


GUIDE TO NURSERY AND LANDSCAPE PLANT PRODUCTION AND IPM

Publication 841

Ministry of Agriculture and Food
Ministry of Rural Affairs

Ontario

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Introduction

Do you need technical or business information?
Contact the Agricultural Information Contact Centre at
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or
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If you are looking for nursery and landscape plant information on the Internet, check out
www.ontario.ca/crops

for factsheets, articles and photos about the production and maintenance of woody plants.

For timely information on plant health issues with trees, shrubs and perennials, check out the ONnurserycrops blog at www.onnurserycrops.wordpress.com. Updates cover insect and mite pests, disease identification, integrated pest management, upcoming educational opportunities, issues, useful links and more. You can follow this blog to get notices of new content by email.

OMAF Publication 841, *Guide to Nursery and Landscape Plant Production and IPM*, contains comprehensive information on pest management, nutrition and water quality. It is a companion guide to OMAF Publication 840, *Crop Protection Guide for Nursery and Landscape Plants*, which contains a listing of products that have been registered for use on nursery and landscape plants. Together these publications replace OMAF Publication 383, *Nursery & Landscape Plant Production and IPM*.

Front Cover Images:

Front cover large: Container-grown emerald cedars (*Thuja occidentalis*) in a coldframe structure with the poly removed, late summer
Front cover small from top to bottom
Top: Close-up of purple lilac flowers (*Syringa vulgaris*)
Centre: Red flowers of shrub roses
Bottom: White flowers of bottlebrush buckeye (*Aesculus parviflora*)

Back Cover Images:

Back cover large: Container-grown deciduous flowering shrubs (*Wiegela, Cornus, Hydrangea*) in a coldframe structure without plastic film cover, late summer
Back cover small from left: Trays of rooted cuttings of euonymus (*Euonymus fortune*)
Centre: Close-up of emerging needles of blue Colorado spruce (*Picea pungens*)
Right: Close-up of foliage of larch (*Larix* spp.) cuttings

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1. Soil, Media and Water Quality Management

When used correctly, fertilizers can help produce high crop yields cost effectively. Always apply fertilizers at a rate consistent with soil fertility, measured by OMAF-accredited testing (see Appendix C, *OMAF-Accredited Soil, Leaf and Greenhouse Media Testing Laboratories*, on page 79). Low-fertility soils may need nitrogen, phosphorus, potassium and micronutrients at levels at least equal to crop removal. However, high-fertility or heavily manured soils may not benefit from added fertilizer due to increased costs and possibly reduced yields.

Field Nursery Production

Field Soil Testing

The OMAF-Accredited Soil Testing Program

Be sure to use an accredited testing service. To be accredited, a laboratory must use OMAF-approved testing procedures, demonstrate acceptable analytical accuracy and precision and provide OMAF fertilizer guidelines based on the test results.

The OMAF-Accredited Soil Testing Program enables optimum fertilizer and lime application for crop production. Use this program, along with plant analysis and observation of plant nutrient-deficiency symptoms, to determine the fertilizer requirements for a specific crop on a specific field.

The program provides guidelines for the amounts of phosphate, potash and magnesium fertilizers needed, plus the type and amount of lime. The application rates provided in this publication should produce high economic yields when accompanied by good management practices. Higher application rates will sometimes produce higher yields, but the increase is likely to be small and not worth the additional cost.

Soil Tests from Unaccredited Laboratories

Some farmers ask OMAF staff to interpret results from unaccredited laboratories. If the laboratory correctly uses tests identical to those used by OMAF-accredited laboratories and expresses test results in the same units, the OMAF fertilizer requirements for phosphate and potash can then be determined.

Soil tests such as exchange capacity, aluminum and copper are not accredited by OMAF because these tests do not contribute to better fertility regimes. For example, research shows that on Ontario soils, using exchange capacity to adjust potash applications can make the process of adjusting soil fertility less reliable.

The laboratories listed in Appendix C on page 79 are accredited to perform soil tests on Ontario soils and to analyze plant and greenhouse media samples. Please note that these labs may also offer other testing services that are not accredited by OMAF.

When to Sample Field Soil

Always allow enough lead time for a soil analysis. Take soil samples in the autumn from fields to be fertilized in the spring. To avoid problems with bad weather in late fall, fields may also be sampled earlier in the season.

How to Sample Field Soil

It is important to sample soil correctly:

- Use a sampling tube or a shovel to sample soils.
- Sample each field or section of a field separately.
- Take at least 20 soil cores, 15 cm deep, from any field or area up to 5 ha in size. Take proportionately more cores from fields larger than 5 ha. One sample should not represent more than 10 ha. The more cores collected, the more likely the soil sample will reliably measure the field's fertility.
- Use a zigzag pattern to distribute the sampling sites evenly across the field.
- If the soil or crops look different in different sections of the field, or if sections of the field were previously fertilized, manured or limed differently, sample those sections separately, even if these areas are too small to fertilize separately in the future.

- Do not sample recent fertilizer bands, dead furrows, areas adjacent to gravel roads, or areas where lime, manure compost or crop residues have been piled.
- Collect the soil in a clean plastic pail. Do not use galvanized pails.
- Break up the lumps and mix the soil thoroughly (preferably with hands).
- Contact the OMAF-accredited lab for soil sample boxes. Place about 250 mL of the collected, well-mixed soil in a plastic bag, put the bag in a soil sample box and label the sample (e.g., date, field, depth, other information). Soils for nitrate-nitrogen analysis must be kept cool (4˚C). However, it's a good idea to keep *all* soil samples cool until they are delivered to the lab for analysis.
- Sample each field once every 2 or 3 years.
- With every soil sample, be sure to enclose a field information sheet describing the soil management practices used on this field (see below).

Field Soil Management Practices

Good soil management practices, including fertilization, play a major role in ensuring a profitable crop yield. In order for laboratories to provide a reliable fertilizer guideline, they need information about the field, the crop to be fertilized, manure application and legume sod plowed down. Record this information on the field information sheet that must accompany each soil sample sent for analysis. For more information, see *Best Management Practices: Managing Crop Nutrients,* Order No. BMP20E.

Field Soil Micronutrient Testing

OMAF offers accredited tests for manganese and zinc. Use these tests in conjunction with visible deficiency symptoms and plant analysis. OMAF-accredited tests are not available for boron, copper, iron or molybdenum.

- Manganese availability decreases with increasing soil pH. Do not add more lime than is needed to correct acidity.
- Control zinc deficiency by preventing soil erosion and using animal manures. If necessary, prompt use of zinc fertilizers and foliar sprays can help to reduce symptoms of zinc deficiency.
- If the soil test exceeds 200, zinc contamination may have occurred.

How to Sample Field Soil Micronutrients

It is important to sample soil correctly. See *How to Sample Field Soil*, on page 1, for soil sampling instructions. Micronutrient deficiencies often occur in small patches. In these cases, soil and plant samples taken from the entire field may not reveal the problem. It is best to sample problem areas separately.

Use clean, plastic containers in good condition. Soils being tested for micronutrients can be easily contaminated by dirty or dusty sampling tools and containers. Do not collect or mix samples in metal containers. Galvanized (zinc-plated) sampling tools will elevate soil test results for zinc.

Foliar Analysis (Plant Tissue Testing)

Foliar analysis is the best way to diagnose micronutrient problems. It measures the nutrient content of plant tissue. OMAF uses foliar analysis to diagnose suspected nutrient disorders in field-grown and container-grown nursery stock. Table 1–1, *Average Foliar Nutrient Content of Healthy Nursery Stock,* on page 3 specifies normal foliar nutrient concentrations for nursery stock. Note that nutrient concentrations in established landscape stock may be somewhat lower.

When to Sample Plant Tissues

Nutrient levels vary widely with plant age. It is best to take plant tissue samples in July or early August for routine analysis or whenever symptoms appear.

How to Sample Plant Tissues

It is important to sample plant tissues correctly. From deciduous trees and broadleaf evergreen shrubs, select approximately 50 fully expanded leaves midway along a shoot of the current season's growth. From conifers, select 15–20 shoots of current season growth, each approximately 10 cm long. Remove the needles and rinse them in distilled water (discard the twigs). Deliver fresh plant materials directly to the laboratory. If they cannot be delivered immediately, air-dry the tissue samples and ship them in paper bags to avoid spoilage. Submit a sample of healthy leaves from the same area to allow comparisons.

See Appendix C on page 79 for a list of labs and the tests provided by each one.

Understanding Soil pH

pH measures soil acidity or alkalinity on a scale from 0 to 14. The midpoint of the scale, 7, is neutral. Values below 7 are increasingly more acid, while values above 7 are increasingly more alkaline. In general, use lime to raise pH (making the soil more alkaline) and sulphur to lower pH (making the soil more acid). Soil pH testing helps determine any necessary pH adjustments.

Soil pH and Nutrient Availability

- Many soils in Ontario have an alkaline pH. At pH levels above 6, iron (Fe) and manganese (Mn) become less soluble (and therefore less available) the higher the pH. Symptoms of iron and manganese deficiency appear as yellow leaves with green veins: a condition called "interveinal chlorosis." Manganese deficiencies are more common in soil than iron deficiencies.
- Most nursery stock grows well between pH 5.0 and pH 7.2.
- Plants such as red maple, pine, red oak, tuliptree and birch may exhibit iron and/or manganese interveinal chlorosis if the pH is above 6.5.
- For ericaceous plants and conifer seed beds, the pH should be below 6.5.
- Long-term use of fertilizers such as ammonium sulphate, ammonium nitrate, urea, potassium sulphate and mono-ammonium phosphate will gradually reduce soil pH over several years. This is most likely to occur on light, sandy soils and can be corrected by liming the soil.
- Anhydrous ammonia causes a marked, though temporary, soil pH increase when first applied.
- Superphosphate and muriate of potash have little or no effect on soil pH.

Buffer pH Testing

Different soils with identical pH values will require different amounts of lime or sulphur to reach a desired pH level depending on clay and organic matter content. Where soil is acidic (pH less than 7), an additional soil test, the buffer pH, determines the amount of lime required to increase soil pH to the target level. The actual lime needed is also determined by the target pH for the crop. The lower the buffer pH value on a soil test, the more lime that will be required to neutralize it. See Table 1–2, *Lime Requirements to Correct Soil Acidity Using Buffer pH* on page 4.

Limestone Type

Both calcitic limestone and dolomitic limestone are available in Ontario. Calcitic limestone is mainly calcium carbonate, while dolomitic limestone is a mixture of calcium and magnesium carbonates. Use dolomitic limestone when the magnesium in the soil is 100 ppm or less. It is an excellent, inexpensive magnesium source for acid soils. Use either calcitic or dolomitic limestone when the magnesium in the soil exceeds 100 ppm.

TABLE 1–1. Average Foliar Nutrient Content of Healthy Nursery Stock

Nutrient	N %	P %	K %	Ca %	Mg %	Mn ppm	Cu ppm	Zn ppm	B ppm	Fe ppm
Field-grown										
Conifers	1.7	0.24	1.0	1.0	0.2	88	6	31	35	87
Broadleaf evergreens	2.3	0.27	1.1	2.5	0.3	25	5	27	42	120
Deciduous trees and shrubs	2.8	0.25	1.7	2.4	0.4	62	7	25	58	133
Container-grown										
Conifers and broadleaf evergreens	2.5	0.4	1.4	2.0	0.3	52	5	24	48	127

Limestone Quality

Two main factors affect the ability of limestone to reduce soil acidity. *Neutralizing value* is the amount of acid a given quantity of limestone neutralizes when it dissolves totally. Neutralizing value is expressed as a percentage of the neutralizing value of pure calcium carbonate. A limestone that neutralizes 90% as much acid as pure calcium carbonate has a neutralizing value of 90. In general, the higher the calcium and magnesium content of a limestone, the less needs to be applied.

Fineness rating describes the limestone's particle size. The more finely ground the limestone, the greater its acid-neutralizing ability. Limestone rock has much less surface area than finely powdered limestone and neutralizes soil acidity much more slowly.

Agricultural Index

OMAF uses the Agricultural Index to compare the acid-neutralizing effectiveness of different limestone samples. Lime with a high Agricultural Index rating is worth more than lime with a lower rating because a smaller quantity achieves the same result.

For example, if ground limestone A has an Agricultural Index of 40, while ground limestone B has an Agricultural Index of 80, the application rate of A must be twice the application rate for B to achieve the same effect. Limestone A is therefore worth half the price of limestone B per tonne.

OMAF soil test guidelines assume an Agricultural Index of 75. To calculate the correct application rate for limestone of a different quality, use the following formula:

Calculating Limestone Application Rates

$$\text{application rate} = \frac{75}{\text{Agricultural Index}} \times \text{application rate from soil test}$$

Raising Soil pH

When soil tests indicate the need to raise pH, use lime. Table 1–2, *Lime Requirements to Correct Soil Acidity Using Buffer pH,* below, gives general lime application rates required to obtain the correct soil pH for most crops, based on soil pH and buffer pH.

TABLE 1–2. Lime Requirements to Correct Soil Acidity Using Buffer pH

Limestone needed (tonnes/hectare) based on an Agricultural Index of 75		
Buffer pH	**Target Soil pH = 6.5**	**Target Soil pH = 6.0**
	Lime if soil pH falls below 6.1	**Lime if soil pH falls below 5.6**
7.0	2	0
6.5	3	2
6.0	9	6
5.5	17	12
5.0	20	20

Tillage Depth

These lime recommendations should increase soil pH to the target value in the top 15 cm of the soil. If the soil is plowed to a greater or lesser depth, proportionately more or less lime will be required to reach the target pH.

Lowering Soil pH

Because lowering the pH of alkaline soils (pH greater than 7) is expensive, it is not practical to acidify large areas. Many fields in southern Ontario vary quite a bit in soil pH. Several soil test samples throughout the field can be taken and used to create a detailed map of soil pH, perhaps with the aid of GPS technology. Plant crops that require more acidic soils in those lower pH zones, according to your soil test map. Avoid growing acid-loving species in high pH soil that will not be able to meet their nutrient requirements.

If the starting soil pH value is 7 or less, sulphur is the first choice for lowering pH. Other acidifying materials (e.g., aluminum sulphate, iron sulphate) are less effective than sulphur and may be toxic to plants. Apply sulphur at least every other year to keep the soil pH near the desired level. Test the soil pH in the spring. If necessary, apply sulphur at the recommended rate to help adjust soil to the correct pH value (see Table 1–3, *Soil Acidification to pH 5.0 Using Sulphur,* on this page). In small areas, an alternative is to lower the soil pH by replacing the soil or amending it with large quantities of acid peat or another acidic organic material. Test the pH of any organic amendment before using it. Leaf mould, compost and peat may be alkaline rather than acidic.

TABLE 1–3. Soil Acidification to pH 5.0 Using Sulphur

Elemental sulphur required (kg/100 m²) each year for 2 successive years		
Initial pH	**Soil Type**	
	Sand	**Loam**
7.0	7.4	22.6
6.5	6.0	17.5
6.0	4.0	12.0
5.5	2.0	6.0

Soluble Salts in Soil

High concentrations of water-soluble salts in the soil interfere with plant water uptake. This can delay or prevent seed germination, kill new transplants and seriously slow the growth of new and established plants. Levels of soluble salts can be tested by measuring electrical conductivity (EC). The EC measurement is expressed in units of millisiemens/cm (mS/cm). See Table 1–4, *Soil Electrical Conductivity (EC) Readings,* on this page. Table 1–4 interprets soil conductivity readings in Ontario field soils using a 2:1 water:soil paste mixture (based on volume).

Ontario soils are naturally low in soluble salts. As a result, these salts rarely cause crop production problems and are not routinely measured in soil tests. However, excessive fertilizer application, road salt run-off and chemical spills can cause soluble salts to build up in the soil. This problem is most severe when soil moisture is low and salt concentrations are high. Improving soil drainage in order to encourage more natural leaching may help reduce levels of soluble salts. If salt problems are suspected, send a soil sample to an OMAF-accredited laboratory for a soil EC reading. See *How to Sample Field Soil*, on page 1, for soil sampling instructions.

TABLE 1–4. Soil Electrical Conductivity (EC) Readings

EC Reading (mS/cm)	Rating	Plant Response
0–0.25	Low	Suitable for most plants when using average amounts of fertilizer
0.26–0.45	Medium	Suitable for most plants when using average amounts of fertilizer
0.46–0.70	High	May reduce seedling emergence and cause slight to severe damage to salt-sensitive plants
0.71–1.00	Excessive	May prevent seedling emergence and cause slight to severe damage to herbaceous and juvenile woody plants
greater than 1.00	Excessive	Expect poor seedling emergence; may cause damage to herbaceous and juvenile woody plants

OMAF-accredited laboratories test for soluble salts by measuring the electrical conductivity (EC) of a soil/water slurry. The higher the concentration of soluble salts, the greater the soil's conductivity. If testing indicates a salt problem, correct it by leaching the soil with water.

Fertilizer Use

Fertilizing Field Nursery Stock

Fertilize nursery stock regularly to achieve optimum growth and maximum profit. Dry and liquid fertilizers produce similar results, so choose a suitable fertilizer formulation on the basis of soil test results, consistent supply, handling equipment available, application cost and cost per kilogram of nutrients. Use Tables 1–7 to 1–10, on pages 7–8, when choosing fertilizer formulations.

OMAF provides reliable soil test information for phosphorus and potassium. See Table 1–5, *Phosphorus Requirements for New and Established Field Nursery Stock*, on this page and Table 1–6, *Potassium Requirements for New and Established Field Nursery Stock*, on page 7. Because field soil nitrogen levels fluctuate rapidly, nitrogen soil tests are unreliable.

Fertilizing Seed Beds and Transplant Liner Beds

Before planting beds in the spring, incorporate about 50 kg of actual nitrogen per hectare. Additional nitrogen may be required when planting particularly rapid-growing species. Add organic matter, such as rotted barnyard manure or compost, at a rate of about 45 t/ha. Growing green manures on the land provides another good source of organic matter. Adjust rates of nitrogen fertilizers if manure is applied. See Table 1–13, *Manure Application Rate and Approximate Nutrients Supplied* on page 16. When fresh, undecomposed organic matter that is low in nitrogen is added to soil, incorporate nitrogen to compensate for microbial decomposition. For example, for every tonne of fresh sawdust, add 15 kg of actual nitrogen. When preparing seed and liner beds, incorporate phosphorus and potassium as indicated by a soil test. In early spring of the second season, apply phosphorus and potassium as indicated by a soil test and apply nitrogen at the rate of 50–75 kg/ha.

Fertilizing Established Field Stock

Fertilize established field stock based on phosphorus and potassium soil test results. See Table 1–5 on this page and Table 1–6 on page 7. As noted earlier, field soil nitrogen levels fluctuate rapidly, making nitrogen tests unreliable. The actual amount of individual nutrients in common fertilizer can vary greatly. Use Table 1–7, 1–8 and 1–9 on page 7 to determine actual amounts of nitrogen, phosphorus and potassium found in common sources of fertilizer. Use Table 1–10, in conjunction with Tables 1–7 to 1–9, to determine how much fertilizer will supply a given quantity of elemental nitrogen per specified area when the percentage of nitrogen in the fertilizer formulation is known.

Apply fertilizer in the spring, 1–2 weeks before growth resumes (just before bud break or as the first flush emerges).

To avoid stimulating succulent growth in the fall, do not apply high rates of nitrogen after mid-July. Apply small amounts of nitrogen regularly throughout the growing season or via a slow-release formulation.

TABLE 1–5. Phosphorus Requirements for New and Established Field Nursery Stock (using the 0.5 N sodium bicarbonate method of phosphorus extraction)

Phosphorus (0.5 N sodium bicarbonate extractant)

Soil Test Value (ppm)	Response*	Phosphate (P_2O_5) Required (kg/ha)	
		New Planting	Established Planting
0–3	HR	140	100
4–5	HR	130	90
6–7	HR	120	80
8–9	HR	110	70
10–12	HR	100	70
13–15	HR	90	60
16–20	MR	70	50
21–25	MR	60	40
26–30	MR	50	30
31–40	MR	40	20
41–50	LR	0	0
51–60	RR	0	0
61–80	NR	0	0
80+	NR	0	0

***Explanation of ratings:**

Response Category	Probability of Profitable Response to Applied Nutrients
High Response (HR)	High (most of the cases)
Medium Response (MR)	Medium (about half the cases)
Low Response (LR)	Low (few of the cases)
Rare Response (RR)	Rare (very few of the cases)
No or Negative Response (NR)	Not profitable to apply nutrients

TABLE 1–6. Potassium Requirements for New and Established Field Nursery Stock (using the 1 N ammonium nitrate method of potassium extraction)

Potassium (1 N ammonium nitrate extractant)

Soil Test Value (ppm)	Response*	Potash (K_2O) Required (kg/ha) (New or Established Planting)
0–15	HR	130
16–30	HR	120
31–45	HR	110
46–60	HR	100
61–80	HR	90
81–100	HR	80
101–120	MR	70
121–150	MR	60
151–180	MR	40
181–210	LR	0
211–250	RR	0
250+	NR	0

***Explanation of ratings:**

Response Category	Probability of Profitable Response to Applied Nutrients
High Response (HR)	High (most of the cases)
Medium Response (MR)	Medium (about half the cases)
Low Response (LR)	Low (few of the cases)
Rare Response (RR)	Rare (very few of the cases)
No or Negative Response (NR)	Not profitable to apply nutrients

TABLE 1–7. Nitrogen Sources

Nitrogen Materials	% Nitrogen (N)	Other Elements Supplied
Ammonium nitrate	34	—
Urea	46	—
Calcium ammonium nitrate	27	4%–6% Calcium (Ca), 0%–2% Magnesium (Mg)
Ammonium sulphate	21	24% Sulphur (S)
Calcium nitrate	15	19% Calcium (Ca)
Potassium nitrate	12	44% Potash

TABLE 1–8. Phosphorus Sources

Phosphorus Materials	% P_2O_5	Other Elements Supplied
Superphosphate	20	20% Calcium (Ca), 12% Sulphur (S)
Triple superphosphate	44–46	21% Calcium (Ca)
Monoammonium phosphate (11-52-0)	48–52	11% Nitrogen (N)
Diammonium phosphate (18-46-0)	46	18% Nitrogen (N)

TABLE 1–9. Potassium Sources

Potassium Sources	% K_2O	Other Elements Supplied
Potassium chloride (muriate)	60–62	—
Potassium sulphate	50	18% Sulphur (S)
Sulphate of potash magnesia	22	11% Magnesium (Mg), 20% Sulphur (S)
Potassium nitrate	44	12% Nitrogen (N)

Fall fertilization can be a great opportunity for increasing nitrogen uptake and plant growth in perennial crops. Plants that are fertilized in the fall usually experience better spring growth than plants that are fertilized in the spring. Apply up to one-third of the year's fertilizer requirement after top growth ceases and the danger of top growth stimulation has passed (late September to late October). Roots of most nursery crops will grow and absorb nutrients whenever soil temperatures stay above 5°C. Nitrogen is either taken up quickly by roots, lost through leaching or sequestered by bacterial activity. By splitting the total annual amount of nitrogen over several applications, losses can be minimized. A total of 100–150 kg of actual nitrogen per hectare can be used in 1 year. Rapid-growing species may need more nitrogen during particular growing conditions.

For optimum fertility, sandy soils need more nitrogen and potassium fertilizers than clay soils. When no soil test is available, apply 100 kg of actual nitrogen per hectare using a 3-1-2 ratio fertilizer. Do not apply fertilizer in late fall or winter. It will not be absorbed because of the cold soil temperatures and may be lost through run-off.

Use Table 1–10, *Nitrogen Equivalency Table*, on this page when determining how much fertilizer is required to apply a specific quantity of elemental nitrogen.

Fertilizing Landscape Plantings

Most soils have enough inherent fertility to grow plants, so there is usually little need to fertilize thriving landscape plants. However, soil health, texture and nutrient-holding capacity can be a real issue in newer residential and commercial sites, especially those developed in the last 20 to 30 years. Fertilize based on soil test results, soil characteristics, type of plant and desired growth. Fertilizing, adding organic matter and improving soil aeration in the root zone can help increase the chance of successful plant establishment after transplanting and improve plant vigour for years to come.

Trees growing in lawn areas benefit from fertilizers applied to the grass. Apply herbicide-free turf fertilizer at a rate slightly above the suggested rate for grass. Any complete, high-nitrogen fertilizer should be adequate for trees and shrubs. Most studies show that nitrogen improves plant growth more than phosphorus and potassium. Distribute the required amount of fertilizer evenly on the soil surface. Begin well beyond the drip-line of the canopy (as much as twice the distance from the trunk to the drip-line). Extend the fertilizer inward to two-thirds the distance between the drip-line and the trunk. If paving obstructs part of the area under the branch spread, reduce the quantity of fertilizer accordingly. For landscape plantings, apply nitrogen at 1.0–1.5 kg actual N per 100 m^2. Irrigate thoroughly after fertilizer application. Increase the application rate in the case of low tree vigour, a long growing season and/or well-drained, sandy soil.

TABLE 1–10. Nitrogen Equivalency Table

% Nitrogen in the Fertilizer	Kilograms of Fertilizer Needed to Supply:		
	0.5 kg of actual nitrogen/100 m^2	50 kg of actual nitrogen/ha	100 kg of actual nitrogen/ha
5	10	1,000	2,000
6	8.33	833	1,667
7	7.14	714	1,429
8	6.25	625	1,250
9	5.55	556	1,111
10	5.00	500	1,000
11	4.55	455	909
12	4.16	417	833
13	3.84	385	769
14	3.57	357	714
15	3.33	333	667
16	3.12	313	625
17	2.94	294	588
18	2.77	278	556
19	2.63	263	526
20	2.50	250	500
21	2.38	238	476
22	2.27	227	455
23	2.17	217	435
24	2.08	208	417
25	2.00	200	400
26	1.92	192	385
27	1.85	185	370
28	1.79	179	357
29	1.72	172	345
30	1.67	167	333
31	1.61	161	323
32	1.56	156	313
33	1.50	152	303
34	1.47	147	294
35	1.43	143	286
46	1.09	109	217

Split fertilizer applications during the year. Apply fertilizer in the spring, after the first foliage flush expands. Fertilize again in the fall after top growth ceases and the danger of growth stimulation has passed (late September to late October). Apply up to one-third of the annual amount of nutrients in the fall. To prevent run-off, do not apply broadcast fertilizer to frozen or saturated soils. *To avoid stimulating top growth into the fall, do not use large amounts of fertilizer with readily available nitrogen between mid-July and mid-September.*

If fertilizer is applied only once, use fertilizers with at least 60% or more of the product in slow-release form. This will ensure the nutrients become available slowly, with minimum leaching. Pressure injecting slow-release fertilizer into the soil is a good way to ensure nutrients remain in the root zone for uptake. Use a sub-surface method of tree fertilization if the soil needs aeration or when it is important not to overstimulate the vegetation growing on the surface.

