INTEGRATED PEST MANAGEMENT FOR TURF

Publication 845

Ministry of Agriculture,
Food and Rural Affairs

Ontario

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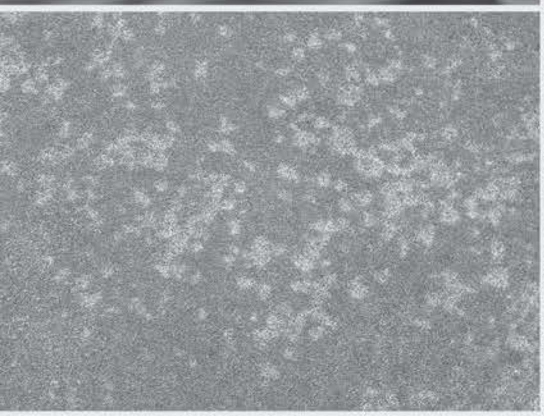

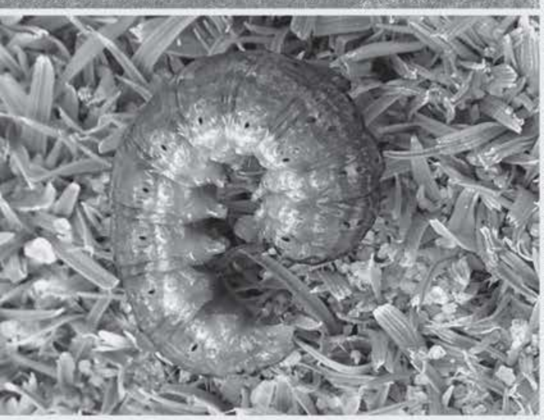

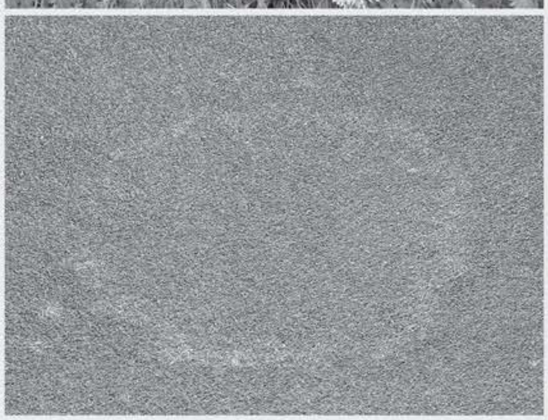

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Integrated Pest Management for Turf

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Editor

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This publication replaces OMAFRA Publication 162, *Diseases and Insects of Turfgrass in Ontario* and OMAFRA Publication 816, *Turf IPM Manual*. It contains information on turfgrass soil management and fertilizer use, turfgrass species and water management for turf that was previously found in OMAFRA Publication 384, *Turfgrass Management Recommendations*. The current OMAFRA Publication 384 has been renamed and is now called *Protection Guide for Turfgrass*. It is a companion publication to this publication (OMAFRA Publication 845, *Integrated Pest Management for Turf)*.

OMAFRA Publication 845, *Integrated Pest Management for Turf* has been designed as a field handbook for golf courses, lawn care, sod growers and the parks sector. It is also recommended study material for the IPM accreditation exam for the Golf Course IPM Accreditation Program which is required under *The Pesticides Act* and Regulation 63/09 and is administered by the IPM Council of Canada. It contains extensive information on the diseases, insects, and weeds that are found in turf in Ontario, including a turf disease identification key, turf disease time profile, turf scouting calendar, turf insect injury key and an example of a pest scouting sheet. This publication, along with OMAFRA Publication 384, *Protection Guide for Turfgrass* provides a complete reference package on turf IPM for Ontario.

All other turfgrass management information for Ontario can be found on the OMAFRA website at *www.ontario.ca/crops*.

Visit ONturf at *www.onturf.wordpress.com*. The ONturf blog provides timely information on turf management in Ontario.

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Contents

5. IPM for Turf Diseases

6. Soil Management and Fertilizer Use

7. Turfgrass Species

8. Water Management

9. Appendices

1. Integrated Pest Management for Turf

Introduction

Integrated Pest Management (IPM) is a process that uses all necessary techniques to suppress pests effectively, economically and in an environmentally sound manner. IPM involves planning and managing ecosystems to prevent organisms from becoming pests. This requires identifying potential pest problems through monitoring, recording weather and pest population levels and establishing thresholds to make treatment decisions to reduce pest populations to acceptable levels. Management strategies may include a combination of biological, physical, cultural and chemical controls. Equally important is evaluating the effectiveness of the treatments.

In an IPM program, turf managers use regular inspections, called scouting or monitoring to collect the information they need to make management decisions. In IPM, a treatment is only used when pest numbers justify it, not as a routine measure. Applying pesticides according to a schedule based on calendar dates is rarely, if ever, done in IPM programs. This eliminates unnecessary pesticide use without sacrificing results. Eliminating unnecessary pesticide use also reduces the chance that pest populations will become resistant to pesticides.

Integrated Pest Management
Integrated pest management is a process for suppressing pests that uses a combination of techniques, including but not limited to:[1]

- planning and managing ecosystems to prevent organisms from becoming pests.
- identifying potential pest problems.
- monitoring and recording populations of pests and beneficial organisms, pest damage and environmental conditions.
- using "thresholds" to make treatment decisions.
- reducing pest populations to acceptable levels using strategies that may include a combination of biological, physical, cultural, and chemical controls.
- evaluating the effectiveness of treatments.

1. Adapted from the Pest Management Regulatory Agency (PMRA)

In IPM it is only necessary to keep pest numbers down to non-damaging levels. It is not necessary or even desirable to eliminate pests altogether. If treatment is needed, turf managers choose the combination of methods that suits the site and local conditions. Implementing an IPM program may result in increased costs for labour, training, record keeping and changes in equipment. On the other hand, IPM programs can reduce costs related to pesticide use (i.e., pesticide purchases, pesticide storage facilities and disposal). IPM programs change and improve as turf managers gain experience, and as new products, tools and information become available.

The advantages of IPM programs are that they:

- provide long-term solutions to pest problems.
- protect the environment and human health by reducing pesticide use.
- reduce costs and liabilities associated with pesticide use.
- prevent pesticide-resistant pests from developing.
- enable turf managers to control pesticide-resistant pests.
- may give good results where pesticides cannot be used.

The basis of a turf IPM program is prevention of pest problems, careful planning and management of the turf. If controls become necessary, the IPM approach gives the turf manager a step-by-step process for managing pest problems. The emphasis on scouting pest populations before making treatment decisions differs from the practice of applying pesticides based on a calendar schedule. The challenge to the turf manager is to approach pest control differently. This approach is more environmentally sound and cost effective than traditional ones.

Planning and Managing Turf

Planning and managing turf are the most important underpinnings of an integrated pest management program. Careful planning of a site results in turf with maximum health and minimum stress.

Planning

Soil conditions

Starting with a quality root zone mix is a necessary foundation for a golf course, sports field or other turf areas. Compacted, poorly drained soils are more prone to diseases, insects and weeds. A properly constructed and drained root zone will help minimize future turf problems. Fertility, pH and organic matter need to be optimized.

Turf selection

Choose the appropriate turf species and cultivars for the intended use. Select cultivars resistant to pests and adapted to the climate and site. Take into account sun and shade and wear patterns. Invest in the best quality seed available. For more information on turfgrass species characteristics and use, refer to Chapter 7, *Turfgrass Species,* on page 91. Plant breeders are continually releasing varieties with improved resistance to drought, shade, insects and diseases. Be aware of new varieties and their attributes and stay up to date with data from turfgrass evaluation programs in your area. Good resources are:

- Guelph Turfgrass Institute variety trials *www.guelphturfgrass.ca.*
- National Turfgrass Evaluation Program trials in the U.S. and Canada at *www.ntep.org.*
- local seed companies.

Management

Water management

Proper irrigation practices, including the frequency and quantity of watering are important for disease, insect, weed and compaction prevention, as well as root health.

Too much water can cause root death because of lack of oxygen, promote root and foliar diseases, increase certain weed populations such as annual bluegrass, leach nutrients and increase thatch.

Too little water can induce dormancy, make turf more susceptible to some insect pests such as hairy chinch bugs and white grub species, as well as weed invasion and wear.

For detailed information on water management, irrigation scheduling, water budgets, water quality and water conservation refer to Chapter 8, *Water Management,* on page 97.

Fertilization

Turf plant health is best maintained through a well-balanced fertilizer program. This can be determined by a soil test for phosporus (P) and potash (K) but not for nitrogen (N). Either too little or too much fertilizer can cause pest problems. Refer to Appendix A, *Accredited Soil Testing Laboratories in Ontario,* on page 103, and the OMAFRA website at *www.ontario.ca/crops* for accredited labs in Ontario. Too much or too little of a nutrient, especially N can cause problems.

Too much N favours shoot growth and reduces root growth, increases diseases such as brown patch and Pythium blight, increases annual bluegrass invasion and decreases wear tolerance.

Too little N increases some diseases such as dollar spot, reduces growth rate and recovery from damage and increases certain weeds such as moss.

For detailed information on fertilizer selection, fertilization rates and timing, pH testing and adjusting refer to Chapter 6, *Soil Management and Fertilizer Use,* on page 83.

Mowing

Proper mowing height and frequency are important turf management considerations. Proper mowing increases the shoot density and thickens the grass. Keep the mower height as high as possible for the turfgrass species and use of the site, without sacrificing turf density. This gives the grass plants more leaf area, so they grow more vigorously, have deeper roots, and are better able to compete with weeds. Mow frequently so that no more than one-third of the leaf blade is removed. Use mulching mowers and leave the grass cuttings on the turf to provide nutrients. This has been shown to replace up to 15% of the nitrogen fertilizer required and does not cause thatch to build up but may not be advisable in cool, wet spring conditions when turf is growing rapidly.

Mowing also injures the plant and pathogens can get into the cut surface. Always mow with a sharp mower blade.

Mowing too low can increase weed infestation, reduce root growth, thin the turf stand and increase susceptibility to certain diseases such as anthracnose. Infrequent mowing can thin the turf stand and remove too much of the functioning leaves. This is known as scalping of the turf which reduces carbohydrate reserves and root growth.

Thatch control

Thatch is a layer of organic matter made up of decaying grass leaves, stems and roots that builds up between the turf and soil surface. It is a common problem on Kentucky bluegrass and fine fescue on golf course fairways, greens and tees, home lawns and on sports fields. It is most common on turf that has been established for several years and is over-watered and over-fertilized.

Thatch harbours disease spores, and many insects also make their home in the thatch. Thatch can restrict grass roots from growing into the soil root zone, resulting in a shallow-rooted turf. Thatch interferes with water infiltration.

Cultural practices that minimize thatch development include:

- frequent mowing.
- proper watering.
- proper fertilization.
- frequent topdressing.

Excess thatch can be prevented and removed by vertical mowing or core aerating. A vertical mower has evenly spaced blades that revolve perpendicular to the turf, slicing into the thatch to remove it mechanically. To core aerate, use a hollow steel-tine core aerator, which removes cores of soil. This physically breaks up the thatch, brings up beneficial soil micro-organisms that help break down the thatch, and alleviates compaction. Dethatch or aerate in spring and fall during periods of good growth, allowing for quick turf recovery.

A moderate layer of thatch is beneficial for most turf because it insulates roots from temperature extremes, reduces water loss and acts as a cushion to reduce compaction from wear. Regular thatch control through verticutting, aeration and topdressing is important.

Aeration

Aeration is one of the cultural practices used extensively on golf courses, sports fields and home lawns. There are several types of aerators, hollow tine, solid tine and slicing. Figure 1-1, on this page, shows a sportsfield that has been aerated.

Figure 1-1. A sportsfield that has been aerated using a hollow tine aerator.

Aeration relieves soil compaction, controls thatch, enhances fertilizer penetration and prepares turf surfaces for overseeding and renovation. Overseeding helps keep turf thick and reduces weed invasion.

Verticutting

Verticutting or vertical mowing slices through thatch using vertical spinning blades and is used to prevent and control thatch.

Topdressing

Topdressing is the addition of sand or a sand/peat mix to smooth the surface and control thatch by diluting it. Topdressing material, frequency and volume depend on the resources available, the turf species and the rate of growth.

Figure 1-2, on page 14, shows the timing for turf cultural practices on golf courses, sportsfields and home lawns.

Growing environment

Turf needs a minimum amount of sunlight to survive. Morning sun is preferred to afternoon sun. This ensures that the turf leaves dry off quickly in the morning, shortening the length of time the leaves are wet which minimizes diseases.

Air movement over turf is essential for evapotranspiration which is necessary for the uptake of certain nutrients and water, and is helpful in reducing turf canopy temperature and turf stress.

"The best defence is a good offence" holds true for turf. Maintaining healthy, stress-free turf is fundamentally important and cannot be overlooked in an integrated pest management plan. Follow these good cultural practices.

Irrigation

Water infrequently and deeply. Time irrigation to minimize leaf wetness. Syringe (water very lightly) to reduce heat stress. Ensure adequate air movement and sun to dry off turf quickly.

Fertilizing

Apply phosphorus (P) and potassium (K) based on a soil test. Adjust nitrogen (N) fertilization according to species and time of year. Use slow-release sources of nitrogen. Use an appropriate quantity of N to reduce dollar spot, red thread, brown patch and Pythium.

N Fertilization timing and rates
P and K rates to be established by a soil test.

	May	June	July	Aug	Sept
golf greens		.15–35 kg N/100 m^2/month			
golf tees		.15–.5 kg N/100 m^2/month			
golf fairways		.25 kg N/100 m^2/month			
sports fields		.5 kg N/100 m^2/month			
home lawns (irrigated)		.5 kg N/100 m^2/month			
home lawns (non-irrigated)		.5 kg N/ 100 m^2		.5 kg N/ 100 m^2	.5 kg N/ 100 m^2

Aeration

	May	June	July	Aug	Sept
golf courses	aerate				aerate
sports fields	aerate monthly				
home lawns	aerate				aerate

Overseeding

	May	June	July	Aug	Sept
golf courses	overseed			overseed	
sports fields	overseed monthly if turf has thinned				

Topdressing

	May	June	July	Aug	Sept
golf courses	topdress every 2–3 weeks in spring and fall and less often in summer				

Figure 1-2. Turf cultural practices calendar.

Mowing

Mow as high as possible. Sharpen mower blades frequently. Use a lightweight mower if possible.

Never remove more than one-third of the leaf blade. Remove clippings from greens only.

Aeration

Aerate at least two times a year to reduce compaction, improve water and pesticide infiltration, improve soil profile, increase soil oxygen and break down thatch.

Topdressing
Topdressing controls thatch by diluting it. Topdressing material, frequency and the volume depend on the resources available, the turf species and the rate of growth.

Identification of Problems

It is essential to identify pest problems correctly to plan an effective integrated pest management program. Careful examination of the turf should be conducted regularly to ensure early identification of problems.

Abiotic problems

Turf damage can be caused by abiotic factors such as flooding, drought, winter injury, nutrient deficiency, fertilizer burn, herbicide injury, hydraulic fluid leaks, localized dry spots, frost, salt, dog urine and scalping.

Biotic problems

Once a pest has been identified, look up information on its biology, including life cycle, behaviour, preferred habitat, typical damage or symptoms and host plants. Knowing about the biology of a species helps to:

- know if the pest has natural enemies that could be conserved or protected.
- plan preventative measures and improve turf management practices.

It is very important to identify beneficial insects and natural enemies. More information on beneficial organisms can be found in Chapter 4, *IPM for Turf Insects,* on page 33.

To identify problems, collect insect specimens or samples of plant damage and compare them with reference materials. Suggestions on where to look and how to sample for common pests are discussed throughout this manual. Before sending samples for diagnostic services, contact the lab for recommendations on how to collect and handle samples.

To identify pests and beneficial species:

- Compare specimens with an insect or weed collection.
- Refer to reference books, factsheets or resources on the Internet.
- Consult experts for help with difficult or unfamiliar species.
- Compare characteristics of damage or signs of disease with photographs.

Be careful when using characteristics of turf damage to diagnose problems because similar-looking damage can have different causes. See *Steps to Help Diagnose a Turf Problem,* on page 16, for a step-by-step guide to identifying turf problems.

Make Your Own Collection
It is often easier to identify an insect or a weed by comparing it to a real specimen than to photographs. Make your own collection of insects (pests as well as beneficial species) and pressed weeds. These are useful for quick reference and for training employees. Also keep photographs of pests, damage and disease symptoms for future reference.

Scouting and Record Keeping

Scouting and record keeping requires regular inspections or counts and writing down the results. Scouting records are necessary to make decisions about whether treatments are needed and when. Scouting records show where the pest problems are and whether they are getting better or worse. The *Pesticide Act* and Regulation 63/09 and the IPM Council of Canada's mandatory Golf IPM Accreditation program requires that all scouting be recorded in the online database on the members section of the IPM Council of Canada site. For more information, visit the IPM Council of Canada website at *www.ipmcouncilcanada.org.*

Plant phenology

Understanding plant phenology and identifying the key pests that are the most troublesome can help narrow down when, where and what to scout. Phenology is the relation between climate and biological events such as plant development, including blooming, leafing out, etc. Plant growth depends on temperature, so the date a particular plant blooms is influenced by the weather. Although the calendar dates may differ from year to year, plants generally develop in the same relationship to each other. For example, wild cherries bloom before lilacs, which bloom before horse chestnuts. Particular cultivars bloom earlier or later than others.

Since insect development also depends on temperature, it can be more accurate to relate the appearance of particular insects to plant phenology than to a calendar date. For example, peak adult flights of black turfgrass ataenius occur at the same time the horse chestnuts in the area begin to flower. Use plant phenology as a guide to help target monitoring to the most likely time to expect the pest. Refer to Chapter 4, *IPM For Turf*

Steps to help diagnose a turf problem

1. Identify the turfgrass species affected.
   - In a mixed stand, check if symptoms are present on one species and not others.
   - Some diseases and insects are specific to one grass species.
   - All species being affected may indicate a disease or insect with a broad host range or an abiotic (non-living) problem, such as drought.

2. Describe the symptoms. Take a step back and look at the entire affected area.
   - The symptoms may appear as spots, rings or general thinning. Some diseases form spots or rings (e.g., necrotic ring spot, dollar spot), while others cause general thinning (e.g., rust). Some insects also cause general thinning.
   - The symptoms may form irregular patches. Some may start as disease spots that coalesce or may be insect damage.
   - The symptoms may be regular or a random pattern. A regular pattern may be caused by equipment, e.g., failing to overlap spray pattern, fertilizer burn or a hydraulic fluid leak. A random pattern is more likely to be biotic (disease or insect damage).
   - Note the part that is affected, e.g., leaves, crowns or roots.

3. Observe the environment of the problem area.
   - Note if the problem is occurring in sun, shade or both.
   - Check the thickness of the thatch. Excessive thatch can make turf hydrophobic and can increase disease and insect problems.
   - Note if the problem is in open areas or near a building.
   - Describe anything unusual about the soil, e.g., compaction, layering or unusual soil texture.
   - Make note of anything unusual about the area.

4. Note the cultural practices being performed.
   - Check the mowing height and mowing frequency.
   - Determine if the turf has been fertilized recently. If so, note the timing/amount/method of application. Certain diseases favour high nitrogen while others favour low nitrogen.
   - Check to see if the turf has been irrigated recently. If so, note the timing/frequency/amount. Some diseases are intensified by irrigation and others by drought.
   - Check to see if the turf has been core-aerated. Some insects like to inhabit aerification holes and some diseases need the wounding of aeration or topdressing to infect the plant.

5. Note the weather conditions.
   - Make note of the recent weather.
   - Check to see what the weather was like right before the problem began.
   - Determine if the problem is getting worse under certain weather conditions.

6. Examine the turf closely (this may require using a hand lens, knife or cup cutter).
   - Look for lesions on turf blades.
   - Look for the presence of mycelium on the turf.
   - Look for the presence of insects, insect frass or silken tunnels in turf, soil or thatch.

7. If in doubt, take a sample.
   - If a disease or insect is suspected, take a sample of turf with the soil intact (6–10 cm^2 with at least 4 cm of soil).
   - If it is a ring or patch, sample the outside edge.
   - If it is general thinning, sample an intermediate area.
   - Wrap the sample in newspaper or paper towel.
   - Do not treat turf with pesticide before sending a sample.
   - Clearly label the sample and insert field observations.
   - Send the sample by courier to the GTI Turf Diagnostics. Contact information and information on collecting and sampling can be found in Appendix B. *Diagnostic Services* or visit their website at *www.guelphturfgrass.ca/diagnostics.html*.

8. If a chemical problem is suspected, take separate samples from the affected and non-affected areas.
   - Sample soil only.
   - Submit sample to a pesticide residue lab.
   - Tell the lab what pesticide(s) or other contaminants you suspect.

