, granular
ha	=	hectare
kg	=	kilogram
km/h	=	kilometres per hour
kPa	=	kilopascal
L	=	litre
m	=	metre
m^2	=	square metre
mL	=	millilitre
mm	=	millimetre
m/s	=	metres per second
SC	=	sprayable concentrate
SP	=	soluble powder
t	=	tonne
W	=	wettable (powder)
WDG	=	water dispersible granular
WG	=	wettable granule
WP	=	wettable powder

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