Fertilizer Application Rates

Use the following formula to determine the nitrogen application rate of any nitrogen fertilizer formulation:

$$\text{kg fertilizer per } 100\text{m}^2 = \frac{100}{\%\text{ N in fertilizer}} \times (0.5\text{ kg N}/100\text{m}^2)$$

To calculate kg of fertilizer/hectare, multiply the result by 100.

Organic Amendments to Soil

Organic Matter Content of Soil

Organic matter helps maintain soil structure, aeration and water penetration. Soil structure and aeration promote root development and plant growth, while rapid water penetration minimizes erosion. When organic matter breaks down and/or is lost through clean cultivation practices, replace it by adding organic amendments to the soil. Table 1–11, *Optimal Organic Matter Content in Agricultural Soils*, on this page provides guidelines for optimal organic matter content in agricultural soils.

TABLE 1–11. Optimal Organic Matter Content in Agricultural Soils

Soil Type	Optimum % Organic Matter
Sandy soils	2–4 +
Sandy loam soils	3–4 +
Loam soils	4–5 +
Clay loam soils	4–5 +
Clay soils	4–6 +

Cover Crops

Cover crops play a major role in soil management. They reduce erosion by providing a ground cover and improve or maintain the soil by adding organic matter. To get the most benefit, plant late-summer and fall cover crops promptly after harvest. While broadcast application and incorporation of cover crop seed can be used to establish cover crops, direct seeding or drilling will ensure faster and more even establishment. See Table 1–12, *Characteristics of Cover Crops Grown in Ontario* on page 10 for more information on some of the common cover crops grown in Ontario.

TABLE 1–12. Characteristics of Cover Crops Grown in Ontario

Species	Normal Seeding Time	Seeding Rate kg/ha	Nitrogen[a] Scavenging Potential	Over-wintering Characteristics	Potential Weed Problem from Volunteer Seed	Nematode Rating[b]	
						Lesion	Root-knot
Grasses							
Ryegrass	April to May or August to early September	13–17	moderate	annual & Italian: partial survival; perennial: overwinters	no	–	–
Spring cereals	mid-August to September	100–125	moderate to high	killed by heavy frost	no	+	–
Sorghum sudan	June to August	50	moderate to high	killed by frost	no	NH[b]	–
Pearl millet	June to August	9–10	moderate to high	killed by frost	no	NH[b]	NH[b]
Winter wheat	September to October	100–125	moderate to high	overwinters well	no	+	NH
Winter rye	September to October	100–125	moderate to high	overwinters very well	no	+[c]	NH
Legumes[d]							
Hairy vetch	August	20–30	low to moderate (fixes N)	overwinters	no	++	+
Red clover	March to April	8–10	low to moderate (fixes N)	overwinters	no	++	+++
Sweet clover	March to April	8–10	low to moderate (fixes N)	overwinters	no	–	–
Non-legume broadleaves							
Buckwheat	June to August	50–60	moderate	killed by first frost	yes	+++	NH
Oilseed radish[e]	mid-August to early September	10–14	high	killed by heavy frost	yes	NH[b]	NH[b]
Nematode Rating Codes: – = poor; + = ability to host; NH = non-hosts							

[a] *The potential for nitrogen uptake is influenced by seeding date, stand establishment and growing conditions. Winterkilled cover crops can accumulate significant amounts of nitrogen the preceding fall. Overwintering cover crops will accumulate a greater portion of nitrogen in the spring. Nitrogen-fixing legumes are less efficient at taking up residual nitrogen.*

[b] *Varietal differences in cover crop species may affect nematode reaction. Select the proper variety selection to ensure this cover crop is not a nematode host as there are documented varietal differences. Some varieties may actually lead to higher nematode populations.*

[c] *Rye whole season rating would be higher (+++).*

[d] *Some diseases caused by* Pythium *and* Phytophthora *can be more severe after legume cover cropping.*

[e] *Oilseed 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

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

Ryegrass (Annual, Italian or Perennial)

Ryegrass is direct seeded in the spring or from August to mid-September. It can also be seeded with a nurse crop in the spring or broadcast into corn in late June to early July with some success. Annual ryegrass gives the most top growth in the seeding year. It often heads 6–8 weeks after seeding. Italian ryegrass (a biennial) does not head in the seeding year, so top growth is considerably less. However, it has the largest, densest root system of the three types. Annual and Italian ryegrass usually suffer considerable winterkill, but part of the stand may survive. Perennial ryegrass normally survives the winter.

Cautions:

Establishment and growth of ryegrasses can be poor during very hot, dry weather. Cultivation or discing may not completely kill overwintering ryegrass. The nitrogen tied up in ryegrass releases more slowly compared to many other cover crops.

Spring Cereals (Oats, Barley, Spring Wheat, Etc.)

Spring cereals can be inexpensive, easy-to-manage cover crops. Stands seeded from mid-August to mid-September will have 20–40 cm of growth by freeze-up. Early-planted cover crops may produce seeds under warm, wet conditions, but little viable seed is usually set. Spring cereal cover crops are generally killed by late, hard frosts. Volunteer spring cereals are sometimes left to grow as a cover crop until freeze-up. These stands may not be very uniform. Most winterkilled spring cereals leave little residue to interfere with early planting.

Cautions:

Very early seeding may result in considerable growth by freeze-up. If left unplowed in the fall, the mat of dead residue will delay soil drying and warming in the spring, which may delay the planting of early-seeded crops. On erosion-prone knolls, spring cereals often have little growth and have been observed to “blow off” by spring.

Sorghum Sudan and Forage Pearl Millet

Sorghum sudan and forage pearl millet are warm-season grasses. They are extremely sensitive to frost. They have extensive root systems and produce a significant amount of top growth. They are both a good option for a mid-summer green manure crop after early-harvested vegetable crops such as peas, sweet corn or cucumbers.

Plant in mid-June, after all threat of frost is past, through to early August. These crops benefit from the warm temperatures of early to mid-summer. Applying approximately 50 kg of nitrogen per hectare will help the crop achieve maximum top growth. A preplant herbicide treatment is suggested to help establish the crop. Frost will control these grasses in early to mid-fall. If earlier control is needed, most burndown herbicides will be effective.

Planting certain cultivars of sorghum sudan (Sordan 79, Trudan 8) and forage millet in rotation with high-value horticultural crops can reduce plant parasitic nematode soil populations below economic thresholds. It may be necessary to grow these varieties under weed-free conditions for more than 1 year to be fully effective. These cover crops may not entirely replace fumigation under high levels of nematode pressure. However, they are useful in keeping nematode levels low and preventing resurgences in the future. Sorghum sudan and pearl millet do not have to be incorporated green for nematode suppression.

Canadian Forage Pearl Millet 101 reduces nematode populations by inhibiting the ability of nematodes to reproduce in its root system.

Cautions:

Mow before the crop reaches 1 m in height. This encourages root development and tillering and prevents the stalks from becoming woody and slow to decompose. To ensure regrowth, do not mow shorter than 15 cm.

Winter Rye

Winter rye is one of the most consistent, flexible and economical cover crops available. It can be seeded later than any other crop and still survive over winter. For good ground cover and erosion protection, seed it at least a month before freeze-up. Typically, that means seeding it from September into late October. Winter rye grows until freeze-up and then begins growing again in late March to early April (slightly earlier than winter wheat). The growth rate is very rapid during May. Kill the stand in late April or early May either by tilling it or applying a herbicide. Winter rye can be seeded earlier than September (without vernalization or the winter cold, it will not produce seed heads). However, the summer heat and common lack of soil moisture may result in an uneven stand.

Cautions:

Rye will grow very rapidly under warm temperatures in early spring, so monitor growth closely and kill the crop before it grows too tall. If rye is left too long, it can deplete soil moisture and incorporation may be difficult. Rye is an excellent host for root-lesion nematode, particularly when grown as a full-season crop.

Winter Wheat

Seed winter wheat from late August through October. It can be seeded outside this time frame, but weather conditions may reduce top growth. Wheat will survive over winter and begin growing again in April. The stand can be killed by tilling it or applying a herbicide. Compared to rye, winter wheat shuts down earlier in the fall and begins to grow later in the spring.

Cautions:

Winter wheat does not generally provide the same amount of green material to return to the soil or the level of weed suppression that rye provides. Early-planted wheat may be more susceptible to infection with the barley yellow dwarf virus (BYDV), although this will have little impact on growth of the wheat as a plowdown or cover crop.

Legumes

Legume cover crops can fix nitrogen from the air, incorporating it into the soil for the succeeding crop. They also protect the soil from erosion and add organic matter. The amount of nitrogen fixed varies between species. Generally, more top growth indicates more fixed nitrogen. Legume cover crops, such as clover, are 80% as effective at scavenging soil nitrogen as grass cover crops. Some legume species have aggressive taproots that can break up subsoil compaction, but this will require more than one season's growth.

Nitrogen release from legumes can be inconsistent because it is a biological process, affected by soil moisture and temperature. This must be accounted for when calculating fertilizer needs. Excess nitrogen release late in the season could lead to excessive vegetative growth in fruiting vegetables and may delay hardening off for winter.

Hairy Vetch

Hairy vetch must be seeded by mid-August to provide good ground cover over winter. Late seeding may result in winterkill. It grows slowly until freeze-up, establishing a very vigorous, fibrous root with moderate top growth. Hairy vetch may also be drilled into winter wheat when the wheat is about 20 cm tall. Seeding at this stage prevents the hairy vetch from causing a problem with wheat harvest but results in much more vetch growth by freeze-up compared to August seedings. Hairy vetch vines resume growth early in the spring (similar to the time for winter wheat) and may reach 150 cm in length if left to maturity. Cover crop stands are usually killed in the spring by tilling or applying herbicide. Vetch's fibrous root system improves soil structure. It also adds large amounts of fresh organic matter to the soil.

Cautions:

Competition from volunteer cereals can lead to poor stands of hairy vetch. On droughty soils, hairy vetch may deplete soil moisture if it is left to grow until early May. Roundup does not kill hairy vetch effectively. Instead, use 2,4-D, MCPA, Banvel or their mixtures. If hormone-sensitive crops are to be planted, apply these sprays in the fall to avoid harming them. Hairy vetch is slow to establish and provide ground cover, leaving the soil open to erosion and weed seed germination.

Red Clover

While not commonly used in horticultural rotation, red clover is often broadcast into winter wheat in March or early April or seeded with spring cereals. Early seeding gives the best stands. Double-cut red clover is more resistant to dry summer conditions. It produces considerably more top growth than single cut (60 cm vs. 25 cm, respectively).

The bulk of red clover growth takes place from mid-summer until a heavy frost. Red clover can be killed in the fall or spring by tilling or applying herbicide. Unless herbicides are also applied, chisel plowing will not kill the stand completely. Red clover plowdown improves soil structure and adds large amounts of organic matter. Nitrogen is fixed and released slowly to the following crop. It gives excellent erosion protection when left unplowed until spring or killed with a herbicide in the fall (but not tilled).

Cautions:

Roundup alone often doesn't kill red clover effectively. Instead, consider 2,4-D, MCPA, Banvel or mixtures. If hormone-sensitive crops are to be planted, apply these sprays in the fall to avoid harming them.

Sweet Clover

Similar to red clover, sweet clover is most commonly seeded into winter wheat in March or early April or seeded with spring cereals. Either yellow- or white-blossom type may be used. White-blossom type produces somewhat taller top growth.

The bulk of sweet clover growth takes place after the grain is harvested until heavy frosts. Top growth will usually be 30–40 cm tall but not dense. A strong taproot is produced, often 30 cm long and 1 cm across at the crown. If allowed to grow the following spring, sweet clover will flower in July at a height of about 180 cm and then set seed and die. Similar to red clover, sweet clover plowdown stands may be killed in the fall or the following spring by tilling or applying herbicides.

Cautions:

Sweet clover is very sensitive to many herbicides and will not tolerate any phenoxy herbicides, including 2,4-D.

Non-Legume Broadleaves

These broadleaf crops cannot fix nitrogen out of the air, but they may absorb large quantities from the soil. 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.

Buckwheat

As a cover crop, buckwheat is most commonly seeded in late June to early August. It grows very rapidly, reaching flower stage and a height of 45–75 cm in about 6 weeks. It has a relatively small fibrous root system and is completely killed by the first frost. Buckwheat provides rapid soil cover and gives good erosion protection during the growing season. It smothers annual weeds and suppresses perennial ones. Moderate amounts of fresh organic matter are returned to the soil. Buckwheat does not fix nitrogen. It can be planted as a green manure crop after early-harvested crops such as peas, snap beans and winter wheat. Buckwheat is often used in organic production systems as a rotation crop to help clean up weed infestations and make phosphorous more available.

Cautions:

The flowers are very attractive to bees. Monitor flowering and take appropriate action to prevent seed set. Late summer seedings may be killed by an early frost before providing significant growth.

Oilseed Radish and Mustard

Oilseed radish is commonly seeded in August or very early September. It is unaffected by early frosts. It can grow to a height of 50–90 cm and blooms in October. If planted too early, the flowers may set seed. Mowing oilseed radish before it flowers will delay seed set while maintaining cover. Leave 10–15 cm of cover crop height to encourage regrowth. The plant has a thick taproot, varying between carrot-shaped and turnip-shaped, with extensive secondary roots. Oilseed radish is killed by freezing in late November or December. It provides a reasonably rapid soil cover and excellent erosion protection over winter. It returns moderate amounts of organic matter to the soil. To ensure good crop growth, make sure the soil contains a large amount of available nitrogen, either from a recent manure application or left over from a previous crop.

Some oilseed radish cultivars (as well as certain mustard cultivars) can help to reduce plant parasitic nematode populations in the soil. The nematode-suppressing cultivars must be incorporated into the soil while they are still green. As the green residue breaks down, it releases a nematode-killing compound (isothiocyanate) into the soil.

Cautions:

Growth will be poor if soil nitrogen levels are low or soil compaction is severe. Scattered volunteer plants usually appear in most crops planted after oilseed radish. To successfully reduce nematode population levels below the economic thresholds, these crops may need to be planted for more than 1 year.

The mild winters of southwestern Ontario may allow some varieties of oilseed radish and mustard to partially overwinter.

For more detailed information on cover crop use and management, see the OMAF website at www.ontario.ca/crops.

Tillage Systems After Cover Crops

In conservation and no-till cropping systems, cover crops can greatly increase the surface residue cover, adding to the potential benefits of the system.

However, there are several management factors to keep in mind:

- Some regrowth of winter annual, biennial or perennial cover crops may occur in the following crop year. Usually this is easily controlled with normal herbicide treatments in the following crop. Allowing a controlled amount of regrowth (for example, windstrips) can provide some spring wind protection.
- Schedule the first conservation tillage operation with overwintering cover crops at least 2 weeks before planting the main crop. This will allow the breakdown of the residue to start.
- Seedbed preparation may be difficult if persistent cover crops are not tilled until spring or if they are allowed to grow too large.
- Cover crops that do not survive over winter may be an option, especially on poorly drained soils or before crops that are planted very early in the spring.
- Consider using 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 they get established.

For more information, see:

- OMAF Publication 611, *Soil Fertility Handbook*
- *Best Management Practices: Managing Crop Nutrients*, Order No. BMP20E
- *Best Management Practices: Soil Management*, Order No. BMP06
- *Best Management Practices: Field Crop Production*, Order No. BMP02
- *Best Management Practices: Nutrient Management*, Order No. BMP05

Applying Manure

Applying manure to fields provides many benefits. It adds organic matter to the soil and supplies many of the nutrients needed for crop production. It increases moisture retention and internal drainage. It also builds structure, increases stability and provides a source of nutrients that supports a diverse biological population in the soil. Keep in mind, however, that many fields require more nitrogen than manure alone can supply.

Store manure in a way that saves the liquid portion and minimizes exposure to air. Do not spread manure from December 1 to March 31 or any time when the ground is frozen and/or covered in snow. For best results, apply manure to cool, moist soils (below 10°C) to minimize nutrient losses.

Manure applications can actually reduce the need to add nitrogen, phosphorus and potassium fertilizers. The nutrient content of manure depends on a variety of factors such as livestock type, age and rations, as well as how the manure is stored and whether water is added. See Table 1–13, *Manure Application Rate and Approximate Nutrients Supplied* on page 16 for general guidelines on the volume of nutrients provided by manure.

Sampling Manure

It is important to know the nutrient content of manure in order to decide how much to apply. This means sending samples to a laboratory for testing. Make sure the manure is sampled correctly, however. For liquid manure, mix the tank contents thoroughly before taking a sample. For solid manure, take forkfuls from many places in the stack, not just from the surface. Mix these samples thoroughly, and then submit 1–2 kg for testing.

Timing of Manure Applications

Manure is made up of two main sources of nitrogen. The readily available mineral nitrogen comes in the form of ammonium. This is a positively charged ion that binds to soil particles and is unlikely to be leached. Generally, if the soil is 10°C or colder, very little ammonium will be converted to nitrate-nitrogen, which can be lost through leaching. This is the reason that manure applied in the late fall has less environmental impact than manure applied in early fall.

The other source of nitrogen is slowly available nitrogen, which comes in an organic form that is bound to carbon. Organic nitrogen is released slowly over time, as a function of temperature and soil aeration.

TABLE 1–13. Manure Application Rate and Approximate Nutrients Supplied

Class of Livestock	Nitrogen (kg/ha)			Phosphate	Potash
	Fall	Spring[a]	Spring C[a]	P_2O_5 (kg/ha)	K_2O (kg/ha)
Liquid manure at 10 m^3/ha (900 gal/acre)					
Cattle and mixed livestock	5	10	12	4	16
Poultry	23	46	58	22	26
Swine	8	15	19	7	14
Solid manure at 10 t/ha (4.5 tons/acre)[b]					
Cattle and mixed livestock	12	24	30	10	44
Poultry	70	140	175	75	96
Swine	15	30	38	20	26

[a] *Spring is spring-applied manure not covered immediately; Spring C is spring-applied manure that is either injected or covered within 1 day.*

[b] *Density of manure in spreader may vary from 400 kg/m^3 (25 lb/ft^3) for heavily bedded or very dry manure to 1,000 kg/m^3 (62 lb/ft^3) for semi-solid and liquid manures.*

Container Production

Using Containers

High-density plastic pots are most commonly used for long-term container growing. Fibre pots are useful for short-term growing, for potting of field-grown stock and for winter storage or spring shipping. Fibre pots are not suitable for long-term growing because they soften, decompose and may be damaged by rough handling. Always remove a fibre pot when planting in the landscape. Recently, growers are testing alternative materials for pots, most notably coco coir. These pots have the added benefits of increasing aeration porosity (the percentage of air in the pore space) in the root zone and being compostable.

Pot colour affects mix temperature and root development. Root growth decreases when media temperatures approach 30˚C. Black and dark green pots may be 10˚C hotter than white or light-coloured pots. The temperature of dark pots may reach almost 40˚C on the inner surface of the sunny side. However, white or light-coloured pots are not widely available unless ordered in large quantities from the manufacturer. Use light-coloured pots along the outside rows of a block and for widely spaced plants. It is acceptable to use dark colours in the centre of a pot-to-pot block, since sunlight will not strike the pot wall. To diagnose high-temperature injury, remove the pot and compare root growth on the sunny and shaded sides of the pot.

Root circling, especially in small circular containers, can result in root constriction and eventual plant decline. The most effective way to prevent root circling is to remove the pot after 1 year, prune the roots and spread them out and then re-pot the plant into a larger container with additional media. Pruning the roots of pot-bound plants discourages root circling after re-potting or planting. Tree species in small containers are particularly vulnerable to root circling. Minimize root circling by using square containers or ones with vertical ribs that direct root growth vertically. There are also various types of perforated containers and growing bags that help prevent root circling and increase the fibrous roots in the root zone. Creating air circulation at the base of the containers (e.g., by placing containers on structures that allow air flow) encourages air pruning and root branching where the roots come in contact with the air.

Consider staking the outside rows of container crops to help prevent plants from blowing over, especially in the case of tall plants.

Potting Media

A successful container-growing operation depends on the potting media. The media ingredients need to be free of insects, diseases and weeds; readily available (to ensure a continuous supply); and reasonably priced. Although growers have traditionally used peat, this material can become compacted from frequent overhead irrigation, it is difficult to re-wet once it dries, it has a poor nutrient-holding capacity, and its pH will increase significantly if the irrigation water has a high level of bicarbonate. Composted bark provides good aeration when mixed with peat. Much of the soilless container media used in Ontario is a mixture of composted bark (50%–65%), sphagnum peat (30%–40%) and other composted waste (up to 10%). Peat- and bark-based media have good aeration and moisture-holding properties but limited nutrient-holding capacity.

Other ingredients may be used to increase aeration, such as perlite, vermiculite and coco coir. A small percentage of sand may be used to give the media additional weight to help prevent blow-over. Composted bark or other composted plant waste may be used to increase water-holding capacity and also help to suppress root-disease organisms in the root zone.

Well-decomposed coarse sawdust is a useful media ingredient. Avoid fresh sawdust due to its very high carbon:nitrogen (C:N) ratio. Generally, the higher the C:N ratio, the more slowly the material will decompose. Fresh sawdust has a C:N ratio of 1,000:1, conifer bark has a ratio of 300:1, while hardwood bark has a ratio of 150:1. Materials with high C:N ratios need large amounts of nitrogen in order to break down. Therefore, the breakdown of fresh sawdust can actually sequester nitrogen from the media's fertilizer. To compensate for a high C:N ratio and enhance decomposition, add 1 kg of actual nitrogen (e.g., 3 kg ammonium nitrate, 34-0-0) per cubic metre of bark.

Using Soilless Media

Soilless media differ greatly from field soils both chemically and physically. Slight changes in media components (source, ratio, etc.) can have significant effects on porosity and drainage. Grower-specific management practices, such as watering and fertilizing, will also have a significant impact on media performance at each nursery. Always test media performance by trialing the new media on a small block of plants first.

Manage fertility closely to achieve maximum crop growth potential. High pH affects the availability of many micronutrients (especially iron and manganese). In nursery production, media pH may gradually increase over the growing season due to high levels of calcium and magnesium (bicarbonates) in southern Ontario's irrigation water. Therefore, avoid starting a crop in a growing media with a pH of more than 6.5. Most growers choose media with a starting pH of 5 or less. Adding coarse sand to the media can also lead to high pH values, since coarse sand contains calcium.

For more information about soilless growing media, see OMAF Publication 370, *Guide to Greenhouse Floriculture Production.*

Determining Media Porosity

Adequate media aeration is vital to root growth. Water-holding ability is also important, though secondary to aeration. Since roots require oxygen to function properly, a poorly aerated media will restrict root growth and actually lead to root death. As container media is mixed, handled and used for potting, the coarser materials may be broken down, creating more fine particles. These fine particles can interfere with drainage and aeration by plugging up pore spaces in the media. The media will also become compacted over time through irrigation. Reduced levels of aeration and drainage will decrease the amount of oxygen available to plant roots. The result is root dieback and root disease. Avoid over-packing media during potting, since this practice will also lead to reduced aeration and reduced root growth. Some growers are choosing coco coir and more coarsely textured peat and bark to increase media aeration over the crop cycle. To avoid aeration problems with media, measure aeration porosity regularly and re-pot plants regularly throughout the production cycle. When considering a new media, test the new media in a small portion of the crop. To select the best media, compare plants grown in standard potting mix with plants grown in a new mix.

The *total porosity* of a mix is the space between mix particles that air or water can potentially fill. The *aeration porosity* of a mix is the percentage of space filled by air after irrigation water has drained out. Aim for a total porosity value above 50% and an aeration porosity between 15% and 30%. Too much aeration will not harm the plants, but the media will require frequent irrigation. A potting mix with a high percentage of particles smaller than 0.5 mm results in low aeration porosity and poor drainage. For pine and yew, use mixes with an aeration porosity of 20%–25%. Juniper and white cedar can tolerate lower aeration porosity in the root zone.

To determine media porosity, the grower will need:

- the average growing pot (#1, #2, etc.)
- a method to cover or plug the pot drain holes (e.g., a plastic bag inside pot)
- graduated cylinders (large and small) or other containers designed for measuring liquids
- some dry potting mix

To calculate the porosity of the potting media, follow these steps:

1. Cover or plug the drain holes of the pot.
2. Fill the pot with water to the normal level of the potting media. Pour this water into the graduated cylinder (or other measuring container) and record the volume of this water. This amount of water is the total volume of the pot [A].
3. Make sure the drain holes are still plugged, and then fill the pot with slightly moist media to the normal level of the potting media. Make sure that the pot is level.
4. Slowly add a measured volume of water to the media until a water slick appears on the surface. The volume of water added is the pore volume of the media [B]. Record this number.
5. Without moving the pot, remove the drain hole covers or plugs. Let the water drain into a bucket, then measure the volume of water that drained. This is the aeration pore volume [C]. Record this number.
6. Calculate the media porosity using the following formula:

Media porosity formula

Total porosity (%)	=	(B / A) x 100
Aeration porosity (%)	=	(C / A) x 100
Water retention porosity	=	Total porosity – Aeration porosity

Sample Calculation:

[A] Total container volume	=	5,180 mL
[B] Pore volume (water added to saturate the media)	=	3,354 mL
[C] Aeration pore volume (water drained from container)	=	1,080 mL

Total porosity	=	(3,354 / 5,180) x (100)	=	65%
Aeration porosity	=	(1,080 / 5,180) x (100)	=	21%
Water retention porosity	=	65% – 21%	=	44%

Adjusting Potting Mix pH

It is important to maintain the correct pH range for container crops. Here are some key points to remember:

- Maintain a potting mix pH between 5.5 and 7.0. High levels of bicarbonates in southern Ontario irrigation water can significantly raise media pH over just one growing season.
- Do not use alkaline sand in the media when growing pH-sensitive crops.
- Acidifying fertilizers may help slow down the rise in pH from bicarbonates in the irrigation water. When using fertilizer injectors, apply fertilizer and acid concentrates as separate solutions.