Insects, on page 33 for examples of plant phenology relationships used to time scouting of turfgrass insects.

Key pests

Pests in turf differ depending on the end use of the turf (i.e., golf course, sports field or home lawn). Know which pests commonly occur in the turf you manage and focus on monitoring the key pests.

Scouting methods

There are two main approaches to scouting: visual inspections and counting methods. The most common techniques are described below. For details on other methods, see the sections on *Scouting* in Chapter 3, *IPM for Turf Weeds,* on page 25, Chapter 4, *IPM for Turf Insects,* on page 33, and Chapter 5, *IPM for Turf Diseases,* on page 63.

Visual inspections

A visual inspection involves making detailed visual observations of the overall appearance of the turf. If there appears to be a problem, look closer. Visual inspection is the most subjective monitoring method. What is seen and recorded depends on the knowledge and skills of the person doing the observation. Visual inspections are useful to determine if there is a problem. They are also useful for checking plant health, soil and moisture conditions and for quickly finding problem sites. If problems are detected, usually a second level of inspection is necessary, often with the aid of a magnifying lens.

Tools for Visual Inspections:

- 10–15× magnifying lens or headband magnifier or dissecting microscope.
- vials or plastic bags (to hold samples to be examined later under a microscope).
- notepad or pre-printed forms, pencils.
- pocket knife.
- small trowel or soil probe for checking soil conditions.

Counting methods

Counting methods for scouting pest populations are well developed for weeds and some insects in turf. The advantage of using counts in monitoring wherever possible is that they give numerical (quantitative) measurements. Unlike visual inspections, counts give numbers that can be compared from year to year as long as the same method is used each time.

For example, count the number of:

- insects in an area of turf.
- weeds in a measured area of turf or along a length of string.
- disease spots per area of turf.
- insects caught in pheromone traps.

Insect traps and scouting methods

Insect traps and scouting methods are used to find out when the first adult insects are present, estimate the time when the population peaks and the size and extent of a pest population.

For more information on the traps and scouting methods for insects refer to Chapter 4, *IPM for Turf Insects,* on page 33.

Pheromone traps

Pheromone traps contain synthetic sex pheromones that mimic the pheromones given off by females to attract males for mating. (See *Semiochemicals: How Insects Communicate,* on this page). Pheromones are specific for each insect species. Pheromone traps are used to find out when the main flights of adult moths or beetles occur. This information can help time sprays or biological controls. The pheromone is usually contained in a rubber or plastic lure that is hung inside the trap. To inspect the trap, open it up and count the captured insects. The most common pheromone trap used in turf is the Japanese beetle trap. For more information on Japanese beetle traps refer to Chapter 4, *IPM for Turf Insects,* page 33.

Check traps weekly at the beginning of adult flights and then several times a week during peak flights. Either count or weigh and record the number or weight of insects caught.

Black light traps

Light traps are commonly used to sample insects that fly at night such as adult black cutworm moths. The simplest light trap consists of a UV light (often called a black light) and a collecting pan with alcohol covering the bottom. The pan is placed below the light, and insects flying toward the light eventually drop into the alcohol. Commercial light traps of various designs are also available.

Weed counts

There are several counting methods for estimating weed populations in turf. They include transect method, grid method and centre line method. For more information on these counting methods refer to Chapter 3, *IPM for Turf Weeds,* on page 25.

Semiochemicals: How Insects Communicate

Semiochemicals, meaning, literally, "message chemicals," are chemical compounds that insects use as signals. These include compounds given off by plants that attract or repel insects as well as message chemicals produced by the insects. Semiochemicals that insects use to communicate with members of their own species are called pheromones.
For example:

- sex pheromones are emitted by females to attract males.
- aggregation pheromones are emitted to attract others.
- alarm pheromones are emitted to warn others.

Sex pheromones are most commonly used in monitoring for a wide range of moth and beetle species. An increasing number of other semiochemicals are becoming available to manage pests by affecting their behaviour. Semiochemicals are being used to disrupt mating in insects, to trap them in large numbers, to attract them to toxic baits or to lure them to places where other treatments can be used.

Reliability of counting methods

The point of counting pests (or pest damage, beneficial species, etc.) is to get an estimate of the pest pressure. The reliability of the counts in showing the true state of the pest population depends on sample size and sample randomness.

Sample size

To get a meaningful figure, count between 10 and 50 samples (such as insects in the soil or weeds in squares of turf) and average the results. The more samples you take, the more likely it is that the average will be a true picture of the pest presence. There is a practical limit because time spent on monitoring is a labour cost. A way to determine how many samples are enough is described in *How many samples are enough?* on this page.

How many samples are enough?

Sampling involves statistical theory and can get very complex. Fortunately for most turf pest monitoring, a reasonably good estimate will do. Here is one way to estimate how many samples to take:

First:
- Take 10 samples and count the pests (e.g., number of weeds/m²).
- Add up the total number of pests in all of the samples and divide by 10 to get the average.

Second:
- Take 40 samples, count the pests, add up the total and divide by 40 to get the average.
- Compare the average of 10 samples with the average from 40 samples.

If the averages are the same or close (within 10%–20% of each other), it shows that the higher number of samples probably wasn't necessary. Taking 10 samples is likely to be enough. If there is a larger difference between the two averages, however, take more samples. Try an average of 15 or 20 samples to see if the averages are closer to the 40-sample average.

Sample randomness

Make sure that samples are picked at random. This means picking them by chance, without looking at them first and deciding which to take. If you intentionally choose an area that appears to have a pest the results could over-estimate the pest situation.

One way to take a sample randomly would be to close your eyes, walk a few steps and take a sample or drop a grid. Another way to ensure randomness is to decide a pattern of sampling ahead of time and stick to it. Ensuring samples are random doesn't mean that you have to sample over a wide area or in places where the pests are not likely to be. It is most efficient to concentrate on sites where the pests are most likely to appear.

Thresholds

Thresholds are the number of pests that turf can tolerate before there is unacceptable damage. This is sometimes referred to as the damage, injury, aesthetic, tolerance or action threshold. When pest levels exceed the threshold, control action should be taken. It is important to remember that most thresholds are simply guidelines. Factors involved in determining thresholds include:

- the overall health and vigour of the turf.
- the part of the turf that is affected (e.g., roots vs. leaves).
- the pest that is causing the damage and the risk of permanent injury or death to the turf.
- the amount of visible damage the pest causes.
- the location of the problem area in the turf (e.g., a golf course green vs. a passive park).
- time of year (damage at the end of the summer will have time to recuperate before the next season).
- the attitudes and perceptions of people who use the turf.
- the cost and effectiveness of treatments.

Thresholds have been established for many common turf insect pests. Weed and disease thresholds are usually more subjective and should be established in consultation with the golf course membership, turf user group, etc.

To decide whether or not treatment is required, use the information from your regular scouting program. Often there is no need to take any action, either because the expected pest is not found or because it remains at numbers well below the threshold. When pest numbers rise higher and are reaching the threshold, treatment should be considered. Sometimes, it is necessary to monitor more often or more widely to be able to make a decision.

Controls

A pesticide control is only needed where preventative or cultural measures have not solved a pest problem or when pest levels exceed the action threshold. The different controls used in a turf IPM program are cultural, physical, biological and chemical.

These can be used separately or in combinations to give the required level of control. Using a combination of controls is usually more effective than relying on any one control.

Cultural controls

Cultural controls or practices are key factors in producing healthy turf. For an overview on cultural controls, see the *Management* section on page 12.

Physical controls

Physical controls include manual and mechanical techniques. Examples of manual techniques include hoeing or pulling weeds. Mechanical controls are machines or devices used to control pests, such as vacuum equipment for insects and cultivators, mowers and line trimmers used to control weeds.

Biological controls

Biological control uses living organisms or by-products of living organisms to control pests. They can be classified as predators, parasites and pathogens. Predators are insects or other organisms that search out and attack target pests. These include beneficial insects, birds and mammals. Parasites are organisms that feed internally on insect pests such as insect parasitic nematodes. Pathogens are disease-causing organisms that attack insects and weeds or compete with other turf diseases. Pathogens include micro-organisms such as fungi, bacteria and viruses. Biological controls specific to insects, diseases and weeds can be found in Chapter 3, *IPM for Turf Weeds,* on page 25, and Chapter 4, *IPM for Turf Insects,* page 33. Further information can be found in OMAFRA Publication 384, *Protection Guide for Turfgrass*.

Chemical controls

Pesticides are defined as any substances used to kill, control, repel or manage insects, rodents, fungi, weeds and other living things considered to be pests. A large variety of chemicals and some micro-organisms are registered as pesticides in Canada for use on turf. Pesticides vary greatly in their toxicity and the way they work. In IPM programs, pesticides should only be used after careful assessment shows that they are the best control for the situation. Best management practices for pesticide use include:

- Apply pesticides only when monitoring shows that the pest is present in the susceptible stage and the threshold has been reached.
- Choose the most selective products with the lowest toxicity and/or shortest residual effect on non-target organisms. Many common pesticides have broad-spectrum activity. They can harm people and other non-target organisms, such as pets, plants, beneficial insects, wildlife, birds and fish.
- Apply pesticides with a properly calibrated sprayer.
- Broadcast applications of residual pesticides pose the most risk. Limit treatments to areas where pests are a problem (spot treatment).

ONLY pesticides with a *Federal Pest Control Products (PCP) Act* registration number on the label may be used for pest control. Pesticide products may only be used for pests and in locations specifically listed on the label. Always read the label before using any pesticide product. The pesticide label is a legal document and failure to follow the label instructions contravenes the *Pest Control Products Act*.

For more information on safe use of pesticides, see OMAFRA Publication 384, *Protection Guide for Turfgrass*.

Pesticides currently registered for use on turf in Ontario can be found in OMAFRA Publication 384, *Protection Guide for Turfgrass*.

Evaluation

Evaluation is an essential part of every IPM program because it helps to determine what worked and what did not work, identify ways to improve the program, assess the costs and benefits of the program, and identify changes to the site and management to prevent or deal more effectively with future problems.

To evaluate an IPM program, you will need accurate records of treatments and results from scouting records of pest numbers and locations before treatment, treatment specifics, including date, time, product names and rates used, scouting records of pest levels after treatment and feedback from golfers, clients or other site users.

2. Developing a Turf IPM Program

The following are general steps for developing an IPM program. Not all of these steps will apply in every case, so use what makes the most sense in your situation.

Set Realistic Objectives

Trying to make a lot of changes at once is hard to do successfully and can be overwhelming. Start with manageable goals and well defined objectives. Write them down. Start by choosing to work on:

- one site, a small part of a large site or a limited number of smaller sites, or
- site(s) with the fewest pest problems, or
- site(s) that are especially problematic or are in need of immediate solutions, or
- key turf pests.

Categorize the Sites

To set priorities for an IPM program, divide turf sites (or parts of large sites) into categories according to the level of maintenance they require and client or customer expectations. This makes it easier to concentrate efforts. Thresholds will vary with the purpose and visibility of the site. The amount of inputs and time spent on cultural practices and treatments also varies with the type of site. High-profile sites usually warrant using the most resources for monitoring and pest management. In contrast, there may be no need to scout or manage pests in some low-profile sites.

The following classification system is used throughout this manual.

- **Class A:** High level of service — residential lawns, golf and lawn bowling greens, golf course tees, irrigated sports fields.

- **Class B:** Moderate level of service —non-irrigated sports fields, commercial lawns, golf course fairways.

- **Class C:** Low level of service — passive park areas (including picnic areas), naturalized areas, golf course roughs.

Assemble Site Background Information

The more background information you have about a turf area, the better your IPM plan will be. Background information includes historical information on pests and cultural practices, expected pest problems, treatments available, resources available and regulatory requirements that may apply.

Collect historical information, including:

- notes, observations and other written records of weather, site conditions, pest problems, turf species, fertilizing schedules, irrigation schedules, etc.
- spray and other treatment records from previous years.
- customer account records showing what work was done.
- staff interviews.

For newly established sites, records will not exist. In this case, past experience with similar turf sites in the region could be used as a guide. This manual has information on pests of the south, central and eastern regions of Ontario.

Find out about pests likely to be a problem and collect information on:

- life cycles and biology.
- the range of host plants that may be affected.
- conditions that favour the pests.
- conditions that prevent pest development.
- natural enemies of the pests.

For more information on weed, disease and insects of turf, refer to Chapter 3, *IPM for Turf Weeds,* on page 25, Chapter 4, *IPM for Turf Insects,* on page 33, and Chapter 5, *IPM for Turf Diseases,* on page 63.

Research the range of treatments available, including:

- which pests they are effective against, and, in the case of pesticides for which pests and locations of use they are registered.
- mode of action of chemical pesticides and how well they are expected to work.

- factors that would limit use to specific times or places, such as temperature, relative humidity, moisture conditions, life stage of the pest affected, toxicity, time of day the pest feeds.
- cost and availability from suppliers.

Make an inventory of the resources available for the IPM program, including:

- budget for labour, supplies, new tools, reference manuals, capital items and training.
- supplies, tools and equipment on hand.

Know the regulatory requirements and guidelines that apply, including:

- provincial legislation regarding pesticide use. These can be found in the *Pesticides Act* and Reg. 63/09 which are available on the e-laws website at *www.ontario.ca/e-laws*.
- water-use restrictions may also be in place, which will affect management plans for turf.

Conduct a Site Assessment

A site assessment is a systematic inspection to collect current, site-specific information. Make a scale map of each site and record this information on it. Producing site maps involves some extra work at the beginning, but they are tools that will be useful for many years. The site map can be as simple as a hand-drawn sketch kept in a binder or as sophisticated as a computerized map with links to electronic files about the site. Software packages for mapping and designing landscapes are available from software dealers.

The types of information to record in making a site assessment include physical characteristics, turf inventory and use patterns.

Physical characteristics

Record soil conditions, such as type (sand, silt, clay), depth of topsoil and drainage.

Take soil tests to determine pH, fertility and organic matter content.

Describe micro-climate conditions. Document micro-climates of temperature, exposure to sun, wind and shade, frost patterns and air circulation that can make a large difference to the health of plants.

Turf inventory

Identify the species of turfgrass and also the cultivars, if possible and record their locations. Many vary widely in growth habit, management and susceptibility to pests. Information on cultivars of turfgrass species may be available from seeding records on golf courses or sports fields. On home lawns, this information is not usually available.

Inspect each site and note whether the turf is healthy, has pest problems, shows signs of nutrient deficiency, thinning, poor drainage, heavily worn areas, etc. Since the basis of an IPM program is prevention by growing healthy turf, this assessment of plant health is essential information.

Use patterns

Note who uses the site, how often and for what purpose. This will be useful for developing acceptable injury levels and selecting the most suitable treatments.

A large municipal park usually contains several areas with differing purposes and users. This can range from picnic areas to playing fields to display gardens. Even within small, residential landscapes, there may also be differences in use and purpose. On a golf course, the appearance of the greens and tees is more important than that of the fairways. In an IPM program, these differences would translate into differences in action thresholds and treatments.

Environmental concerns

In the site assessment, look for conditions that should be taken into consideration, such as:

- potential for runoff that might erode soil or carry pesticides and fertilizers into water bodies, ditches or storm drains.
- use by wildlife, such as birds, mammals, butterflies, bees and others.
- impact on neighbouring properties, as a result of changes to the landscape design or the type of treatments used.

Draft an IPM Program

Here are some suggestions to help get started:

Identification resources

Proper identification ensures that every pest or turf injury problem is recorded and that no treatment action is taken until the problem has been identified. An important step is to make sure the problem is a pest and not abiotic. Chapter 4, *IPM for Turf Insects,* on page 33, and Chapter 5, *IPM for Turf Diseases,* on page 63, have colour photographs of turf diseases and insects and can be used to identify problems. Another helpful resource is a digital photograph collection as well as actual specimens of insects and pressed weeds. In addition to this manual there are many useful reference books and Internet sites available for information about turf pests, cultural practices, treatments and controls.

Scouting

Make a list of all expected pests on the site and draft a scouting program based on the time of year that the pest problem is expected. Chapter 4, *IPM for Turf Insects* Figure 4-11, on page 40 shows a scouting calendar for turf insects. Choose a scouting method and make up a recording sheet. See Appendix C, *Turf Scouting Record,* on page 105 for an example. The mandatory Golf IPM Program in Ontario requires golf superintendents to use a web-based scouting database found on the members section of the IPM Council of Canada website at *www.ipmcouncilcanada.org*. Set up a filing or record management system so that information on each site is easy to find and use. Include site maps, scouting records, action thresholds and treatment information.

Thresholds

Take into account the users and category of each site, and set action thresholds for the pest populations. To start with, these may simply be a best guess, based on experience or on information in publications. For suggestions, see the sections titled *Thresholds* in Chapter 3, *IPM for Turf Weeds,* on page 25, and Chapter 4, *IPM for Turf Insects,* on page 33. Thresholds mentioned in this publication are guidelines or starting points only. Thresholds may vary considerably depending on numerous factors including the site, the client and the intended turf use, etc.

Review your thresholds regularly at least once a year to fine-tune them in light of experience.

Controls

Establish a list of preferred treatments for each pest. Have the preferred products in stock so you can act immediately if scouting shows that the action thresholds have been reached. For biological controls, contact suppliers well beforehand, to find out about availability, recommendations on use and shipping arrangements. Order special tools such as pheromone traps or magnifying lenses. Purchase equipment, such as flamers or infrared weeders, super-heated water applicators for weeds in patios, etc.

Evaluation

Establish a schedule for evaluating the effects of treatments. After the busy season is over, schedule an IPM review to evaluate the results of your efforts and plan for next year's improvements. Include monitoring records, financial accounts and feedback from staff, as well as clients or site users.

Revise the IPM Program

Revisit your objectives and, as you gain experience and confidence, widen the scope of your IPM program to include more sites, other pests and additional techniques. With each year of experience you will be able to:

- improve monitoring methods and record sheets.
- refine action thresholds.
- identify equipment you need to modify or purchase.
- determine staff training needs.

Mandatory Golf IPM Accreditation Program

Introduction

Under the cosmetic pesticides ban and Regulation 63/09 golf courses are excepted from the ban provided certain conditions are met. A golf facility must become accredited by an IPM body approved by the Ministry of the Environment and Climate Change. That body is currently the IPM Council of Canada. The golf facility must first register with the IPM Council of Canada Golf IPM Accreditation Program and then achieve accreditation through reporting and an environmental auditing process.

A registered golf facility must employ an IPM Certified Agent to manage their IPM program and submit a fee annually.

IPM Certified Agent

An IPM Certified Agent must hold a valid Ontario Landscape Exterminator Licence, successfully complete an IPM exam administered by The University of Guelph, Ridgetown Campus and pay an annual registration fee to be certified. Starting the year following successful completion of the IPM exam, the IPM Certified Agent must obtain 6 hours of Continuing Education Credits per year by attending IPM related courses, seminars, webinars, etc. and pay the annual registration fee to retain their certification status.

Golf facility IPM accreditation

Level 1 accreditation

The IPM Council of Canada Golf IPM Accreditation Program requires that registered golf facilities successfully complete an annual desk review for audit.

The following forms must be submitted for the annual desk review audit:

- Scouting Forms
- Staff IPM Training Documentation Forms
- Sprayer Calibration Forms
- Pest Control Products Application Forms
- Annual Report — Class 9 Pesticide Use
- Annual Desk Review Audit Submission List

Level 2 accreditation

Golf facilities that have successfully completed annual desk reviews must submit to an on-site audit once every three years to verify information submitted on annual desk reviews. After successful completion of the on-site audit, the golf facility will achieve IPM Accreditation Level 2.

Public meeting

The Ministry of the Environment and Climate Change also requires golf facilities to prepare an Annual Report of Class 9 pesticide use (this is the same form required as part of the IPM Council of Canada Golf IPM Accreditation Program desk review audit). The Ministry also requires that golf facilities hold a public meeting annually to present the Annual Report.

For more information on Ontario's cosmetic pesticides ban and Regulation 63/09 visit *www.ontario.ca/pesticideban*.

For information on rules to follow when using pesticides on golf courses, visit *www.ontario.ca* and search for 'pesticides and golf courses.'

For more information on the Golf IPM Accreditation Program visit the IPM Council of Canada website at *www.ipmcouncilcanada.org*.

3. IPM for Turf Weeds

When designing and seeding turf areas, plan for long-term weed management by starting with the correct drainage, soil preparation and choice of turfgrass species and cultivars. When weed populations exceed tolerance levels in turf, it is usually because the turf has thinned out as a result of improper management (fertility, mowing, etc.) or poor growing conditions such as drought, compaction, poor drainage, excess shade, insect and disease damage, etc. Weeds will colonize any opening in the turf. The key to managing turf weeds is preventing conditions that allow for weed invasion and implementing proper cultural practices. Cultural practices that have in impact on weed management are discussed under *Cultural Controls* on page 28.

The IPM program for turf weeds described in this manual should be treated as a starting point only. It should be adapted to suit specific site requirements and revised as new products and methods are developed.

Weed Biology

Knowing about weed biology is helpful to identify weeds, know their life cycle and determine the best type of control and control timing. Understanding weed biology begins with knowing the life cycle of the weed.

An annual is a plant that completes its life cycle from seed to mature plant in one year. Summer annuals complete their life cycle from spring to fall. Winter annuals complete their life cycle from fall to spring.

A biennial is a plant that completes its life cycle in two years. Flowering and seed production take place in the second year.

A perennial is a plant that may flower and produce seed in one year, but survives for several years.

Major annual species of broadleaf weeds infesting turfgrass in Ontario are black medick, chickweed and prostrate knotweed.

Major perennial broadleaf weed species infesting turfgrass in Ontario are dandelion, broad and narrow leaved plantain, bird's-foot trefoil, ground ivy, white clover and henbit. Major annual grassy weed species infesting turfgrass in Ontario are crabgrass and annual bluegrass. Major perennial grassy weed species infesting turfgrass in Ontario are quackgrass, orchard grass and creeping bentgrass.

Identification

Collect leaves or whole plants and identify weeds by species if possible. Find out whether the plants are annuals or perennials, grasses, broadleaf weeds and if they are noxious weeds. This information is important to help decide the management methods and when to use them. Identification resources include:

- reference books and plant guides.
- resources on the Internet.
- staff at garden centres, community colleges and botanical gardens.
- professional diagnostic services.

Weeds that cannot be positively identified should be carefully collected and photographed and submitted for identification. Weed specimens for identification can be sent to the GTI Turf Diagnostics or the Pest Diagnostic Clinic, Laboratory Services Division, University of Guelph (See Appendix B, *Diagnostic Services,* on page 103, or visit *www.guelphlabservices.com* for identification and recommendations. There is a fee for this service.

An additional resource is the OMAFRA online Weed Gallery that can be found at *www.ontario.ca/crops*.

Noting which species of weeds appear, and where, can help you diagnose the type of stress the turf is experiencing so that it can be corrected (see Table 3–1, *Conditions Favouring Weed Invasion in Lawns,* on page 26).

Table 3-1. Conditions Favouring Weed Invasion in Lawns

Weed	Conditions
Annual bluegrass *Poa annua*	Low fertility, compaction, mowing too short and excessive moisture
Algae (various)	Thin turf, wet conditions, high or low nitrogen depending on species
Black medick *Medicago lupulina*	Low fertility and drought
Buttercup *Ranunculus* spp.	Excessive moisture
Chickweed *Stellaria media*	Thin turf, excessive moisture and shade
Clover *Trifolium repens*	Low nitrogen, drought and compaction
Crabgrass *Digitaria* spp.	Thin turf, low fertility and compaction
Creeping bentgrass *Agrostis palustris*	High fertility, excessive watering and mowing too short
Moss (various)	Heavy shade, low fertility, low pH and compaction
Plantain *Plantago* sp.	Low fertility, compaction, mowing too short and drought
Prostrate knotweed *Polygonum ariculare*	Compaction, low fertility and drought
Rough bluegrass *Poa trivialis*	High fertility, excessive watering and shade

Scouting

Most scouting programs for weeds in turf are based on visual inspections (rough estimations) or on weed counts, which give a more accurate picture of the weed situation. For more information on the principles of sampling, see the section *Counting methods,* on this page.

Keep written records of all counts, as well as notes from visual inspections for future reference. Photographs can also be helpful.

Counting methods

Transect method

Use a rope or string to stake out a 10 m transect (straight line) through an average section of turf (Figure 3-1, on this page). Walk taking large steps (roughly 1 m long) along the string in two directions (up one side and down the other) and record what you see in front of your foot (Figure 3-2, on this page). It will either be a turfgrass plant, a weed or a bare patch. If you repeat this 5 times you will get 100 observations which is easily converted to a percent weed cover. Transect lines can be marked or knotted to show where to sample or you can pace along the length of the line and record the plants seen near your toe after each large stride.

Figure 3-1. Transect method shows a 10 m length of string placed at random in the turf.

Figure 3-2. Transect method showing the foot pointing at a spot to record weed or grass.

Grid method

The grid method involves placing a grid at random over an area of turf. The grid displayed (Figure 3-3, on page 27) has 25 transect points where the strings cross. Record the number of weeds at the 25 transects. Repeating 4 times gives percent weed cover.

Figure 3-3. Grid with 25 transects used for the grid method.

Example: $\frac{\text{15 weeds}}{\text{100 transect points}} = \text{15\% weed cover}$

Centreline method

Walk the centre of sports fields from goal post to goal post and record if there is a weed in front of your foot or grass every second step.

Which method

Once you choose a method, use the same one each time so that counts and averages can be compared from one year to the next.

When and how often

The scouting schedule depends on the category of the site, its history of weed problems and available resources. Schedule monitoring to coincide with periods of active vegetative growth or flowering periods, when some weeds are easiest to see. See Table 3-2, *Examples of Action Level/Thresholds for Weeds,* on this page, for guidelines on how often to scout. Figure 3-4, on this page, gives guidelines on what time of year to scout for the various types of weeds.

Table 3-2. Examples of Action Levels/Thresholds for Weeds

Site Classification	Site Examples	Action Level/ Threshold	Scouting Frequency	Comments
Class A	Golf greens and tees, bowling greens, irrigated sports fields, home lawns	From weed free to 5%–10% weed cover	2 x a year (spring and fall)	Usually sprayed when 10%–15% weed cover is reached.
Class B	Sports fields, commercial lawns, golf course fairways, general park areas	From 20%–50% weed cover	1 x a year	Allowed as long as the function of the site is not compromised.
Class C	Passive park areas, including picnic areas, naturalized areas, golf course roughs	Greater than 50% weed cover	Every 2nd or 3rd year	Controls may only be needed in the interest of public safety (i.e., to maintain sightlines, remove fire hazards or if noxious weeds are present).

	May	June	July	Aug	Sept	Oct
Spring annual broadleaf weeds	scout	scout				
Winter annual broadleaf weeds				scout	scout	scout
Perennial weeds	scout	scout			scout	scout
Winter annual grassy weeds				scout	scout	scout
Summer annual grassy weeds	scout	scout				

Figure 3-4. Weed scouting calendar.

Thresholds

On general-use turf, in parks and other public facilities, the need for treatment often depends on how many weeds the users will tolerate. On sports turf, safety considerations also influence treatment decisions because bare areas or large weedy patches can increase the slipping hazard. Playability is a key consideration in deciding when to treat on golf course and lawn bowling greens and the tolerance is usually very low, in fact it is often zero. On home lawns the threshold may vary considerably because of homeowner's tolerances.

Examples of some guidelines of action levels/thresholds used by turf managers in Ontario are shown in Table 3-2, *Examples of Action Levels/Thresholds for Weeds,* on page 27.

Develop action levels/thresholds using scouting information for major sites or for each class of site. These should be quantitative (stated in terms of a number or measurement) for any sites where herbicide use is being considered. For future reference and to help in later evaluation, write down the criteria used to make action decisions, such as percentage of weed cover, presence of noxious weeds species, risk of spread to adjacent turf and cost.

Establishing weed thresholds

Example methodology for fairways and sports fields

Step 1: In the spring, identify 2–3 areas that have acceptable broadleaf weed infestation, marginal weed infestation and unacceptable weed infestation. This should be done with a group. Examples of people who should take part in this are the greens committee at a private course, regular customers at a public golf course or user groups on a municipal sports field. This exercise can be done anytime in the spring except when dandelions are in full bloom.

Step 2: Within each of the areas identified above, stake or mark out areas of roughly 10 × 10 m in each of the areas and name or number them.

Step 3: Using a point quadrat or the transect method which have been described previously, determine the percent weed cover in each of the areas. Record the findings.

Step 4: Take the averages within each of the categories of acceptable, marginal and unacceptable infestation.

These values become the thresholds for broadleaf weeds. The percent weed cover that is unacceptable becomes the action threshold. Spray a herbicide when the weed levels are unacceptable and perhaps spot spray where they are marginal.

Cultural Controls

Turf establishment

Turfgrass species selection

Select turfgrass species to match the growing environment and the intended use. Always use certified seed. Fine fescues are shade tolerant, tolerate low maintenance and will out-compete weeds in those environments. Turf-type perennial ryegrass varieties are quick to establish in newly seeded areas and will crowd out germinating weeds. Kentucky bluegrass, although slow to establish, is very competitive against weed invasion once established.

Timing of seeding

Seeding at the appropriate time for the selected species and geographic region greatly reduces the competition from both annual and perennial weeds. The best time of year to seed most cool season turfgrass species in Ontario is mid-August to mid-September. Turfgrass seeded in the summer is usually overrun with both annual and perennial broadleaf weeds and annual grassy weeds. For more information on turfgrass species, see Chapter 7, *Turfgrass Species,* on page 91.

Mowing

Mowing stimulates bud development and tillering, making turf thick and dense. Dense turf shades the soil and prevents weed seeds from germinating. Mow as high as possible for the turfgrass species and use. The longer the grass blades, the deeper the roots. Avoid scalping the turf. Mowing removes annual weeds and flowers, prevents them from setting seed and helps reduce the spread of weeds. Never remove more than one-third of the grass blade. Maintain sharp mower blades. Use mulching mowers and leave the grass clippings on the turf to provide nutrients.

Fertilizing

A balanced fertilizer program is important in establishing a thick, dense and healthy turf stand. Regular, timely fertilizer applications can help turf out-compete broadleaf and grassy weeds. Studies implementing fertilizer only as a tool for weed control showed that weed cover could be reduced to less than 5% simply by fertilizing with 0.5 kg/N per 100 m^2 four times a season for five seasons. Too few nutrients applied to the turf leads to increased susceptibility to weed infestation and some diseases. Too much fertilizer may lead to soft, weak grass that is also prone to disease and will not stand up to traffic.

For more specific information on a balanced turf fertilizer program, see Chapter 6, *Soil Management and Fertilizer Use,* on page 83.

Irrigating

Irrigating turf is important when normal rainfall does not provide enough moisture. Irrigate weekly, using 2.0–2.5 cm of water per application to help produce thick, deep-rooted turf. Frequent, light irrigation results in shallow roots and encourages the germination and growth of shallow-rooted weeds such as crabgrass and creeping bentgrass. Too much irrigation leads to infestation of annual bluegrass. Provide adequate irrigation near trees and hedges because they compete with turf for available moisture.

During extended dry periods, turf may turn brown and become dormant. Turf can survive from 4–6 weeks in a dormant state during summer dry periods without negative impact. Once the rains return, the turf will green up in 7–10 days. Allowing turf to go dormant makes it more susceptible to weed invasion. The top of the soil has a reserve of weed seeds that will germinate if they get adequate light and moisture.

For more information on turf irrigation, irrigation scheduling for golf courses, sports fields, home lawns and sod farms and water conservation, see Chapter 8, *Water Management,* on page 97.

Compaction

Avoid soil compaction to prevent invasion by weeds that thrive in compacted soil such as knotweed and annual bluegrass. Although aeration helps, the best approach is to reduce traffic. Provide mechanical aeration as required, preferably with hollow-tine aerators instead of solid-tine equipment. Aerate once a year or more depending on the type of turf and use patterns. Avoid compaction from overuse. Rotate goal mouth areas and entrance points onto turf areas for people and equipment. Alternate the direction of mowing. Establish a sports field closure policy during poor weather and limit play on sensitive or stressed sports fields. Re-sod or overseed damaged areas to discourage weed infestation.

Physical Controls

Hand removal

Hand-pull if there are only a few weeds. There are several well-designed hand tools on the market that make weed pulling more efficient. This is easiest when the soil is moist but can be done any time during the growing season. Take care to disturb the soil as little as possible. Once the weed is pulled, sprinkle turfgrass seed in the opening to close the gap in the turf quickly and prevent weed seeds in the soil from germinating.

Heat treatment

Various systems are available that deliver high temperatures to kill weed leaves. Handheld flamers (Figure 3-5, on this page) or infrared radiation applicators with a probe tip can be used as a spot treatment to control broadleaf weeds in turf or for non-selective vegetation control.

Figure 3-5. Hand held propane flamer.

How it works

High temperatures destroy plant cells and the proteins in them. It is only necessary to heat the leaf long enough to destroy the waxy cuticle of the leaf and disrupt the cells. Torching or boiling the plants until damage can be seen immediately is not necessary and may stimulate re-growth of some established perennials. Effects of heating may be visible in as little as an hour or take up to several days to show.

Timing

Seedlings, annuals, young perennials and germinating seeds are most susceptible to heat damage. Weeds that are less than a few centimetres tall (the 4–5 leaf stage) are easiest to control. At this stage roots are also killed by the heat treatment. They are usually killed by a single treatment. Heat treatments do not penetrate into the soil or below a layer of gravel, so they do not kill the roots of established perennials. Perennials may require several treatments in a season to deplete the roots and kill the plant.

Plants in dry conditions appear to be more susceptible to heat treatments than in cool and moist conditions. Under moist conditions, several treatments may be needed annually, one in spring to kill the majority of seedlings followed by a treatment after fall rains cause another flush of germination. Regular treatment prevents establishment of perennials.

Broadleaf weeds are more easily damaged by heat than grasses. The growing tips of grasses are encased in a heat-resistant sheath, which makes it possible to selectively control weeds in turf using a flamer (practice the technique in a low-visibility area first).

Use

Heat can be used as a spot treatment to control weeds in turf. It can be used to control vegetation where non-selective control is required, such as hard surfaces where any plant growth is undesirable. These include gravelled areas, cracks in sidewalks and pavements. It can also be used where all vegetation must be kept very short like around fire hydrants, sign posts, utility poles, metal sprinkler heads and along fence lines.

Precautions

Where flamers are used, the risk of causing a fire or damaging plastic fittings, such as sprinkler heads, must be taken into account. When using the flamer, direct the hottest part of the flame (the cone-shaped area around the flame) at the weeds. Hold the nozzle above the plant and slowly pass it over once.

Biological Controls

There is currently considerable research in the area of bio-herbicides with the aim of bringing effective and affordable products to the market place for Ontario turf managers and homeowners operating under the cosmetic pesticide ban.

Over the past few years two biological herbicides have been registered for use on turf. The first was a bio-herbicide that contains the fungus *Sclerotinia minor* and was marketed to lawn care operators and homeowners in Ontario. It had good efficacy in a very narrow range of environmental conditions and needed to be watered in and irrigated for several days after application to be effective. However, due to the nature of lawn care, there was a very narrow window to apply this product and it was not always applied when conditions were ideal. Also, homeowners were not always diligent in following a herbicide application with irrigation. Because of these factors, this bio-herbicide did not deliver the efficacy that the lawn care operators and homeowners were expecting and it is no longer marketed.

A second biological herbicide has recently received registration. It is based on the fungus *Phoma macrostoma.* Currently, the cost of production for this bio-herbicide is too high to be able to bring an affordable bio-herbicide to market. There is an ongoing effort to streamline production to be able to produce the product in a more cost-effective manner.

Chemical Controls

Knowing whether a weed is an annual or a perennial is important because it affects control decisions. See page 25 for description of weed biology.

Control of annual weeds should focus on preventing seeds from spreading and preventing dormant seeds in the soil from germinating by minimizing disturbances to the soil and maximizing turf health. For perennial weeds, controls are usually used before the plants bloom, when nutrient reserves in the roots are at their lowest, and the plant is least able to grow new leaves. Some hard-to-kill perennials are more susceptible to herbicides in the fall.

If a herbicide treatment is necessary, make sure the product selected is:

- effective and registered for the specific weed type.
- applied as a spot treatment instead of a broadcast application wherever possible.
- not phytotoxic to desirable turf species (some common turf herbicides kill bentgrasses).
- applied at the right time to have the greatest effect on target plants.

For more information on weed management and herbicides currently registered for use on turf in Ontario see OMAFRA Publication 384, *Protection Guide for Turfgrass*. Additional information on weeds, herbicides and management can be found in Publication 75, *Guide to Weed Control*.

Evaluation

After any type of treatment, turf areas should be inspected for results at intervals appropriate to the type of treatment. Schedule an inspection 2–3 weeks after a herbicide treatment. Use this information, along with other scouting records, observations from field staff, feedback from clients, budget records, etc., to assess the effectiveness of the turf IPM program and find ways to improve it for the next year. After several seasons of good cultural practices, recording and evaluating, there should be better turf quality and lower weed populations.

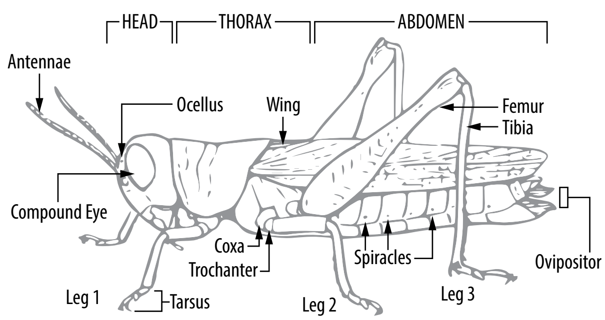
If scouting shows that weed populations continue to rise, re-evaluate your turf management practices. The goal should be to improve the health of the turf so that it is more competitive with weeds.

4. IPM for Turf Insects

Root feeding, crown and thatch feeding and foliage and stem feeding insects can cause direct damage to turf. In addition, some insects such as ants, are a pest of turf that do not feed directly on the plant but their activities cause damage to the turf. Understanding insect biology can aid in identification, understanding life cycles and insect control and are all part of a turf insect IPM program.

Biology of Insects

An insect body is distinguished from other animals by its hard exoskeleton made of a tough, impervious material called chitin. It is divided into three parts: head, thorax and abdomen (Figure 4-1, on this page). The head is the sensory centre that includes the eyes, antennae, and mouthparts. The thorax is the part of the insect that has the legs and wings attached. The abdomen contains the digestive tract and reproductive organs.



A grasshopper showing the general structure of an insect.

Figure 4-1. General structure of an insect.

Mouth parts and damage

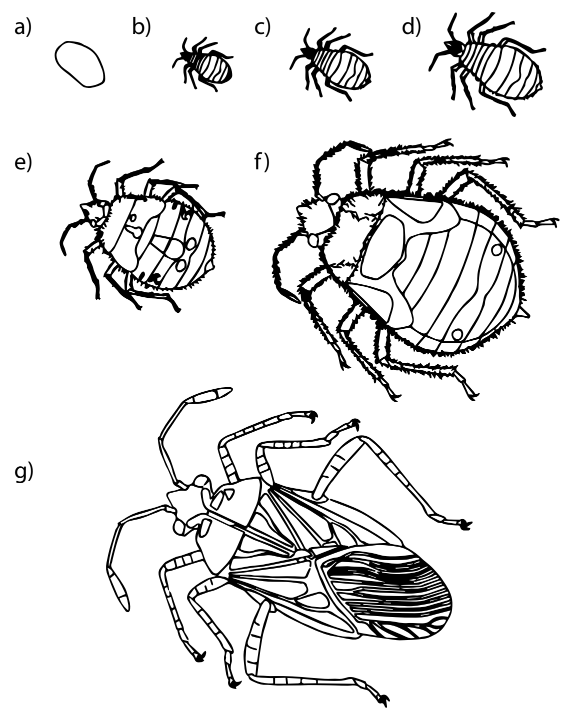
Insects have one of three types of mouthparts: chewing, piercing/sucking/rasping, and siphoning. Each causes different plant damage. The most common mouth parts for turf insects are chewing and piercing/sucking/rasping. Chewing mouthparts are comprised of strong mandibles that allow insects to eat parts of the turfgrass plants directly. Insects in this group include all grubs species, black cutworm, sod webworm, annual bluegrass weevil, bluegrass billbug and ants. Piercing/sucking/rasping mouthparts are similar to a hypodermic needle which is inserted into plants to remove sap. Turfgrass plants become shriveled and yellow. Insects in this group include hairy chinch bugs, leatherjackets and turfgrass scale.

Metamorphosis

All insects begin as an egg and then hatch into an immature feeding and growing stage. This stage is called either a nymph or a larva depending on what form of metamorphosis the insect undergoes (incomplete vs. complete).

In incomplete metamorphosis nymphs gradually change in size but their shape remains similar from the egg to the adult stage. Insects feed on the same food and stay in the same habitat their whole life.

Figure 4-2, on this page, shows an example of an insect with incomplete metamorphosis.