- Irrigation water can be acidified with nitric or phosphoric acid, depending on the bicarbonate content of the water. For more detailed information on acidifying irrigation water, see Chapter 3, "Water, Growing Media and Crop Nutrition," in OMAF Publication 370, *Guide to Greenhouse Floriculture Production.*
- *Juniperus* and *Thuja* will grow adequately at a higher pH, but plants such as *Betula*, *Hydrangea*, *Syringa*, *Rhododendron* and *Taxus* will exhibit iron and/or manganese chlorosis if the pH is above 7.0.

Fertilizing Container Stock

Most container mixes contain little or no soil, resulting in low nutrient-holding capacity. Synthetic fertilizers are required to provide crop nutrients for container-grown plants.

Fertilizers may impact the environment, especially surface and groundwater systems. Organic substrates found in container mix, such as peat and bark, are generally negatively charged. This means that they repel negatively charged molecules, such as nitrates and phosphates. As a result, nitrates and phosphates leach easily from most container substrates, so it is important to provide them in small quantities over the course of the growing season. Controlled-release (slow-release) fertilizers deliver nutrients to the root zone for root uptake in a timed-release format that minimizes losses out of the container. Putting fertilizer on the surface of the media (top dressing) is very efficient in container production. Since pots are susceptible to blow-over, some growers place fertilizer just below the media surface or incorporate the controlled-release fertilizer so it is distributed throughout the media.

To help reduce impacts on the environment and maximize the efficiency of a fertilizer program, take measures to reduce leaching from containers. Reduce the amount of irrigation water used during each irrigation event to minimize the amount of water (leaching fraction) coming out from the bottom of the pot. Pulse or cyclic irrigation (e.g., 20 minutes on, 60 minutes off, 15 minutes on) can also significantly reduce both the leaching fraction and the total amount of irrigation water required. Pulse irrigation will also reduce the concentration of nutrients that can leach out of the bottom of the pot. A leaching fraction of 10%–15% will minimize nutrient loss while preventing salt buildup in the root zone. Design and construct container production areas so that they collect and divert irrigation and leachate water run-off for storage and re-use.

How to Sample and Test Container Media

In general, organic substrates are low in fertility (N-P-K). This makes regular media testing a vital part of successful container production. Sample media every 2 weeks for pH, soluble salt (EC) and nutrient analysis. Once a pattern of nutrient levels has been established, monitoring can be limited to testing every 2 weeks for pH and EC readings, along with an occasional nutrient analysis. For more information about measuring media pH and EC, see OMAF Publication 370, *Guide to Greenhouse Floriculture Production*.

Here are some key points to remember:

- Use a small-diameter sampling probe to sample container-grown stock. To obtain a sample, remove the pot and take a core through the media, midway between top and bottom of the container and midway between the stem and the edge of the pot.
- Take samples from at least 10 pots and then mix them to get one pooled sample of media for testing. A pooled sample will better represent the nutrient status of media in that block. To reduce the impact on the root systems, take smaller media samples from a greater number of pots. Some horticulturalists remove fertilizer prills from the media samples, while others include them. To be consistent between each sampling, remove fertilizer prills from media supplies.
- Refrigerate the sample until it can be delivered to the lab.
- If water-soluble fertilizer is applied with each irrigation event, sample the soil 30 minutes after the application ends.
- If a dry surface fertilizer (granular or pellet) is used, always sample before adding the fertilizer. Insert the probe carefully, avoiding any surface fertilizer residue.

- When both are applied at recommended rates, water-soluble fertilizers normally produce lower salt concentrations than pre-incorporated controlled-release fertilizers.
- Analyze all soil samples from container potting mixes at an OMAF-accredited laboratory using a saturated paste analysis for greenhouse media. Compare these test results with previous samples and with the ranges in Table 1–14, *Media Nutrient Levels for Most Container Crops in Greenhouse Media Tests*, on page 21 to determine trends in pH, EC and nutrient status. Analysis results can then be correlated with plant growth and health symptoms to help establish thresholds for irrigation water and media test results.
- Adding an active source of controlled-release fertilizer in the pot will help keep crops healthy and marketable in retail nursery centres.

Using Water-Soluble Fertilizers

Apply water-soluble fertilizers through a low-volume irrigation system (e.g., drip, spray stakes) using an accurate concentrate diluter or injector. Remember that fertilizer nutrients are salts, so too much fertilizer can actually damage roots.

In theory, water-soluble fertilizers are applied at every watering. However, this may not be the most efficient use of fertilizer. There is evidence that intermittent fertilizer application can result in similar levels of plant growth compared to constant fertilizing.

When water-soluble fertilizers do not contain micronutrients (e.g., iron), add these to the mix before potting or as soluble trace elements during the growing season. Composted waste materials (e.g., composted vegetable waste) are quite often a good source of micronutrients. Dry materials with added bulking agents are less concentrated than compost, making them easier to blend into the mix. Use these as recommended by the manufacturer.

Commercial water-soluble fertilizers come in various formulations (e.g., 24-10-20 or 28-7-7). Use them at the rate of 100–200 ppm nitrogen (i.e., up to 83 g of 24-10-20 per 100 L of water). Fertilizers with high percentages of phosphorus (e.g., 10-52-10) should only be used at very low rates or blended with other low-phosphorus fertilizer formulations.

Avoid the use of water-soluble fertilizers on media with low aeration porosity. In this case, watering to fertilize may cause poor growth due to low aeration. Controlled-release fertilizers may be a better choice.

Using Controlled-Release Fertilizers

Controlled-release (encapsulated) fertilizers work well with container stock. There are three ways to apply them: incorporate controlled-release fertilizers into the potting mix, top-dress them on the media surface or create 2–4 pockets just below the media surface and dibble them into these pockets. Use as suggested by the manufacturer. Incorporating or dibbling controlled-release fertilizers can actually prolong the release pattern of the product and improve plant growth over the season compared to top dressing. Incorporating or dibbling controlled-release fertilizers can also prevent spillage losses that are common with top dressing.

Avoid excessive mixing when preparing a potting mix. Mixing may break fertilizer particles, which can cause problems due to excessive fertilizer salt release. Use potting mixes with pre-incorporated, controlled-release fertilizers quickly, especially during warm weather.

Several controlled-release fertilizer formulations now contain micronutrients. When controlled-release fertilizers do not contain micronutrients (e.g., iron), add these according to the manufacturer's recommendation. Supplemental fertility, particularly nitrogen, may benefit fast-growing crops when using controlled-release fertilizers. In container media, nitrate-nitrogen levels can be determined using the greenhouse media testing protocol at a commercial lab. When media tests show nitrate-nitrogen values under 39 ppm, add supplemental nitrogen to plants.

TABLE 1–14. Media Nutrient Levels for Most Container Crops in Greenhouse Media Tests

Nutrient Concentration		What to Do
Nitrogen (as water-soluble nitrate-nitrogen NO_3N)		
Low	0–39 ppm	Add extra nitrogen to the feeding program.
Normal	100–199 ppm	Continue fertilizing with nitrate-nitrogen and test total salts (EC).
Excess	250+ ppm with high salts	Discontinue fertilizing with nitrate-nitrogen and check total salts as root damage may occur. An exception is when the media contains a significant amount of bark that is not fully composted. Bark mix: Because this media has a high C:N ratio, higher levels of nitrogen are required to ensure enough nitrogen is available to the crop for optimal growth.
Phosphorus (as water-soluble P)		
Low	0–2 ppm	Add additional phosphorus to the feeding program.
Normal	6–9 ppm	Continue fertilizing with phosphorus and test total salts (EC).
Excess	50+ ppm	Discontinue fertilizing with phosphorus.
Potassium (as water-soluble K)		
Low	0–59 ppm	Add additional potassium to the fertility program.
Normal	150–250 ppm	Continue fertilizing with potassium and test total salts (EC).
Excess	350+ ppm	Discontinue fertilizing with potassium and leach with low EC irrigation water. Note that plants may tolerate high levels potassium if the media contains a high proportion of organic material. (Leaching is not effective for removing controlled-release fertilizer that has been incorporated in the media.)
Soluble salts (EC) in mS/cm (mhos x 10^{-3}/cm)		
Low	0.75–2.0	Check for adequate nitrate-nitrogen and potassium levels.
Normal	2.0–3.5	Continue the fertilizer program.
Excess	3.5+	Discontinue the fertilizer program. Note that plants may tolerate high levels if the media contains a high proportion of organic material.
Calcium (as water-soluble Ca)		
Low	0–79 ppm	Add extra soluble calcium to the feeding program. (Calcium levels are easily raised by adding dolomitic lime or gypsum to the media.)
Normal	200–300 ppm	Continue the fertilizer program.
Excess	400+ ppm	Consider reducing the use of fertilizers or media components with significant sources of calcium (e.g., lime, gypsum or soluble calcium).

TABLE 1–14. Media Nutrient Levels for Most Container Crops in Greenhouse Media Tests *continued*

Nutrient Concentration		What to Do
Magnesium (as water-soluble Mg)		
Low	0–29 ppm	Apply 0.5 kg/1,000 L of magnesium sulphate in water.
Normal	70–200 ppm	Continue the fertilizer program.
Excess	200+ ppm	Consider reducing the use of fertilizers or other media components with significant sources of magnesium (e.g., dolomitic lime or soluble magnesium).
Miscellaneous		
Sulphate levels should not exceed 300 ppm in a greenhouse media test.		
Chloride levels should not exceed 50 ppm in a greenhouse media test.		
pH should fall between 5.0 and 6.5 in a greenhouse media test.		

Check soil test values in early June of the second growing season after using pre-incorporated controlled-release materials. If necessary nutrients are missing, apply supplemental controlled-release fertilizer. Some controlled-release materials are rated to provide nutrition for two growing seasons and others for only 3-4 months.

Controlled-release fertilizers may produce inconsistent soil test results if prills break during sampling, shipping or testing. Most horticulturalists will remove prills before mixing and testing media samples for lab analysis, especially if the prills are at the beginning of their release pattern. It is important to be consistent with media sampling protocols. It is also helpful to take notes about the sampling block (age of media, fertilizer dates, age of plants, etc.).

Measuring Nutrient Levels in Container-Grown Crops

For accurate results, it is important to sample media correctly. See *How to Sample and Test Container Media*, on page 19, for sampling instructions.

Woody plants use nitrogen in the form of both nitrates and ammonium. Under most summer conditions, ammonium nitrogen converts quickly to nitrate-nitrogen due to micro-organism activity. Current container media tests measure nitrate-nitrogen. However, ammonium-nitrogen can be measured on request. Controlled-release fertilizers in the media may produce inconsistent nutrient test results, especially if capsules break during sampling, shipping or testing. Monitor crops for growth and plant health, and compare media tests with nutrient levels listed in Table 1–14, *Media Nutrient Levels for Most Container Crops in Greenhouse Media Tests* on page 21. OMAF-accredited laboratories report container media nutrients in parts per million (ppm). For more information, see OMAF Publication 370, *Guide to Greenhouse Floriculture Production*.

Irrigation Water

Water Quantity

The use of irrigation water for nursery crops usually peaks in late spring and summer. This is also the period of peak water use for most other agricultural operations and, historically, the period when Ontario receives the least rainfall. Nursery growers must conform to the Ministry of the Environment (MOE) regulations regarding daily usage of water.

The taking of water in Ontario is governed by the *Ontario Water Resources Act* (OWRA) and the *Water Taking and Transfer Regulation* (Regulation 387/04). Section 34 of the OWRA requires anyone taking more than a total of 50,000 L of water in a day from a lake, stream, river or groundwater sources, including spring-fed ponds, to obtain a permit from the MOE to take water. All permit holders must collect and record the volume of water taken daily and report this data annually to the MOE. Water conservation is an important part of MOE's Permit to Take Water program. When making an application for a permit, document current or proposed conservation measures.

- **For further information, see the Ministry of Environment's *Permit to Take Water Manual,* the *Guide to the Permit to Take Water Application Form* and other related factsheets online at www.ontario.ca/environment.**
- **Also see *Best Management Practices: Irrigation Management,* Order No. BMP08E.**

Irrigation Water Quality

Irrigation water quality is one of the most important components of a container growing system, yet it is often overlooked. Container-grown crops are irrigated every day, and the chemistry of that irrigation water can have a significant influence on the characteristics of the soilless media, the media solution and the nutrient solution. Over successive irrigation cycles, the chemical properties of the water affect the pH, soluble salts, bicarbonate level and other chemical properties of the media and media solution. Irrigation water quality has a major impact on root growth and, therefore, crop quality. The media in smaller pots is affected more quickly than in larger pots, due to the reduced buffering capacity of the smaller media volume. Symptoms of poor water chemistry may include nutrient deficiency symptoms, such as interveinal chlorosis. Poor water quality can actually reduce the availability of certain nutrients to plants and cause root dieback.

pH is a measure of the concentration of hydrogen ions (H^+) in solution. A high number of H^+ ions results in a low pH, while a low number of H^+ ions gives a high pH. pH is measured on a scale of 1–14, where a pH below 7.0 is acidic, a pH above 7.0 is basic or alkaline, and a pH of 7.0 is neutral. The higher or lower the pH, the more strongly basic or acidic the solution. The pH scale is logarithmic, so each unit in the pH scale represents a 10-fold change in the concentration of H^+ ions. pH can affect the chemistry and availability of dissolved fertilizer nutrients in the soil solution. High pH makes iron and manganese unavailable for plant uptake. The pH of water can also make some pesticides less effective. For example, high pH is known to reduce the efficacy of pesticides such as captan, dimethoate and flumioxazin. pH can change quickly in water and soilless media. For this reason, it is important to know the alkalinity of the irrigation water.

Alkalinity is a measure of the capacity of water to neutralize acids (or hydrogen ions). Alkalinity determines the buffering capacity of water; it defines how resistant the water is to a change in pH. In most sources of irrigation water in Ontario, bicarbonates (HCO_3^-) have the greatest influence on alkalinity. It is not unusual to have groundwater with more than 200 ppm of bicarbonates. These bicarbonates originate from the underlying limestone (calcium and magnesium carbonate) base. High concentrations of bicarbonates neutralize the hydrogen ions, resulting in a lower concentration of H^+ and therefore a higher pH. It is important to note that although there is a general correlation between pH and bicarbonate, the pH level does not determine the buffering capacity of the water. To determine the actual buffering capacity of water, the amount of bicarbonates (or calcium carbonates) present in the water source must be known.

For example, irrigation water from rainwater collected in a cistern may have a pH of 8.3, but its buffering capacity is quite low. Therefore, rainwater would have very little effect on the pH of container media. A chemical analysis of the water would uncover a negligible amount of bicarbonates. In contrast, irrigation water from groundwater sources with a pH of 8.3 would likely have high buffering capacity and would significantly influence the pH of the container media. This in turn would significantly affect nutrient availability in the root zone and, potentially, the efficacy of some pesticides. As these examples show, it is not enough to know the pH level of irrigation water: growers also need to know the level of bicarbonates in order to manage it properly to produce healthy crops.

The high levels of bicarbonates in irrigation water will influence soilless media over time, especially when overhead irrigation is the main method of watering. Although soilless media starts out with a low pH (e.g., 5.0), the buffering capacity of soilless media components is very low. This means irrigating with alkaline water will raise the media pH to 6.0–6.5 within the first 6 weeks. Symptoms of nutrient deficiency may be apparent after just a few months, especially in the case of pH-sensitive crops (rhododendrons, azaleas, red and pin oak, birch, lilac, hydrangea, etc.).

High levels of bicarbonates in irrigation water make it more difficult to lower the pH to an acceptable level for growing plants. Although acidifying fertilizers (those that contain ammonium-nitrogen and sulphur) can help neutralize some of the bicarbonates, acid injection may be the only effective solution for very alkaline water (i.e., water with >200 ppm bicarbonates). High levels of bicarbonates and high pH can be corrected by injecting nitric or sulphuric acid or a combination of both. If acid is used to correct water pH, make sure the injector is rated to handle acid. The volume of acid that needs to be added depends on the bicarbonate level of the water. For more information on water quality and correcting pH, see Chapter 3, "Water, Growing Media and Crop Nutrition," in OMAF Publication 370, *Guide to Greenhouse Floriculture Production*.

Soluble salts in irrigation water can also significantly affect plant growth in container production. The concentration of soluble salts is assessed by measuring electrical conductivity (EC). The soluble salts of most concern in irrigation water are sodium, chloride and sulphates. The pH and alkalinity of the irrigation water have a direct effect on the pH and alkalinity of the soilless media and the media solution. The EC of the irrigation water has a direct effect on the EC of the soilless media and the media solution too. High EC in the media solution can be the result of over-fertilizing or using poor-quality irrigation water. Either way, it can interfere with the crop's root function, and the resulting reduction in water and nutrient uptake may lead to root damage and death. Symptoms of high concentrations of soluble salts include small, dark-green leaves, wilting (even when the media is wet), marginal leaf necrosis, stunting and death. The specific symptoms may vary depending on the level of salts in the water and the salt tolerance of crop. If the EC of irrigation water is higher than the suggested ranges (see Table 1–15, *Acceptable Ranges for Chemical Properties of Irrigation Water*, on page 25), use alternative water sources on the most sensitive plants (e.g., herbaceous material and young woody material) and/or dilute water to bring the EC down to an acceptable level. Many plants can tolerate a higher EC if they are watered regularly and leached periodically.

TABLE 1–15. Acceptable Ranges for Chemical Properties of Irrigation Water

These ranges are general guidelines. Ornamental crops vary greatly in their sensitivity to soluble salts and the chemical properties of water, depending on their species, size and age and on the volume of the container.

Chemical Property	Acceptable Range for Most Container-Grown Woody Crops	Acceptable Range for Most Container-Grown Herbaceous Perennials/Greenhouse Crops
pH	5.0–7.0	5.0–7.0
EC (soluble salts)	less than 1.75 mS/cm	less than 1.0 mS/cm
Calcium carbonates ($CaCO_3$)	less than 150 ppm	less than 120 ppm
Bicarbonates (HCO_3)	less than 150–200 ppm (lower if not being leached with rainfall)	less than 100–150 ppm (lower if not being leached with rainfall)
Sodium (Na)	less than 70 ppm	less than 60 ppm
Chloride (Cl)	less than 140 ppm	less than 100 ppm
Sulphur (S)	less than 70 ppm	less than 70 ppm
Sulphates (SO_4)	less than 200 ppm	less than 200 ppm
Iron (Fe)	—	less than 5 ppm
Boron (B)	less than 0.8 ppm	less than 0.5 ppm

Water Testing

Along with media and leachate analysis, it is useful to test irrigation water throughout the growing season. Water quality is usually best in the spring, when water volumes are at their highest because of snowmelt and high rainfall. Unless road run-off contributes significantly to your source of irrigation water, soluble salts are more dilute in spring, giving lower EC values. Bicarbonate levels are also lower in spring. For these reasons, test irrigation water quality in the spring and compare it with summer and early fall water tests.

Iron levels can be a problem in irrigation water since iron is easily oxidized and forms precipitates that can block irrigation lines or cause uneven spray patterns. Calcium and magnesium (carbonates) will cause similar issues. Test water samples for a number of chemical attributes (see Table 1–15 above). In OMAF Publication 370, *Guide to Greenhouse Floriculture Production*, see Table 1–8, *Maximum Desirable Concentrations of Specific Ions in Raw Water Used for Irrigation Purposes in a Greenhouse Using Soilless Substrates*.

Collect samples of irrigation water below the water surface but above the bottom, around the level where the intake line sits. Try to collect water samples when the bottom sediment hasn't recently been disturbed. Collect approximately 500 mL and refrigerate the sample until it can be submitted to the lab.

When lab results indicate certain chemical properties appear beyond the acceptable range, options may include:

- finding an alternative source of irrigation water where chemical properties fall within the acceptable ranges
- finding an alternative source of irrigation water for plants that are most sensitive or have the smallest container volume
- leaching excess solutes from container media through supplemental irrigation with the same water source
- treating the irrigation water to remove salts — reverse osmosis, for example is an effective but costly solution that is limited by the capacity of the treatment system

2. Insect and Disease Management

Insects, mites, fungi, bacteria, nematodes and viruses are all examples of pests found on plants. In nature, most pest populations are kept in check by predators, pathogens, competing organisms or the natural resistance of a healthy host plant. When other factors such as stress enter the system, pests may become economically damaging.

In production systems, pests have an even greater chance of becoming damaging. Crops are often produced in a monoculture system, allowing pests to move more easily from host to host. As well, some production practices can be quite stressful. For example, container-grown plants have high root-zone temperatures in the summer that can result in root mortality. A reduction in roots will decrease plant health and resistance to pest invasion. Successful growers look for early signs of plant stress and manage that stress to help prevent pest problems.

Integrated Pest Management

Integrated pest management (IPM) is an approach to pest management that utilizes all available tools to reduce pest populations to an acceptable level in a cost-effective, environmentally rational manner. These tools include monitoring, cultural control, physical control, biological control and chemical control. IPM involves accurately identifying a pest, understanding its biology and most susceptible life stage, establishing action thresholds, choosing appropriate management techniques and evaluating their effectiveness. Today, nursery growers are adopting a more integrated approach to pest management that allows them to decrease their use of chemical pesticides by making more informed decisions. Landscape professionals and arborists in Ontario must operate under the *Pesticides Act* as amended by the *Cosmetic Pesticides Ban Act, 2008.* The requirements are detailed in Ontario Regulation 63/09.

When making decisions about pest management, one must determine the level of a pest population that can be tolerated. These levels (called *action thresholds*) depend on many factors. Because the diversity of ornamental plants and plant pests is so great, data for specific pest action thresholds is often unavailable. By keeping good records, growers and landscape maintenance professionals can develop their own action thresholds. Action thresholds may be measured by the number of pests present, the percentage of plant parts showing symptoms or the level of pest injury that can be sustained before the economic loss from that injury is equal to the cost of controlling the pests (the *economic injury level*). Most healthy ornamental plants can tolerate moderate levels of pests, but landscape clients and retail garden centre customers may have lower tolerances.

Monitoring

Monitoring is the most important aspect of IPM. Monitoring data provides the basis for making informed decisions about pest management practices. Monitoring programs consist of regular physical examinations of all production areas during the growing season, including winter propagation. Most monitoring activities for pests are carried out on a weekly basis.

Early detection is the key to preventing pests from reaching levels of economic injury and may help minimize the use of pesticides.

Crop Scouts

Crop scouts monitor plant health and report observations to help direct the pest management program. Crop scouts should:

- sample plants regularly from each production block and look closely under branches, in branch crotches, on leaf undersides and on the newest emerging leaves for any unusual symptoms
- examine the crown and root systems regularly to monitor for diseases, insects and physiological problems
- communicate with growers and irrigation staff regularly to discuss plant production practices and how they might impact crop quality and pest management programs

See Table 2–1, *Host Symptoms and Possible Causes of Insect Injury*, on page 38 and Table 2–2, *Symptoms and Possible Causes of Insect Injury (by Visible Insect Matter)*, on page 38 for more information.

Crop scouts need a basic understanding of crop health. This includes some background in crop production, plant pathology, entomology and weed science. Since a wide array of woody and herbaceous ornamentals are grown in Ontario, label blocks of plants clearly (include cultivar names and planting date) and mapped them for reference. In the case of landscape properties, a basic map with plant names is an excellent reference for monitoring. Correctly identifying the host is often critical to correctly identifying the pest.

With a wide array of crop species comes an extensive group of organisms (insects, mites and micro-organisms) that may be encountered during crop production. Not all these organisms are plant pests; many are incidentals and just happen to be there or are feeding on other non-plant organisms. To help identify pests, the crop scout should have diagnostic references that outline identifying characteristics, host lists, biology and life cycle of the plant pests typically encountered in Ontario. This information can be used not only to identify the pest but also to target the life cycle stage in order to utilize various management methods. A hand lens (e.g., 10x to 20x) is a necessary tool for observing a pest's identifying characteristics. Diagnostic references may include ornamental woody and herbaceous reference books, government and university publications, and websites. For more information on diagnostic references, see the OMAF Nursery and Landscape webpage at www.ontario.ca/crops. The Pest Diagnostic Clinic offers pest identification services (see Appendix E, *Diagnostic Services*, on page 81).

Growing Degree Days (GDD) and Phenology Models

In the past, calendar dates were used to determine when to apply pesticides. This often led to unnecessary pesticide applications and applications that did not necessarily coincide with the susceptible developmental stage of the pest. Today, pest management techniques include models based on temperature, weather data and plant-pest phenology (development). The underlying principle is basic: plants and insects need a certain amount of heat to pass through the various stages of development. The temperature data is often expressed as growing degree days (GDD). To calculate these, collect maximum and minimum temperatures over a 24-hr period. Then use the formula below to calculate GDDs with various base temperatures (i.e., 10°C, 50°F). Add GDDs for each day to get a running total of GDD accumulations in your area. Do not subtract any negative GDD values.

Growing degree days formula:

$$\frac{\text{Daily Maximum Temperature} + \text{Daily Minimum Temperature}}{2} - \text{Base Temperature*} = \text{Growing Degree Days}$$

** Base temperature is a constant.*

Sample calculation (at base 10°C):

$$\frac{17°C + 5°C}{2} - 10°C = 1\ \text{GDD}\ (10°C)$$

> **Growing degree day figures are meant to enhance the effectiveness of a monitoring program, not replace it.**

Growers and landscapers use GDD models to help predict when different pests will emerge based on temperature data they have collected themselves or obtained from the local weather office. The GDD pest models can be used to fine-tune the monitoring program and anticipate pests early. Over time, recorded temperature data for plants and plant pests have revealed that certain plants and insects pass through developmental stages at the same time. For example, when the *Magnolia* x *soulangiana* flowers are in the pink bud stage, the overwintering spruce gall adelgid nymphs are starting to feed and are susceptible to applications of insecticides. The fruiting and flowering characteristics of certain common ornamentals in the landscape have been linked to the developmental stages of plant pests. These plants are referred to as "plant phenology indicators" (see Table 2–3, *Common Phenology Plant Indicators for Ontario*, on page 39). Some horticulturalists have found plant phenology indicators to be more accurate than GDD models.

Where plant health monitoring will be carried out in many locations (as in the case of landscape maintenance), use plant phenology indicators to direct the monitoring program. The combined use of GDD data and plant phenology indicators can give a clearer picture of the timing of pest emergence and opportunities for control. For more information, see Tables 2–4 to 2–17, starting on page 41.

For more information on timing and management methods for ornamental pests in Ontario, see the ONnurserycrops blog at www.onnurserycrops.wordpress.com.

Monitoring Tools

Many tools exist to help crop scouts monitor plant pests. Although they are collectively called "traps," many of these tools are not always effective at managing pest populations. More often, they are useful for collecting data about insect emergence and populations.