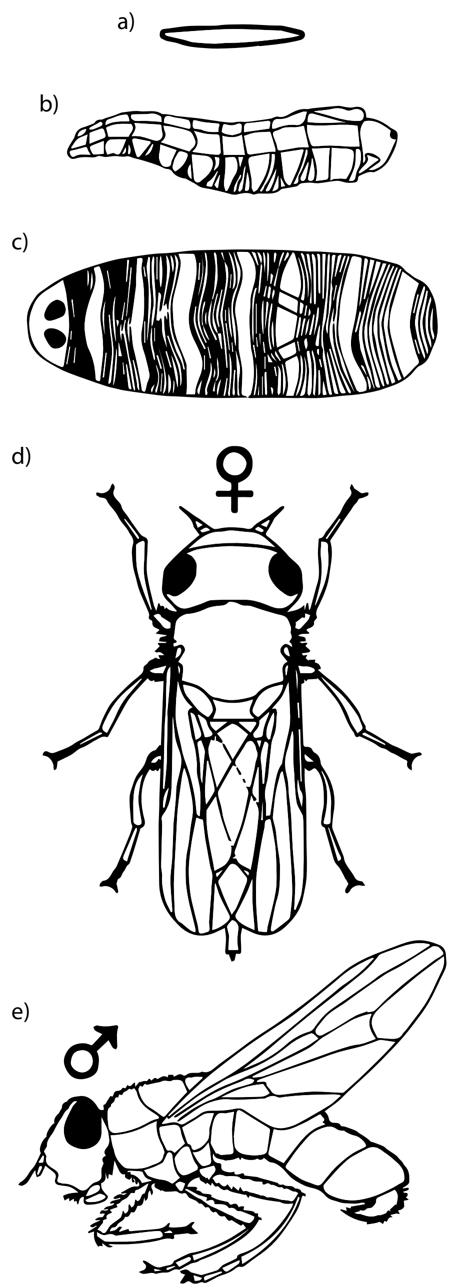


Incomplete metamorphosis of a plant bug, showing the a) egg, b) first nymphal instar, c) second nymphal instar, d) third nymphal instar, e) fourth nymphal instar, f) fifth nymphal instar, and g) the adult.

Figure 4-2. Incomplete metamorphosis.

Complete metamorphosis is the most common type of insect metamorphosis. The insect feeds and grows as a larva that changes into a pupa then becomes an adult. Larva often feed on different food than the adult or the adult does not feed at all.

Figure 4-3, on this page, shows an example of an insect with complete metamorphosis.



Complete metamorphosis of a root maggot fly. a) egg, b) larva, c) pupa, and d) adult female and e) adult male.

Figure 4-3. Complete metamorphosis.

Life cycles

Insects can complete a generation in several years, in one year or have several generations per year. Some insects overwinter as adults, some as larvae and some do not successfully overwinter in Ontario but return to the province each spring from areas in the south. For more information on turfgrass insect life cycles refer to Table 4-1, *Turf Insect Summary* on page 35.

Insect Identification

Most turf insect pests can be seen with the naked eye. Smaller insects may require a hand lens. Sometimes the insect is not present but damage may be evident. By-products of insect feeding (frass) may be present such as fecal pellets, sawdust-like frass or silk in the case of caterpillars. The part of the plant damaged and the way in which damage occurs are important clues in determining which insect is causing the damage.

If you suspect an insect problem, search carefully among turf leaves and in thatch. Cut and fold back a section of sod or use a soil probe or cup cutter to remove a section of turf. Inspect the thatch layer, roots and soil for larvae, pupae and/or adult insects. Collect insects and identify them from guides and other references or preserve them for later identification by an expert.

In this chapter adult and larval descriptions, damage and life cycles are given for the major turf insect pest that occur in Ontario (pages 33–52) and are summarized in Table 4-1, *Turf Insect Summary*, on page 35. If unable to identify a turf insect pest, samples can be sent to The GTI Turf Diagnostics. Contact information and information on collecting and sampling can be found in Appendix B. *Diagnostic Services,* on page 103, or visit their website at *www.guelphturfgrass.ca/diagnostics.html*.

Scouting

For general information on scouting techniques and frequency refer to Chapter 1, *Integrated Pest Management for Turf,* page 11. Table 4-1, *Turf Insect Summary*, on page 35, includes a summary of insect scouting techniques, thresholds and plant phenological relationships for most turfgrass insect pests. Visual inspections can be used to determine the presence of insect damage to turf. If insect damage is suspected after visual inspections, a specific insect scouting technique can be used depending of the insect you are looking for.

Table 4-1. Turf Insect Summary

Where insect feeds	Insect	Damaging Stage	Adult stage	Overwintering stage	Generations per Year	Distribution Factors	Plant phenological relationship	Scouting Technique	Threshold $0.1\ m^2$ (unless otherwise stated)
Foliar & stem	black cutworm *Agrotis ipsilon* Hufnagel	caterpillar	moth	Black cutworms do not overwinter in Ontario. Adult moths return in spring from southern United States.	2–3	Golf course pest. Inhabit aeration holes.	Not documented	soap solution	4–10 per $1.0\ m^2$
Foliar & stem	sod webworm *Crambus* sp., *Pediasia* sp. and *Chrisoteuchia* sp.	caterpillar	moth	mature caterpillar	2–3	Mainly a home lawn pest. Found occasionally on golf course fairways and fescue roughs.	Not documented	soap solution	Greater than 6
Crown & thatch	annual bluegrass weevil *Listronotus maculicollis*	larva	weevil	adult weevil	1–2	Golf course pest. Prefers closely mown annual bluegrass.	Forsythia full bloom coincides with the first wave of migration from overwintering sites. The second wave peaks at full bloom of horse chestnut.	adults: soap flush larvae: saturated salt solution	3–5 per cup changer
Crown & thatch	bluegrass billbug *Sphenophorus parvulus* Gyllenhal	larva	weevil	adult weevil	1	Prefers Kentucky bluegrass.	Not documented	larvae: cup changer	Not known
Crown & thatch	European cranefly *Tipula paludosa*	leather-jacket	crane fly	leatherjacket	1	Found throughout many areas of southwestern Ontario on home lawns and golf courses. Prefer wet soils.	Not documented	leatherjackets: saturated salt solution	Not known
Crown & thatch	hairy chinch bug *Blissus leucopterus hirtus*	nymph, bug	adult bug	adult bug	1	Excess thatch, non-irrigated turf, found in Kentucky bluegrass and fine fescues in home lawns.	Peak egg laying is when bird's-foot trefoil is in full bloom.	coffee can	Greater than 20–25 per can
								cup changer plug submerged in water	Greater than 10 per cup changer
Crown & thatch	turfgrass scale *Lecanopsis formicarum* Newstead	mature nymph	scale	mature nymph	1	Occurs on Kentucky bluegrass and fine fescue. Often found on sodded lawns, 3–5 years old.	Not documented	None	Not known
Soil (root feeders)	black turfgrass ataenius *Ataenius spretulus*	grub	Scarab beetle	adult beetle	1–2	Golf course pest. Closely mowed annual bluegrass and creeping bentgrass turf.	Full bloom of Van Houtte spirea and horse chestnut signals presence of adult flights and oviposition.	adults: soap flush grubs: cup changer	Greater than 20–50

Table 4-1. Turf Insects Summary (con't)

Where insect feeds	Insect	Damaging Stage	Adult stage	Overwintering stage	Generations per Year	Distribution Factors	Plant phenological relationship	Scouting Technique	Threshold 0.1 m^2 (unless otherwise stated)
Soil (root feeders)	*Aphodius granarius*	grub	Scarab beetle	adult beetle	1–2	Golf course pest. Closely mowed annual bluegrass and creeping bentgrass.	Not documented	adults: soap flush grubs: cup changer	Not known
Soil (root feeders)	June beetle *Phyllophaga* spp.	grub	Scarab beetle	adult beetle or larva	3-year cycle	Prefer sandy soils.	Not documented	cup changer	3–5 non-irrigated turf
Soil (root feeders)	European chafer *Rhizotrogus majalis*	grub	Scarab beetle	grub	1	Prefer sandy soils.	Full bloom of catalpa coincides with peak adult flights.	cup changer	Greater than 20 on irrigated turf; 5–10 on non-irrigated turf
Soil (root feeders)	Japanese beetle *Popillia japonica*	grub	Scarab beetle	grub	1	Found mainly in Niagara Peninsula and areas near Lakes Ontario, Huron and Erie.	Not documented	grubs: cup changer adults: Japanese beetle pheromone trap.	Greater than 10 on irrigated turf

Where, when and how often to scout

Where to scout often depends on known "hot spots" or areas that have a history of the insect pest in question. The time to start scouting for each insect pest is dependent on the life cycle. The frequency of scouting also depends on the category of turf, the insect and the life cycle. The higher the category of priority of the turf, the more frequent the scouting should be. Insects that cause damage very quickly should be monitored more frequently during the period of their life cycle that they cause damage.

Figure 4-11, on page 40, indicates the month when scouting should take place for each insect pest. It also indicates when damage is expected to occur.

Visual inspections

Walk over the turf areas noting damaged areas which may show up as patches of wilting, yellowing or browning turf or bare areas. Also look for signs that birds or other animals are pulling up the turf, indicating the possible presence of insects. For close visual inspections, use a hand lens and a soil probe or other tool to search deep in the thatch layer and root zone. Look for:

- life stages of insects such as larvae or pupae on the surface or among the roots in the soil.
- symptoms of chewing or sucking on leaf blades, missing leaf blades.
- silken webbing in the thatch layer.
- insect frass (excrement), either soft green pellets or sawdust-like frass.

Table 4-2, *Turfgrass Insect Injury Key,* on page 37, has been developed to help identify turf insect damage.

Specific insect scouting techniques

There are several scouting techniques that can be used to determine if insects are present and how many are present. Each method is specific for certain insects.

Table 4-2. Turfgrass Insect Injury Key

This key is composed of pairs of opposing statements (A and B) followed by either an insect name or a number. If there is a number at the end of the statement, refer to the pair of statements listed with that number and choose again from the pair of opposing statements. An insect name at the end of the statement indicates which insect causes the damage in the statement.

No.	Statement	Insect Name/Key Number
1A.	Turf not normally damaged and not generally discoloured, with no obvious feeding damage but with solid mounds.	2
1B.	Turf appears discoloured (browning, yellowing) or has obvious feeding damage present (e.g., missing leaves or stems, ragged or chewed leaves).	5
2A.	Mounds of soil present.	3
2B.	Mounds of soil absent.	5
3A.	Ants associated with mounds, 2.5–7.5 cm in diameter, resembling a small volcano with a hole in the middle.	ants
3B.	Mounds with no ants.	4
4A.	Mounds 2.5–7.5 cm in diameter, usually located within turf canopy and thatch that look like extruded castings.	earthworms
4B.	Large mounds of soil brought to the surface, large hole in the centre of the mound, associated with tunnels under turf.	moles
5A.	Turf spongy under foot, easily pulled up.	6
5B.	Soil under turf firm.	7
6A.	Turf spongy under foot that, when pulled, separates at the soil/thatch interface.	scarab grubs
6B.	Turf spongy under foot that, when pulled, separates at the turf/thatch interface, with soft pellet-like frass present.	sod webworm, cranberry girdler
7A.	Turf sparse, no chewed leaf blades or small chewed holes.	8
7B.	Turf sparse, chewed leaf blades.	10
8A.	Individual grass plants or small groups of grass plants turn yellow. When a “tug test” (sharp pulling of turf blades) is performed, the blades pull out easily. Stems and thatch have sawdust frass evident.	annual bluegrass weevil or bluegrass billbug
8B.	When “tug test” performed, turf does not pull out easily, no frass evident.	9
9A.	Dead patches yellow to brown and sunken in summer. Inspection of base of plants reveals red, brown or black-and-white insects from 1–3 mm long.	hairy chinch bugs
9B.	Dead patches yellow in spring. Inspection of base of plants reveals small pink, waxy or cottony-coated insects.	turfgrass scale
10A.	Leaf margins chewed on long grass or cropped down in spots on short grass (e.g., golf course putting greens) and soft, pellet-like frass present.	cutworms
10B.	Turf sparse, leaves removed, inspection at top of soil or in thatch reveals grey/brown maggots 1–2.5 cm long.	European cranefly larvae (leatherjackets)

Modified from Shetlar, D.J. 1995. Key to Turfgrass Pests. In R.L. Brandenburg and M.G. Villani (eds). Handbook of Turfgrass Insect Pests. Entomological Society of America, Lanham, MD.

Soap flush or irritating drench

Use this method for caterpillars (sod webworm and cutworm), black turfgrass ataenius, *Aphodius* and annual bluegrass weevil adults. See Figure 4-4, on this page. This method does not work for beetle larvae (grubs).

Mix 15–30 mL of liquid dish soap (not detergent) in 4–8 L of water. Do not use more soap, because concentrated soap solutions can burn the grass leaves. Pour the soapy mixture over roughly a 0.3 m² area.

Figure 4-4. Soap flush for monitoring turf insects.

Saturated salt solution

Use this method for leatherjackets, annual bluegrass and bluegrass billbug larvae and pupae. Mix 360 g of table salt with 1 L of water in a shallow container. Stir to dissolve the salt. Submerge cup cutter sized plugs (either 10.8 cm or 5.5 cm diameter) in the salt solution (Figure 4-5, on this page). If using the larger plugs, cut in four pieces. Wait for up to 1 hour to allow insect larvae to float.

Figure 4-5. Salt soak for monitoring turf insects.

Flotation

Flotation methods are for scouting for hairy chinch bug nymphs and adults.

Method I

Make a cylinder by cutting out the bottom and the top of a large can (approximately 20 cm in diameter). Force the cylinder sharp side down into the turf using a circular twisting motion. Fill the cylinder with water and wait for approximately 2–5 minutes (Figure 4-6, on this page). Chinch bugs will float to the surface of the water.

Figure 4-6. Flotation method I for monitoring for hairy chinch bugs.

Method II

Place a cup changer-sized plug (10.8 cm diameter) of turf taken from the edge of a damaged area and submerge in a bucket of water (Figure 4-7, on this page). Chinch bugs will float to the top of the water after 2–5 minutes. The turf plug can be replaced into the lawn.

Figure 4-7. Flotation method II for monitoring for hairy chinch bugs.

Soil sampling

This method works for grubs, weevils and leatherjackets. Use a shovel to cut a measured section of turf or remove a plug of turf with a golf course cup cutter (10.8 cm diameter) or other tool (Figure 4-8, on this page). Turn the sample over and break apart the soil looking for larvae in the thatch and the soil. Count and record the number of larvae found in the sample. Replace the sod or cup changer plug.

Figure 4-8. Cup changer method for sampling for turf insects.

Traps

Black light trap

Black light traps are used to catch nocturnal flying species such as black cutworm adult moths. Solar and battery powered commercial models are available. They consist of a light source, a series of baffles, a funnel and a collection jar. They can be used to determine first flights and peak flights.

Pheromone trap

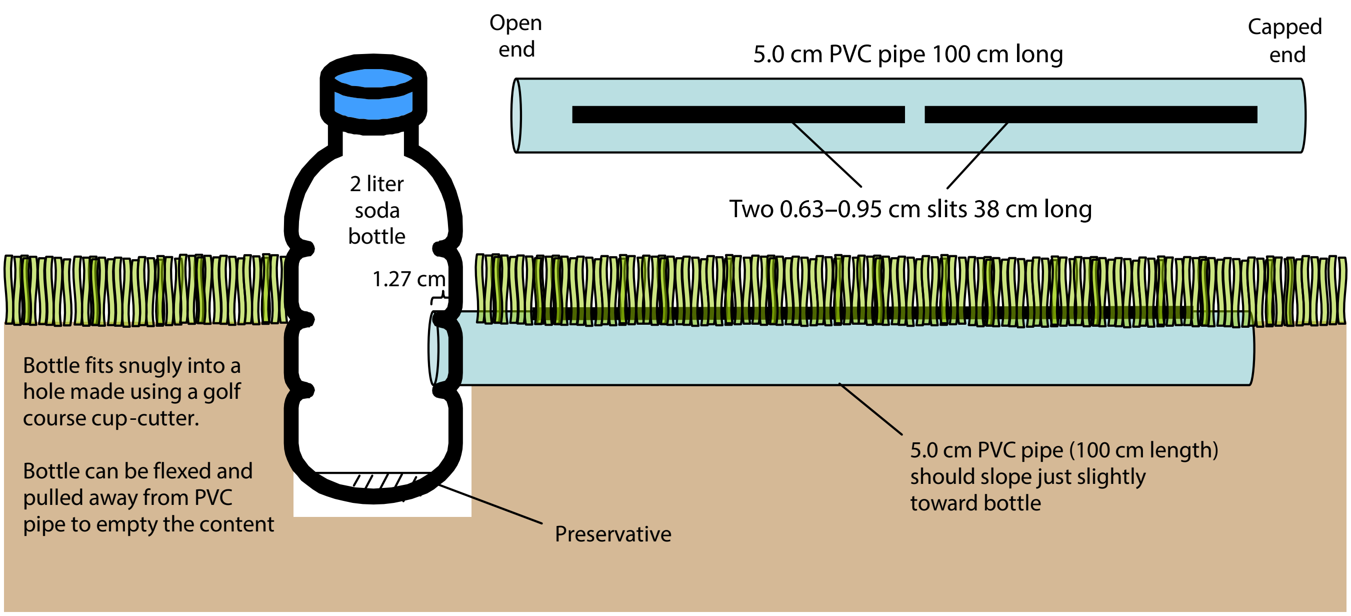
The presence of Japanese beetle, including date of first flights and peak flights can be determined using a Japanese beetle pheromone trap. The trap consists of a slotted vane with a hole in it and a collection container. A pheromone lure and a floral lure must also be placed on the trap. Figure 4-9, on this page, shows the trap with the lures attached. Traps should be placed 3 m downwind of the foliage that the beetles are feeding on and roughly 3–3.5 m from the ground. Empty traps often in areas of high Japanese beetle populations. Beetles can be frozen and counted or weighed.

Figure 4-9. Japanese beetle trap for monitoring adult Japanese beetles.

Richmond linear pitfall traps

These traps are used to monitor for annual bluegrass weevil adults in the spring (Figure 4-10, on this page). They consist of a 1 m length of 5 cm diameter PVC pipe inserted into a 2 L empty pop bottle. The PVC pipe has a slot sawn through the top edge of the pipe.

The pipe is placed at soil level with the slots facing up. The trap is placed along a rough area on the patch of insect migration from protected areas to fairways.



Adapted with the permission of Douglas Richmond, Purdue University

Figure 4-10. Richmond linear pitfall trap.

Record keeping

Regardless of which scouting technique you are using, always record the information, including the date, on a form, map or diagram for future reference. The required recordkeeping for the mandatory Golf IPM Accreditation Program is an online scouting database on the members section of the IPM Council of Canada website at *www.ipmcouncilcanada.org.*

Thresholds

For general information on thresholds, see Chapter 1, *Integrated Pest Management for Turf,* page 11. Thresholds have been established by entomologists for many turf insect pests and provide guidelines for action. They are simply guidelines. Where there are established thresholds they are listed in the section below or under the insect pest name. Refer to Table 4-1, *Turf Insect Summary* on page 35, for details on insect thresholds.

The periods of scouting and damage illustrated here are general guidelines based on field observations and pest biology research in Ontario, but may vary from year to year.

Figure 4-11. Turf insect calendar.

Control Methods

Cultural control

General information on cultural controls that are a necessary part of a turf IPM program can be found in Chapter 1, *Integrated Pest Management for Turf,* page 11.

Selection of turfgrass species

Select turfgrass containing high levels of endophytes. Endophytes produce toxins that repel or kill leaf- and stem-feeding insects such as chinch bugs, webworms, armyworms, aphids, leafhoppers and billbugs. Cultivars of perennial ryegrass, tall and fine fescues that contain endophytes are available from seed suppliers. Manage turf to minimize annual bluegrass. Annual bluegrass is very susceptible to damage from annual bluegrass weevil.

Irrigation management

Many of the root feeding turf insect pests (white grub species) are more of a problem on non-irrigated sites or their damage can be minimized by proper irrigation management. European crane fly larvae prefer heavy, poorly drained wet sites so reducing irrigation in these areas can help create a less favourable environment for this pest. Damage from hairy chinch bugs can often be minimized with adequate irrigation.

Biological controls

Beneficial insects

Beneficial predatory insects can be very abundant in turf. These include ants, ground beetles, spiders, rove beetles and other groups that feed mainly on the eggs or larval stages of insects. Naturally occurring parasitic wasps and flies may also be abundant in turf. Turf management practices which preserve these naturally occuring predators are an important part of a turf IPM program.

Spiders

Spiders are often abundant in turfgrass. All species are predatory, feed mainly on insects and kill their prey by injecting venom as they bite. Some kinds of spiders make small webs in the grass. Others are free-living and rely on ambush or speed to capture their prey.

Ground Beetles

Ground beetles are fast-moving, beneficial insects that are abundant in turf (Figure 4-12, on this page). Both the adults and the soil-inhabiting larvae prey on eggs or larvae of insects, and some species may be important in reducing populations of sod webworms, white grubs or other pests.

Figure 4-12. Ground beetle.

Rove Beetles

Rove beetles are fast-moving, slender, elongate, dark-coloured insects that can usually be identified by the very short elytra that leave much of the abdomen exposed beyond their apices as seen in Figure 4-13, on this page. Most species are predaceous and beneficial.

Figure 4-13. Rove beetle. *(Photo: Dave Cheung, University of Guelph)*

Big-Eyed Bug

Big-eyed bugs are important predators of hairy chinch bugs. They possess piercing, sucking mouth parts that allow them to feed on the liquid contents of chinch bugs as seen in Figure 4-14, on page 42. Big-eyed bugs resemble chinch bugs but are more robust and have large eyes that protrude out of the side of their head. They also move more rapidly than chinch bugs.

Figure 4-14. Big-eyed bug preying on a hairy chinch bug nymph. *(Photo: Dr. David Shetlar, Ohio State University)*

Ants

Ants are mostly beneficial because they prey on the eggs and active immature stages of pest insects. They may play an important role in helping buffer turfgrass against pest outbreaks. Ants are sometimes troublesome, especially on and around golf greens, because the mounds they build interfere with the putting surface.

Wasps

Wasps of several families are sometimes observed hovering over turfgrass in the spring or fall. They are parasitic on turf insects. The scoliid wasps are relatively large, hairy, dark-coloured wasps with yellow or orange markings on the abdomen. Larvae of these wasps are external parasites of white grubs. The tiphiid wasps (Figure 4-15, on this page) are smaller black-and-yellow wasps that parasitize the larvae of Japanese beetles and other scarabs. Females of both groups search out a grub in the soil, sting it to paralyze the grub temporarily and then deposit an egg on the host. Once hatched the maggot-like larva attaches itself to the white grub, pierces the host with its mouthparts and feeds upon the body fluids, ultimately killing the grub.

Figure 4-15. Parasitic wasp. *(Photo: Dr. David Shetlar, Ohio State University)*

Centipedes

Centipedes are fast-moving predators that feed on insects and spiders.

Earthworms

Earthworms feed at night on organic matter on or in the soil. Golf superintendents or landscape managers sometimes regard earthworms as a nuisance because they deposit soil on the turf surface as “castings” that disrupts the smoothness and uniformity of greens or other fine turf.

Earthworms mix organic matter into the soil and break it down in their gut before bacteria and fungi further break it down. Decomposition of thatch is usually much faster when earthworms are abundant. The burrowing activity of earthworms is critical for air and water infiltration in soil. Two-thirds of the total pore space in soils may consist of earthworm tunnels.

Pesticides used on turf can be toxic to earthworms. Considering the importance of earthworms in aerating and enriching the soil, enhancing water infiltration and breaking down thatch, turfgrass managers would be advised to conserve worm populations whenever possible.

Mites

Predatory mites help reduce populations of plant-feeding mites and may also prey on the eggs of pest insects such as sod webworms.

Nematodes and bio-insecticides

As a result of the cosmetic pesticide ban there is a growing interest from manufacturers and end users for insect bio-controls for turf insect pests that are allowed (Class 11 pesticides). To date, there are only a few insect bio-pesticides in this class. Insect parasitic nematodes are living organisms and as such are not regulated by the *Pesticides Act* and Regulation 63/09.

Information on insect parasitic nematodes species for the control of turf insects as well as best management practices for their use can be found in OMAFRA Publication 384, *Protection Guide for Turfgrass*.

Bacteria and fungi

Bacteria can either be ingested by insects and the bacteria produce toxins in the insects gut or the toxin produced by the bacteria can be used as a pesticide. The most common bacteria species are *Bacillus thuringiensis* (*Bt*). There are many strains and each targets a specific insect order. Currently, none of the *Bt* bio-insecticides that are commercially available in Ontario are registered for use on turf pests.

Fungi that attack turf insect pests are naturally occuring in the soil. They produce mycelium and spores that infect insects. One example is the bio-insecticide MET52 (containing the fungus *Metarhizium anisopliae*). It is registered for use against hairy chinch bugs. Trials with the fungus *Beauvaria bassiana* have been conducted against hairy chinch bugs and European chafer but these turf pests have not been added to any of the pesticide labels as of November 2014.

For current information on bio-pesticides registered for use on turf in Ontario refer to OMAFRA Publication 384, *Protection Guide for Turfgrass*.

Chemical controls

Insecticides are important in an IPM program when cultural practices and biological controls are not effective at reducing insect numbers to non-damaging levels. If possible, avoid broadcast or blanket applications of insecticides. These have been shown to reduce the natural populations of the beneficial insects and mites that eat the eggs and larvae of turf pests. Where possible, use spot treatments with selective insecticides. This reduces treatment costs and protects beneficial species.

If an insecticide treatment must be used, make sure the product selected is effective and registered for the specific insect. Apply as a spot treatment instead of broadcast application wherever possible. Be sure to apply it at the right time to have the greatest effect on target species. For example, timing pesticide applications for larval control is critical and must be determined by monitoring, since chemical treatments are more effective when larvae are actively feeding in the root zone.

OMAFRA Publication 384, *Protection Guide for Turfgrass,* contains precautions and guidelines for using pesticides on turf as well as information on products registered for turf on insects, diseases and weeds.

Evaluation

At the appropriate interval after any type of treatment, use visual inspections or counting methods to assess the effect of cultural practices, biocontrol or an insecticide application. Check problem areas the following season at the appropriate time in the life cycle of the insect to look for damage or count populations.

Use this information, along with other scouting records, observations from staff, feedback from clients and user groups to assess the effectiveness of the turf IPM program and find ways to improve it for the following year.

Foliar and Stem Feeding Insects

Black cutworm

Scientific name: *Agrotis ipsilon* (Hufnagel)

Adult description: Adults are dull, grey moths with black markings and the wing span is 2.5–3.7 cm. They have dagger shaped black marking towards the outer edge of the forewings. When at rest, their wings lay outstretched in the shape of a triangle as seen in Figure 4-16, on this page.

Figure 4-16. Adult black cutworm.

Larval description: Larvae are stout, light grey green to nearly black caterpillars with few hairs and a series of small black, shiny dots along their abdomens as seen in Figure 4-17, on this page. They have typical caterpillar characteristics of a hard head-capsule, three pairs of thoracic legs and five pairs of abdominal prolegs (false legs). They can grow up to 3–4.5 mm in length. Larvae curl their bodies when disturbed.

Figure 4-17. Black cutworm.

Damage: The damage caused by larval (caterpillar) feeding can occur on all cool season turfgrasses. Damage is most evident on golf course greens. Larvae dig burrows in thatch or occupy aeration holes. Stems, leaves, and the crown of grass plants may be injured. Linear and irregular sunken brown patches may surround aeration holes as seen in Figure 4-18. Small areas of turf are affected by individual larvae. Heavy infestations can result in large areas of damage. Birds feeding on the cutworms on a golf green can cause additional damage (Figure 4-19, on this page).

Figure 4-18. Typical black cutworm damage on golf greens.

Figure 4-19. Typical damage to golf green caused by birds feeding on black cutworms.

Life history: Black cutworms have complete metamorphosis. They do not overwinter in Canada. In the spring, moths are carried by southeasterly winds from the southern United States into Ontario. Adult moths are active only at night. Females lay their eggs on the tips of individual leaf blades. Daily mowing of golf greens removes eggs before they hatch. If clippings are dumped in close proximity to the green, young larvae will move back into the green. Larvae hatch in 5–10 days, and immediately begin feeding on the grass leaves, feeding only at night. During the day they hide in moist locations such as aeration holes and/or burrows lined with bits of grass and debris. Caterpillars feed for 20–40 days before they pupate. Pupae take 2 weeks to mature. There are two or three overlapping generations in Ontario.

Scouting: Black light traps can be used to determine when flights of adult cutworms occur. A soap flush (15 mL of dishwashing liquid in 4 L of water) can be used to monitor for larvae on closely mown turf. Soft green pellet-like frass found in thatch is associated with cutworm damage (Figure 4-20, on page 45). The suggested threshold is 4–10 per 1 m^2.

Often confused with: Black cutworms are often confused with foliar diseases of turfgrass such as dollar spot.

Cultural control: Dispose greens clippings away from greens to remove cutworm eggs. Mow greens before dawn to mechanically injure cutworms.

Figure 4-20. Soft green pellet-like caterpillar frass.

Figure 4-22. Sod webworm.

Sod webworms

Scientific names: There are thought to be four species of sod webworm in Ontario. Two belong to *Crambus* sp., and one each to *Pediasia* sp. and *Chrisoteuchia* sp.

Adult description: Adults are small tan moths, 0.6–1.2 cm long. Some species, like the silver-striped webworm, have a white stripe along the leading edge of the forewing as seen in Figure 4-21, on this page. Mouth parts form a snout, typical of this group of snout moths. Wings are folded around their abdomen at rest.

Figure 4-21. Adult sod webworm moth.

Larval description: Full grown caterpillars are 2 cm long and vary in colour from greenish to brown or grey as seen in Figure 4-22, on this page. They have rows of darker spots along their back and are sparsely covered with long hairs. The head capsules are brown and they have three pairs of thoracic legs and five pairs of abdominal prolegs (false legs).

Damage: Sod webworm feed on all species of turfgrass. They are mostly a problem on home lawn turf and roughs and fescue mounds on golf courses. Early signs of damage are scattered, irregular brown patches of wilted turf. As infestation continues these areas grow until an entire lawn can be damaged. The dead grass pulls away easily in clumps, revealing soft green pellet-like frass particles embedded in the thatch as seen in Figure 4-20, on this page.

Damage is species dependent. It ranges from individual notched leaves to severed grass stems and leaves which are pulled into silken tunnels. Cranberry girdler feeds in the thatch cutting off the turfgrass crowns and stems from the roots. This causes damage similar to grub damage. Thatch pulls away from roots like a carpet but at the thatch/grass interface. There are several generations throughout the summer resulting in large numbers of sod webworms by mid-late summer. The major period of damage is late August and September.

Life history: Sod webworm has complete metamorphosis. It overwinters as final instar caterpillars, pupates in the spring and adults emerge and become active in the warm evenings of late May and June and can be seen darting out of the turf when disturbed. Adults hide during the day in the turfgrass or in nearby bushes. They fly in the evenings laying eggs randomly into the lawn. As many as 400 eggs may be laid by females of some species but in most species 30–50 eggs is normal.

Small caterpillars hatch from eggs and then they mine the surface tissue of turfgrass leaves. Following that they work their way down the margin of the leaf blade, giving it a notched appearance. Larger larvae construct silken burrows in the thatch where they hide during the day. There are two or three generations of some species in Ontario so life stages of several species may overlap. By late September, full-grown caterpillars become dormant after burrowing into the thatch or soil and overwinter.

Scouting: A soap flush (15 mL of dishwashing liquid in 4 L of water) can be used to monitor for larvae on home lawn turf in late August to late September as seen in Figure 4-4. For more information on soap flushes see the *Scouting,* page 34. Soft green pellet-like frass found in thatch is associated with sod webworm damage (Figure 4-20, on page 45). The suggested threshold is six or more caterpillars per 0.1 m^2.

Sod webworm damage is often confused with grub damage.

Cultural control: Endophyte-enhanced cultivars of perennial ryegrass, tall fescue and fine fescue resist sod webworm feeding.

Crown and Thatch Feeding Insects

Annual bluegrass weevil

Scientific name: *Listronotus maculicollis* (Dietz)

Adult description: Adult weevils are 3–4 mm in length with a typical weevil curved snout. They are dull brown to black in colour with scales on wing covers that are yellow to greyish white in colour as seen in Figure 4-23, on this page. The snout of annual bluegrass weevils is much shorter than bluegrass billbug. Antennae rise from the tip of the snout.

Figure 4-23. Adult annual bluegrass weevil.

Larval description: Annual bluegrass weevil larvae are straight to slightly crescent-shaped, creamy white as seen in Figure 4-24, on this page. They are legless and have a reddish to dark brown head capsule. They range in size from 1–4.5 mm from 1–5th instar. Pupae resemble the adults and start out creamy white but turn a reddish brown as they mature.

Figure 4-24. Annual bluegrass weevil larva.

Damage: Annual bluegrass weevil damage is caused by larval feeding. It occurs in mid-late June on fairways, tees, collars of greens and other closely mowed turf composed mainly of annual bluegrass (*Poa annua*). Damage begins as small patches of yellow to brown wilted annual bluegrass on collars and perimeters of fairways that may coalesce into large dead areas as seen in Figure 4-25, on page 47. At first, individual stems turn yellow and can be pulled out easily with the "tug test" because they are weakened or severed. Older larvae are in the soil or thatch and feed at the crowns and cause the bulk of the damage. Stems and leaves have a characteristically U-shaped end where larvae have severed them and there may be sawdust like frass associated with annual bluegrass weevil damage. Feeding by second generation larvae seems to be less severe and scattered, rarely resulting in damage.

Life history: Adults spend the winter in protected areas along defined tree lines in leaf litter adjacent to the low mowed areas of annual bluegrass. They become active as the weather warms up early in the spring and walk back into low mowed turf areas. Adult migration appears to be bimodal. The first wave of adults start migrating when the flowering shrub forsythia begins to bloom and peak at full bloom of forsythia (Figure 4-26, on page 47) and early bloom of magnolia (Figure 4-27, on page 47). The second wave of adults peaks at full bloom of horse chestnut (Figure 4-28, on page 48) and full bloom of bridal wreath spirea (Figure 4-29, on page 48).

Figure 4-25. Typical annual bluegrass weevil damage.

Females chew a small hole in the grass stem and insert one or two eggs between the leaf sheath and stem. Egg hatch takes 4–5 days. Young larvae feed within the stem. Larger larvae drop to the soil and feed on roots and stems in the thatch/soil interface. After four or five weeks of feeding, the larvae burrow into the soil and construct a small earthen cell where they change to the pupal stage. Pupae are quite active when disturbed. They take 5–10 days to transform into soft, tan-coloured adults (callow adults). Adults gradually darken as they mature. There may be a second generation in parts of southwestern Ontario. Winter migration begins in August and by early to mid-September the adults have moved to their overwintering sites by flying to the tree lined protected areas adjacent to their summer feeding sites.

Figure 4-26. Forsythia full bloom.

Figure 4-27. Early bloom of magnolia.

Figure 4-28. Full bloom of horse chestnut.

Figure 4-29. Full bloom of bridal wreath spirea.

Often confused with: Annual bluegrass weevil damage is often confused with anthracnose basal rot.

Scouting: A soap flush (15 mL of dishwashing liquid in 4 L of water) can be used to monitor for adults migrating from overwintering sites as seen in Figure 4-4, on page 37. A saturated salt solution can be used for all other stages such as egg to 5th instar larvae (360 g salt per L of water) as seen in Figure 4-5, on page 38. For more information about soap flushes and saturated salt solution see *Scouting* section on page 34.

Thresholds: The threshold is 3–5 larvae per cup changer for the spring generation.

Cultural control: Minimize the amount of annual bluegrass on golf course fairways, tees, etc. If large number of adults are observed in soap flushes, spray insecticide on fairway perimeters only.

Bluegrass billbug

Scientific name: *Sphenophorus parvulus* (Gyllenhal)

Adult description: Adult weevils are black to grey and 7–8 mm long as seen in Figure 4-30, on this page. They have a typical weevil curved snout with the antennae rising from the base of the snout. Wing covers have parallel row indents with pits in between the rows.

Figure 4-30. Adult bluegrass billbug.

Larval description: Larvae are straight to slightly crescent-shaped, creamy white, legless with reddish to dark brown head capsule (Figure 4-31, on page 49). Mature larvae are slightly bigger than annual bluegrass weevil and are 8 mm long. Pupae are creamy white and resemble adults and turn brown as they mature.

Figure 4-31. Bluegrass billbug larvae.

Damage: The preferred host is Kentucky bluegrass but it will feed on perennial ryegrass, tall fescue and fine fescue. It is mainly a pest of home lawns and other areas of turf comprised of high cut Kentucky bluegrass. It begins as small patches of yellow to brown wilted Kentucky bluegrass as seen in Figure 4-32, on this page. Young larvae feed within grass stems. Individual grass stems can be pulled up easily when using the "tug test". Older larvae reside in the thatch and feed on the crowns of grass plants. Frass as seen in Figure 4-33, on this page, may be evident in the thatch layer where bluegrass billbugs have been feeding. The main period of feeding damage is mid-July to the end of August.

Figure 4-32. Typical bluegrass billbug damage.

Figure 4-33. Bluegrass billbug frass.

Life history: Bluegrass billbug has one generation per year. Adult weevils overwinter in protected areas in leaf litter, hedgerows and foundations of buildings. They become active early in the spring, wandering back to lawns or other turf areas. They can be seen on paved areas or around the foundations of buildings. During this period they feed briefly on grass leaves and stems. By late June females deposit eggs under the leaf sheaths. After the eggs hatch, the larvae feed in the stem of the grass plants. When they outgrow the stem they move to the soil and feed on the crowns and roots. By the end of August feeding has stopped and new adults emerge. By October adults have moved back to overwintering sites

Often confused with: Bluegrass billbug damage is often confused with drought and summer dormancy.

Scouting: A saturated salt solution can be used for all larval stages.

Thresholds: No thresholds have been established.

Degree day model: Using March 1 as a starting date and 10ºC as the base temperature the adult migration from overwintering sites begins between 155–195 DD. Larvae emerge from stems 513–575 DD. The damage period occurs at 739–825 DD.

Cultural control: Lawns composed of grasses high in endophytes are more resistant to bluegrass billbug feeding and damage.

European crane fly

Scientific name: *Tipula paludosa* (Meigen)

Adult description: Adults resemble large mosquitoes as seen in Figure 4-34, on this page, and range in length from 1.5–2.5 cm and have a greyish-brown body. They have two narrow wings and very long, slender brown legs and are relatively weak flyers. They do not bite.

Figure 4-34. Adult crane fly.

Larvae description: Larvae are light grey to greenish-brown with irregular black specks. They range in size from 0.5 cm in length in the first instar to 3–4 cm at maturity and are called leatherjackets (Figure 4-35, on this page). Pupae are formed inside the last instar cuticles called puparia. Pupae are brown and spiny and 3–4 cm in length as seen in Figure 4-36, on this page. Adults emerge, leaving the puparia behind.

Figure 4-35. Leatherjacket.

Figure 4-36. European crane fly pupae.

Damage: Leatherjackets feed primarily on turf on home lawns, golf courses, sod farms and pasture grasses. They feed during the day at or below the surface of the turf on root hairs and roots. At night, they come to the surface of the turf and eat stems and grass blades. Damage starts as yellow spots and thinning progressing to bare patches of soil as seen in Figure 4-37, on this page. Peak damage in Ontario occurs in May. Secondary pests such as skunks and starlings can also cause damage. Skunks dig up small patches of turf in search of leatherjackets and birds peck them out of turf during May and June. On putting greens birds peck out leatherjackets leaving small holes as seen in Figure 4-38, on page 51.

Figure 4-37. Typical leatherjacket damage.

Figure 4-38. Damage to golf green caused by birds pecking for leatherjackets.

Life history: European crane flies complete one generation per year in Ontario. Adults emerge throughout September, depending on the location within Ontario. Females will mate and lay their eggs within 24 hours of emerging. Eggs can be present in the soil from the beginning of September until the middle of October. One female can lay 200–300 eggs. Eggs are very susceptible to drying out and require moisture to hatch. Egg hatch occurs in 10–14 days. Larvae are present from the beginning of October until the end of August the following year. They pass through 3–4 instar molts in the fall and generally overwinter as third or fourth instars.

In the fall and early spring, larvae feed in the top of the thatch and on the leaf blades. Later in the spring, the larger instars reside in the soil (1–3 cm deep) during the day and feed on the grass blades at night. Feeding by the fourth instar larvae causes the majority of the damage in the spring. Heavy spring rains often force the larvae to the surface of the turf and onto hard surfaces such as driveways and sidewalks. By mid-June, the larvae cease feeding, move down in the soil (3–5 cm) and remain in a non-feeding stage until pupation. Pupation occurs from late August through early-to-mid-September, when the pupae wriggle to the top of the soil in the late night to early morning and the adults emerge. Empty pupal cases look like small twigs protruding from closely mowed turf.

Often confused with: Damage from leatherjackets is often confused with black cutworm damage.

Scouting: A saturated salt solution can be used for all larval stages.

Thresholds: No thresholds have been established in Ontario.