- Most *baited traps* are pheromone (mating) lures or other lures (e.g., floral lures) to attract insects. Place at least two traps per monitoring area about 1–2 weeks before adults are expected to emerge. Place traps on the windward side of the monitoring area. Try to use the same type of pheromone and brand of trap from location to location and from year to year.
- *Refuge traps* provide places for insects to hide (e.g., burlap traps for black vine weevil adults and gypsy moth larvae).
- *Sticky traps* (yellow, blue, etc.) catch adult flying insects (e.g., aphids, whiteflies, leafminer adults, thrips, leafhoppers).
- *Tape* wrapped around stems and small branches (sticky side out) will capture scale insect crawlers for monitoring purposes.
- *Tapping trays* are useful for monitoring pests such as mites, plant bugs and caterpillar droppings. They consist of a white surface fixed on a frame (or a sheet of white paper on a clipboard) that is held beneath a branch. When the branch is tapped, pests drop onto the white surface, where they are visible.
- *Pitfall traps* can be used to monitor flightless pests (such as root weevil adults and slugs). They are a cup-shaped trays placed in the ground so that the top of the tray is level with the surface of the ground.

Monitoring Data Records

Record observations in an organized and accessible system (e.g., a computer data file). This monitoring data is very useful in fine-tuning action thresholds and pest management strategies in future years. Organize monitoring data under headings such as:

- date (month/day/year)
- location (e.g., farm X, block C, south side)
- host (including cultivar or variety, stage of development)
- pest and host symptoms (including pest population, pest stage of development, percentage of plants or plant parts showing symptoms)
- GDD and/or plant phenology indicators
- action taken (e.g., pesticides, rate, area treated, cultural methods)

A sample Pest Monitoring Record Sheet can be found in Appendix G, *Pest Monitoring Record Sheet*, on page 86.

Indicator Plants

Indicator plants are ornamentals that seem to attract specific pests first. For example, *Caragana* and *Acer* serve as indicator plants for leafhoppers. Examine these plants at the beginning of each monitoring cycle. By observing indicator plants, it is possible to detect pest problems before they reach economically damaging levels and affect the rest of the crop.

Cultural Control

Cultural control activities are plant care and best management practices that help prevent the pest from becoming a problem. They include the following examples:

- Avoid irrigating late in the day, since leaf wetness periods that extend into the night may increase disease problems. Where disease is a problem, try to irrigate enough to adequately wet the root zone but less often so the soil can dry out a little between irrigation events to encourage deeper rooting.
- Grow plant cultivars that are tolerant of diseases and insects. For example, *Betula nigra* and its cultivars are more tolerant of bronze birch borer than *Betula pendula*.
- Steam-pasteurize propagation media before reusing it.
- It is very difficult to sterilize pots and inserts. Always start the propagation phase of disease-susceptible species with new pots or trays. This will help minimize the risk of transferring disease (e.g., *Fusarium*) from organic residue on used pots.
- Select only healthy plants for cuttings and budwood to avoid introducing problems into the production system.

Physical or Mechanical Control

Physical means, such as manually removing infested plants or plant parts, can be an important part of IPM.

- Remove infested plant material or pests (including weeds) from production areas and landscapes and destroy them. Use supplemental irrigation if natural precipitation is inadequate.
- Cultivate field soils to uproot weeds and expose soil-dwelling insects to natural predators.
- Apply sticky bands on the trunks of landscape trees to trap or exclude crawling insects and breeding adults and their egg masses (e.g., adult gypsy moths).
- Use yellow sticky tape to trap flying insect pests in propagation greenhouses.
- When new plant material is received by a nursery, hold it in a quarantine area (away from production areas) and monitor it for any pests or diseases.

Biological Control

There are many natural predators and parasites that keep pest populations in check. For example, predatory mites feed on many species of pest mites. Ladybird beetles (larvae and adults) and lacewings (larvae) are common predators outdoors. They feed on soft-bodied insects such as aphids, mites and scale nymphs. Ichneumonid wasps are also common parasites. The adult females lay their eggs inside soft-bodied insects such as aphids. The wasp eggs hatch and feed on the contents of their aphid host, eventually killing the host. Many broad-spectrum insecticides used to reduce pest populations also reduce populations of natural predators. When monitoring for pest populations, look for natural predators and parasites, as they are also an important aspect of pest control that can reduce the need for chemical pesticides in some situations. When choosing a pesticide, consider those that have the least impact on natural predators and parasites.

Many biological control organisms are commercially available in Ontario. Most of the biological control products that are commercially available target insects and mites and are most successful in closed systems such as greenhouses. Some predatory insects can be effective in the field, especially where a continuous supply of pollen and nectar are available throughout the growing season. Many adult predators and parasites need the energy they obtain from flower pollen and nectar in order to reproduce. If they can't find the required food source, they will leave the area and reproduce somewhere else. Predatory mites may also reduce pest mite populations in the field over the long term. Recent studies with entomopathogenic nematodes (*Heterohabditis megidis*) have shown excellent control of root weevils in container production and about a 50% reduction of root weevil populations in the field. For more information on biological control products, see OMAF Publication 370, *Guide to Greenhouse Floriculture Production.*

Chemical Control

When all other methods of management fail or when pest populations are threatening the economic value of the plants, pesticides may be the most effective solution. The pesticide program is an important part of IPM. Choose the most appropriate product that is least toxic while still effective, keeping in mind the pest and host plants it will be used on. Make pesticide applications in accordance with monitoring observations. Apply the product to coincide with the susceptible stage of the pest (according to monitoring observations). Before using a pesticide, read the product's label and understand its relative toxicity, mode of action, persistence and proper and safe application. For more information on pesticide safety, see OMAF Publication 840, *Crop Protection Recommendations for Nursery and Landscape Plants*.

Chemical pest control products are an important tool in crop production, but they must be used carefully to minimize their impact on the environment and prevent the development of pesticide resistance. While a particular level of pesticide is lethal to most individuals within a population, some individuals may survive the pesticide application and will pass on these genes to the next generation. Over time, this can lead to widespread resistance within the population. Pests become resistant to chemical pesticides when the products are used incorrectly or too often. Make note of the chemical family of each pesticide and rotate chemical families during the application period for each target pest. (Insecticides and fungicides used to protect ornamentals are listed by product name in OMAF Publication 840, *Crop Protection Guide for Nursery and Landscape Plants*.)

Best Management Practices

Growers and landscape professionals can have a major influence on plant health by considering environment (media, soil, irrigation, temperature, hardiness zone, light, spacing, planting location, etc.) and nutrients (type, rate, delivery). Slight changes in environment and nutrient availability can have dramatic effects on plant health. In the landscape, a significant portion of pest problems are due to inappropriate site conditions (e.g., soil drainage, light exposure, competition). Before installing landscape material, consider the basic needs of the plants (hardiness zone, soil pH, sunlight requirements, soil type, water, etc.). By following practices that produce and maintain healthy plants, growers can prevent many plant pests from causing economic damage.

Implementing a biosecurity protocol will help to minimize the risk of introducing and transmitting biological hazards to, within and between production facilities. Biological hazards include plant pathogens, parasites and pests. A biosecurity protocol outlines the best management practices for effective sanitation. Ensure all employees and visitors follow the protocol. Some examples include ensuring that all visiting vehicles are parked in designated areas and that all visitors check in at the office. This policy will ensure that all visitors are aware of the facility's biosecurity protocol. Footbaths and hand/boot washing stations placed at key points throughout the facility can help reduce the introduction and spread of pests.

Best Management Practices (BMPs) are an integral part of good crop management. Every grower should have guidelines to produce and maintain plants in a responsible manner, both for the health of the plants and the health of the environment. Many BMPs focus on effective water and fertilizer use, the recycling of plastics and the responsible use of pesticides. Monitor irrigation water quality and analyze growing media/leachate to catch problems early.

Sample irrigation water from each water source in the spring, summer and fall. It is good to test at least three times per year, since water levels change throughout the seasons, influencing the concentration of harmful salts. Have the samples tested for pH, EC, bicarbonates, sodium, chloride and sulphates at an accredited lab. See Appendix C, *OMAF-Accredited Soil, Leaf and Greenhouse Media Testing Laboratories*, on page 79, for a list of accredited labs and Table 1–15, *Acceptable Ranges for Chemical Properties of Irrigation Water* on page 25 for a comparative table of chemical properties of good-quality irrigation water.

In the nursery, sample the container media every 2 weeks. Alternatively, the leachate can be sampled every 2 weeks using the Pour-Thru Procedure (or Virginia Tech Extraction Method) for nursery crops as follows:

1. Allow 30–60 minutes to let pots drain after the last irrigation.
2. Place saucers underneath the pots or place the pots inside other pots with a plastic bag in between.
3. Pour enough distilled water over the pot surface to collect about 50 mL of leachate from the pot bottom. Take leachate samples from at least five pots per block (or irrigation zone) to get a good representation of the block.
4. Submit the samples to an accredited lab.

(For more details on the Pour-Through Procedure, see www.ces.ncsu.edu/depts/hort/hil/hil-401.html.)

Compare EC and pH over time and monitor fertilizer salts (e.g., N, P, K) in the soil solution. Over time, develop a database that correlates salt levels and pH with healthy plant growth. This approach allows spikes in salt levels to be detected early. When they are, using remedial watering to leach out salts will help avoid root injury before plant damage occurs. Analysis will also reveal any drop in fertilizer salt levels, when supplemental applications may be warranted. In the field or landscape, sample soils where new plantings are planned or where plant growth seems to be below optimum. For directions on testing container media see "How to Sample and Test Container Media," page 19, and Table 1–14, *Media Nutrient Levels for Most Container Crops,* on page 21. For directions on testing field soil see "How to Sample Field Soil," on page 1, as well as Table 1–5, *Phosphorus Requirements for New and Established Field Nursery Stock* on page 6 and Table 1–6, *Potassium Requirements for New and Established Field Nursery Stock* on page 7.

For more information, see:

- ***Best Management Practices: Integrated Pest Management,* Order No. BMP09**

Insects and Mites Affecting Trees and Shrubs

Insects and mites are broadly classified according to their feeding habits and the associated damage they cause to woody plants. Classifications include defoliators, sucking insects, borers, gall makers and soil pests.

Some damage is distinctive, allowing identification of the insect that caused it without even seeing the pest at work (see Table 2–1, *Host Symptoms and Possible Causes of Insect Injury* on page 38). Other pests develop within the plant tissues, concealed from view. A hand lens (e.g., 10x–20x) can be helpful to see some tiny pests such as mites.

Defoliators

Defoliating insects eat foliar tissue. They may feed singly or in dense colonies and have diverse feeding habits. For example, some defoliators consume entire leaves, while others eat only interveinal tissue. Some skeletonize the leaf surface, leaving only the leaf veins behind, while others mine between the leaf surfaces.

Some defoliators are visible on leaves, while others hide within a web, folded leaf or portable shelter. However, all defoliators damage plants by reducing the leaf area. This interferes with photosynthesis, depriving the plant of food. It also interferes with the transportation and translocation of food within the plant. Some common types of defoliators are listed below. As well, see "A Compendium of Pests and Diseases with Recommended Practices" in OMAF Publication 840, *Crop Protection Guide for Nursery and Landscape Plants.*

Caterpillars

Caterpillars are moth and butterfly larvae. They may feed in colonies or individually. Caterpillars have three pairs of true legs on the abdomen, close to the head. They also have up to five pairs of fleshy "pro-legs" located further back along the abdomen. Loopers or "inch worms" are examples of caterpillars that have two to three pairs of fleshy pro-legs.

Leaf-Eating Beetles

Many beetles feed on leaves both as adults and as larvae. Beetles can completely devour, skeletonize or mine the leaves.

Leafminers and Casebearers

Leafminer and casebearer larvae develop within leaf tissues or in a protective case of leaf fragments and frass that they carry to cover themselves while feeding. Although the pests are often concealed, their characteristic tunnels make leafminer infestations easy to identify. The tunnels may be straight, serpentine or irregular. Leafminers can be moth, sawfly, beetle or midge larvae.

Sawflies

Sawflies feed in colonies and quickly strip foliage from their host plants. In Southern Ontario this usually occurs during June and July. The adults have two pairs of wings and often resemble small bees, ranging in colour from amber to black. The larvae of most species look similar to caterpillars, with three pairs of true legs on the abdomen (close to the head). They usually have six or more pairs of fleshy "pro-legs" located further back along the abdomen.

Sucking Insects

Sucking insects include aphids, lacebugs, leafhoppers, mealybugs, mites, scales, spittlebugs and thrips. This group of pests weakens trees and shrubs by sucking the sap. Some also inject secretions that injure or kill plant cells. Most species, though small and inconspicuous, are very troublesome pests.

Because the foliage of infested plants is not chewed or torn, these plants may suffer severe injury before symptoms appear. Signs of damage include mottling and fading leaf colour, curling and twisting leaves, wilting foliage and tender shoots, hardening flower buds and malformed flowers or leaves.

Some common types of sucking insects are listed below. As well, see "A Compendium of Pests and Diseases with Recommended Management Practices," in OMAF Publication 840, *Crop Protection Guide for Nursery and Landscape Plants*.

Aphids

Aphids (plant lice) are small, soft-bodied, pear-shaped insects that vary from green to shades of red, brown or black. Some aphids feed on the leaves, while others feed on the roots and are often associated with a woolly mass. Leaf-feeding aphids commonly cluster on new growth or on the underside of leaves. The light-coloured cast skins of nymphs often remain attached to the lower surface of a leaf, similar to leafhoppers.

Aphids secrete a sweet sticky substance called "honeydew" that attracts ants, flies and wasps. Honeydew can be a nuisance when it coats objects beneath infested plants. A black sooty mould may grow on the honeydew, making the plants unsightly. This fungus does not infect the plant host and dies as soon as the honeydew is gone.

Leafhoppers

Leafhoppers are small, wedge-shaped, active insects that run, hop or fly when disturbed. Leafhoppers are usually greenish or yellow in colour, although some are striped. They commonly injure woody hosts such as apple, caragana, elm, honeylocust, hoptree, maple and rose.

Leafhoppers feed on the undersides of leaves, causing stippling or bleaching. Small yellowish dots appear on the upper surface of the affected leaves. The light-coloured cast skins of nymphs often remain attached to the lower surface of a leaf (similar to aphids), providing a critical clue to help identify the pest problem. Be cautious: it's easy to confuse leafhopper injury with that caused by two-spotted spider mite.

One species of leafhopper common to woody nursery crops is the potato leafhopper (*Empoasca fabae*). Their feeding causes leaves to become stunted and distorted and the leaf margins to turn black. It is often misdiagnosed as extreme temperature injury or burn. Symptoms are first noticeable in early June. Maple trees (sugar, Norway) are a favourite host, but potato leafhoppers can also be found on other deciduous trees.

Mites

Mites are very tiny animals related to spiders and ticks. They are not true insects. Sometimes called "spider mites," they produce webbing between plant needles or leaves. This keeps the mites from becoming dislodged and protects them from their natural enemies.

Mites reproduce rapidly during hot, dry weather and may produce several generations a year. They attack evergreens and deciduous trees, causing speckling, bleaching or bronzing of foliage. Tiny spherical eggs or broken eggshells appear as specks or spots. In severe mite infestations, foliage may drop prematurely.

Serious mite damage happens quickly, so it is important to identify mite infestations early in the season. Most mites are not visible with the naked eye. To identify a mite infestation, use a 10x–20x hand lens. Alternatively, hold a sheet of white paper under a branch and tap the branch sharply. Some mites will drop onto the paper, where they appear as tiny specks about the size of a pencil dot as they crawl about.

Mite species commonly associated with trees are:

- European red mite (*Panonychus ulmi*) on fruit trees
- oak red mite (*Oligonychus bicolor*) on oaks
- honeylocust spider mite (*Eotetranychus multidigituli*) on honeylocust
- maple spider mite *(Oligonychus aceris)* on silver-red maple hybrids
- spruce spider mite (*Oligonychus ununguis*) on spruce, hemlock, arborvitae and juniper
- two-spotted spider mite (*Tetranychus urticae*) on elm, linden, rose and ornamental fruit trees
- rust mites (various) on elm, honeylocust, maple, oak and privet

Thrips

Thrips are very tiny, slender-bodied insects that affect the leaves and flowers of several woody and herbaceous plants. They have piercing, sucking mouthparts and often feed from the inside of a leaf, leaf bud or flower bud. Thrips damage is often not apparent until infested buds open and reveal mottled and distorted growth.

Plant Bugs

This group of insects removes plant sap using piercing, sucking mouthparts. Both adults and nymphs cause damage, often injuring young, developing shoots and leaves. Symptoms of damage include stippled leaves, deformed leaves and stunted shoots.

A new introduction to southern Ontario, the brown marmorated stink bug (*Halyomorpha halys*) is a plant bug that feeds by sucking on the developing fruit, leaves and twigs of several species of fruit and ornamental woody plants. Although it does not kill plants, it has the potential to cause significant injury to trees and shrubs in the nursery and landscape. This brown stink bug can be identified by the distinctive two white bands on its antennae, white bands on legs and the white triangles in between dark bands on the edges of the membranous wings (seen at the edge when the wings are at rest). It is also a nuisance pest because it overwinters in homes.

Scale Insects

Scale insects are tiny and immobile for most of their lives. They often blend in with the host plant and feed from the undersides of the current season's twigs and leaves, making them difficult to detect. Because they are sucking insect pests, they produce honeydew and are often associated with honeydew-foraging insects (ants, wasps) and sooty mold is often found growing on the honeydew deposits. For ease of identification, scales are divided into three groups called armoured scales, soft or unarmoured scales and mealybugs.

Armoured Scales

Armoured scales are common on trees and shrubs. The scales vary in length or diameter from 2–3 mm and secrete a hard, waxy covering over their bodies. Armoured scales may be circular, oblong or pear-shaped. Examples include oystershell scale and euonymus scale.

Soft Scales

Soft scales can be large (up to 6 mm long) and are convex in shape when mature. They are either bare or enclosed in waxy or cottony secretions. Examples include Fletcher scale and magnolia scale.

Mealybugs

Mealybugs are soft-bodied insects that are usually covered with a powdery, cottony-wax material. They range from about 5–8 mm long when full grown. Unlike other scale insects, mealybugs are mobile (albeit slow moving) throughout their entire life cycle. The most common mealybug seen on outdoor ornamentals is the taxus mealybug.

Borers

Borers are beetle and moth larvae that tunnel into the buds, shoots, bark or wood of trees and shrubs. Some species attack healthy trees but most attack trees and shrubs already weakened from another stress. The larval stage feeds from within the tree (in the bark, cambium or inner wood). Emerald ash borer (*Agrilus planipennis*) and Asian long-horned beetle (*Anoplophora glabripennis*) are two of the newest borers found in Ontario. For more information see "A Compendium of Pests and Diseases with Recommended Management Practices," in OMAF Publication 840, Crop Protection Guide for Nursery and Landscape Plants. Emerald ash borer and Asian long-horned beetle are quarantine pests. This means that movement of the insects and the infested plants or plant parts is regulated to help prevent further spread into un-infested areas. For more information, contact the closest office of the Canadian Food Inspection Agency (www.inspection.gc.ca).

It is important to prevent borer injury, since infested plants may be damaged beyond repair before the pest makes itself known. Signs of damage include dying twigs and branches; dark, discoloured or dead areas under the bark (peachtree borer); and chewed matter or sawdust under the bark (red oak clearwing moth). Sap and sawdust-like borings may cling to bark and litter the ground (linden borer, carpenterworm).

Borers also provide an entrance for disease-causing fungi. They can weaken the structure of trees, making them more susceptible to wind damage. Borers may eventually girdle and kill the tree. The most serious borers are those whose larvae feed in the cambium: the green, sap-conducting and generative tissue located just under the bark. This includes the bronze birch borer and the emerald ash borer.

Gall Makers

Galls are abnormal vegetative growths produced by a plant in response to insect irritations or substances that mimic plant growth hormones. Causes include feeding, stinging, egg-laying or toxin injection. This reaction generally benefits the pest by creating a protected feeding site within host tissue.

Aphids, mites, midges, gall wasps and some beetles and moth larvae can all produce galls. Galls vary greatly in size, colour and complexity, but each insect species produces a characteristic gall formation from plant tissue. Oak and hickory trees are the favourite hosts for several hundred different gall insects. Galls may form anywhere on a tree. They mar the appearance and shape of trees and may kill leaves and branches, although they rarely kill the tree.

Soil Pests

Pests below the soil line can seriously damage plants before making themselves known. It can be difficult to determine the extent of the pest problem or the effectiveness of treatment. Monitoring programs should include examination of crowns and roots below the soil, especially where symptoms of stress are evident. Some common types of soil pests are listed below.

Japanese Beetles

Japanese beetles (*Popillia japonica*) are a quarantine pest. This means that the movement of Japanese beetles and infested plants or soil is regulated to help prevent further spread into un-infested areas. While Japanese beetles do not kill nursery crops in Ontario, the adults are significant defoliators. It is important to control infestations and prevent new ones. Established populations exist in several provinces of Canada. Contact your local CFIA office (see Appendix D, *Other Contacts*, on page 80 for a current list, or refer to the CFIA website at www.inspection.gc.ca).

Japanese beetle larvae are C-shaped, milky-white grubs about 25 mm long. They have brown heads and three pairs of legs. A V-shaped arrangement of spines on the last abdominal segment (raster) distinguishes them from other grubs. The larvae feed on the roots of turf and nursery stock.

Managing Japanese Beetles in Nurseries

Refer to the Canadian Food Inspection Agency Directive D-96-15, *Phytosanitary requirements to prevent the spread of Japanese beetle,* Popillia japonica, in Canada and the United States (www.inspection.gc.ca). Use the following strategies to reduce injury and grub populations:

- Treat container-grown stock with CFIA-approved insecticides. See CFIA guidelines regarding the treatment of Japanese beetle to allow for shipping of nursery stock (www.inspection.gc.ca).
- Watch for emerging adult beetles. Check the OMAF Nursery-Landscape Blog (www.onnurserycrops.wordpress.com) to see if adult beetles have been reported.
- Monitor for adult Japanese beetles using pheromone traps beginning around the time *Catalpa speciosa* is beginning to bloom (around mid-June in southern Ontario). Note that traps are used for monitoring, not for control. To avoid attracting beetles to your nursery, place pheromone traps in nearby pastures, vacant fields or fencerows, well away from crops. Research shows that if fewer than 4,000 beetles are trapped at peak flight, a larval population likely has not been established (especially in clean cultivated soils).
- Scout fencerows and hedgerows once adult beetles emerge. Look for beetles feeding on leaves of indicator plants (e.g., grapevines, roses), especially in early morning or late afternoon. Skeletonized leaves are a sign of Japanese beetle injury.
- Remove wild grape and other weedy host plants from the area. Adult beetles feed on different host plants than their larvae. Discourage adult beetles from feeding in the area by removing food sources. For a list of common host plants, see OMAF Factsheet *Japanese Beetle in Nurseries and Turf.*
- Control beetles in fencerows and hedges first. If beetles are observed feeding, apply insecticides before 7 AM, when adult beetles are sluggish and slow.
- Discourage egg-laying in the nursery by eliminating suitable egg-laying sites near desirable host plants. Japanese beetles lay eggs in turf areas such as pastures and grassy, weedy areas. Almost all grasses support larval populations, while alsike clover, crown vetch, white Dutch clover and Canadian mammoth clover do not.
- Keep the ground around the plant free from vegetation. When the root ball is dug, the soil that comes with it should be free of potential host plants. Provide an extra-wide clean, cultivated area at the base of trees.
- Cultivating to a depth of 7.5 cm may destroy 25%–30% of the larvae. Cultivating is most effective in early fall and late spring.
- During droughts, Japanese beetles prefer to lay their eggs in low, wet, poorly drained areas and irrigated fields.
- Containers with soilless media are not preferred egg-laying sites. Avoid the use of field soils in container media.
- Maintain a good weed control program in the field and in the container yard.

Other White Grubs

In addition to Japanese beetle larvae, the larvae of European chafers (*Rhizotrogus majalis*) and June beetles (*Phyllophaga* sp.) make up the group of insects called "white grubs." White grubs larvae move into a distinctive "C" shape when uncovered in the soil. They have a brown head capsule, three pairs of legs and an abdomen with a uniform width. Larvae of various white grub species are very similar-looking. To identify the larva species, closely examine the tiny spines on the raster (the last segment of the body). June beetle larvae have two parallel rows of stout spines on the raster and a Y-shaped anal slit. Japanese beetle larvae have two short rows of stout spines in a distinct "V" pattern on the raster and a crescent-shaped anal opening. European chafer larvae have two nearly parallel rows of spines on the raster that diverge slightly at the hind end and a Y-shaped anal slit. Mature June beetle larvae are the largest (up to 4 cm long), followed by European chafer (1.5 cm) and Japanese beetle (1.25 cm). The adult beetles fly and may cause feeding damage on the foliage of outdoor ornamentals.

Although white grub larvae traditionally attack turf, they have been expanding their host range. In the last several years, white grub larvae have been found feeding on the roots and crowns of woody nursery stock in the field. There have also been several cases of white grubs feeding on vegetable crops and cash crops in southwestern Ontario. Monitor for grub populations in late summer. Registered insecticides for preventive purposes are most effective when used at the beginning of adult flight periods since these products will be present in the soil when the eggs are hatching. Registered insecticides (including nematodes) for curative or rescue purposes are most effective when applied by late summer when the grubs are still small enough to be susceptible and are feeding near the surface. Some indicator species (hosts) for white grub adults include Japanese tree lilac, elm and cherry, while fir and spruce are larval hosts.

Root Weevils

Root weevils are small (up to 1 cm long), white larvae that feed on the crown and roots from under the soil, which often severely damages or kills the plant. Root weevils have a brown head capsule and no legs and are fatter in the centre of their abdomen than at their ends. The absence of legs and uneven thickness distinguishes them from white grub larvae. The two most common root weevils in Ontario are black vine weevil (*Otiorhynchus sulcatus*) and strawberry root weevil (*Otiorhynchus ovatus*). Strawberry root weevils feed on crops such as white cedar and Colorado spruce, while black vine weevils have a much larger ornamental host range. No male adult specimens have ever been observed in either of these species. Strawberry and black vine root weevils are flightless and resemble a beetle except for the fact they have a long snout. These adults crawl around and feed during the night by cutting notches into leaves. The leaf notches rarely lead to serious damage but are an indication that a weevil population is present. Inspect crowns and roots for the larvae: the most damaging weevil life stage. Weevil larvae can be found feeding on roots and crowns any time from September through May. This is the period when weevil larvae are most likely to be present.