Examples of thresholds used by turf managers for leatherjackets in British Columbia are:

- Class A sites: 2.0–2.5 larvae/0.1 m^2 in spring
- Class B sites: 5–10 larvae/0.1 m^2 in spring
- Class C sites: over 10 larvae/0.1 m^2 in spring or 30 larvae/0.1 m^2 in fall (the higher level in the fall is acceptable because many larvae die over winter)

Cultural control: Maintain a healthy turf stand, through proper mowing and fertility. Improve drainage to help dry out soils and deter females from laying eggs. Newly hatched larvae also have poor survival in dry soils.

For more information on European crane fly see OMAFRA Factsheet *European Crane Fly.*

Hairy chinch bug

Scientific Name: *Blissus leucopterus hirtus* (Montandon)

Adult description: Adults are very small, about 3–3.5 mm long, black and white in color, with reddish-brown legs with two pairs of wings which are folded over the back of the insect (Figure 4-39, on this page). Forewings are thickened at the base with black markings, a black triangle at the base of the wings and a black triangle at the tip of the forewings. The hindwings are transparent. Some adults may have very short wings. Adults and nymphs (Figure 4-39, on this page) have piercing-sucking mouth parts. Nymphs (immature stages) look similar to the adults but are smaller in size, reddish color

Figure 4-39. Hairy chinch bug adult (top) and nymph (bottom). *(Photo: Dr. David Shetlar, Ohio State University, Bugwood.org)*

with a white stripe across their back, and have wing buds that do not cover the entire abdomen. Hairy chinch bugs have incomplete metamorphosis so there is no pupal stage.

Nymph description: Immature nymphs are bright red in colour when they first hatch, and begin to darken from brick red to grey/brown when they are nearly mature as seen in Figure 4-40, on this page. Larger nymphs have a characteristic white band across their abdomen, which is eventually covered by the enlarging wings as the insects become larger and mature. Wing pads are present on the last instar.

Figure 4-40. Hairy chinch bug nymph.

Damage: Damage is caused by nymphs feeding with their piercing-sucking mouthparts. It is mostly on home lawns but can be found occasionally on sod farms. Damage occurs first in areas near hedgerows, flower beds, and other overwintering sites. It begins as small fist sized sunken irregular brown patches in mid-late July. Areas appear sunken because nymphs have sucked the juices out of the plant (Figure 4-41, on this page). It spreads quickly in sunny areas of lawns and is worse during hot, dry summers (Figure 4-42, on this page). Entire lawns can be killed, leaving sunken dead patches of turf. Damage can be diagnosed by pulling the dead grass blades which remain well rooted and will not pull away when tugged.

Figure 4-41. Early hairy chinch bug damage.

Figure 4-42. Late summer hairy chinch bug damage.

Life history: Hairy chinch bugs have one generation per year in Ontario. Adults move into protected areas under hedges, in flower beds or near foundations in leaf litter and mulch to overwinter. In the spring when temperature reaches 7°C adults move out from these areas by walking and occasionally flying. Adults feed and mate in spring. Females lay eggs in the leaf sheath and on turf roots. Peak egg laying coincides with early bloom of bird's-foot trefoil and white clover (Figure 4-43, on page 53). Eggs hatch in 7–10 days. The small nymphs hatch and feed by piercing the plant tissue and sucking out the juices. Feeding lasts for 4–6 weeks. The bulk of the damage is caused by the late instars (stages) in mid-July to mid-August. Nymphs prefer sunny locations to feed. Adults begin to appear by early August and may feed for several weeks. In hot weather in late summer, adults migrate in large numbers searching for overwintering sites.

Figure 4-43. Bird's-foot trefoil in early bloom.

Often confused with: Hairy chinch bug damage is often confused with drought and bluegrass billbug damage.

Scouting: For information on hairy chinch bug scouting methods see *Scouting* on page 34.

Threshold: If more than 20 chinch bugs are found with the cylinder method, damage is likely to occur. If more than 10 chinch bugs are found using the cup changer and bucket method, damage is likely.

Cultural control: Endophyte-enhanced cultivars of perennial ryegrass, tall fescue and fine fescues resist hairy chinch bug feeding. Hairy chinch bugs cause less damage on irrigated sites.

For more information on hairy chinch bug refer to OMAFRA Factsheet *Hairy chinch bugs in lawns.* This factsheet can be found on the OMAFRA website at *www.ontario.ca/crops*.

Turfgrass scale

Scientific name: *Lecanopsis formicarum* (Newstead)

Adult description: Oblong adult females have the typical scale shape (hard clam-shaped cover) with a yellow centre and broad, brown lateral stripes on each side as seen in Figure 4-44, on this page. The underside of the insect has sucking mouth parts. They are about 1.5 mm wide by 2.5 mm long. Females produce a cottony mass of silk containing about 400 salmon-pink colored eggs (Figure 4-45, on this page).

Figure 4-44. Adult turfgrass scale.

Figure 4-45. Turfgrass scale eggs. *(Photo: Dr. Mark Sears, University of Guelph)*

Larval description: Larvae of scale insects are called crawlers. They are minute elongate-oval crawlers that are reddish in colour, very active and roughly the size of the head of a pin. There are two additional nymphal instars that occur during the remainder of the summer and fall. The mature nymphs are the size of a kernel of uncooked rice, pink in colour and have a waxy coating (Figure 4-46, on page 54).

Figure 4-46. Mature turfgrass scale nymphs. *(Photo: Dr. Mark Sears, University of Guelph)*

Damage: Damage from turfgrass scale occurs on Kentucky bluegrass, fescues and creeping bentgrass. It appears as thin areas of turf that do not green up and resume growing rapidly in the early spring. In some areas the grass is killed. This is caused by the mature nymphs feeding on the plant sap on the crowns of the grass plants. First instar nymphs or crawlers are found during the early part of July and they can cover the leaf blades so that they are a rusty red color. Intermediate stages of nymphs do not move and feed on the tillers of host grasses, usually at the base of leaves and stems. Later in the season they feed on rhizomes.

Life history: In Ontario, mature nymphs are found during the fall and overwinter in this stage. Nymphs become adults in May and June and produce cottony masses of silk containing eggs. Eggs hatch into crawlers that are found in late June and July. At the peak of their activity, crawlers move to the tips of the grass blades, turning the turf reddish and are dispersed by wind or rain. First-stage nymphs are present in July and August. Intermediate-stage nymphs are present from August into October and the final stage, mature nymph overwinters.

Often confused with: Turfgrass scale injury is often confused with winter injury.

Scouting: There is no specific scouting method for this insect pest.

Cultural control: Washing lawns with a high pressure hose when scale crawlers are seen in a lawn may provide some control.

Soil Inhabiting Insects

Black turfgrass ataenius

Scientific name: *Ataenius spretulus* (Haldeman)

Adult description: Adult beetles are quite small, 5 mm long, black and shiny. See Figure 4-47, on this page. Their wing covers have a series of longitudinal grooves. A distinguishing feature is several rows of very small spines along the hind legs as seen in Figure 4-48, on this page.

Figure 4-47. Adult black turfgrass ataenius.

Figure 4-48. Spines on hind legs of black turfgrass ataenius.

Larval description: Immature stages are called grubs. They range in size from less than 2.0 mm long upon hatching to about 5.0 mm when mature (Figure 4-49, on this page). They have the typical C–shape of all grub species. They have a a yellow-brown head capsule and three pairs of legs and are milky white in colour. As they feed and mature they accumulate material in their gut, giving the tip of their raster (an area on the underside of the abdomen near the tip) a dark appearance. On the raster is a series of very small and randomly placed spatulate spines with an anal slit that is broadly curved with two lobes beneath as seen in Figure 4-50, on this page.

Figure 4-49. Typical black turfgrass ataenius grubs.

Figure 4-50. Raster pattern of black turfgrass ataenius grubs. *(Photo: Dr. David Shetlar, Ohio State University)*

Damage: Black turfgrass ataenius is a pest of closely mown golf course turf (annual bluegrass and creeping bentgrass). Damage is typical of that caused by all members of the scarab beetle grubs which feed on grasses. Grubs feed on the turfgrass roots and roots of other plants. Initially grass blades wilt and die in irregular patches as seen in Figure 4-51, on this page. Dead patches of turf can be easily pulled loose from the soil like a carpet. Turf turns yellow in mid-July as if drought stressed. The majority of damage is caused by third instar grubs. Dead patches increase in size until the grubs stop feeding and change into the pupal stage. The occurrence of a second generation in Ontario and the extent of damage caused is not consistent. The majority of the damage in Ontario has been associated with the first-generation grubs.

Figure 4-51. Black turfgrass ataenius damage.

Life history: Black turfgrass ataenius have one generation a year in Ontario. Occasionally there is a second generation. Adults overwinter in leaf litter at the edge of wooded areas, in roughs and the perimeter of golf holes. Adults return to the turf on golf courses beginning in early May and can be found on greens and tees through to mid-late June. Adult migration coincides with *Poa annua* seed head production or when 100–150 growing degree days (GDD) above 13°C beginning on April 1. Peak egg laying coincides with full bloom of horse chestnut (Figure 4-28, on page 48) and full bloom of bridal wreath spirea (Figure 4-29, on page 48). Eggs are laid in fairways and can also be laid on greens and tees. Grubs hatch quickly and feed until the end of July.

In late July to early August third instar grubs finish feeding and migrate several cm deep into the soil to pupate. Callow (light brown) adults appear a short time later. Second generation adults may lay eggs in the turf or search for new overwintering sites. Second generation eggs are found when 650–700 GDD base 13°C beginning on April 1 have accumulated, or when Rose of Sharon (Figure 4-52, on page 56) begins to bloom which is normally in late July.

Figure 4-52. Full bloom of Rose of Sharon.

Often confused with: Black turfgrass ataenius grub damage is often confused with June beetle grub damage, annual bluegrass weevil damage or drought.

Scouting: For information on soap flushes and soil sampling for insects see *Scouting* on page 34.

Cultural control: Cultural control includes proper irrigation promoting deep roots, aeration, balanced fertility and increased mowing height.

Aphodius granarius

Scientific name: *Aphodius granarius* — there is no common name for this pest.

Adult description: Adult *Aphodius granarius* resemble black turfgrass ataenius but are slightly smaller, 3–5 mm long, black and shiny. The hind legs of Aphodius have two rows of tibial spines as seen in Figure 4-53, on this page.

Figure 4-53. Tibial spines of *Aphodius granarius.*

Larval description: The immature stages are grubs and are often mistaken for black turfgrass ataenius grubs.

They range in size from less than 2.0 mm long upon hatching to about 5.0 mm when mature and have the typical C-shape of all grub species, with a yellow-brown head capsule and three pairs of legs. Raster (an area on the underside of the abdomen near the tip) pattern is two rows of spines forming a shallow V and the anal slit is one lobe that is indented in the middle as seen in Figure 4-54, on this page.

Figure 4-54. Raster pattern of *Aphodius granarius* grubs. *(Photo: Cornell University collection: NYSAES)*

Damage: *Aphodius granarius* is a minor pest of golf courses in Ontario. Grubs feed on the same turfgrass species as black turfgrass ataenius. Refer to damage cause by black turfgrass ataenius (page 55).

Life history: Little is known about the life history of *Aphodius granarius*. Adults are present on golf greens in May and again in August and September. Adults of this species feed on decaying vegetation such as thatch.

Peak grub damage occurs in late June which is about a month earlier than black turfgrass ataenius.

Often confused with: *Aphodius granarius* damage is often confused with June beetle grub damage, annual bluegrass weevil damage, black turfgrass ataenius damage and drought.

Scouting: For information on soap flushes and soil sampling for insects, see *Scouting* on page 34.

Cultural control: Cultural practices that help mitigate *Aphodius granarius* damage are proper irrigation promoting deep roots, aeration, balanced fertility and increased mowing height.

White grubs or June beetles

Scientific name: *Phyllophaga* sp. It is thought that seven species occur in Ontario.

Adult description: Adult June beetles are typical scarab beetles ranging in colour from black to light brown and ranging in size from 13–23.5 mm in length with long, spiny legs. They are the largest of the scarab species found in Ontario. Wing covers range from smooth and shiny to very hairy and dull (Figure 4-55, on this page). The tarsal claw of June beetle adults have a distinct tooth (Figure 4-56, on this page).

Figure 4-55. Adult June beetle.

Figure 4-56. Tarsal claw of adult June beetle.

Larval description: Larvae of June beetles are white grubs. They have a brown head capsule, C-shaped body and three pairs of legs. They range in size from 6.6 mm to 25–38 mm when full grown. The distinguishing features are two parallel rows of stout spines which converge at the tip on the raster and a Y-shaped anal slit with the base of the Y much shorter than the arms as seen in Figure 4-57, on this page.

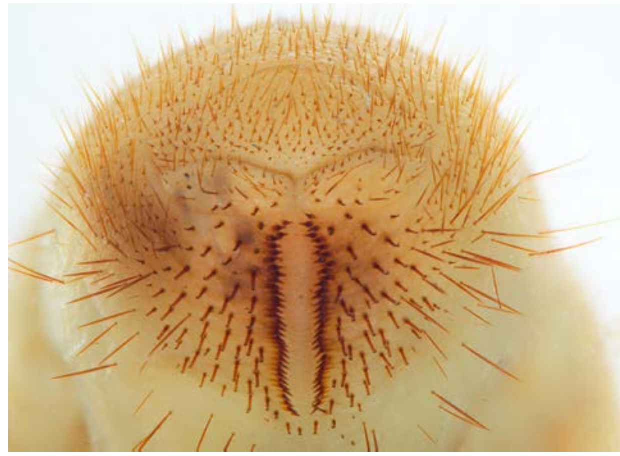


Figure 4-57. Raster patterns and anal slit of June beetle grubs. *(Photo: Dave Cheung, University of Guelph)*

Damage: White grubs feed on the roots of all turfgrass species, pasture grasses, field crops as well as many species of shrubs and tree seedlings. In turfgrass, turf appear wilted, turns yellow and dies in patches.

These patches can spread quickly. Loose mats of dead and dying turf can be lifted like a carpet because all of the roots have been eaten (Figure 4-58, on page 58). The major season of damage is during June and July of the 2nd year of their 3 year life cycle. Adult beetles can also cause extensive damage by feeding on the foliage of many broadleaf trees and shrubs, such as oak, poplar, maple, willow and ash. Secondary damage can be caused to turf by insect eating birds, skunks and raccoons.

Figure 4-58. June beetle grub damage.

Life history: June beetles have a three year life cycle. Large numbers of adults fly at night beginning in late May through to mid-late June. Adults are attracted to street lamps and lights from windows. Females lay eggs in late May or June in grassy area. Eggs hatch in a few weeks and the small larvae feed on grass roots for the remainder of the summer. Second instar grub spends the winter in the soil. They resume feeding in early to late May and feed until late October. They molt into third instars in June and it is that stage that causes the majority of the damage. They overwinter as third instar grubs. Mature third instar grubs return to the surface, feed for a short time the following spring and then molt into the pupal stage. The pupae are converted to the adult during the summer. They overwinter as mature adults in the soil and emerge from the soil the following May/June to initiate another cycle.

Often confused with: June beetle grub damage is often confused with drought and damage from other grub species.

Scouting: Soil sampling using a golf course cup changer can be used to monitor for grubs. Take a plug roughly 10 cm deep and inspect the soil for grubs. Replace soil and turf plug. Multiply the number of grubs per cup changer by 10.5 to determine the number of grubs per 0.1 m^2. Scout for white grubs several weeks after a heavy flight of adult beetles occurs. Start with sandy soil areas because adults prefer to lay eggs in light textured soils. The threshold is 3–5 grubs per 0.1 m^2.

Cultural control: Cultural controls for grubs include proper irrigation promoting deep roots, aeration, balanced fertility and increased mowing height.

For more information on June beetles, refer to OMAFRA Factsheet *Grubs in Lawns*. This factsheet can be found on the OMAFRA website at *www.ontario.ca/crops*.

European chafer

Scientific Name: *Rhizotrogus majalis* (Razoumowsky)

Adult descripton: Adults are typical scarab beetles are very similar to June beetles, except that they are slightly smaller and fawn coloured and are about 14 mm in length as seen in Figure 4-59, on this page. They have yellow hairs on the margin of their wing covers. The tarsal (foot) claws do not have a distinct tooth, unlike June beetles (Figure 4-60, on this page).

Figure 4-59. Adult European chafer.

Figure 4-60. Tarsal claw of European chafer.

Larval description: Larvae of this insect are white grubs. They have a brown head capsule, three pairs of legs and a distinctive C shaped body. The raster has two nearly parallel rows of spines which diverge at the tip and a Y-shaped anal slit in which the base of the Y is 1/3 to 1/4 the length of the arms as seen in Figure 4-61, on this page.

Figure 4-61. European chafer grub raster pattern and anal slit. *(Photo: Dave Cheung, University of Guelph)*

Damage: Damage occurs on all common species of turfgrasses as well as on many other grasses, legumes, and crops such as potatoes, corn, beans and ginseng. Adults do not feed to any extent. The first sign of damage is wilted turf that turns yellow and dies. Dead brown patches are irregular and increase in size throughout the fall. Areas of turf can be lifted like a carpet because the roots have been eaten.

It is more of a problem on sandy, light textured soils. The majority of the damage is from 3rd instar grubs feeding in early fall. The damage will continue to spread into late fall. If fall has abundant rainfall, grubs may be present and feeding but there may be no damage. Secondary damage can be caused by starlings, skunks and other small mammals digging in the turf looking for grubs.

Life history: European chafers have one generation a year. Between late June and mid- July beetles emerge from the turf at dusk. Peak adult flights which coincide with full bloom of catalpa (Figure 4-61, on this page). Adult beetles crawl up grass stems and then fly up to and around trees where they mate for roughly one hour. In the absence of trees they swarm around lamp poles and chimneys. Swarms of mating beetles can be seen around trees at dusk and they sound like swarms of honey bees. Adults are active at dusk and fly back to the ground each night for two to three weeks. Females lay between 25–50 eggs and they prefer to lay their eggs in mowed turf. Grubs hatch in mid to late July and become mature 3rd instar grubs in seven to eight weeks in mid-late September. Grubs overwinter in the 3rd instar and return to the surface in early April and feed very briefly. Phenological relationships exist between the presence of pupae and the full-bloom period of bridal wreath spirea (Figure 4-29, on page 48).

Figure 4-62. Full bloom of catalpa.

Often confused with: Damage from European chafer is often confused with drought and damage from other grub species

Scouting: The best time to begin monitoring for grubs is roughly a month after peak adult flights. Soil sampling using a golf course cup changer can be used to monitor for grubs. Take a plug roughly 10 cm deep and inspect the soil for grubs. Replace soil and turf plug. Multiply the number of grubs per cup changer by 10.5 to determine the number of grubs per 0.1 m^2. Scout for white grubs several weeks after a heavy flight of adult beetles occurs. Start with sandy soil areas because adults prefer to lay eggs in light textured soils. The threshold is 5–10 grubs per 0.1 m^2 on non-irrigated turf greater than 20 per 0.1 m^2 on irrigated turf.

Cultural control: Cultural controls for grubs include proper irrigation promoting deep roots, aeration, balanced fertility and increased mowing height.

For more information on European chafers refer to OMAFRA Factsheet *Grubs in Lawns.* This factsheet can be found on the OMAFRA website at *www.ontario.ca/crops*.

Japanese beetle

Scientific name: *Popillia japonica* (Newman)

Adult description: Adults are scarab beetles but are very distinctive with bright metallic green thorax, copper coloured wing covers and six tufts of white hairs along either side of their abdomen as seen in Figure 4-63, on this page. They are slightly smaller than European chafer adults and are 8–12 mm long.

Figure 4-63. Japanese beetle adult.

Larval description: Larvae of this insect are white grubs. They have a brown head capsule, three pairs of legs and a distinctive C shaped body. They range in size from 1.5–25 mm long when mature. The distinguishing features of the larvae are two short rows of stout spines in a V pattern on the raster, and a crescent-shaped anal slit as seen in Figure 4-64, on this page. Pupae resemble the adult but the wings and legs are folded closely to the body.

Figure 4-64. Raster pattern and anal slit of Japanese beetle grub. *(Photo: Dave Cheung, University of Guelph)*

Damage: Adults differ from many other scarab family members by feeding on a wide variety of fruits, vegetables and foliage plants and can cause damage (Figure 4-65, on this page). Grubs are a considerable problem on turf and they damage roots of many woody ornamentals and vegetables. Damage to turf has the typical wilt and yellowing symptoms of grub damage beginning in September. By mid-late September damage can range from patchy areas of dead turf to very large dead areas by mid-late October. Third instar grub feeding causes the majority of the damage. Dead turf can be lifted from the soil like a carpet because the roots have been eaten. Secondary damage can be caused by starlings, skunks and other small mammals digging in the turf looking for grubs.

Figure 4-65. Adult Japanese beetle feeding damage wild grape leaves.

Life history: Japanese beetles have a one year life cycle in Ontario. Adult beetles emerge during the first two weeks of July and live for 30–45 days and feed on a wide variety of plants. Each female can lay 40–60 eggs in the soil under suitable plant species. Grubs hatch in two weeks and begin to feed on roots. Grubs molt through 2 instars. Grubs reach the third instar by late October and move down in the soil and overwinter. The following spring grubs move back to the surface and feed briefly before they pupate in June and remain in the soil for 1–3 weeks before new adults emerge. Both fall and spring are periods of potential turf damage by grubs and by July adults emerge and cause damage to ornamental plants.

Often confused with: Damage from Japanese beetle grubs is often confused with drought and damage from other grub species.

Scouting: Japanese beetle traps are available commercially. They consist of a trap, a sex attractant and a floral lure. These traps can collect large numbers of adults but are best used to monitor adult activity. More information on Japanese beetle traps can be found in *Traps* section on page 39. Soil sampling for grubs can be done using a golf course cup changer. Take a plug roughly 10 cm deep and inspect the soil for grubs. Replace soil and turf plug. Multiply the number of grubs per cup changer by 10.5 to determine the number of grubs per 0.1 m^2. Scout for white grubs several weeks after a heavy flight of adult beetles occurs. Start with sandy soil areas because adults prefer to lay eggs in light textured soils. The threshold is 10 grubs per 0.1 m^2 on irrigated turf.

Cultural control: Cultural controls for grubs include proper irrigation promoting deep roots, aeration, balanced fertility and increased mowing height.

For more information on Japanese beetles, refer to OMAFRA Factsheet *Grubs in Lawns.* This factsheet can be found on the OMAFRA website at *www.ontario.ca/crops.*

Other Turf Insect Pests

Turfgrass ant

Scientific name: *Lasius neoniger*

Adult description: Turfgrass ants are relatively small and light tan to dark brown as seen in Figure 4-66, on this page. The colony consists of workers which are 3 mm in length and queens about 10 mm in length. They have an opening in their abdomen to spray venom/formic acid at other insects.

Figure 4-66. Turfgrass ant. *(Photo: Dr. David Shetlar, Ohio State University)*

Damage: Turfgrass ants do not feed on the turfgrass plant. They inhabit nests below the putting surface on putting greens, tees and fairways. They produce small mounds of excavated soil that form a crater-like opening at the entrance to their nests that are roughly 2–4 cm in diameter. These mounds smother the grass below and leave bare areas in the turf and dull greensmower blades. They are usually concentrated within 1–2 m of the perimeter of greens as seen in Figure 4-67, on this page.

Figure 4-67. Ant mounds on the perimeter of a sand based green.

Social behavior and seasonal activity: The turfgrass ant is native to North America. It is a social insect that lives in colonies. They feed on small insects and insect eggs. They are predators of cutworm eggs and larvae, white grub eggs and small grubs. Food is shared by regurgitation. Small insecticide doses can reach the entire nest. The colony is comprised of thousands of female worker ants and one reproductive queen. The colony is composed of multiple interconnected chambers from 25–30 cm deep. Each chamber is capped with a crater like sand mound.

Ant populations increase from early spring to late summer as the colony grows. The queen produces eggs in the spring. The offspring develop through May to July. These new adult workers begin to emerge and build more mounds. In late summer a large portion of the colony develops into winged reproductive females and males (drones). In mid-summer reproductive females and males swarm by the thousands on warm days in late afternoon. Females and drones mate while flying. Newly mated queens form a new chamber in the nest and lay eggs to produce workers to colonize the nest. Ants hibernate in the colonies over the winter and begin to be active again in early spring.

Scouting: Use visual inspection in the spring to observe ant mounds around the perimeter of greens in the spring.

5. IPM for Turf Diseases

Diseases

Plant pathology is the study of agents and environmental conditions that cause disease in plants, of the mechanisms and processes by which these factors produce disease in plants, of the interactions between disease-causing agents and diseased plants, and of the methods of preventing and managing plant disease. The aspect of plant pathology that is most important in integrated pest management (IPM) is the prevention and management of plant disease.

The first step, before dealing with the problem, is to be able to recognize it and understand some of the conditions that lead to it. Disease is a condition in which an organism or a part of it is affected by some factor which interferes with normal growth or development or the normal functioning of its organs and tissues. Something is diseased when it looks abnormal or is performing abnormally. To be able to identify a disease, it is necessary to know what is normal and what is a symptom of a disease. Symptoms are external and internal reactions or alterations of a plant as a result of a disease. Some normal growth conditions can resemble diseases, but where there is a disease, there is also a causal agent or agents. These agents can be divided into two broad groups: abiotic (non-infectious and non-living) or biotic (living and infectious).

The abiotic agents are things such as synthetic chemicals (air & soil pollutants, pesticide injury), nutrient imbalances (deficiencies and excesses), temperature (low or high), soil conditions (low or high moisture, compaction, nutrient status, incorrect pH), light (low or high), and weather (wind, hail, rain, and ice).

The biotic agents are alive and are called pathogens. A pathogen is a disease-causing organism. Plant pathogens are either parasitic higher plants, protozoans, nematodes, viruses, mycoplasmas, bacteria or fungi. The major turfgrass diseases are caused by fungi, but be aware that the other pathogen groups are not as well studied and thus little is known about the diseases they cause.

Fungi

Fungi are a large group of organisms including moulds, mildews, mushrooms, rusts and smuts. Most have a microscopic filamentous body (called a mycelium) composed of threads called hyphae. Fungi live on dead organic matter as saprophytes or on living tissues as parasites. Unless a distinct structure such as a mushroom or masses of mycelium are produced, fungi are not usually visible to the naked eye, and a dissecting scope (40×) or even a microscope (100–1,000×) is required to see the organisms.

Disease triangle

The amount of disease is governed by a principle known as the disease triangle (Figure 5-1, on this page). The three sides of the triangle are pathogen, host, and favourable environmental conditions. These must all be present for disease to develop. One leg of the triangle involves the pathogen which is measured by the amount of inoculum. The inoculum is the pathogen or its parts that can cause infection. The degree to which disease is caused by a pathogen is called its virulence.

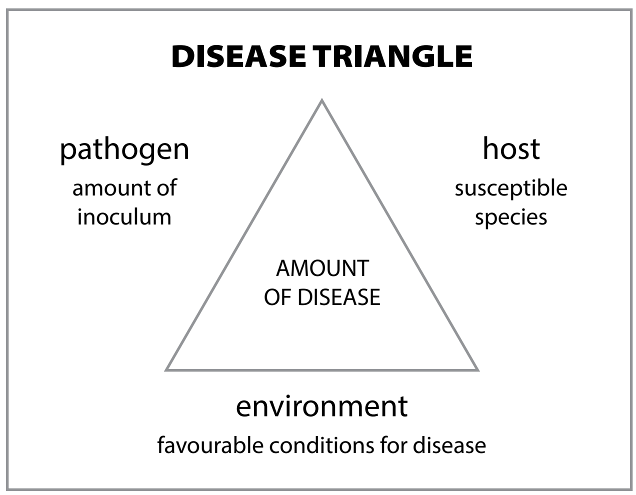


Figure 5-1. Disease triangle where the three necessary factors for disease are presented in a triangle.

Pathogens differ with respect to the kinds of plants that they attack (different turfgrass species) and the plant parts that they infect (leaf blades, stems or roots). Some pathogens are restricted to a single host species, others to one genus, while others have a wide host range. Most obligate parasites are usually specific to the host species or even host tissue that they can attack. That is, they have a very small and specific host range. Pathogens that do not exclusively require living host tissues usually attack many different plant species and plant parts. Each plant species is susceptible to attack by only a small number of plant pathogens.

Disease cycle

For every infectious disease, a series of distinct events occurs in succession leading to the development and perpetuation of the disease and the pathogen. This is called the disease cycle and consists of inoculation, pre-penetration, penetration, infection, and dissemination. Efficient and effective management of the disease seeks to exploit some weakness in this process.

In the inoculation phase, the pathogen contacts the plant in the form of inoculum (spores or mycelium). How and where the inoculum survives prior to infection will influence the management practices for the disease. For example, some pathogens survive in the thatch and thus dethatching is a management option. For pathogens with vectors, consider protecting the plant against the vector in addition to protecting it against the pathogen. A vector is an organism that can transport a pathogen.

In the pre-penetration process, spore germination or nematode hatching, particular conditions are required. To control the disease, try to influence the micro-climate to exclude these conditions. For example, spore germination is favoured in the presence of available nutrients. By applying another organism that can live on these nutrients, favourable conditions can be altered. Using another living organism to decrease disease is a form of biological control.

Pathogens enter plants by direct penetration, through natural openings or through wounds. If a pathogen is strictly a wound-entry organism, attempt to reduce wounding or protect wounds to reduce the chances of infection. Infection is the process where pathogens establish contact with susceptible cells or tissues and feed off them. Infections often directly result in discoloured, malformed or necrotic (dead and discoloured) areas on the plant.

Some infections remain latent and do not appear until favourable conditions trigger them. The pathogen grows on or within the host, causing symptoms later. Then it may reproduce, spreading the disease to other plants.

Most pathogens cannot move on their own and rely on air, water or vectors such as insects or animals to transport them. This process of dissemination may also involve wind, rain, irrigation, flooding, contaminated seeds, infected transplants, boots, tractors, or other equipment.

Diagnosis

When diagnosing a turfgrass problem, there are certain things to keep in mind. Many turfgrass disorders are not caused by living agents but are actually physiological disorders such as drought stress or too much fertilization. Note the pattern and colour of affected areas (symptoms), e.g., patch of brown grass. Examine individual plants, roots, crowns, and leaves, and note the presence of lesions, stunting, and changes in colour on plant (symptom), e.g., elliptical lesions on grass blade. Look for signs of mycelium, sclerotia, masses of spores (structures of the pathogen). Many pathogens produce similar symptoms. Look for signs to diagnose, e.g., black threads on roots.

Consider environmental factors existing and occurring previously such as leaf wetness, temperatures, soil pH, soil moisture, soil texture, humidity, rainfall, dew, wind, slope, drainage and compaction. Most turf diseases have very short incubation periods (between infection and symptoms). Table 5-1, *Key to Turfgrass Diseases of Ontario,* on page 65, can be used to help diagnose and identify turf diseases. If there are symptoms but no signs, take a sample and cover it with a plastic bag to keep it moist. Keep it warm and check in a day or two for signs.

A pocket knife, eye piece (10× hand lens) and plastic bags are helpful tools for sampling and diagnosis.

The environmental conditions limit when the pathogens are active and also when the symptoms are visible (Figure 5-2 on page 66).

More information on disease diagnosis can be found in Chapter 1, *Integrated Pest Management for Turf* in the section *Steps to Help Diagnose a Turf Problem* on page 16. If unable to diagnose a disease, send a sample to GTI Turf Diagnostics. Contact information and information on collecting and sampling for disease, weed and plant identification can be found in Appendix B, *Diagnostic Services* on page 103, or on the Guelph Turfgrass Institute website at *www.guelphturfgrass.ca/diagnostics.html*.

Table 5-1. Key to Turfgrass Diseases of Ontario

I. At Snowmelt

	Symptom	Disease
A.	Non-circular patterns or streaks of bleached or dead grass across large areas, particularly if snow cover was absent during very cold weather	Abiotic winter injury
B.	Patches of dead grass up to 30 cm across after snowmelt	
	1. Little or no snow cover with abundant rain; irregularly shaped patches less than 10 cm across; wet grass sometimes covered with pink fuzzy growth; reddish-bronze at patch margins.	Fusarium patch
	2. At least 1 month of snow cover; circular brown or bleached patches up to 30 cm; wet grass sometimes covered with light pink fuzzy growth; no sclerotia present.	Pink snow mould
	3. More than 2 months of constant snow cover; circular patches up to 30 cm; wet grass covered with white to grey-white growth at patch margins; small sclerotia on top of fuzzy white growth or in dead plant tissues.	Grey snow mould
	a. Reddish-brown to dark brown sclerotia up to 5 mm across; more than 2 months of snow cover.	*Typhula incarnata*
	b. Small, round black sclerotia up to 2 mm across; more than 3 months of snow cover.	*Typhula ishikariensis*

II. Spring or Fall

	Symptom	Disease
A.	Irregular patterns in grass	
	1. Powdery growth on leaf surfaces; distinct leaf spots not usually evident.	
	a. White powdery fuzzy growth on leaf surface; in shaded areas, grass thins out.	Powdery mildew
	b. Black streaks in leaves, which split into ribbons and curl; irregular patches or thinning out of grass.	Leaf smuts
	c. Pink or reddish growth on leaves and sheaths; red, threadlike growths extend beyond the leaf tips; low nitrogen grass.	Red thread/pink patch
	2. Seedling turf is thin or bare in spots; seedlings wilt and collapse; soil very wet.	Damping-off
	3. Leaf lesions of oval tan spots with dark borders.	Leaf spot
	4. Irregular spots on leaves; tip dieback; dark specks present in older leaves.	Ascochyta leaf blight
	5. Diffuse patches or blighting during wet weather.	
	a. microscopic hairlike structures on dead tissues	Anthracnose basal rot
	b. thick-walled oospores on infected roots	Pythium root rot
	6. Blue, grey, creamy yellow or black covering on leaves that are easily wiped off; after prolonged rainfall.	Slime moulds
B.	Circular patches or rings of dead grass	
	1. Circular yellow tufts of grass usually less than 10 cm across; following prolonged wet period.	Yellow tuft
	2. Irregularly shaped patches less than 10 cm across; common after prolonged wet period; wet grass sometimes covered with pink fuzzy growth; reddish-bronze at patch margins.	Fusarium patch
	3. Yellow rings with green centres; patches may be larger than 50 cm.	Yellow patch
	4. Rings initially yellow, then reddish-brown and finally straw-coloured; creeping bentgrass most susceptible; centre often invaded by weeds or other grasses; common in high soil pH and newly built sand greens.	Take-all patch
	5. Straw-coloured dead rings in well-watered Kentucky bluegrass, up to 90 cm across.	Necrotic ring spot
	6. Rings or arcs up to several metres across; often with outer ring of dark green grass or mushrooms.	Fairy ring

III. Summer

	Symptom	Disease
A.	Diffuse blighting or irregular patches.	
	1. Leaf spotting in a wet spring followed by a hot, dry period leads to irregular patches of dead grass with dark lesions on crowns or rhizomes; grass pulls out easily and resembles insect damage.	Melting out
	2. Seedling turf is thin or bare in spots; seedlings wilt and collapse; soil very wet.	Damping-off
	3. Bright orange or reddish-brown spots on leaves less than 3 mm across; during dry periods late in summer.	Rusts
	4. Diffuse blighting or patches with bronze colour in creeping bentgrass; microscopic, hairlike structures on dead tissues.	Anthracnose basal rot
	5. Diffuse blighting or patches in low-lying or poorly drained areas; dead and dying roots with thick-walled oospores in infected tissues.	Pythium root rot
	6. Irregular patches of dead grass; very thick thatch; hydrophobic soils.	Localized dry spot

Table 5-1. Key to Turfgrass Diseases of Ontario (con't)

III. Summer		
	Symptom	**Disease**
B.	Large areas wilt and turn brown, often during very hot, very humid weather	
	1. Grass turns yellow, then reddish-brown; small, black, hairy structures on dead tissues; most common on annual bluegrass.	Anthracnose foliar blight
	2. Grass rapidly turns brown and dies in patches (shorter grass) or diffuse blighting (taller grass), often following drainage or traffic patterns; cottony-white fuzzy growth around patches when wet.	Pythium blight
C.	Round patterns in grass	
	1. Patches 2–15 cm across during humid weather.	
	a. Dead grass blades matted, slimy-looking and straw-coloured; dead grass may occur in streaks following drainage, traffic or equipment-use patterns; white, cottony growth over wet leaves.	Pythium blight
	b. Straw-coloured patches up to 5 cm across; cobweb-like growths may be found with dew; leaf blades have straw-coloured lesions with dark borders, often in an hourglass shape.	Dollar spot
	2. Circular patches up to 50 cm or even 1 m across.	
	a. Straw-coloured; centres often remain green; pronounced during drought.	
	i. mostly on Kentucky bluegrass or fine fescues	Necrotic ring spot
	ii. mostly on creeping bentgrass	Take-all patch
	iii. mostly on annual bluegrass	Summer patch
	b. Light brown patches; following wet periods; purple brown ring at patch margin during heavy dew.	Brown patch
	3. Rings or arcs up to several metres across. These fairy rings may have one, two or all three symptoms below.	
	a. Dead rings with green centres	Fairy ring (killing ring)
	b. Stimulated green rings or arcs	Fairy ring (stimulated ring)
	c. Ring or arcs of mushrooms sprouting after wet weather	Fairy ring (mushroom ring)

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Snow moulds	=====	=====	====								=====	=====
Fusarium patch	=====	=====	=====	=====	=====				=====	=====	=====	=====
Red thread		=====	=====	=====	=====	=====		=====	=====	=====		
Yellow patch	=====	=====	=====	=====	=====					=====	=====	=====
Leaf spots	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====
Brown ring patch					=====	=====		=====	=====			
Dollar spot				=====	=====	=====	=====	=====	=====	=====		
Brown patch						===	=====	=====				
Anthracnose blight				=====	=====	=====	=====	=====	=====	=====		
Anthracnose rot				=====	=====	=====	=====	=====	=====	=====		
Pythium blight					=====	=====	=====	=====	=====			
Pythium root rot				=====	=====	=====	=====	=====	=====	=====	=====	
Rust							=====	=====	=====	=====		
Take-all patch				=====	=====	=====	=====	=====	=====	=====		
Necrotic ring spot				=====	=====	=====	=====	=====	=====	=====		
Summer patch					=====	=====	=====	=====	=====			
Bentgrass dead spot				=====	=====	=====	=====	=====	=====	=====		

SHADING = Visible symptoms, and DASHES = Periods of pathogen activity.

Figure 5-2. Turfgrass disease time profile (Southern Ontario).

Winter Diseases

Grey snow mould, also known as Typhula blight, snow scald and winter scald

Pathogen: *Typhula incarnata* and *T. ishikariensis.*

Hosts: All cool season turfgrasses are susceptible, particularly creeping bentgrass, annual bluegrass, and perennial ryegrass. Kentucky bluegrass, red fescue, and tall fescue are moderately susceptible.

Symptoms: Grey snow mould symptoms are circular patches up to 30 cm across, visible in spring, after snowmelt on short turf, Figure 5-3, on this page. On long cut turf, there is general blighting rather than distinct patches. Patches have a scalded or bleached appearance ranging in size from 10–20 cm, but often overlap to form large irregular patches. Fungal hyphae are often found in a ring in the outer patch as seen in Figure 5-4. Sclerotia can also be found on dead leaf blades after snowmelt. They can be up to 5 mm across for *Typhula incarnata* and up to 2 mm across for *T. ishikariensis* (Figure 5-5, on this page). Grey and pink snow mould patches can be mixed together (Figure 5-6, on this page).

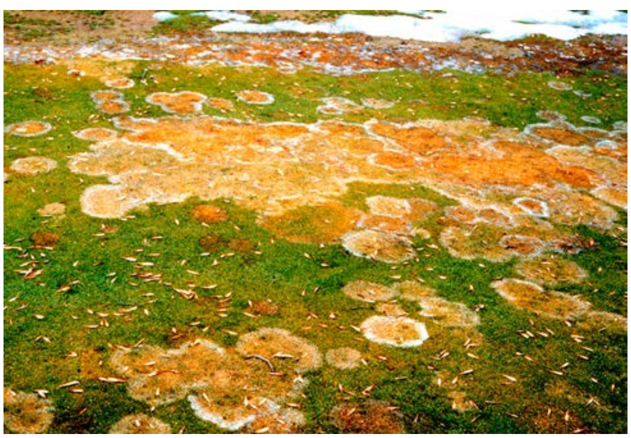


Figure 5-3. Snow mould symptoms are apparent as the snow melts. *(Photo: Dr. Tom Hsiang, University of Guelph)*

Figure 5-4. Patches of grey snow mould may be surrounded by a whitish-grey mycelium visible immediately after snowmelt.

Figure 5-5. Sclerotia of grey snow mould are visible by eye. *(Photo: Dr. Tom Hsiang, University of Guelph)*

Figure 5-6. Grey snow mould (left) and pink snow mould (right) patches can be mixed together. The presence of sclerotia are the best indicators of grey snow mould. *(Photo: Dr. Tom Hsiang, University of Guelph)*

Disease Cycle: The fungus survives through the summer as sclerotia in the thatch or soil. In winter, sclerotia germinate under snow cover and fungal hyphae infect turfgrass plants, especially as they weaken after long periods of snow cover. In spring, the damage is evident after snowmelt, but the fungus is no longer active after snowmelt. Extended periods of snow cover of 2 months for *T. incarnata* disease, and 3 months or more for *T. ishikariensis* can cause heavy damage.