Weevil larvae are difficult to control with chemicals since they can be found well below the soil surface and are protected by the soil. Recent studies have shown that entomopathogenic nematodes (e.g., *Heterohabditis bacteriophora*) control root weevils extremely well in container production but reduce root weevil populations in the field by only 50%. Irrigation seems to limit their effectiveness in field production soils, especially where soils are sandy. Adult weevil populations can be reduced by using registered contact insecticides applied to the foliage during the early evening. Indicator species for root weevils include *Taxus, Rhododendron, Euonymus, Thuja, Heuchera* and *Sedum*.

Plant Parasitic Nematodes

Nematodes are tiny, thread-like roundworms that feed and multiply in or on a wide range of plant roots. Necrosis (dead tissue) or localized swellings in roots may indicate possible feeding sites. Nematodes may also spread soil-borne viruses and permit the development of secondary bacterial and fungal infections. Nematodes are often more prevalent in wet, poorly drained soils (especially during the growing season following a rainy year). They are more common in low-lying areas of the field. Although populations will rise dramatically during a wet growing season, symptoms of the infestation often don't show up until the following year.

Treat potential nematode problem areas before planting, using registered products such as Basamid and Vapam. Use these materials according to the manufacturer's instructions. Manage nematode diseases by rotating crops, sterilizing the soil and using disease-free planting material. For directions on sampling for nematodes, see Appendix E, *Diagnostic Service*, on page 81.

Consult the OMAF website at www.ontario.ca/crops for detailed information about nematode problems, preplant soil fumigation and the fumigation of established crops. For more information, see "Soil Fumigants" in OMAF Publication 840, *Crop Protection Guide for Nursery and Landscape Plants.*

TABLE 2–1. Host Symptoms and Possible Causes of Insect Injury

Category	Symptom	Possible Causes
Chewed leaves and/or chewed flowers	pieces of leaf or flower missing entire leaves or flowers missing	caterpillars (moth larvae, butterfly larvae) beetle larvae or adult beetles sawfly larvae grasshoppers snails slugs
Discoloured leaves	bleached leaves bronzed leaves silvered leaves stippled leaves streaked leaves	lace bugs plant bugs spider mites leafhoppers aphids psyllids thrips
Plant part distortion	mined leaves skeletonized leaves curled/cupped leaves galls on leaves, stems, flowers, twigs twisted growing points	beetle larvae caterpillars sawflies aphids gall wasps gall flies psyllids eriophyid mites
Plant dieback	dying leaves, twigs, branches dying whole plant holes and frass wilting	twig pruners root-feeding beetle larvae boring insects scales adelgids

Soybean Cyst Nematode

The soybean cyst nematode, *Heterodera glycines*, is a concern in southwestern Ontario, especially in Kent, Perth, Elgin, Essex and Prescott and Russell counties. While most field-grown nursery stock does not host this pest, practicing good soil management can help reduce its spread.

- Do not grow nursery stock on fields recently used to produce soybeans.
- Do not use equipment in nursery fields that was used to cultivate soybean fields. Attached soil can spread the nematode cysts.
- Prevent soil erosion.
- Many weeds act as host plants to soybean cyst nematode. Good weed control will reduce populations.
- Nematicides are ineffective against this pest.

TABLE 2–2. Symptoms and Possible Causes of Insect Injury (by Visible Insect Matter)

Symptom	Possible Causes
Dark fecal spots	aphids soft scales leafhoppers mealybugs psyllids whiteflies
Honeydew Sooty mould	lacebugs greenhouse thrips some plant bugs sawfly adults
Silken mats Spittle Tents Webs	leaf rollers leaftiers spittlebugs tent caterpillars webworms
Sap flow	larvae of certain kinds of moths and beetles
Pitch tubes	bark beetles
Cast skins	aphids cicadas clearwing moth larvae lacebugs leafhoppers
Pitch mass	larvae of certain kinds of moths and beetles
Flocculence (cottony waxy material)	adelgids aphids certain scales mealybugs psyllids
Slime	slugs snails

Phenology and Growing Degree Day Tables for Monitoring

Over time, recorded temperature data for the phenological development of plants and plant pests have revealed that certain plants and insects pass through developmental stages at the same time. For example, when the *Magnolia* x *soulangiana* flowers are in the pink flower bud stage, the overwintering spruce gall adelgid nymphs are starting to feed and are susceptible (vulnerable) to pesticide applications. The fruiting and flowering characteristics of certain common ornamentals in the landscape have been linked to the developmental stages of plant pests and diseases. These plants are referred to as "plant phenology indicators" (see Table 2–3, *Common Phenology Plant Indicators for Ontario*, on this page). The plant phenology indicator species listed in this table can be used to more efficiently monitor for pests and diseases on nursery and landscape plants in Ontario. Some horticulturalists have found plant phenology indicators to be more accurate than GDD models. Use plant phenology indicators to estimate the developmental life stages of common insect pests and diseases that affect nursery and landscape plants in your monitoring program. The combined collection of GDD data and plant phenology indicators can give a clearer picture of the timing of pest emergence and opportunities for monitoring and then management.

Once you know the current developmental stages of the plant phenology indicator species in your crop production area or landscape, you can look up the corresponding common pests to scout for. Tables 2–4 to 2–17 outline phenology plant characteristics, GDD summaries and corresponding pests and diseases that can help when planning plant health monitoring schedules. The presence of a "V" in the "Stage" column indicates this pest is vulnerable to pesticides, which may include horticultural oil.

Obtain the daily maximum and minimum temperatures needed to calculate GDDs from weather stations such as Environment Canada or Weather Innovations Incorporated or obtain them from on-farm weather stations.

Many of the plant phenology and pest models that follow have been developed by horticultural expert Donald A. Orton, who wrote *Coincide: The Orton System of Pest and Disease Management*. This valuable book provides detailed information on the timing for the most vulnerable life stages of common nursery and landscape pests based on plant phenology observations from over 20 years of field research. *Coincide* is available from the Labor of Love Conservatory, Wheaton, Illinois (www.laboroflove conservatory.com).

TABLE 2–3. Common Phenology Plant Indicators for Ontario

Acer platanoides	Norway maple
Acer rubrum	red maple
Acer saccharinum	silver maple
Acer saccharum	sugar maple
Aesculus hippocastanum	horsechestnut
Aesculus parviflora	bottlebrush buckeye
Amelanchier laevis	serviceberry, shadberry
Catalpa speciosa	northern catalpa
Cercis canadensis	redbud
Cirsium arvense	Canada thistle
Cornus alternifolia	pagoda dogwood
Cornus mas	cornelian cherry dogwood
Crataegus phaenopyrum	Washington hawthorn
Daucus carota	wild carrot (Queen Anne's lace)
Gleditsia triacanthos	honeylocust
Hamamelis vernalis	spring-blooming witchhazel
Hamamelis virginiana	fall-blooming witchhazel
Hydrangea arborescens 'Grandiflora'	hills of snow hydrangea

TABLE 2–3. Common Phenology Plant Indicators for Ontario *continued*

Hydrangea paniculata 'Grandiflora'	panicle hydrangea
Kolkwitzia amabilis	beautybush
Lonicera korolkowii 'Zabelii'	zabel honeysuckle
Lonicera tatarica	tartarian honeysuckle
Magnolia x *soulangiana*	saucer magnolia
Philadelphus	mock orange
Pinus mugo	mugo pine
Prunus x *cistena*	purpleleaf sand cherry
Prunus serotina	wild black cherry
Prunus triloba	flowering almond
Ribes odoratum	golden or flowering currant
Robinia pseudoacacia	black locust
Salix caprea	pussy willow
Sambucus canadensis	American elder, elderberry
Solidago canadensis	Canada goldenrod
Sorbus aucuparia	European mountain ash
Spiraea nipponica 'Snowmound'	snowmound spiraea
Spiraea x *vanhouttei*	bridal wreath spiraea
Syringa reticulata	Japanese tree lilac
Syringa villosa	late lilac
Syringa vulgaris	common lilac
Ulmus pumila	Siberian elm
Viburnum carlesii	Koreanspice viburnum
Viburnum dentatum	arrowwood viburnum
Viburnum lantana	wayfaring tree viburnum
Viburnum opulus	European cranberrybush viburnum
Weigela florida	old-fashioned weigela
Yucca filamentosa	Adam's needle

TABLE 2–4. Monitoring for Common Insect Pests and Diseases in Late March to Early April (1–25 GDD[a] Base 10°C)

Plant Phenology Indicators

Green Leaf Bud Stage	Flower Bud	Starting Bloom	Full Bloom
Gleditsia triacanthos *Syringa vulgaris*	*Syringa vulgaris*	*Acer rubrum* *Acer saccharum* *Cornus mas* *Salix caprea*	*Acer saccharinum*

Nursery and Landscape Host Plants

Plant	Pest	Developmental Stage ***(V) indicates this pest is vulnerable to pesticides***
Apple	Eastern tent caterpillar	Overwintering egg mass on small twigs
	San Jose scale	Overwintering nymphs (V)
Cherry	Eastern tent caterpillar	Overwintering egg mass on small twigs
Crabapple	Eastern tent caterpillar	Overwintering egg mass on small twigs
Deciduous trees and shrubs	Adelgids, mealybugs, mites, scales	Look for overwintered eggs, nymphs (V) on plants that were infested last year
	Gypsy moth	Overwintering egg mass on tree trunks, other wooden objects
Elm	Elm bark beetle	Adults (V), eggs under bark
Evergreen trees and shrubs	Spruce spider mite	Overwintering eggs (V) on twigs and foliage
Hawthorn	Eastern tent caterpillar	Overwintering egg mass on small twigs
Honeylocust	Honeylocust mite	Treat overwintering adult females (V) before they lay eggs, as the *Hamamelis vernalis* and silver maple blooms but before *Cornus mas* blooms.
Maple	Gall mites and wasps	Adults (V), eggs on new leaves
Pear	San Jose scale	Overwintering nymphs (V)
Pine	European pine shoot moth	Overwintering larvae in buds and tips (V)
	Pine bark aphid	Overwintering nymphs, hatching nymphs (V)
	Pine shoot beetle	Adults (V), eggs under bark
	White pine weevil	Adults (V) in leaf litter, on terminals
Spruce	Cooley and eastern spruce gall adelgid	Overwintering nymphs next to buds becoming active
Willow	San Jose scale	Overwintering nymphs (V)

[a] GDD = Growing degree days. For more information, *see page 28.*
The presence of a "V" in the "stage" column indicates this pest is vulnerable to pesticides, which may include horticultural oil.

TABLE 2–5. Monitoring for Common Insect Pests and Diseases in Mid-April to Late April (25–55 GDD[a] Base 10°C)

Plant Phenology Indicators

Green Leaf Bud Stage	Flower Bud	Mid-Bloom	End Bloom	New Leaves
Gleditsia triacanthos *Syringa vulgaris*	*Acer platanoides* *Amelchier laevis* *Magnolia* x *soulangiana*	*Acer rubrum* *Cornus mas* *Forsythia* sp. *Magnolia stellata* *Salix caprea*	*Acer saccharinum*	*Ulmus pumila*

Nursery and Landscape Host Plants

Plant	Pest	Developmental Stage ***(V) indicates this pest is vulnerable to pesticides***
Apple, cherry, crabapple, hawthorn	Apple scab	Protect apple and crabapple leaves with fungicides as soon as buds begin to open
	Eastern tent caterpillar	Young larvae (V), small tents in twig crotche
Birch	Birch leafminer	Tiny, black sawfly adults around new leaves; use sticky traps to monitor
Cherry	Eastern tent caterpillar	Overwintering egg mass on small twigs
Crabapple	Eastern tent caterpillar	Overwintering egg mass on small twigs
Deciduous trees and shrubs	Adelgids, mealybugs, mites, scales	Look for overwintered eggs, nymphs (V) on plants that were infested last year
	Gypsy moth	Overwintering egg mass on tree trunks, other wooden objects
Elm	Elm bark beetle	Adults (V), eggs under bark
Evergreen trees and shrubs	Spruce budworm	Larvae (V)
	Spruce spider mite	Overwintering eggs (V) on twigs and foliage
Hawthorn	Eastern tent caterpillar	Overwintering egg mass on small twigs
Maple	Gall mites and wasps	Adults (V), laying eggs on new leaves

Pine	European pine shoot moth	Overwintering larvae in buds and tips (V)
	Pine bark aphid	Overwintering eggs, hatching nymphs on bark
	Pine shoot beetle	Adults, eggs under bark
	White pine weevil	Adults (V), eggs on terminals
	Zimmerman pine moth	Overwintering larvae
Spruce	Cooley and eastern spruce gall adelgid	Overwintering nymphs next to buds (V)
Viburnum	Viburnum leaf beetle	Eggs on twig undersides (visible as rows of brown bumps); prune out
Yew	Fletcher scale	Overwintering nymphs on undersides of twigs and foliage

[a] GDD = Growing degree days. For more information, see page 28.
The presence of a "V" in the "stage" column indicates this pest is vulnerable to pesticides, which may include horticultural oil.

TABLE 2–6. Monitoring for Common Insect Pests and Diseases in Late April to Mid-May (55–100 GDD[a] Base 10°C)

Plant Phenology Indicators

Leafing Out	Flower Bud	Early Bloom	Full Bloom
Acer saccharinum *Ulmus pumila*	*Aesculus hippocastanum* *Gleditsia triacanthos* *Spiraea* x *vanhouttei* *Syringa vulgaris*	*Amelanchier laevis* *Cercis canadensis* *Cornus florida* *Viburnum carlesii*	*Acer platanoides* *Acer saccharum* *Magnolia* x *soulangiana* *Prunus* x *cistena*

Nursery and Landscape Host Plants

Plant	Pest	Developmental Stage ***(V) indicates this pest is vulnerable to pesticides***
Apple	Apple scab	Protect apple and crabapple leaves with fungicides as soon as buds begin to open
	Cedar-apple, cedar-quince, cedar-hawthorn rust	Begin fungicide applications to protect rosaceous hosts (where galls on juniper are sporulating)
	Eastern tent caterpillar	Larvae (V); remove tents
Ash	Ash plant bug	Protect foliage with insecticides as ash trees are breaking bud to target susceptible newly-hatched nymphs
Basswood	White grubs	C-shaped grubs in soil around damaged roots
Beech	Gypsy moth	Egg hatch at first bloom of *Cercis canadensis*
Birch	Birch leafminer	Larvae (visible as small blotches in leaves)
Boxwood	Boxwood psyllid	Newly hatched nymphs (V) feed on new leaves

TABLE 2–6. Monitoring for Common Insect Pests and Diseases in Late April to Mid-May (55–100 GDD[a] Base 10°C) *continued*

Nursery and Landscape Host Plants

Plant	Pest	Developmental Stage ***(V) indicates this pest is vulnerable to pesticides***
Cherry	Eastern tent caterpillar	Overwintering egg mass on small twigs
	Peachtree borer	Look for sawdust at soil line as sign of active overwintering larvae just under loose bark
Crabapple	Cedar-apple, cedar-quince, cedar-hawthorn rust	Begin fungicide applications to protect rosaceous hosts (where galls on juniper are sporulating)
	Eastern tent caterpillar	Overwintering egg mass on small twigs
Deciduous trees and shrubs	Adelgids, mealybugs, mites, scales	Inspect plants that were infested last year
	Fall cankerworm	Larvae (Vulnerable to insecticides such as B.t.)
	Gypsy moth	Eggs masses beginning to hatch
Dogwood	Dogwood borer	Larvae (look for holes and fresh sawdust on trunk and large branches); destroy larvae
Eastern white cedar	Fletcher scale	Nymphs (V)
Elm	Gypsy moth	Egg hatch at first bloom of *Cercis canadensis*
Euonymus	Euonymus webworm	Larvae (look for yellow larvae and webbing on shoots) (V)
Evergreens	Spruce budworm	Larvae (V)
	Spruce spider mite	Hatching nymphs (V)
	White grubs	C-shaped grubs in soil around damaged roots
Fir	Balsam twig adelgid	Nymphs (V)
	Spruce spider mite	Hatching nymphs (V)
Hawthorn	Cedar-apple, cedar-quince, cedar-hawthorn rust	Begin fungicide applications to protect rosaceous hosts (where galls on juniper are sporulating)
	Eastern tent caterpillar	Overwintering egg mass on small twigs
Hickory	Gypsy moth	Egg hatch at first bloom of *Cercis canadensis*
Honeylocust	Honeylocust pod gall midge	Newly hatched larvae (V) start feeding on emerging foliage
Juniper	Cedar-apple, cedar-quince, cedar-hawthorn rust	Begin fungicide applications to protect rosaceous hosts (where galls on juniper are sporulating)
Lilac	Lilac borer	Larvae (look for holes and fresh sawdust on trunk and large branches); destroy larvae
	White grubs	C-shaped grubs in soil around damaged roots

Linden	Gypsy moth	Egg hatch at first bloom of *Cercis canadensis*
Maple	Gall mites and wasps	Adults, eggs on new leaves
Oak	Gypsy moth	Egg hatch at first bloom of *Cercis canadensis*
Pear	Pear trellis rust, cedar-apple, cedar-quince, cedar-hawthorn rust	Begin fungicide applications to protect rosaceous hosts (where galls on juniper are sporulating)
Pine	European pine sawfly	Larvae (look for small, green larvae on new growth) (V)
	Pine bark aphid	Newly hatched nymphs (V)
	Pine spittlebug	Look for nymphs inside spittle masses on new growth; remove by hand
	White pine weevil	Larvae in terminals; prune out
	Zimmerman pine moth	Overwintering larvae (V)
Spruce	Cooley and eastern spruce gall adelgid	Nymphs found on undersides of buds (V)
	Gypsy moth	Egg hatch at first bloom of *Cercis canadensis*
	Spruce spider mite	Hatching mites (shake branch over paper and look for reddish to brown and black mites) (V)
Viburnum	Snowball aphid	Nymphs (inspect new leaves) (V)
	Viburnum leaf beetle	Hatching larvae (inspect egg sites and leaf undersides) (V)
Yew	Fletcher scale	Nymphs (V)

[a] GDD = Growing degree days. For more information, *see page 28.*
The presence of a "V" in the "stage" column indicates this pest is vulnerable to pesticides, which may include horticultural oil.

TABLE 2–7. Monitoring for Common Insect Pests and Diseases in Mid-May to Late May (100–150 GDD[a] Base 10°C)

Plant Phenology Indicators

Early Bloom	Full Bloom	Late Bloom
Prunus serotina *Sorbus aucuparia*	*Aesculus hippocastanum* *Gleditsia triacanthos* *Lonicera korolkowii* *Ribes odoratum* *Spiraea* x *vanhouttei* *Syringa vulgaris* *Viburnum lantana*	*Amelanchier laevis* *Cercis canadensis*

TABLE 2–7. Monitoring for Common Insect Pests and Diseases in Mid-May to Late May (100–150 GDD[a] Base 10°C) *continued*

Nursery and Landscape Host Plants

Plant	Pest	Developmental Stage ***(V) indicates this pest is vulnerable to pesticides***
Apple	Cedar-apple, cedar-quince, cedar-hawthorn rust	Begin fungicide applications to protect rosaceous hosts (where galls on juniper are sporulating)
	Eastern tent caterpillar	Larvae (V); remove tents
	Gypsy moth	Larva (V) feeding on foliage
Ash	Ash plant bug	Protect foliage with insecticides as ash trees are breaking bud to target susceptible newly-hatched nymphs
Beech	Gypsy moth	Larva (V) feeding on foliage
Birch	Birch leafminer	Adults, then newly hatched larvae; look for small blotches in leaves for larvae (V)
Boxwood	Boxwood psyllid	Waxy, white nymphs (not as susceptible) on new foliage
Cherry	Cedar-apple, cedar-quince, cedar-hawthorn rust	Continue fungicide applications to protect rosaceous hosts (where galls on juniper are still sporulating)
	Eastern tent caterpillar	Larvae (V); remove tents
	Gypsy moth	Larva (V) feeding on foliage
	Peachtree borer	Look for sawdust at soil line as sign of active overwintering larvae just under loose bark
Crabapple	Cedar-apple, cedar-quince, cedar-hawthorn rust	Begin fungicide applications to protect rosaceous hosts (where galls on juniper are sporulating)
	Eastern tent caterpillar	Overwintering egg mass on small twigs
Deciduous trees	Gypsy moth	Larva (V) feeding on foliage
Eastern white cedar	Eastern tent caterpillar	Larvae (V); remove tents
Elm	Elm leafminer	Adults emerge (V)
	Gypsy moth	Larva (V) feeding on foliage
Euonymus	Euonymus webworm	Larvae (look for yellow larvae and webbing on shoots) (V)
Evergreens	Spruce spider mite	Hatching nymphs (V)
Fir	Balsam twig adelgid	Nymphs (V)
Hawthorn	Cedar-apple, cedar-quince, cedar-hawthorn rust	Begin fungicide applications to protect rosaceous hosts (where galls on juniper are sporulating)
	Eastern tent caterpillar	Overwintering egg mass on small twigs
Hickory	Eastern tent caterpillar	Larvae (V); remove tents

Juniper	Cedar-apple, cedar-quince, cedar-hawthorn rust	Begin fungicide applications to protect rosaceous hosts (where galls on juniper are sporulating)
Lilac	Gypsy moth	Larva (V) feeding on foliage
	Lilac leafminer	Larvae (look for new mines in leaves) (V)
Linden	Gypsy moth	Larva (V) feeding on foliage
Maple	Gall mites and wasps	Larvae hatching
Oak	Gypsy moth	Larva (V) feeding on foliage
Pear	Pear trellis rust, cedar-apple, cedar-quince, cedar-hawthorn rust	Begin fungicide applications to protect rosaceous hosts (where galls on juniper are sporulating)
Pine	European pine sawfly	Larvae (look for small, green larvae on new growth) (V)
	Pine needle scale	Newly hatching reddish crawlers (V)
	Pine spittlebug	Look for nymphs inside spittle masses on new growth; remove by hand
	White pine weevil	Larvae in terminals; prune out
Spruce	Gypsy moth	Larva (V) feeding on foliage, lower branches first
	Spruce spider mite	Hatching nymphs (shake branch over paper and look for tiny, slow mites) (V)
Viburnum	Snowball aphid	Nymphs on new leaves (V) (they are only vulnerable to pesticides 1–10 days after egg hatch)
	Viburnum leaf beetle	Hatching larvae (inspect egg sites and leaf undersides) (V)
Yew	Taxus mealybug	Small, whitish nymphs (V) in branch crotches

[a] *GDD = Growing degree days. For more information, see page 28.*
The presence of a "V" in the "stage" column indicates this pest is vulnerable to pesticides, which may include horticultural oil.

TABLE 2–8. Monitoring for Common Insect Pests and Diseases in Late May to Early June (150–200 GDD[a] Base 10°C)

Plant Phenology Indicators

Early Bloom	Full Bloom	Candling (15–20 cm)	Late Bloom	Ripe Seed	Dropping Seed
Cornus alternifolia *Prunus serotina* *Viburnum opulus*	*Aesculus hippocastanum* *Lonicera korolkowii* *Prunus serotina* *Sorbus aucuparia* *Spirea* x *vanhouttei* *Syringa vulgaris*	*Pinus mugo*	*Aesculus hippocastanum* *Gleditsia triacanthos* *Lonicera korolkowii* *Ribes odoratum* *Viburnum lantana*	*Ulmus pumila*	*Acer saccharinum*

Nursery and Landscape Host Plants

Plant	Pest	Developmental Stage ***(V) indicates this pest is vulnerable to pesticides***
Apple	Cedar-apple, cedar-quince, cedar-hawthorn rust	Continue fungicide applications to protect rosaceous hosts (where galls on juniper are still sporulating)
	Eastern tent caterpillar	Larvae (V); remove tents
Ash	Oystershell scale	Crawlers (V)
Birch	Birch leafminer	Larvae (V) (look for small blotches in leaves)
	Bronze birch borer	Adults laying eggs (V)
Boxwood	Boxwood psyllid	Waxy, white nymphs
Cherry	Eastern tent caterpillar	Larvae (V); remove tents
Crabapple	Eastern tent caterpillar	Larvae (V); remove tents
	Cedar-apple, cedar-quince, cedar-hawthorn rust	Continue fungicide applications to protect rosaceous hosts (where galls on juniper are still sporulating)
Deciduous trees	Fall cankerworm	Larvae (V)
	Gypsy moth	Larvae (V)
	Oystershell scale	Crawlers (V)
Eastern white cedar	Cedar leafminer	Small, greyish-white adult moths (visible when foliage is disturbed) (V)
Euonymus	Euonymus webworm	Larvae (look for yellow larvae and webbing on shoots) (V)
Evergreens	Spruce spider mite	Nymphs and adults (V)

Hawthorn	Eastern tent caterpillar	Larvae (V); remove tents
	Cedar-apple, cedar-quince, cedar-hawthorn rust	Continue fungicide applications to protect rosaceous hosts (where galls on juniper are still sporulating)
Holly	Holly leafminer	Small, grey, adult flies (V); use sticky traps to trap
Honeylocust	Honeylocust plant bug	Nymphs and adults (look for tiny, green plant bugs; adults have wings) (V)
Juniper	Cedar-apple, cedar-quince, cedar-hawthorn rust	Continue fungicide applications to protect rosaceous hosts (where galls on juniper are still sporulating)
Lilac	Lilac borer	Adult flight (as lilacs begin to bloom), mating and egg-laying; treat trunk and large branches with registered pesticides
	Lilac leafminer	Larvae (look for new mines in leaves) (V)
Maple	Gall mites and wasps	Larvae inside leaf galls
Pear	Pear trellis rust, cedar-apple, cedar-quince, cedar-hawthorn rust	Continue fungicide applications to protect rosaceous hosts (where galls on juniper are still sporulating)
Pine	European pine sawfly	Small, green larvae on new growth (V) when the *Aesculus carnea* starts to bloom
	Pine needle scale	Reddish crawlers (V)
	Pine spittlebug	Look for nymphs inside spittle masses on new growth and remove by hand
	White pine weevil	Larvae in terminals; prune out
Spruce	Spruce gall adelgid	Egg hatch
	Spruce spider mite	Hatching nymphs (shake branch over paper and look for tiny, slow mites) (V)
	Yellow headed spruce sawfly	Eggs, young larvae (V)
Viburnum	Viburnum leaf beetle	Larvae feeding on leaf undersides
Willow	Imported willow leaf beetle	Adult emergence
Yew	Taxus mealybug	Small, whitish nymphs (V) in branch crotches

[a] GDD = Growing degree days. For more information, see page 28.
The presence of a "V" in the "stage" column indicates this pest is vulnerable to pesticides, which may include horticultural oil.

TABLE 2–9. Monitoring for Common Insect Pests and Diseases in Early June to Mid-June (200–250 GDD[a] Base 10°C)

Plant Phenology Indicators

Early Bloom	Full Bloom	Candling (15–20 cm)	Late Bloom	Ripe Seed	Dropping Seed
Spiraea nipponica *Viburnum dentatum* *Weigela florida*	*Aesculus hippocastanum* *Cornus alternifolia* *Lonicera korolkowii* *Prunus serotina* *Robinia pseudoacacia* *Sorbus aucuparia* *Spirea* x *vanhouttei* *Syringa vulgaris* *Viburnum opulus*	*Pinus mugo*	*Aesculus hippocastanum* *Gleditsia triacanthos* *Lonicera korolkowii* *Ribes odoratum* *Viburnum lantana*	*Ulmus pumila*	*Acer saccharinum*

Nursery and Landscape Host Plants

Plant	Pest	Developmental Stage ***(V) indicates this pest is vulnerable to pesticides***
Apple	Eastern tent caterpillar	Larvae (V); remove tents
Ash	Emerald ash borer	Adults emerge and are active around foliage exposed to direct sunlight
	Oystershell scale	Crawlers (V) just starting to hatch
Birch	Birch leafminer	Larvae (examine second flush of leaves for small blotches) (vulnerable to systemic insecticides)
	Bronze birch borer	Adults; finish bark applications before eggs are laid
Boxwood	Boxwood psyllid	Waxy, white nymphs on new foliage
Cherry	Eastern tent caterpillar	Larvae (V); remove tents
Crabapple	Eastern tent caterpillar	Larvae (V); remove tents
Deciduous trees	Gypsy moth	Larvae (V)
	Oystershell scale	Crawlers (V) just starting to hatch
Eastern white cedar	Cedar leafminer	Small, greyish-white adult moths (visible when foliage is disturbed) (V)
	Strawberry root weevil	Adult weevils that feed on new shoots, girdling them at the base
Elm	Elm leaf beetle	Larvae that cause holes and skeletonize foliage (V)
Euonymus	Euonymus scale	Crawlers hatch (V)

Evergreens	Spruce spider mite	Nymphs and adults (V)
Hawthorn	Eastern tent caterpillar	Larvae (V); remove tents
Holly	Holly leafminer	Small, grey, adult flies (V); use sticky traps to trap
Honeylocust	Honeylocust plant bug	Adults (look for tiny, green bugs with wings) (V)
Larch	Larch casebearer	Adults (look for tiny moths with dark wings that are easily disturbed)
Lilac	Lilac borer	Adult flight, mating and egg-laying; treat trunk and large branches with registered pesticides (V)
	Lilac leafminer	Larvae (look for new mines in leaves) (V)
Maple	Gall mites and wasps	Larvae inside leaf galls
Mountain ash	Mountain ash sawfly	Groups of yellow-green larvae (V)
Pine	Pine needle scale	Tiny, red crawlers (V)
	White pine weevil	Larvae in terminals; prune out
Roses and other ornamentals	Two-spotted spider mite	Tiny mites on the undersides of leaves (feeding causes yellow spots) (V)
Spruce	Spruce spider mite	Hatching nymphs (shake branch over paper and look for tiny, slow-moving mites) (V)
	Yellow headed spruce sawfly	Young larvae (V)
Viburnum	Viburnum leaf beetle	Larvae feeding on leaf undersides
Yew	Black vine weevil	Early emergence of overwintering adults (V)
	Taxus mealybug	Small, whitish nymphs (V) in branch crotches

[a] *GDD = Growing degree days. For more information, see page 28.*
The presence of a "V" in the "stage" column indicates this pest is vulnerable to pesticides, which may include horticultural oil.

TABLE 2–10. Monitoring for Common Insect Pests and Diseases in Mid-June (250–300 GDD[a] Base 10°C)

Plant Phenology Indicators

Early Bloom	Full Bloom	Late Bloom	Ripe Seed	Dropping Seed
Kolkwitzia amabalis *Philadelphus*	*Cornus alternifolia* *Robinia pseudoacacia* *Spiraea nipponica* *Viburnum dentatum* *Viburnum opulus* *Weigela florida*	*Aesculus hippocastanum* *Lonicera korolkowii* *Prunus serotina* *Sorbus aucuparia* *Spirea* x *vanhouttei* *Syringa vulgaris*	*Ulmus pumila*	*Acer saccharinum*

Nursery and Landscape Host Plants

Plant	Pest	Developmental Stage ***(V) indicates this pest is vulnerable to pesticides***
Apple	Eastern tent caterpillar	Larvae (V); remove tents
Ash	Emerald ash borer	Adults emerge and are active around foliage exposed to direct sunlight
	Oystershell scale	Crawlers (V) very active
Birch	Birch leafminer	Larvae (examine second flush of leaves for small blotches in leaves) (V)
	Bronze birch borer	Finish bark applications before eggs are laid
Boxwood	Boxwood psyllid	Waxy, white nymphs on new foliage
Cherry	Eastern tent caterpillar	Larvae (V); remove tents
	Peach tree borer	Newly hatched larvae (V) move to bark; apply insecticides
Crabapple	Eastern tent caterpillar	Larvae (V); remove tents
Deciduous trees	Gypsy moth	Larvae (V)
	Oystershell scale	Crawlers (V) very active
Eastern white cedar	Cedar leafminer	Small, greyish-white adult moths (visible when foliage is disturbed) (V)
	Strawberry root weevil	Adult weevils that feed on new shoots, girdling them at the base
Elm	Elm leaf beetle	Larvae that cause holes and skeletonize foliage (V)
Euonymus	Euonymus scale	Tiny, orange crawlers on twigs and leaf undersides (V)
Evergreens	Spruce spider mite	Nymphs and adults (V)
Hawthorn	Eastern tent caterpillar	Larvae (V); remove tents
Holly	Holly leafminer	Small, grey, adult flies (V); use sticky traps to trap
Larch	Larch casebearer	Adults (look for tiny moths with dark wings that are easily disturbed)

Lilac	Lilac borer	Adult flight, mating and egg-laying; treat trunk and large branches with registered pesticides (V)
Mountain ash	Mountain ash sawfly	Groups of yellow-green larvae (V)
Pine	Pine needle scale	Tiny, red crawlers (V)
Roses and other ornamentals	Two-spotted spider mite	Tiny mites on the undersides of leaves (feeding causes yellow spots) (V)
Spruce	Spruce spider mite	Hatching nymphs (shake branch over paper and look for tiny, slow-moving mites) (V)
	Yellow headed spruce sawfly	Larvae (V)
Viburnum	Viburnum leaf beetle	Larvae feeding on leaf undersides
Yew	Black vine weevil	Early emergence of overwintering adults (V)
	Taxus mealybug	Small, whitish nymphs (V) in branch crotches

[a] GDD = Growing degree days. For more information, see page 28.
The presence of a "V" in the "stage" column indicates this pest is vulnerable to pesticides, which may include horticultural oil.

TABLE 2–11. Monitoring for Common Insect Pests and Diseases in Mid-June to Late June (300–400 GDD[a] Base 10°C)

Plant Phenology Indicators

Early Bloom	Full Bloom	Late Bloom
Catalpa speciosa *Syringa reticulata* *Syringa villosa*	*Catalpa speciosa* *Kolkwitzia amabalis* *Philadelphus* *Syringa reticulata* *Viburnum dentatum*	*Aesculus hippocastanum* *Cornus alternifolia* *Kolkwitzia amabalis* *Robinia pseudoacacia* *Spiraea nipponica* *Viburnum opulus*

Nursery and Landscape Host Plants

Plant	Pest	Developmental Stage ***(V) indicates this pest is vulnerable to pesticides***
Ash	Oystershell scale	Crawlers (V)
Birch	Bronze birch borer	Larvae hatching and boring into bark
Cherry	Peach tree borer	Young larvae may still be susceptible to bark applications of insecticides
Deciduous trees	Oystershell scale	Crawlers (V)
Eastern white cedar	Bagworm	Newly hatched larvae with cases on foliage (V)
	Cedar leafminer	Small, greyish-white adult moths (visible when foliage is disturbed) (V)
	Strawberry root weevil	Adult weevils that feed on new shoots, girdling them at the base

TABLE 2–11. Monitoring for Common Insect Pests and Diseases in Mid-June to Late June (300–400 GDD[a] Base 10°C) *continued*

Nursery and Landscape Host Plants

Plant	Pest	Developmental Stage ***(V) indicates this pest is vulnerable to pesticides***
Elm	Elm leaf beetle	Larvae that cause holes and skeletonize foliage (V)
Euonymus	Euonymus scale	Tiny, orange crawlers on twigs and leaf undersides (V)
Evergreens	Spruce spider mite	Nymphs and adults (V)
Fir	White grubs	Japanese beetle pupae, European chafer and June beetle eggs (V) in soil
Japanese tree lilac	White grubs	Japanese beetle adults (V) and Japanese beetle pupae, European chafer and June beetle eggs (V) in soil
Juniper	Bagworm	Newly hatched larvae inside cases (V) on foliage
	Juniper scale	Tiny, yellow nymphs (V)
Larch	Larch casebearer	Adults (look for tiny moths with dark wings that are easily disturbed)
Maple	Potato leafhopper	Monitor *Caragana* and *Acer* as indicator plants; treat with insecticides at first sign of leafhopper (V)
Mountain ash	Mountain ash sawfly	Groups of yellow-green larvae (V)
Roses and other ornamentals	Two-spotted spider mite	Tiny mites on the undersides of leaves (feeding causes yellow spots) (V)
Spruce	Bagworm	Newly hatched larvae inside cases on foliage (V)
	Spruce spider mite	Hatching nymphs (shake branch over paper and look for tiny, slow-moving mites) (V)
	White grubs	Japanese beetle pupae, European chafer and June beetle eggs (V) in soil
Viburnum	Viburnum crown borer	Newly hatched larvae (V) susceptible to bark applications of insecticides
Yew	Black vine weevil	Early emergence of overwintering adults (V)

[a] *GDD = Growing degree days. For more information, see page 28.*
The presence of a "V" in the "stage" column indicates this pest is vulnerable to pesticides, which may include horticultural oil.

TABLE 2–12. Monitoring for Common Insect Pests and Diseases in Late June to Early July (400–500 GDD[a] Base 10°C)

Plant Phenology Indicators

Early Bloom	Full Bloom	Late Bloom	Fruiting
Cirsium arvense *Hydrangea arborescens* 'Grandiflora' *Sambucus canadensis*	*Catalpa speciosa*	*Philadelphus* *Syringa reticulata* *Weigela florida*	*Amelanchier laevis* *Lonicera tartarica*

Nursery and Landscape Host Plants

Plant	Pest	Developmental Stage ***(V) indicates this pest is vulnerable to pesticides***
Apple	San Jose scale	Newly hatched crawlers (V), repeat applications 7–10 days later
Cherry	Peach tree borer	Adults
Deciduous trees	Green peach aphid	Look for honeydew, sooty mould and tiny green aphids (V)
Eastern white cedar	Strawberry root weevil	Adult weevils that feed on new shoots, girdling them at the base
Euonymus	Euonymus scale	Second-generation of eggs start to hatch into crawlers (V)
Fir	White grubs	Japanese beetle pupae and adults, European chafer and June beetle eggs (V) in soil
Honeylocust	Honeylocust mite	Shake leaves over white paper and look for tiny, reddish-brown mites (V)
Japanese tree lilac	White grubs	Japanese beetle pupae and adults (V), European chafer and June beetle eggs (V) in soil
Juniper	Juniper scale	Tiny, yellow nymphs (V)
Maple	Cottony maple scale	Crawlers hatching (V)
	Potato leafhopper	Monitor *Caragana* and *Acer* as indicator plants; treat with insecticides at first sign of leafhopper (V)
Mountain ash	Mountain ash sawfly	Groups of yellow-green larvae (V)
Pear	San Jose scale	Newly hatched crawlers (V), repeat applications 7–10 days later
Pine	Redheaded pine sawfly	Small, yellow larvae on old needles (V)
	White grubs	Japanese beetle, European chafer and June beetle eggs (V) in soil
Roses and other ornamentals	Two-spotted spider mite	Tiny mites on the undersides of leaves (feeding causes yellow spots) (V)
Spruce	White grubs	Japanese beetle, European chafer and June beetle eggs (V) in soil
Willow	San Jose scale	Newly hatched crawlers (V), repeat applications 7–10 days later
Yew	Black vine weevil	Early emergence of new-progeny adults (V)

[a] *GDD = Growing degree days. For more information,* *see page 28.*
The presence of a "V" in the "stage" column indicates this pest is vulnerable to pesticides, which may include horticultural oil.

TABLE 2–13. Monitoring for Common Insect Pests and Diseases in Early July to Mid-July (500–700 GDD[a] Base 10°C)

Plant Phenology Indicators

Early Bloom	Full Bloom	Late Bloom	Fruiting
Cichorium intybus *Daucus carota*	*Cirsium arvense* *Daucus carota* *Hydrangea arborescens* 'Grandiflora' *Sambucus canadensis* *Yucca filamentosa*	*Catalpa speciosa* *Hydrangea arborescens* 'Grandiflora' *Yucca filamentosa*	*Lonicera tartarica*

Nursery and Landscape Host Plants

Plant	Pest	Developmental Stage
Ash	European fruit lecanium scale	Crawlers (V); repeat applications will be necessary
Deciduous trees	Green peach aphid	Look for honeydew, sooty mould and tiny green aphids (V)
Eastern white cedar	Fletcher scale	Crawlers (V); repeat applications will be necessary
	Strawberry root weevil	Adult weevils that feed on new shoots, girdling them at the base
Elm	European elm scale	Crawlers (V)
	Japanese beetle	Adult beetles emerge and are active on foliage (V)
English oak	European fruit lecanium scale	Crawlers (V); repeat applications will be necessary
Euonymus	Euonymus scale	Egg-laying, egg hatch (second generation) (V)
Fir	White grubs	Japanese beetle, European chafer and June beetle eggs (V) in soil
Grape vine	Japanese beetle	Adult beetles emerge and are active on foliage (V)
Honeylocust	Honeylocust mite	Shake leaves over white paper and look for tiny, reddish-brown mites (V)
Japanese tree lilac	White grubs	Japanese beetle adults (V) and Japanese beetle, European chafer and June beetle eggs (V) in soil
Juniper	Juniper scale	Tiny, yellow nymphs (V)
Maple	Cottony maple scale	Crawlers on leaves and twigs (V)
	Potato leafhopper	Monitor *Caragana* and *Acer* as indicator plants; treat with insecticides at first sign of leafhopper (V)
Mountain ash	Mountain ash sawfly	Groups of yellow-green larvae (V)
Pine	Redheaded pine sawfly	Small, yellow larvae on old needles (V)
	White grubs	Japanese beetle, European chafer and June beetle eggs (V) in soil

Roses and other ornamentals	Japanese beetle	Adult beetles emerge and are active on foliage (V)
	Two-spotted spider mite	Adult mites emerge (V), tiny spider mites on the undersides of leaves (feeding causes yellow spots on foliage)
Spruce	Spruce bud scale	Crawlers (V)
	White grubs	Japanese beetle, European chafer and June beetle eggs (V) in soil
Yew	Black vine weevil	Early emergence of new-progeny adults (V)
	Fletcher scale	Crawlers (V)

[a] *GDD = Growing degree days. For more information, see page 28.*
The presence of a "V" in the "stage" column indicates this pest is vulnerable to pesticides, which may include horticultural oil.

TABLE 2–14. Monitoring for Common Insect Pests and Diseases in Mid-July to Late July (700–900 GDD[a] Base 10°C)

Plant Phenology Indicators

Early Bloom	Full Bloom	Late Bloom	Fruiting	Yellow Fruit	Ripe Seed	White Flowers Turning Green
Cichorium intybus *Daucus carota* *Hibiscus syriacus*	*Daucus carota*	*Daucus carota*	*Viburnum lantana*	*Sorbus aucuparia*	*Cirsium arvense*	*Hydrangea arborescens* 'Grandiflora'

Nursery and Landscape Host Plants

Plant	Pest	Developmental Stage ***(V) indicates this pest is vulnerable to pesticides***
Ash	Fall webworm	Yellow, fuzzy larvae inside webs at ends of branches; manually remove
Deciduous trees	Green peach aphid	Look for honeydew, sooty mould and tiny green aphids (V)
Eastern white cedar	Strawberry root weevil	Adult weevils feed on new shoots, girdling them at the base
Euonymus	Euonymus scale	Second-generation crawlers (V)
Grape vine	Japanese beetle	Adult beetles that skeletonize foliage (V)
Honeylocust	Honeylocust mite	Shake leaves over white paper and look for tiny, reddish-brown mites (V)
Pine	Pine needle scale	Second-generation crawlers (V)
	Redheaded pine sawfly	Small, yellow larvae on old needles (V)
Roses and other ornamentals	Japanese beetle	Adult beetles that skeletonize foliage (V)
	Leafhoppers	Monitor *Caragana* and *Acer* as indicator plants; treat with insecticides at first sign (V)
	Two-spotted spider mite	Tiny mites on the undersides of leaves (feeding causes yellow spots) (V)
Yew	Black vine weevil	Early emergence of new-progeny adults (V)

[a] *GDD = Growing degree days. For more information, see page 28.*
The presence of a "V" in the "stage" column indicates this pest is vulnerable to pesticides, which may include horticultural oil.

TABLE 2–15. Monitoring for Common Insect Pests and Diseases in Early August to Late August (900–1,100 GDD[a] Base 10°C)

Plant Phenology Indicators

Early Bloom	Full Bloom	Late Bloom	Fruiting	Orange Fruit
Solidago canadensis	*Hibiscus syriacus* *Hydrangea paniculata* 'Grandiflora' *Solidago canadensis*	*Hydrangea paniculata* 'Grandiflora'	*Viburnum lantana* *Viburnum opulus*	*Sorbus aucuparia*

Nursery and Landscape Host Plants

Plant	Pest	Developmental Stage ***(V) indicates this pest is vulnerable to pesticides***
Ash	Fall webworm	Yellow, fuzzy larvae (V) inside webs at ends of branches; manually remove or apply B.t. when larvae are small
Birch	Fall webworm	Yellow, fuzzy larvae (V) inside webs at ends of branches; manually remove or apply B.t. when larvae are small
Cherry	Fall webworm	Yellow, fuzzy larvae (V) inside webs at ends of branches; manually remove or apply B.t. when larvae are small
	Peach tree borer	Larvae under bark
Deciduous trees	Green peach aphid	Look for honeydew, sooty mould and tiny green aphids (V)
Eastern white cedar	Strawberry root weevil	Adult weevils that feed on new shoots, girdling them at the base
Euonymus	Euonymus scale	Second generation of crawlers (V)
Grape vine	Japanese beetle	Adult beetles that skeletonize foliage
Honeylocust	Honeylocust mite	Shake leaves over white paper and look for tiny, reddish-brown mites (V)
Magnolia	Magnolia scale	Egg hatch just beginning
Roses and other ornamentals	Japanese beetle	Adult beetles that skeletonize foliage
	Two-spotted spider mite	Tiny mites on the undersides of leaves (feeding causes yellow spots) (V)
Walnut	Fall webworm	Yellow, fuzzy larvae (V) inside webs at ends of branches; manually remove or apply B.t. when larvae are small
Yew	Black vine weevil	Early emergence of new-progeny adults (V)

[a] GDD = Growing degree days. For more information, see page 28.
The presence of a "V" in the "stage" column indicates this pest is vulnerable to pesticides, which may include horticultural oil.

TABLE 2–16. Monitoring for Common Insect Pests and Diseases in Late August to Mid-September (1,100–1,300 GDD[a] Base 10°C)

Plant phenology indicators

Early Bloom	Full Bloom	White Flowers Turning Pink	Late Bloom	Orange Fruit
—	—	*Hydrangea paniculata* 'Grandiflora'	*Solidago canadensis*	*Sorbus aucuparia*

— *No plant phenology indicator species in these developmental stages*

Nursery and Landscape Host Plants

Plant	Pest	Developmental Stage ***(V) indicates this pest is vulnerable to pesticides***
Ash	Fall webworm	Yellow, fuzzy larvae inside webs at ends of branches; manually remove
Deciduous trees	Green peach aphi	Look for honeydew, sooty mould and tiny green aphids (V)
Euonymus	Euonymus scale	Second generation of crawlers (V)
Grape vine	Japanese beetle	Adult beetles that skeletonize foliage
Honeylocust	Honeylocust mite	Shake leaves over white paper and look for tiny, reddish-brown mites (V)
Magnolia	Magnolia scale	Crawlers (V)
Roses and other ornamentals	Japanese beetle	Adult beetles that skeletonize foliage
	Two-spotted spider mite	Tiny mites on the undersides of leaves (feeding causes yellow spots) (V)

[a] *GDD = Growing degree days. For more information, see page 28.*

The presence of a "V" in the "stage" column indicates this pest is vulnerable to pesticides, which may include horticultural oil.

TABLE 2–17. Monitoring for Common Insect Pests and Diseases in Mid-September to Late October (1,300–1,700 GDD[a] Base 10°C)

Plant Phenology Indicators

Early Bloom	Full Bloom	Late Bloom	Fruiting	Ripe Seed	Fall Foliage Colour
Hamamelis virginiana *Solidago* sp.	*Hamamelis virginiana* *Solidago* sp.	*Solidago canadensis*	*Viburnum dentatum*	*Daucus carota*	*Acer saccharum*

Nursery and Landscape Host Plants

Plant	Pest	Developmental Stage ***(V) indicates this pest is vulnerable to pesticides***
Apple	Eastern tent caterpillar	Shiny, grey egg mass bands on small twigs; prune out
Ash	Fall webworm	Yellow, fuzzy larvae inside webs at ends of branches; manually remove
Cherry	Eastern tent caterpillar	Shiny, grey egg mass bands on small twigs (prune out)
	Peach tree borer	Larvae; examine cankered regions and remove infested plants
Crabapple	Eastern tent caterpillar	Shiny, grey egg mass bands on small twigs (prune out)
Evergreens	Spruce spider mite	Shake branches over white paper and look for tiny, slow-moving mites (V)
Hawthorn	Eastern tent caterpillar	Shiny, grey egg mass bands on small twigs (prune out)
Honeylocust	Honeylocust mite	Shake leaves over white paper and look for tiny, reddish-brown mites (V)
Pine	Zimmerman pine moth	Larvae (V)
Spruce	Cooley and eastern spruce gall adelgid	Tiny, grey, fuzzy nymphs next to buds (vulnerable when the *Acer saccharum* are in fall colour)
	Spruce spider mite	Shake branches over white paper and look for tiny, slow-moving mites (V)
Woody ornamentals	Overwintering insects and mites	Overwintering scales, mites, mealybugs and adelgids; flag affected plants for dormant oil application

[a] *GDD = Growing degree days. For more information, see page 28.*
The presence of a "V" in the "stage" column indicates this pest is vulnerable to pesticides, which may include horticultural oil.

Diseases Affecting Trees and Shrubs

Diseases are broadly classified according to the types of damage they cause to woody plants. Categories include foliar diseases, crown and root rots, cankers, vascular wilts, viruses and abiotic diseases.

Diseases can be caused by many factors such as bacteria, fungi, moulds, viruses and environmental conditions. Some common nursery and landscape plant diseases are listed below. As well, see "A Compendium of Pests and Diseases with Recommended Management Practices" in OMAF Publication 840, *Crop Protection Guide for Nursery and Landscape Plants*.

Foliar Diseases

Most disease symptoms appear first on plant foliage. However, damaged foliage may not necessarily mean there is a leaf disease. Leaves may wilt, turn yellow or brown, spot, drop off or deform due to diseases not directly associated with the leaves. For example, plant foliage can change in response to vascular wilts, root diseases or cankers elsewhere on the plant. Non-infectious agents such as drought, wet soil (overwatering) and air pollution can also cause disease-like symptoms on the foliage. Quite often root problems aren't detected until foliar symptoms begin to appear. Before diagnosing any plant problem, always check that the roots are white and firm, not brown and mushy.

Most foliar diseases develop in response to high humidity and extended periods of leaf wetness. Schedule irrigation so that crops that are sensitive to foliar diseases are only watered in the early to mid-morning, never late in the day or at night. This will ensure the shortest possible periods of leaf wetness and minimize foliar diseases.

Downy mildew, powdery mildew, leaf spots, anthracnose and needlecast are common diseases that infect foliage directly. Rust diseases that cause leaf spots on broadleaf hosts are also discussed under "Cankers" on page 63 (due to their symptoms on the alternate host).

Botrytis (Grey Mould)

This disease, caused by the fungus *Botrytis cinerea*, can affect succulent tissue of bulbs, stems, leaves and flowers. It often attacks open or fading flowers and leaves, succulent soft growth and damaged tissue. Symptoms vary from host to host. In very humid air, botrytis causes a fuzzy grey growth on infected plant parts.

High humidity promotes botrytis outbreaks. Reduce humidity by providing good air circulation around plants. Remove all fading, senescing and diseased plant parts promptly, especially when wet weather is predicted. Avoid overhead irrigation late in the day, and never leave old leaves or flowers on plants or on the surrounding soil surface.

Downy Mildew

Downy mildew appears early in the season. Under very high humidity, it can produce grey to brown downy growth (sporulation) on the undersides of leaves. Once the humidity drops (by mid-morning, for example), the downy growth will disappear. Discoloured, purplish, angular spots may appear on the upper surface of the leaves.

Warm or cool wet weather and poor air circulation promote downy mildew. Reduce humidity by providing good air circulation around plants. Remove all fading, senescing and diseased plant parts promptly, especially when wet weather is predicted. Avoid overhead irrigation late in the day, and never leave old leaves or flowers on plants or on the surrounding soil surface.

Powdery Mildew

Several species of fungi cause powdery mildew. Powdery mildews produce powdery white mats on upper leaf surfaces and young tissue. Wind-borne spores can cause secondary infections, although individual powdery mildew species do not spread readily from one kind of plant to another.

Powdery mildew usually appears after the mid-season, when warm days follow cooler nights. It affects many woody ornamentals, such as *Syringa, Rosa, Ligustrum* and *Amelanchier*, and several herbaceous perennials. Because the fungus grows mainly on the plant surface, it can be managed with fungicides at the first sign of symptoms. In some cases, as with roses, severe deformation may result.

On some ornamental plants (e.g., *Physocarpus*) powdery mildew can appear as exceptionally thick and wooly. On others (e.g., *Coreopsis, Sedum, Berberis*) powdery mildew appears as a variable leaf spot and the characteristic white mycelium and spores may not be visible. On these plants, it is often misdiagnosed.

To reduce powdery mildew, place plants in a sunny location with good air circulation. Where possible, use resistant or tolerant plant cultivars. Overhead watering during the day may reduce the spread and development of powdery mildew. Avoid overhead irrigation late in the day, as this will promote spore development at night.

Leaf Spot and Anthracnose

"Anthracnose" refers to several plant diseases that cause dead spots on leaves or fruits. This disease may also affect the twigs, causing a canker and dieback. Infected areas may coalesce into large necrotic spots as the disease spreads. In severe cases, this condition defoliates the plant. Leaf spotting itself is not harmful. However, extensive annual defoliation year after year can lead to plant decline and death.

Cool, wet, cloudy spring weather promotes infection by fungi that cause leaf spot and anthracnose. *Catalpa, Populus, Juglans, Carya, Crataegus, Acer, Quercus, Platanus, Philadelphus, Sorbus* and *Aesculus* are common hosts. Sycamore anthracnose (*Gnomonia plantani*) can be severe in Ontario and has been linked to the death of many trees in the eastern United States.

Needlecast

Needlecast diseases are fungi affecting pines (*Pinus*), spruce (*Picea*) and firs (*Abies*). New needles generally become infected just after the new growth starts. Tiny black fruiting bodies may develop along the infected needles, often in place of the tiny white stomates. Needles infected the previous season are "cast" (i.e., fall off) during the following summer and fall. Needlecast can be serious in 1–4-year-old plants at Ontario tree nurseries.

Apple Scab

Although "scab" describes a fungal disease on fruit, this disease also causes purplish blotches on leaves of *Malus*.

Apple scab (*Venturia inaequalis*) can lead to the defoliation of crabapples when cool, wet weather occurs in mid-to-late spring, during leaf emergence. Minimize apple scab through cultural practices. Plant the trees in open, sunny areas with good air movement and maintain tree health. Prune the trees regularly to encourage air circulation through the canopy. Since the disease overwinters on fallen leaves, collect these leaves in the late summer and remove them from the area. This practice may prove ineffective if other diseased trees are growing nearby. If leaf removal is not possible, try using a mower to mulch leaves as they drop throughout the autumn season. The smaller leaf sections will accelerate bacterial breakdown, resulting in fewer fungal fruiting bodies to produce infective spores the following spring.

Where possible, plant scab-resistant crabapple cultivars. If cool, wet weather persists during leaf emergence or scab symptoms begin to appear, apply registered fungicides. Apply the first spray when the green leaf tips appear. Repeat every 7–10 days until leaves harden off.

Pyracantha Scab

Pyracantha scab *(Venturia pyracanthae*) destroys the fruit of susceptible firethorn varieties. Spraying is necessary most years. The cultivars 'Orange Glow,' 'Orange Charmer' and 'Mohave' have some resistance to this disease.

Crown and Root Rots

Soil fungi such as *Pythium* and *Phytophthora* cause the roots and crowns of many plants to rot. These fungi are most often associated with overwatering or poor soil drainage. The lower leaf parts, petioles and stems of diseased plants develop a water-soaked appearance. Eventually, the plant rots off at ground level. For ornamentals, protectant fungicides (such as Subdue MAXX) can be incorporated into the media at time of potting to reduce *Pythium* and *Phytophthora* diseases.

Rhizoctonia and *Fusarium* fungi cause a brown cankering of plant stems and roots below ground. *Thielaviopsis* causes severe root rot in infected plants. Tissues affected by a *Thielaviopsis* infection are more black than brown, helping to distinguish it from other infections. When this condition affects seedlings, the disease is called "damping-off." *Thielaviopsis* is more common in floriculture crops than in nursery crops.

The Canadian Food Inspection Agency (CFIA) regulates the importation of SOD host nursery stock in Canada. These regulations can be found on the CFIA website in Directive D-01-01, *Phytosanitary Requirements to Prevent the Entry of* Phytophthora ramorum. The list of plant genera regulated for *Phytophthora ramorum* can be found in Appendix 1 of this directive.

For the most up-to-date information on Sudden Oak Death, contact your local Canadian Food Inspection Agency office (see Appendix D, *Other Contacts,* on page 80) or consult the CFIA website at www.inspection.gc.ca. Another excellent reference is www.suddenoakdeath.org.

The Canadian Nursery Industry has its own domestic phytosanitary certification program (Clean Plants) to limit the spread of this and other pests. For more information, see "Nursery Programs" at www.canadanursery.com.

Cankers

Cankers kill bark and cambial tissues in localized branch and stem areas. Bark in affected areas may discolour, split or be easily removed, exposing the wood below. Subsequently, the underlying cambium and wood are killed and will turn brown or reddish brown to black. Fruiting "pustules" of the disease organism usually form on the areas of dead bark. Cankers may girdle a stem or branch, killing portions of the plant.

Canker diseases can be annual or perennial. They commonly damage hosts weakened by factors such as drought, marginal hardiness, root disturbance or a poor root environment. Weak parasitic fungi (species of *Cytospora, Nectria, Valsa* and *Hypoxylon*) cause damaging canker diseases that a healthy, vigorous host would resist by compartmentalizing (sealing off the fungus inside callus tissue). While fungi may be the main cause of some canker growth, the original tissue damage may be due to sunscald, freeze-thaw or mechanical injury.

Some canker diseases (e.g., white pine blister rust, chestnut blight and butternut canker) can be very serious to forest health. "Monoculture" growing systems used in plantations and forest nurseries may provide conditions for serious canker diseases.

Boxwood blight (*Cylindrocladium buxi*) is a serious canker disease of boxwood. Boxwood blight causes small, discontinuous, black, rod-shaped cankers along the lower stems and branches. This fungus kills precious cambial tissue under the bark. Boxwood blight also causes a leaf blight, but it is the cankers that are a better diagnostic sign of this disease.

Sudden oak death (SOD) is a disease caused by the pathogen *Phytophthora ramorum,* a fungus-like organism that thrives in cool, wet conditions. This is a serious disease that has been associated with the death of hundreds of thousands of oak trees in California since it was first detected in the 1990s. It is also responsible for the death of many trees in several European countries. Since its detection, SOD disease surveys have shown that this organism can infect and spread on over 65 genera of plants, many of which are grown as ornamental plants. Ornamental plants are traded widely between countries, and nursery stock has been identified as a major pathway of unnatural spread for SOD. Because of this, SOD-host nursery stock is regulated throughout parts of the world. In North America, this includes several counties of California and one in Oregon. Of the many host plants, six high-risk genera have been associated with the spread of SOD via nursery stock: *Camellia, Rhododendron, Viburnum, Pieris, Kalmia* and *Syringa.*

Chemical control for canker diseases is not always effective. Thoroughly prune diseased branches well below the affected areas. Remove and destroy infected material. For long-term management, improve host health and vigour using cultural means.

Rust

Rust diseases involve fungi that cause reddish-brown (rusty) spots on leaves, twigs or stems or gelatinous orange structures on evergreens. They frequently distort the shape of infected plant parts. Some rusts have only one host plant, but most require two hosts, each at a different phase of their life cycle. While both hosts are necessary for the disease organism to thrive, one host plant may be severely damaged while the other suffers little or no damage.

Bacterial Blights

Fire blight, a bacterial disease caused by *Erwinia amylovora*, affects many members of the *Rosaceae* family including *Amelanchier, Aronia, Chaenomeles, Cotoneaster, Crataegus, Malus, Photinia, Prunus, Pyracantha, Pyrus, Sorbus* and *Spiraea*. Flowers, spurs, twigs and leaves turn brown and dry out. Dead leaves remain on the plant and appear scorched. In warm, humid weather, an amber material may be exuded from recently infected parts. Bleeding perennial cankers may appear on limbs, trunks or roots as the infection spreads. Fire blight infections can be severe if conditions are warm and wet when the host trees are blooming and leaves are emerging. Rain, wind and insects can spread this disease from plant to plant. Manage fire blight by pruning cankers 0.3 m below the affected area when the trees are dormant and by removing nearby infection sources, such as neglected apple or pear trees. Always disinfect pruning instruments after each pruning cut. Bactericidal sprays at flowering may be helpful. For more information, see OMAF Publication 360, *Guide to Fruit Production.*

Bacterial blight (*Pseudomonas syringae* pv. *syringae*) has been linked to dieback on container nursery stock. Many deciduous, woody shrubs including lilacs (*Syringa*), mock orange (*Philadelphus*) and ornamental cherry (*Prunus)* are susceptible to this bacteria. Symptoms first appear when container stock is uncovered in the spring, revealing blackened shoots and buds that have been killed. Extreme changes in temperature coupled with extended periods of leaf wetness seem to encourage the development of bacterial blight in container production. Some growers have reduced disease incidence by installing drip irrigation systems to keep foliage dry and delaying the removal of poly cover over high-value, susceptible stock. To help reduce disease pressure, apply bactericides after leaves drop in the autumn and then again as the buds begin to swell and break during spring.

Other bacteria cause leaf spots on foliage. *Pseudomonas* and *Xanthomonas* species of bacteria infect foliar tissue during hot, humid weather and often show up in July during exceptionally hot summers. They cause angular leaf spots on several species of deciduous flowering shrubs such as *Hydrangea*. The margins of the leaf spots are usually delineated by minor leaf veins, creating a pattern similar to an aerial view of fields and roads. Bactericidal applications may be used to protect the disease from spreading to other foliage. However, pesticides will not cure existing infections.

Crown Gall

The bacterium *Agrobacterium tumefaciens* causes rough, irregular galls up to several centimeters in size. Crown gall can affect most woody plants, including rosaceous hosts, euonymus, willow and nut trees. It occurs mainly near the soil line at the root collar but also on roots and aerial parts such as top-grafted willow stems. While not a true canker disease, crown gall is included in this section because it disrupts the plant's vascular system, resulting in girdling.

This bacterium can live in the soil without host plants for about 2 years. It enters the plant through wounds such as those caused by cultivation, pruning or grafting. To limit the incidence of crown gall on susceptible top-grafted standards (e.g., *Salix*), grow the plants in polyhouses where they are sheltered from wind that could blow soil particles and bacteria onto wounds. Use sanitary propagation practices such as sterilizing grafting tools after each cut. Remove or replace infested soils, or leave them fallow for 2 years before replanting. Chemical controls are not always effective.

Vascular Wilts

Fungi or bacteria entering a plant's vascular system can reduce the amount of water that reaches the leaves, causing wilt. In the early stages of wilt, leaves may recover temporarily during cool, moist periods. Eventually, the wilt becomes established and the leaves and twigs die, leading to branch mortality and the eventual death of the entire plant. Serious vascular wilt diseases include Dutch elm disease (*Ceratocystis ulmi*) and Verticillium wilt (*Verticillium dahliae*).

To avoid wilt diseases, use resistant plant cultivars and grow susceptible crops in disease-free soil. See Table 2–18, *Woody Plants Resistant to Verticillium Wilt* on this page, and Table 2–19, *Woody Plants Susceptible to Verticillium Wilt* on page 66. Sometimes it is possible to maintain plants infected with Verticillium wilt by improving vigour through pruning, fertilizing and watering. Since these disease organisms live in the plant, surface application of fungicides will not be effective. *Verticillium* is a soil-borne fungus that persists in the soil for many years. Verticillium wilt has been associated with field-grown trees where root systems were repeatedly wounded by cultivation or pruning. When considering a field for the production of *Verticillium*-susceptible trees, test soil for *Verticillium* populations first.

TABLE 2–18. Woody Plants Resistant to Verticillium Wilt

All monocots (grass-like) plants	
All conifers	
The following broadleaf plants:	
Betula	birch
Carya	hickory
Celtis	hackberry
Cercidiphyllum	katsura tree
Chaenomeles	flowering quince
Cornus	dogwood
Crataegus	hawthorn
Fagus	beech
Gleditsia	honeylocust
Ilex	holly
Juglans	butternut, walnut
Liquidambar	sweetgum
Malus	apple, crabapple
Morus	mulberry
Platanus	plane tree, sycamore

TABLE 2–18. Woody Plants Resistant to Verticillium Wilt *continued*

All monocots (grass-like) plants	
All conifers	
The following broadleaf plants:	
Populus	poplar
Pyracantha	firethorn
Pyrus	pear
Quercus	oak
Rhododendron	rhododendron
Salix	willow
Sorbus	mountain ash
Tilia	linden
Zelkova	Japanese zelkova

TABLE 2–19. Woody Plants Susceptible to Verticillium Wilt

Acer	maple
Aesculus	buckeye, horsechestnut
Amelanchier	serviceberry
Buxus	boxwood
Calluna	heath
Catalpa	catalpa
Cercis	red bud
Cladrastus	yellowwood
Cotinus	smokebush
Daphne	daphne
Eleagnus	Russian olive
Fraxinus	ash
Gymnocladus	Kentucky coffee tree
Hibiscus	hibiscus
Koelreuteria	golden rain tree
Ligustrum	privet
Liriodendron	tulip tree
Lonicera	honeysuckle
Magnolia	magnolia
Phellodendron	cork tree
Prunus	cherry and other stone fruit
Rhododendron	azalea
Rhus	sumac
Ribes	currant, gooseberry
Robinia	black locust
Rosa	rose
Sambucus	elder
Spiraea	spirea
Syringa	lilac
Ulmus	elm
Viburnum	viburnum
Vitis	grape vine
Wiegela	wiegela

Viral Diseases

Viral diseases appear on plants as mottled yellow foliage, misshapen or wrinkled leaves, aborted flowers or stunted growth. There are no pesticides effective against viruses. Remove diseased plants and destroy them to prevent the virus from spreading to the rest of the block.

Most viral diseases spread via insects and infected tools such as pruning equipment, knives and shears. To reduce the spread of viral diseases, reduce the levels of sucking insects such as aphids, thrips, leafhoppers and mites. Disinfect all tools and implements before using them again. Samples of symptomatic plants can be sent to the Pest Diagnostic Clinic (see Appendix E, *Diagnostic Service*, on page 81) to analyze for virus particles. Destroy infested plants where possible to prevent further spread to other susceptible crops.

Ash Yellows

Plants show reduced growth, stunting and smaller leaves. Symptoms can vary with the age of the plant. In some cases, plants develop chlorotic leaves and witches' brooms (a proliferation of shoots at the tips of branches).

Elm Yellows

Leafhoppers probably transmit these mycoplasma-like organisms. Leaves of infected trees begin to turn yellow, twist and droop (epinasty) by mid-summer. The infected leaves often drop, and the branch dies shortly after.

Rose Mosaic

Rose mosaic symptoms can include leaf discolouration, chlorotic mottling, ring spots, light green or chlorotic line patterns, vein clearing, banding and white or yellow mosaics. Specific symptoms vary with the cultivar, the environment and the strain of virus.

Abiotic Diseases

Abiotic diseases principally affect foliage and/or root system function. They are usually related to extreme environment (too hot, too dry, too wet, etc.). These diseases cause many plant problems, often predisposing affected plants to attack by secondary disease organisms. The result can be gradual dieback and death.

Weather, soil conditions and human environmental disturbances cause these conditions. Control measures depend on eliminating or avoiding damaging factors (e.g., salt injury), obtaining resistant plants and improving growing conditions. Sudden exposure to full sunlight after a cloudy, wet period can cause late-spring leaf scorch in *Acer* and *Fagus*.

Root scorch created by high salt levels in the soil is a common abiotic condition. It is the result of salty groundwater or run-off containing road salt. It can only be alleviated by increasing soil aeration and leaching the soil with low-salt water.

The ability of a plant to accommodate environmental change varies with the type of plant, its age and condition, and the nature and intensity of the changes. Oak, maple, ash and spruce have difficulty adjusting to new conditions such as soil compaction, drought, excessive water (causing reduced aeration in the root zone), changes in soil level or root damage during construction. Exotic species such as Norway spruce may not be as well adapted to the Ontario climate as native species.

Dieback

Nursery and landscape ornamentals often exhibit dieback of leaves and small branches. Symptoms may appear on individual branches or entire plants. Dieback may appear suddenly or develop so gradually that the true impact does not show for several years.

Some of the environmental and cultural causes of dieback include girdling wires, strings and ropes left on after transplanting. Root problems, soil conditions, waterlogging, changes in soil grade, sunscald and freeze-thaw temperatures may also be at fault.

Light-to-moderate infestations of insects and diseases can also cause dieback symptoms. Some examples include scale insects, wood-boring insects, bark-boring insects, root-feeding weevils, white grub larvae, cankers, rusts, fire blight and vascular wilts.

Fall Needle Drop in Conifers

As shorter, cooler autumn days approach, older needles (2–3 whorls back) towards the inside of many conifers begin to turn yellow or brown. In some cases, these needles start to drop. Although this is usually a natural process, the degree of discolouration and leaf drop may relate to stress during the growing season. Low vigour caused by drought, transplanting, poor drainage, soil compaction, insects and disease make needle drop worse. Pines lose their oldest needles (closest to the trunk). White pines (*Pinus strobus*) often lose needles that are 2 years old or older. Branchlets of Eastern white cedar (*Thuja occidentalis*) often turn brown on the inside of the branches and fall off. Fir (*Abies*) and spruce (*Picea*) may lose needles on 1–3-year-old wood.

Needle Desiccation on Conifers

Winter desiccation may cause conifer needles to turn brown and drop in the spring. Many factors can lead to this condition, especially dry, windy weather while the soil is frozen. Roots cannot absorb enough water from the frozen soil to compensate for the foliar desiccation caused by winter winds. Warm afternoon temperatures in late winter can also contribute to foliar water loss.

Good growing conditions during the previous growing season help plants resist winter damage. Roots in the upper soil surface are sensitive to drying and high temperatures. If these roots die during the growing season, they may not be able to store enough water to recover from moisture losses during the winter.

Salt Damage

Woody plants are affected by road salt, both from run-off into the soil and airborne spray created by traffic. Salty run-off from sidewalks and roadways can accumulate in the soil around the root system and lead to physiological drought in the plant. When plant tissues are wet and temperatures are above freezing, sodium and chloride ions (the most common ingredients in road salt) enter plant tissues and accumulate. Repeated road salt injury weakens plants, making them susceptible to damage from many insects and diseases.

Salt spray causes more plant damage than run-off. It can affect plants located 100 or more metres away from a road. Symptoms appear more quickly in warm weather and are usually more severe on the side facing the road. Evergreen foliage and dormant buds can absorb salts and be killed.

Salt Damage Symptoms on Conifers

Symptoms of salt damage on conifers include:

- needle browning, beginning at the tip
- needle browning and twig dieback on the side facing the road, with little or none on the opposite side
- no needle browning or dieback on branches near the ground under continuous snow cover
- needle and twig dieback that is less severe the further the tree is from the road
- browning that appears in late February or early March and becomes more obvious through spring and summer

Salt Damage Symptoms on Deciduous Plants

Symptoms of salt damage on deciduous plants include:

- slow bud break on terminal parts of branches facing the road
- leaves that fail to emerge on terminal parts of branches facing the road
- new growth on branches facing the road that develops as multiple shoots just behind dead branch tip, causing a tufted or witches' broom appearance to branches
- flower buds facing the road side that do not open, while normal flowering occurs on plants further away from the road
- injury that becomes evident as buds begin to break

Leaf Scorch

Scorch happens when plants have difficulty taking up water, usually during hot, dry weather. Scorch appears as sudden leaf death or browning on leaf margins or between leaf veins, often in the heat of the summer. The veins frequently remain green.

Recently transplanted ornamentals are at the greatest risk because their root system is limited. Plants experiencing root injury due to construction, soil compaction, chemicals, drought or extreme heat can also show symptoms of scorch.

3. Rodents and Deer

Rodents and deer can cause significant injuries to nursery and landscape plants. Controlling these pests can be difficult and often requires long-term strategies. For additional information, see the OMAF Factsheet *Rodent and Deer Control in the Orchard*.

Vole and Mouse Control

Voles and mice are common pests in agricultural production systems and around buildings. Voles can cause significant economic injury to nursery stock. They are most commonly a problem when there is a lack of food available. Voles are brown or grey rodents with stocky bodies and short legs. Unlike mice, they have a short tail and their ears lie flat against their body. Voles are active day and night, year-round. Females can start reproducing when they are just 3 weeks old. Voles chew on roots and girdle tree and shrub stems and trunks. There are two types of voles: pine voles and meadow voles (also known as "meadow mice" or "field mice"). The meadow vole is more common in Ontario.

Meadow voles make shallow runways along the soil surface. In spring and summer, they feed on grass seeds, herbs and bulbs. In fall and winter, they feed on the bark of woody plants. The feeding injury is more extensive in winters with continuous, prolonged snow cover. Pine voles burrow underground, feeding mainly on rootlets and stripping the bark off larger roots.

Vole and Mouse Control Options

Voles need shelter, food and protection from predators to survive. Manage vole populations by eliminating one or more of these requirements.

In the landscape, maintain good weed control for a distance of at least 60 cm from tree trunks and shrub stems.

In a nursery with cover crops between tree rows, maintain a herbicide strip at least 1.2 m wide at the base of each tree. Mow the cover crop short in late summer, since dense stands provide shelter for rodents. Make sure tree guards extend at least 45 cm up the tree trunk. Anchor the guards firmly into the soil, about 8 cm deep. Keep them secure and free from trash.

Where possible, encourage populations of natural predators such as hawks, owls, crows, ravens, weasels, foxes, coyotes, raccoons, skunks, cats and snakes that feed on voles. Predation may not manage high vole populations, but it may help to reduce populations in normal years.

Use mouse baits (rodenticides) where voles have caused damage in the past. Begin baiting the field border in early September to help prevent vole populations from exploding in autumn. Alternate between a zinc phosphide bait and an anticoagulant bait (see Table 3–1, *Rodenticides*, on page 70). Multiple applications of zinc phosphide are not recommended because voles can become bait shy after the first application and continue to avoid bait for 2–4 months.

Use bait stations to extend the life of the bait and create a safe haven for rodents to feed. Bait stations will also keep poisonous bait out of reach of pets and other non-target animals. An inverted T bait station made of 1.5-inch (3.8 cm) ABS pipe is probably the most effective type of bait station available. In this station, place several spoonfuls of bait in the neck, which is capped to protect the bait from the elements. Longer necks can be used in areas where there is substantial snowfall. Set about 25 stations/ha (10/acre). (In field production, bait can be broadcasted over infested areas on sunny fall days when no rain is expected.)

Precautions for Handling Poison Baits

It is important to handle poison baits safely. Consider the following points when carrying out a vole management program:

- The baits listed in Table 3–1, *Rodenticides* on page 70, are recommended for use with commercial nursery plantings only.
- Mark all poison bait storage containers POISON.

- Store poison baits away from children, pets and livestock.
- Do not inhale zinc phosphide dust or fumes.
- Do not keep bait containing zinc phosphide in a building used by people or animals.
- Do not use bait mixing equipment or bait application equipment for any other purpose.
- Wear rubber gloves or other protective gloves when handling bait, as you would when handling hazardous insecticides.
- Wash your hands after handling poison baits.
- Keep dogs and cats that are enthusiastic mousers away from the nursery for at least 2–3 days to prevent them from catching dying mice.
- Do not handle dead mice or voles with your bare hands.
- Dispose of dead mice and voles away from human and animal contact.

TABLE 3–1. Rodenticides

Many rodent baits are available in mountable mini-blocks and pellets.

Method of Action	Generic Name	Trade Name	Target Pests
Anticoagulant	brodifacoum	Ratak +	Norway rats, roof rats, house mice
	bromadiolone	Boot Hill, Maki	Norway rats, roof rats, house mice
	cellulose	Rode-trol	mice and rats
	chlorophacinone	Ground Force, Rozol	Norway rats, roof rats, house mice, meadow voles
	difethialone	Generation, Hombre	Norway rats, roof rats, house mice
	diphacinone	Ramik Brown, Ramik Green	mice and voles
Acute poison	zinc phosphide	many products available	meadow voles, deer mice, mice, Norway rats, roof rats

Rabbit Control

Rabbits feed on the bark, twigs and buds of many woody plants. They seem to prefer thinner-barked plants such as fruit trees, crabapple, flowering dogwood, sweetgum, holly, privet, pine, birch and young maple.

Rabbit Control Options

Fencing may provide control for smaller areas. Use 25-mm wire mesh fencing, staked every 2 m with sturdy posts. Secure the fence bottom in the ground. Rabbits will not burrow under the fence, but they will squeeze through any opening they can find. Extend the fence at least 60 cm above the maximum snow level. Individual tree guards may also be used. Trap rabbits and remove them from the area. Encourage natural predators. Shooting rabbits can help keep numbers low, but first consult with local authorities regarding firearm bylaws and regulations. Rabbit management needs to be maintained all year round.

Use rabbit repellents to discourage feeding. The rabbit repellent must have long-lasting adhesive qualities to be effective. Repellants must also taste unpleasant to the rabbit or have an undesirable odour. Apply repellant on all plant parts that the rabbit can reach. Take into account the height added by deep snow. Chemical repellents consist of commercial thiram-based mixtures (e.g., Skoot) and ammonia fatty acid soaps (e.g., Hinder). Mix thiram-based repellents with white exterior latex paint for an effective repellent. Combine 400 g Thiram 75WP with 2 L of water. Slowly stir this mixture into 4 L of white exterior latex paint. Do not use oil-based paints because they are toxic to trees.

Deer Control

Deer feed on the buds, shoots and leaves of many woody plants. Feeding causes growth setback and poorly shaped plants. For more information on deer control, see OMAF Factsheet *Rodent and Deer Control in the Orchard*.

Deer Control Options

To help keep deer out of production areas, erect fences around plants that are attractive to deer (e.g., yew, hemlock, rosaceous plants). Use wire mesh fencing at least 2.4 m high, and support it with sturdy posts. Electric fences may provide some control. Where regulated hunting seasons, special hunts and other measures have not satisfactorily reduced deer damage, deer-removal permits may be issued to farmers to cull those deer that are causing significant crop damage. These permits are issued to farmers, or their agents, only after several conditions have been satisfied. Farmers wishing to obtain a deer-removal permit must first request a damage evaluation report from the Ministry of Natural Resources. These permits are a last resort.

Thoroughly applied repellents may prevent deer from browsing if the deer have alternate sources of food. When food is scarce, however, repellents may not work. Chemical repellents consist of commercial thiram-based mixtures (e.g., Skoot) and ammonia fatty acid soaps (e.g., Hinder). Replace these taste repellents every 3–4 weeks during the winter. Apply when no rain is forecast for 24 hr and temperatures range between 4˚C–27˚C. Apply to all susceptible plant parts. Spray the outer portions of trees and shrubs to a height of 2 m.

Odorous repellents may discourage deer from feeding. Odorous repellents include blood meal, moth flakes, perfumed soaps and human hair. Some research shows that soap bars hanging in the field discourage deer. Use small soap bars (e.g., those available from hotels). Any brand of soap can be used. Drill a hole in each bar of soap, leaving the wrapper in place. Hang the soap from a branch about 75 cm above the ground using a twist tie or string. Each bar of soap will protect a radius of about 1 m.

Bags of human hair may also deter deer, though this approach has had inconsistent results. Place two handfuls of human hair in some nylon stocking or a fine mesh bag. Hang the bags on outer tree branches or from the perimeter of the area that needs protection. Place the bags up to 90 cm apart and 75 cm above the ground. Keep the bags in place from mid-fall to early spring, replacing them monthly.

4. Weed Management

A weed management program combines cultural, mechanical and chemical methods appropriate to the situation. Effective weed management depends on weather conditions, soil type and the cropping history. Before attempting corrective action, identify problem weeds and learn about their growth habits. For an every-growing knowledge base of weed information, see www.weedinfo.ca.

In April 2009, the Ministry of Environment amended the *Pesticides Act* with the *Cosmetic Pesticides Ban Act, 2008* and Ontario Regulation 63/09. Pesticides are now classified for sale and use under 11 different classes. Note that agriculture (including nursery production) is excepted. For more information on the legislation, see the Ministry of the Environment's website at www.ontario.ca/pesticideban.

Once the weed population has been assessed, minimize potential problems before planting. Eliminate possible weed sources and prevent weeds from establishing.

Weed Control Principles

Many weed problems can be avoided by using weed-free crop seeds and transplants and by preventing weeds from going to seed. Monitor weed growth in both crop areas and the surrounding non-crop areas. Enhancing the activity of soil organisms (i.e., bacteria, fungi, earthworms, insects) creates a strong defense against weeds by increasing crop vigour while making weed seeds decay faster in the soil. Practices that increase soil biological activity (e.g., applying composted plant waste, composted manure, cover crops) can reduce weed problems.

Reducing Weeds Before Planting

Use Cover Crops for Weed Suppression

If a nursery field is removed from production, plant a cover crop or green manure crop before replanting the field. Plow-down crops such as rye, red clover, buckwheat, sudan grass, millet and oilseed radish are typical cover crops. Cover crops suppress weed growth through crop competition and allelopathy (exuding chemicals to prevent weed seed germination). Cover crops also reduce wind erosion of the soil, and their residues increase soil organic matter. Improved soil tilth is quite evident in the first crop after a cover crop. See "Cover Crops" on page 9.

Controlling Perennial Weeds

Many perennial weeds can present problems for nursery crops. These weeds include quack grass, bindweed, vetch, wild grape, perennial nightshade, thistles, ground ivy, burdock, horsetail, toadflax, milkweed, asters, nut sedge, willow herb and goldenrod. Consider the following points:

- Always attempt to minimize (or eliminate) perennial weeds in the preplanting year.
- If necessary, apply a systemic herbicide such as Roundup to perennial weeds in the preplanting year. Follow directions on the product label, and always use the recommended application rate for the weed in question. To achieve long-lasting management, apply herbicides at the proper stage of weed growth (for most perennial broadleaf weeds, this is just before blooming).
- It can be difficult to control perennial weeds among established plantings because of crop sensitivity to some herbicides and the inability to practise clean cultivation in established nurseries.
- Repeated cultivation will control some perennial weeds, such as bindweed. Clean weed debris from the cultivator before entering weed-free soils.
- Use non-selective herbicides (such as Gramoxone and Roundup) before planting a green manure crop and before plowing it under. Short-residual herbicides such as 2,4-D may be used with tolerant green manure crops. However, avoid herbicides that leave a soil residue in the planting year (e.g., Simadex).

Crop Rotation

Crop rotation is an important part of any long-term weed control strategy. After plowing a cover crop, it is best to replant the field with different nursery stock. For example, if the previous crop was conifers, plant deciduous stock. This permits a change in tillage methods, row widths, harvesting and herbicide selection. Crop rotation helps break weed cycles and minimizes weed population increases. Short rotations using several crops will increase the yield and profit of individual crops. Choose a crop that competes well with the problem weeds identified.

Stale Seedbeds

The stale seedbed technique involves preparing seedbeds early in the growing season. Allow the weeds to germinate. Several weeks later, control the weeds using glyphosate or paraquat. Once the weeds die, seed or transplant the crop into the bed, disturbing the soil as little as possible.

Preparing Container Beds

Prepare container bed areas with a gravel layer and/or ground coverings such as opaque materials woven from plastic. These surface coverings must exclude light to prevent weed-seed germination. Ground coverings may be reused for several years before it is necessary to replace them. Keep container beds and roadways weed-free by physical removal or chemical mowing. Remove all pulled weeds and discard them well away from the growing area. Do not allow seeds into nearby containers.

Remove existing weeds from container stock before the weeds bloom. Flowering weeds can disseminate hundreds of seeds by wind or by catapulting the seeds. Many container weed species are annuals that produce several generations of seedlings per year since their seeds do not need to overwinter before germinating. Every fall, thoroughly remove actively growing weeds from container stock as polyhouses are covered. This will help to prevent the weed population from successfully overwintering in the protected environment of the polyhouse. Be sure to remove the rosettes of winter annuals such as shepherd's-purse and Canada fleabane. Also remove the established plants and seedlings of common and mouse-eared chickweed. If not removed, these plants will flower by May or earlier.

Managing Weed Sources

Minimize weed sources using the following mechanical, cultural and/or chemical weed control measures:

- Control seed escapes using mechanical removal or chemical mowing before the weeds set seed.
- Prevent weeds from setting seed in adjacent non-cropped areas.
- Mow at regular intervals to prevent weeds from flowering.
- Use string trimmers in appropriate areas, such as along fences.
- Find the source of weeds that disseminate into the field or container yard. These include poplars, willows, willow herb and Canada fleabane.
- Control weeds around irrigation ponds to avoid sowing small-seeded weeds into container stock with each watering.
- Establish a thick grass cover around irrigation ponds to help reduce weeds while stabilizing the bank.
- Install a filtering system in the irrigation line to remove weed seeds from irrigation water.

Mechanical Weed Control

Mechanical weed control methods can reduce weeds and weed sources. Plant only weed-free seedlings and transplants. Do not bring weeds from one field to another. Keep equipment free from weed debris when moving it between fields. Cultivate weedy fields last.

Rotary Hoes

Rotary hoes have fingers that lift and mix the soil, uprooting small weeds. Rotary hoes tend to damage crops less than harrows do. The hoes break up soil crusts and incorporate surface-applied herbicides into the soil. This activates the chemicals and improves the weed control. Use rotary hoes during late-morning or afternoon hours. Crop plants are more pliable at these times, reducing injuries, and the hot sun can dry out the uprooted weeds.

For good results, maintain sufficient speed (generally 10–20 km/hr). Cultivating at slow speeds will not generate enough force to lift weeds out of the ground, and it may cause more crop damage. On light soils or in loose soil conditions, keep rotary hoes shallow.

Inter-Row Cultivation

Inter-row cultivation or scuffling of row crops uproots small weeds and cuts off larger ones. Many kinds of equipment can perform this task. When using shovels, allow 50% overlap for thorough weed control. Keep the cultivation shallow and use shields to protect small crops. The first cultivation is crucial, since weeds escaping this pass usually grow to maturity. Row cultivation works well alongside herbicide applications. Shallow cultivation (2.5–5.0 cm) reduces the disturbance of any herbicides applied (conserving the herbicide layer will prevent weed seedlings from emerging and establishing themselves in the soil).

Mowing

Mowing and cutting help to control weeds. Mow perennial weeds at the bud stage, when root reserves are low and seeds have not set. If a herbicide is to be applied later in the season, allow enough time for weed regrowth after mowing.

Managing Herbicide Resistance

More than 120 herbicide-resistant weed species exist throughout the world. See the OMAF Factsheet *Herbicide Resistant Weeds Order* for a list of weeds that show resistance in Ontario. Use herbicides conservatively.

Delaying Herbicide Resistance

Repeated use of the same herbicide tends to create resistant weeds. Resistance develops at different rates with different herbicides, weed species and weed populations. To help minimize resistant weeds, follow these strategies:

Identify and monitor weeds. Resistant weeds look exactly like susceptible weeds, but they do not experience the injury and mortality that happens to other members of the population. These "escapes" are common after herbicide applications. Sometimes 10%–30% of a weed population can become resistant before the issue is noticed. Survey fields regularly and apply diagnostic methods to catch problems as they arise.

Prevent weed spread. Clean all implements when leaving a field, and never allow resistant weeds to go to seed.

Use alternatives to chemical controls. Use mechanical weed controls, such as rotary hoeing or cultivation, wherever possible.

Rotate crops and herbicides. Do not use the same herbicides every year. Rotate crops and spray the new crop with herbicides from a group with a different mode of action or site of action. Where registered, use tank or formulated mixtures with multiple active ingredients that kill the same weed in different ways.

Keep records. Keep accurate records of crop rotation and herbicide usage for each field. Long-term weed control planning is easier with good records.

Communicate. Consult with farmer organizations, universities, extension specialists, agribusinesses, friends and neighbours about herbicide resistance problems. Inform the provincial weed inspector or industry contacts of any resistance issues that arise so they can act to prevent weed spread.

Diagnose. Resistance is not the only reason that weeds may survive a herbicide application. It is important to rule out other factors that can affect herbicide performance. Examples include misapplication, unfavourable weather conditions, improper application timing and weed flushes following a non-residual herbicide application. If resistance appears possible, check for the following:

- Did the product control other weeds listed on the label? Chances are only one weed species will prove herbicide resistant in a given field situation. If several other weed species that are normally susceptible also survived, other factors probably caused the lack of weed control.
- Did the same herbicide(s) from the same group with the same action site fail in the same field area last year?
- Have you used the same herbicide(s) from the same group year after year?

If at least one of these situations applies, the weed escapes may be resistant to the herbicide. Try controlling the weeds with a herbicide from another group or use appropriate non-chemical weed control methods. Do not let the weeds go to seed. Contact the Provincial Weed Inspector, as well as the herbicide supplier and the appropriate chemical company, to develop a comprehensive management program.

5. Appendices

Appendix A: Ontario Ministry of Agriculture and Food Advisory Staff

Jen Llewellyn

Nursery Crops Specialist
Bovey Building
University of Guelph
Guelph, ON N1G 2W1

Tel: 519-824-4120, ext. 52671
Fax: 519-766-1704
E-mail: jennifer.llewellyn@ontario.ca

www.ontario.ca/crops
www.onnurserycrops.wordpress.com

Mike Cowbrough

Provincial Weed Inspector
Crop Science Building
University of Guelph
Guelph, ON N1G 2W1

Tel: 519-824-4120 ext. 52580
Fax: 519-763-8933
E-mail: mike.cowbrough@ontario.ca

www.ontario.ca/crops

Other Ontario Ministry of Agriculture and Food contacts

Agricultural Information Contact Centre

1 Stone Rd. W.
Guelph, ON N1G 4Y2

Tel: 1-877-424-1300 or 519-826-4047
Fax: 519-826-7610
E-mail: ag.info.omaf@ontario.ca

Provides province-wide, toll-free technical and business information to commercial farms, agri-businesses and rural businesses.

A complete list of Ontario Ministry of Agriculture and Food Agriculture Development Branch Staff is available on the OMAF website at www.ontario.ca/crops.

Appendix B. Ontario Ministry of Environment — Regional Contact Information

Region/County	Address	Telephone/Fax
Central Region Toronto, Halton, Peel, York, Durham, Muskoka, Simcoe	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 Haldimand, Norfolk, Niagara, Hamilton-Wentworth, Dufferin, Wellington, Waterloo, Brant	Ontario Government 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 Frontenac, Hastings, Lennox & Addington, Prince Edward, Leeds & Grenville, Prescott & Russell, Stormont/Dundas & Glengarry, Haliburton, Peterborough, Kawartha Lakes, Northumberland, Renfrew, Ottawa, Lanark, District of Nipissing (Twp. of South Algonquin)	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 Elgin, Middlesex, Oxford, Essex, Kent, Lambton, Bruce, Grey, Huron, Perth	733 Exeter Rd. London, ON N6E 1L3	Tel: 519-873-5000 Toll-free: 1-800-265-7672 Fax: 519-873-5020
Northern Region (East) Manitoulin, Nipissing, Parry Sound, Sudbury, Algoma (East), Timiskaming, Sault Ste. Marie	199 Larch St. Ste. 1201 Sudbury, ON P3E 5P9	Tel: 705-564-3237 Toll-free: 1-800-890-8516 Fax: 705-564-4180
Northern Region (West) Algoma (West), Cochrane, Kenora, Rainy River, Timmins, Thunder Bay	435 James St. S. Ste. 331 Thunder Bay, ON P7E 6S7	Tel: 807-475-1205 Toll-free: 1-800-875-7772 Fax: 807-475-1745
Standards Development Branch	Pesticides Section 40 St. Clair Ave. W. 7th Floor Toronto, ON M4V 1L5	Tel: 416-327-5519 Fax: 416-327-2936
Approvals Branch	Pesticides Licensing 2 St. Clair Ave. W. 12A Floor Toronto, ON M4V 1L5	Tel: 416-314-8001 Toll-free: 1-800-461-6290 Fax: 416-314-8452

Appendix C. OMAF-Accredited Soil, Leaf and Greenhouse Media Testing Laboratories

Laboratory	Media Tested	Address	Phone/Fax/Website/ E-mail	Contact
A & L Canada Laboratories East	Soil, leaf	2136 Jetstream Rd. London, ON N5V 3P5	Tel: 519-457-2575 Fax: 519-457-2664 aginfo@alcanada.com www.alcanada.com	Ian McLachlin Greg Patterson
Accutest Laboratories	Soil, leaf	146 Colonnade Rd. Unit #8 Nepean, ON K2E 7Y1	Tel: 613-727-5692 Fax: 613-727-5222 phaulena@accutestlabs.com www.accutest.com	Peter Haulena Rob Walker Lorna Wilson
Brookside Laboratories Inc.	Soil	301 South Main St. New Knoxville, OH 45871 USA	Tel: 419-753-2248 Fax: 419-753-2949 greg@blinc.com www.blinc.com	Greg Meyer
Forest Resources and Soils Testing Laboratory	Soil	955 Oliver Rd. BB1005D Thunder Bay, ON P7B 5E1	Tel: 807-343-8639 Fax: 807-343-8116 soilslab@lakeheadu.ca	Leni Meyer
SGS Agri-Food Laboratories	Soil, leaf, greenhouse media	503 Imperial Rd. Unit #1 Guelph, ON N1H 6T9	Tel: 519-837-1600 or 1-800-265-7175 Fax: 519-837-1242 lab@agtest.com www.agtest.com	Papken Bedirian Jack Legg
Soil and Nutrient Lab, University of Guelph	Soil, leaf	P.O. Box 3650 95 Stone Rd. W. Guelph, ON N1H 8J7	Tel: 519-767-6226 Fax: 519-767-6240 www.guelphlabservices.com/AFL/GrowersSoil.aspx	Nicole Fisher Mark Flock
Stratford Agri Analysis	Soil, leaf	1131 Erie St. Box 760 Stratford, ON N5A 6W1	Tel: 519-273-4411 or 1-800-323-9089 Fax: 519-273-4411 laboratory@daconutrition.com www.stratfordagri.ca	Keith Lemp Jim Brimner

Appendix D. Other Contacts

Agriculture & Agri-Food Canada Research Centres

www.agr.gc.ca/index_e.php

Eastern Cereals and Oilseeds Research Centre

960 Carling Ave.
Ottawa, ON K1A 0C6
Tel: 613-759-1858

Greenhouse and Processing Crops Centre

2585 County Road 20
Harrow, ON N0R 1G0
Tel: 519-738-2251

Southern Crop Protection and Food Research 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

Canadian Food Inspection Agency Regional Offices (Plant Protection)

www.inspection.gc.ca

Belleville

345 College St. E.
Belleville, ON K8N 5S7
Tel: 613-969-3333

Brantford

625 Park Rd. N., Ste. 6
Brantford, ON N3T 5P9
Tel: 519-753-3478

Hamilton

709 Main St. W., Ste. 101
Hamilton, ON L8S 1A2
Tel: 905-572-2201

London

19-100 Commissioners Rd. E.
London, N5Z 4R3
Tel: 519-691-1300

St. Catharines

395 Ontario St., Box 19
St. Catharines, ON L2N 7N6
Tel: 905-937-8232

Ottawa District

38 Auriga Dr., Unit 8
Ottawa, ON K2E 8A5
Tel: 613-274-7374, ext. 221

Toronto

1124 Finch Ave. W., Unit 2
Downsview, ON M3J 2E2
Tel: 416-665-5055

University Of Guelph

Main Campus

Guelph, ON N1G 2W1
Tel: 519-824-4120
www.uoguelph.ca

Alfred Campus

Alfred, ON K0B 1A0
Tel: 613-679-2218
Fax: 613-679-2423
www.alfredc.uoguelph.ca

Kemptville Campus

Kemptville, ON K0G 1J0
Tel: 613-258-8336
Fax: 613-258-8384
www.kemptvillec.uoguelph.ca

Ridgetown Campus

Ridgetown, ON N0P 2C0
Tel: 519-674-1500
www.ridgetownc.on.ca

Department of Plant Agriculture

www.plant.uoguelph.ca

Department of Plant Agriculture, Guelph

50 Stone Rd. W.
Guelph, ON N1G 2WI
Tel: 519-824-4120, ext. 56083
Fax: 519-763-8933

Department of Plant Agriculture, Simcoe

1283 Blueline Rd., Box 587
Simcoe, ON N3Y 4N5
Tel: 519-426-7127
Fax: 519-426-1225

Department of Plant Agriculture, Vineland

Box 7000, 4890 Victoria Ave. N.
Vineland Station, ON L0R 2E0
Tel: 905-562-4141
Fax: 905-562-3413

Lab Services Division

P.O. Box 3650, 95 Stone Rd. W.
Guelph, ON N1H 8J7
Tel: 519-767-6299
www.uoguelph.ca/labserv

Trace Organics and Pesticides

Tel: 519-767-6485

Pest Diagnostic Clinic

Tel: 519-767-6256

Vineland Research And Innovation Centre

4890 Victoria Ave. N.
Vineland Station, ON L0R 2E0
Tel: 905-562-0320
Fax: 905-562-0084
www.vinelandresearch.com

Appendix E. Diagnostic Services

Samples for disease diagnosis, insect or weed identification, nematode counts and *Verticillium* testing can be sent to:

Pest Diagnostic Clinic

Laboratory Services Division

University of Guelph
95 Stone Rd. W.
Guelph, ON N1H 8J7
Tel: 519-767-6299
Fax: 519-767-6240
aflinfo@uoguelph.ca
www.guelphlabservices.com

Payment must accompany samples at the time of submission. Submission forms are available at www.guelphlabservices.com/AFL/submit_samples.aspx.

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. If the soil is bare, remove the top 2 cm 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. 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:

up to 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 soil and root samples from 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 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 and Food 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 three 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 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 them 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 them 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.

Appendix F. The Metric System

Metric units

Linear measures (length)

10 millimetres (mm)	=	1 centimetre (cm)
100 centimetres (cm)	=	1 metre (m)
1,000 metres (m)	=	1 kilometre (km)

Square measures (area)

100 m × 100 m = 10,000 m^2	=	1 hectare (ha)
100 hectares	=	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 measures

1,000 milligrams (mg)	=	1 gram (g)
1,000 grams (g)	=	1 kilogram (kg)
1,000 kilograms (kg)	=	1 tonne (t)
1 milligram/kilogram	=	1 part per million (ppm)

Weight-volume equivalents (for water)

1 gram (0.001 kg)	=	1 millilitre (0.001 L)
10 grams (0.01 kg)	=	10 millilitres (0.01 L)
100 grams (0.10 kg)	=	100 millilitres (0.10 L)
500 grams (0.50 kg)	=	500 millilitres (0.50 L)
1,000 grams (1.00 kg)	=	1 litre (1.00 L)

Dry–liquid equivalents

1 cubic centimetre (cm^3)	=	1 millilitre (mL)
1 cubic metre (m^3)	=	1,000 litres (L)

Approximate dry weight equivalents

Metric		*Imperial*
100 grams/hectare (g/ha)	=	1½ ounces/acre (oz/acre)
200 grams/hectare (g/ha)	=	3 ounces/acre (oz/acre)
300 grams/hectare (g/ha)	=	4¼ ounces/acre (oz/acre)
500 grams/hectare (g/ha)	=	7 ounces/acre (oz/acre)
700 grams/hectare (g/ha)	=	10 ounces/acre (oz/acre)
1.10 kilograms/hectare (kg/ha)	=	1 pound/acre (lb/acre)
1.50 kilograms/hectare (kg/ha)	=	1¼ pounds/acre (lb/acre)
2.00 kilograms/hectare (kg/ha)	=	1¾ pounds/acre (lb/acre)
2.50 kilograms/hectare (kg/ha)	=	2¼ pounds/acre (lb/acre)
3.25 kilograms/hectare (kg/ha)	=	3 pounds/acre (lb/acre)
4.00 kilograms/hectare (kg/ha)	=	3½ pounds/acre (lb/acre)
5.00 kilograms/hectare (kg/ha)	=	4½ pounds/acre (lb/acre)
6.00 kilograms/hectare (kg/ha)	=	5¼ pounds/acre (lb/acre)
7.50 kilograms/hectare (kg/ha)	=	6¾ pounds/acre (lb/acre)
9.00 kilograms/hectare (kg/ha)	=	8 pounds/acre (lb/acre)
11.00 kilograms/hectare (kg/ha)	=	10 pounds/acre (lb/acre)
13.00 kilograms/hectare (kg/ha)	=	11½ pounds/acre (lb/acre)
15.00 kilograms/hectare (kg/ha)	=	13½ pounds/acre (lb/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 × 0.015	=	ounces per acre
kilograms per hectare × 0.89	=	pounds per acre
tonnes per hectare × 0.45	=	tons per acre

Application rate conversions continued

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. quarter 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)

Metric conversions		*Approximate*
5 mL	=	1 tsp
15 mL	=	1 tbsp
28.5 mL	=	1 Imp. fl oz

Approximate liquid equivalents

Litres/ Hectare		*Approximate Gallons/ Acre*	
		Imp. Gallons	**U.S. Gallons**
50	=	4.45	5.35
100	=	8.90	10.70
150	=	13.35	16.05
200	=	17.80	21.40
250	=	22.25	26.75
300	=	26.70	32.10

metric to Imperial or U.S. (approximate)

Length		
1 millimetre (mm)	=	0.04 inches (in.)
1 centimetre (cm)	=	0.40 inches (in.)
1 metre (m)	=	39.40 inches (in.)
1 metre (m)	=	3.28 feet (ft)
1 metre (m)	=	1.09 yards (yd)
1 kilometre (km)	=	0.62 miles (mi)

Area		
1 square centimetre (cm^2)	=	0.16 square inches (in^2)
1 square metre (m^2)	=	10.77 square feet (ft^2)
1 square metre (m^2)	=	1.20 square yards (yd^2)
1 square kilometre (km^2)	=	0.39 square miles (mi^2)
1 hectare (ha)	=	107,636 square feet (ft^2)
1 hectare (ha)	=	2.5 acres (acre)

Volume (dry)		
1 cubic centimetre (cm^3)	=	0.061 cubic inches ($in.^3$)
1 cubic metre (m^3)	=	1.31 cubic yards (yd^3)
1 cubic metre (m^3)	=	35.31 cubic feet (ft^3)
1,000 cubic metres (m^3)	=	0.81 acre-feet
1 hectolitre (hL)	=	2.8 bushels (bu)

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 US gallons (US gal)

Weight		
1 gram (g)	=	0.035 ounces (oz.)
1 kilogram (kg)	=	2.21 pounds (lb)
1 tonne (t)	=	1.10 short tons
1 tonne (t)	=	2,205 pounds (lb)

Pressure		
1 kilopascal (kPa)	=	0.15 pounds/square inch ($lb/in.^2$)

Speed		
1 metre per second	=	3.28 feet per second (ft/sec)
1 metre per second	=	2.24 miles per hour (mph)
1 kilometre per hour	=	0.62 miles per hour (mph)

Temperature		
°F	=	(°C × 9/5) + 32

Imperial or U.S. to metric (approximate)		
Length		
1 inch (in.)	=	2.54 centimetres (cm)
1 foot (ft)	=	0.30 metre (m)
1 yard (yd)	=	0.91 metre (m)
1 mile (mi)	=	1.61 kilometre (km)
Area		
1 square foot (ft^2)	=	0.09 square metres (m^2)
1 square yard (yd^2)	=	0.84 metre (m^2)
1 acre	=	0.40 hectare (ha)
Volume (dry)		
1 cubic yard (yd^3)	=	0.76 cubic metre (m^3)
1 bushel (bu)	=	36.37 litres (L)
Volume (liquid)		
1 fluid ounce (Imp.)	=	28.41 millilitres (mL)
1 pint (Imp.)	=	0.57 litre (L)
1 gallon (Imp.)	=	4.55 litres (L)
1 gallon (U.S.)	=	3.79 litres (L)
Weight		
1 ounce (oz)	=	28.35 grams (g)
1 pound (lb)	=	453.6 grams (g)
1 ton	=	0.91 tonne (t)
Pressure		
1 pound per square inch (lb/in^2)	=	6.90 kilopascals (kPa)
Temperature		
°C	=	(°F – 32) × 5⁄9

Abbreviations

%	=	per cent (by weight)
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
m2	=	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

Appendix G. Pest Monitoring Record Sheet

Date (MM/DD/YY)	**Location** (farm, block, landmarks)	**Host** (include variety/cultivar, development stage, container vs. field)	**Pest and/or Symptoms** (development stage, population, % of crop showing symptoms)	**GDD, Plant Phenology Indicator**	**Action Taken** (pesticides, cultural measures, etc.)

www.ontario.ca/crops