Management: Minimize thatch and prevent succulent growth into late fall, by mowing until leaf growth stops. Avoid applying nitrogen any later than 6 weeks before dormancy. In the spring, after damage has occurred, rake matted areas to encourage drying. Promote new growth by lightly fertilizing damaged turf. Fungicides can be applied just before snowfall as a preventive measure.

Pink snow mould and Fusarium patch (also known as Microdochium patch)

Pathogen: *Microdochium nivale* (formerly known as *Fusarium nivale* or *Gerlachia nivalis*).

Hosts: All cool season turfgrasses can be hosts.

Symptoms: Pink snow mold patches are orange to red-brown up to 25 cm across (Figure 5-6, on page 67, and Figure 5-7, on this page). Fuzzy hyphal growth is white to pink, often on the outer margin of patches after snowmelt. Pink snow mold patches are more bleached white on Kentucky bluegrass than on creeping bentgrass (Figure 5-8, on this page). No sclerotia are produced, which distinguishes this disease from grey snow mould (Figure 5-6, on page 67).

Figure 5-7. Pink snow mould symptoms are apparent as the snow melts.

Figure 5-8. Pink snow mould on Kentucky bluegrass (left) and creeping bentgrass (right). *(Photo: Dr. Tom Hsiang, University of Guelph)*

In spring and fall, the pathogen causes Fusarium patch with no snow cover (Figure 5-9, on this page, and Figure 5-10, on this page). Fusarium patches are small, up to 5 cm across, often intensely reddish-brown. Around the edges of pink snow mould patches, there may be intense fungal activity after snowmelt giving this bronze outer zone (Figure 5-11, on this page).

Figure 5-9. Fusarium patch on creeping bentgrass causing irregular shaped patches.

Figure 5-10. Fusarium patch on Kentucky bluegrass causing small distinct round sunken patches.

Disease Cycle: The fungus survives through the summer as spores and mycelium in thatch or soil. In autumn, under cool, wet weather and even without snow cover, spores may germinate or mycelium may grow from thatch or soil and infect leaves, causing Fusarium patch. Under snow cover, grass blades are infected leading to typical pink snow mould patches.

The circular reddish brown patches with fuzzy hyphal growth at the edges are evident in the spring after the snow has melted. The fungus may continue activity well into the spring and cause Fusarium patch under cool wet conditions. The fungus is not active under warm summer conditions, although it may sometimes be seen after prolonged wet periods in summer.

Figure 5-11. Actively growing Fusarium patch causing reddish margins at the edge of a pink snow mould patch.

Management: Minimize thatch, since this is where the fungus survives summer as mycelium and spores. Prevent succulent growth into late fall, by mowing until leaf growth stops, and not applying nitrogen any later than 6 weeks before dormancy.

After damage has occurred, rake matted areas to encourage drying. Promote new growth by lightly fertilizing damaged turf. In autumn, remove surplus water, improve air circulation, rake leaves and avoid heavy topdressings. Fungicides can be applied just before snowfall as a preventive measure, and with wet cool weather in the spring and fall.

Spring and Fall Diseases

Red thread

Pathogen: *Laetisaria fuciformis* was formerly called *Corticium fuciforme*. Pink patch, a closely related disease, is caused by *Limonomyces roseipellis*.

Hosts: Nearly all northern grasses can be affected, but perennial ryegrass and fine leaf fescues are most susceptible.

Symptoms: Diffused yellowing appears in the spring and increases into early summer under cool moist weather with temperatures between 15°C and 25°C, when turf is growing slowly. It subsides with the higher summer temperatures and recurs in late summer and autumn, when severe symptoms can be seen. It occurs on home lawns with perennial ryegrass and fine fescue and on golf courses on perennial ryegrass especially in unfertilized roughs. Typical symptoms are reddish-brown diffuse patches, from 5–35 cm or more (Figure 5-12, on this page).

Infected leaf blades look water-soaked, and then die off to a straw colour. Pink-red gelatinous threads or tiny pink cushions can be seen growing from leaf blades (Figure 5-13, on this page).

Figure 5-12. Red thread disease on perennial ryegrass causing diffuse-patch blighting.

Figure 5-13. Gelatinous red-pink strands of hyphae of red thread disease growing from and between leaf blades of perennial ryegrass.

Disease Cycle: Red thread overwinters as dormant mycelium in diseased or dead tissue. In the spring, under moist conditions, the mycelium invades slowly growing leaf tissue. It spreads from leaf to leaf by mycelial strands directly, by wind or traffic. Fungal activity declines with higher summer temperatures and drier conditions. With cooler moist conditions in late summer, epidemics can occur as the turf goes dormant.

Management: Fertilize since low nitrogen conditions favour this disease (as with dollar spot). Late season fertilization may not stimulate turf growth sufficiently, or make the turf more susceptible to snow moulds. Minimize leaf wetness periods with proper watering, good drainage and air circulation. No fully resistant cultivars are available, but damage is usually insignificant.

Yellow patch (cool weather brown patch)

Pathogen: *Rhizoctonia cerealis.*

Hosts: All cool season turfgrasses, especially creeping bentgrass and annual bluegrass can be affected. Kentucky bluegrass, perennial ryegrass and fescues are less susceptible. Perennial ryegrass and fescues are the most resistant.

Symptoms: Start out as white to straw-coloured patches on turf (Figure 5-14, on page 71). Larger patches are up to 1 m across, with turf in the centre recovering inside a white-yellow ring. On turf mowed at heights higher than 1 cm, irregular straw coloured lesions can be observed. The turf is not usually severely damaged and symptoms disappear with warmer weather.

Figure 5-14. Yellow patch disease on creeping bentgrass.

Life Cycle: The fungus survives through the summer and winter as sclerotia or mycelium in thatch or soil. Under cool wet weather, sclerotia germinate or mycelium grows from thatch and infects leaves.

Management: Minimize thatch and avoid succulent growth going into the late fall by mowing until leaf growth stops. Apply nitrogen (particularly fast-release types) no later than approximately 6 weeks before dormancy. Avoid lush growth too early in spring. Improve drainage and reduce shade and increase air circulation.

Leaf spots

Pathogen: Species of *Bipolaris*, *Curvularia* or *Drechslera* species, all formerly *Helminthosporium* species.

Hosts: All turfgrasses, particularly Kentucky bluegrass are hosts of leaf spots.

Symptoms: Symptoms first appear in early spring as small, water-soaked spots on the lower leaves. The spots darken to a reddish-purplish-brown and enlarge to form oval spots extending the entire width of the leaf with a bleached-out centre and a dark margin (Figure 5-15, on this page). If infections spread to leaf sheaths and rhizomes and girdle them, this causes melting out under hot wet conditions.

Figure 5-15. Leaf spots develop on blades of Kentucky bluegrass with a bleached-out centre and a dark margin.

Disease Cycle: These fungi survive winter as spores and dormant mycelium in thatch or infected tissue. In the spring, large numbers of spores are produced which are splashed onto leaves where they infect and produce new crops of spores. With warmer weather, the conditions are less favourable for new infections, but the fungi continue their activities in infected tissue, spread to crowns and cause further damage leading to a phase known as melting out.

Management: Use resistant Kentucky bluegrass cultivars (see National Turfgrass Evaluation Program Reports). Avoid close mowing, heavy thatch build-up and early season heavy applications of nitrogen.

Necrotic ring spot

Pathogen: *Ophiosphaerella korrae* (formerly *Leptosphaeria korrae*).

Hosts: Kentucky bluegrass is the major host with some reports on fine fescues.

Symptoms: Symptoms on Kentucky bluegrass turf are diseased ring-patches from 10 cm and up to 1 m wide (Figure 5-16, on page 72). Younger, inner leaves may have a red-purple-bronze colour prior to turning brown.

Dead patches appear sunken. Older patches may have turf surviving or weeds and grasses invading the centre to give a ring appearance, and patches can merge. Damage may persist after the fungus is no longer active, since roots are killed. Severely infected plants have few roots, because the fungus invades roots, rhizomes and crowns. Abundant dark coloured strands are apparent on the surface of roots (runner hyphae) (Figure 5-17, on this page). Roots of creeping bentgrass infected with take-all patch disease or roots of annual bluegrass infected with summer patch disease will have dark strands as well.

Figure 5-16. Necrotic ring spot disease of Kentucky bluegrass forming dead rings.

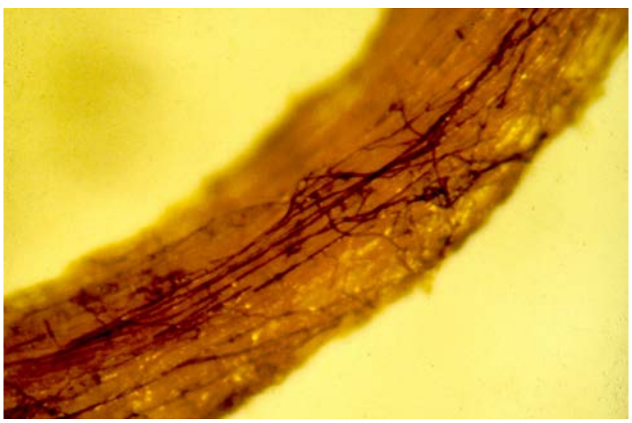


Figure 5-17. Dark threads of mycelium visible on roots of Kentucky bluegrass infected with necrotic ring spot disease. These runner hyphae are also found on creeping bentgrass attacked by take-all patch, and annual bluegrass attacked by summer patch. *(Photo: Dr. Tom Hsiang, University of Guelph)*

Disease Cycle: Spores may serve as the initial inoculum. Mycelium in thatch and diseased tissue overwinters and infects more roots starting in spring under wet cool conditions. Summer heat and dryness stop disease progress, but symptoms may become evident due to drought. The fungus becomes active again in the fall with wet cool weather.

Management: Fertilize and lightly water frequently to promote recovery growth. Avoid heavy daily irrigation and reduce thatch. Core aerate to relieve compaction, improve drainage and promote rooting. Use less susceptible Kentucky bluegrass cultivars. Water in fungicides in spring and fall when fungus is active.

Take-all patch (formerly Ophiobolus patch)

Pathogen: *Gaeumannomyces graminis* (formerly *Ophiobolus graminis*).

Hosts: Bentgrasses are the major hosts. Bluegrasses and perennial ryegrass are less severely and rarely damaged.

Symptoms: Typical symptoms are small patches with saucer-shaped depressions. Patches enlarge to 1 m across over years and can merge. Weeds or other grasses often invade the centre.

Susceptible grasses are killed with resistant plants/weeds taking over or invading patches (Figure 5-18, on page 73). Around the patch margin, the bronzed ring of infected grass has little root hold and the dead plants can be peeled off (like grub damage).

Thick brown strands or mats of runner hyphae can be found on roots, rhizomes, stolons or under leaf sheaths (Figure 5-17, on this page). Roots of creeping bentgrass infected with take-all patch disease, or roots of annual bluegrass infected with summer patch disease will have dark strands as well.

Infected roots show a dark discoloration which is more visible when wet. Roots then turn dark-brown and become black and brittle under dry conditions. Infections occur in late spring, but symptoms are most often seen in summer after stress of hot dry weather. This disease is found in infertile, compacted, alkaline (pH greater than 7.0 in upper 2.5 cm), and poorly drained soils. After 2 or 3 years, the symptoms decrease.

Figure 5-18. Take-all patch disease of creeping bentgrass. Weeds or other grasses often invade the centre.

Disease Cycle: Fungus overwinters in infected roots and stems and debris as dormant mycelium. Most infections are caused by mycelium contacting roots of growing plants. Grasses infected in the spring may recover by summer, unless drought occurs or irrigation is withheld.

Management: Reduce soil pH with acidifying (ammonium) fertilizers or sulphur, or use lower pH sand. Blighted appearance can remain for months or years. Overseed with resistant species or renovate.

Water in fungicides in spring and fall when fungus is active.

Summer Diseases

Summer patch

Pathogen: *Magnaporthe poae.*

Hosts: Summer patch is a problem on annual bluegrass and less frequently on Kentucky bluegrass and fine fescues. There are very sporadic reports of it on creeping bentgrass.

Symptoms: Symptoms on annual bluegrass are diseased ring-patches from 10 cm–1 m wide (Figure 5-19, on this page). Older patches may have turf surviving or weeds and grasses invading the centre to give a ring appearance, and patches can merge. Damage may persist after the fungus is no longer active, since roots are killed. Severely infected plants have few roots left, because the fungus kills crowns and roots. Abundant dark coloured strands are apparent on the surface of roots (runner hyphae) (Figure 5-17, on page 72).

Roots of creeping bentgrass infected with take-all patch disease, or roots of annual bluegrass infected with summer patch disease will also have dark strands. Summer patch is one of the causes of annual bluegrass dieback in summer, where roots are often unhealthy (Figure 5-20, on this page).

Figure 5-19. Summer patch disease of annual bluegrass.

Figure 5-20. Annual bluegrass plant in summer with unhealthy roots. *(Photo: Dr. Tom Hsiang, University of Guelph)*

Disease Cycle: Spores may serve as the initial inoculum. Mycelium in thatch and diseased tissue overwinters and infects more roots starting in spring when temperatures are higher than 15°C under wet cool conditions. Summer heat and dryness stop disease progress, but symptoms may become evident due to drought. The fungus becomes active again in the fall with wet cool weather.

Management: Fertilize and lightly water frequently to promote recovery growth. Avoid heavy daily irrigation. Reduce thatch and core aerate to relieve compaction, improve drainage and promote rooting.

Water in fungicides in spring and fall when fungus is active.

Dollar spot

Pathogen: *Sclerotinia homoeocarpa* is the current name but this fungus is being renamed.

Hosts: All turfgrasses especially creeping bentgrass.

Symptoms: On close-cut grass, there are small 5 cm wide straw-coloured patches (Figure 5-21, on this page). Individual leaves can be bleached out with dark margins. Individual patches may be up to 7 cm across, but patches may merge. Long leaves may have "hourglass" lesions with a narrow bleached centre and brown borders and a bleached inner region and dark margins bordering the live green areas (Figure 5-22, on this page). Cobweb-like mycelium can form after warm days (greater than 25°C) and nights (greater than 20°C) and heavy morning dew (Figure 5-23, on this page).

Figure 5-21. Dollar spot patches on creeping bentgrass.

Figure 5-22. Dollar spot disease causing hourglass lesions on leaf blades. A bleached inner region and dark margins bordering the live green areas. *(Photo: Dr. Tom Hsiang, University of Guelph)*

Figure 5-23. Cobweb like mycelium.

Disease Cycle: Mycelium and sclerotial flakes overwinter in foliage, thatch and soil. Fungal growth begins at 15°C, is favoured by humidity and temperatures in the 20°C range. Mycelium grows out of the thatch or from diseased foliage and infects new foliage. Inoculum may be spread with field equipment.

Management: Apply nitrogen to low nitrogen turfs. Control thatch and compaction. Enhance quick drying of turf by reducing shade and increasing air circulation. Avoid drought and night watering.

Brown patch (Rhizoctonia patch)

Pathogen: *Rhizoctonia solani.*

Hosts: All turfgrasses are susceptible but bentgrasses, annual bluegrass and perennial ryegrass are the most susceptible.

Symptoms: Brown patch forms patches with discoloured centres that turn yellow and then turn brown and can increase in diameter up to 1 m across (Figure 5-24, on page 75). A purplish "smoke ring" can be present on lower cut turf less than 2 cm on dewy mornings (Figure 5-25, on page 75). The smoke ring disappears when turf dries off. On longer turf large brown patches with bleached thinned turf up to 1 m across may develop. Irregularly shaped leaf lesions with brown borders can be found on individual leaves.

Figure 5-24. Brown patch causing visible brown discoloration.

Figure 5-25. Brown patch on creeping bentgrass with a purple smoke ring at patch margin. *(Photo: Dr. Tom Hsiang, University of Guelph)*

Disease Cycle: The fungus survives in soil or thatch as sclerotia or mycelium. The overwintering fungus begins to develop when air temperatures are 15°C up to low 30s°C. Wet foliage is needed for disease development.

Management: Reduce shade and increase air circulation. Reduce nitrogen levels during summer. Maintain soil pH greater than 7. Avoid night watering. Brown patch occurs under similar environmental conditions as Pythium blight but there is more recovery from brown patch.

Anthracnose foliar blight

Pathogen: *Colletotrichum cereale* (formerly called *Colletotrichum graminicola*).

Hosts: Annual bluegrass is the most severely affected turfgrass species and it can be killed in the summer by this disease. Kentucky bluegrass, red fescue and other turfgrasses are also susceptible and may show some lesions, but generally they are not killed by this disease.

Symptoms: Infection and discoloration can occur in cool weather, but serious damage follows high temperature and humidity and stressful conditions. Discoloration is first observed in patches from a few centimetres to a few metres in diameter on annual bluegrass. Widespread mottling can occur with creeping bentgrass unaffected while annual bluegrass turns yellow (Figure 5-26, on this page).

Small yellow lesions develop on leaves. The lesions have black centres and leaves turn brown.

Black spore-producing acervuli erupt from stomates on dead tissues (Figure 5-27, on page 76). Eyelash-like black spore-producing structures of the anthracnose fungus, called acervuli, are visible on dead and dying tissue.

Figure 5-26. Anthracnose killing annual bluegrass during hot humid weather (Pythium blight streaks in the background). *(Photo: Pest Diagnostic Clinic, University of Guelph)*

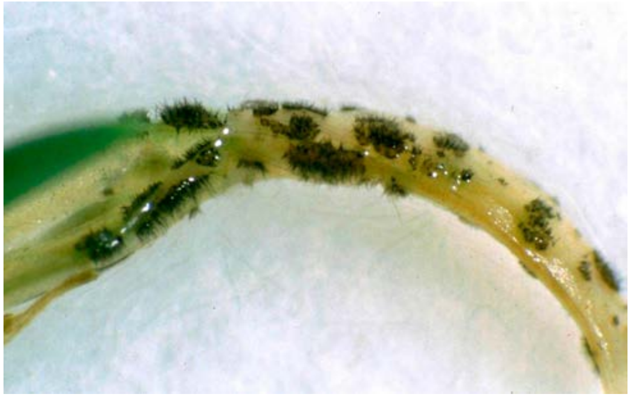


Figure 5-27. Eyelash-like black spore-producing structures of the anthracnose fungus, called acervuli, visible on dead and dying tissue. *(Photo: Dr. Tom Hsiang, University of Guelph)*

Disease Cycle: Anthracnose overwinters in diseased or dead tissues as mycelium and spores. Spores are produced throughout the growing season. Symptoms develop with temperatures greater than 25°C and high relative humidity. On dead tissue, spores are produced and then splashed and windblown to other plants. Symptoms can develop very quickly, and a sward can be completely blighted in two days.

Management: Syringe turf at 10 a.m. and 2 p.m. on days when temperatures exceed upper 20s°C. Use a balanced fertilization regime. Don't irrigate in the evening. Avoid turf stress, drought or nitrogen deficiency. Control thatch by core aeration. Alleviate and avoid soil compaction. Mow with light weight mowers. Annual bluegrass may be weak in the summer because of stress and anthracnose becomes the secondary killer.

Anthracnose basal rot

Pathogen: *Colletotrichum cereale.*

Hosts: Anthracnose basal rot is most severe on creeping bentgrass and is less of a problem on annual bluegrass.

Symptoms: Anthracnose basal rot is characterized by widespread yellowing and thinning out of creeping bentgrass turf (Figure 5-28, on this page). Roots and crowns become rotted and pull out easily. It is a common disease after stress periods, including cultural operations such as coring and verticutting.

Figure 5-28. Anthracnose basal rot in the cool, wet season attacking mostly creeping bentgrass.

Disease Cycle: The disease overwinters in diseased or dead tissues as mycelium and spores. Spores are produced throughout the growing season. Symptoms develop during prolonged wet periods, whether cool or warm. On dead tissue, spores are produced and then spread by splashing water or wind.

Management: Reduce compaction and minimize thatch and root zone wetness periods. Water in fungicides.

Pythium blight (also known as cottony blight)

Pathogen: Species of *Pythium* which are not true fungi, but are more closely related to algae.

Hosts: Creeping bentgrass, annual bluegrass and perennial ryegrass are the most susceptible hosts.

Symptoms: Early symptoms are similar to dollar spot (especially in the afternoon), with small spots about 5 cm in diameter. The spots are darker, with a water-soaked look and continue to increase in size. During wet periods, such as the early morning, water-soaked leaves collapse and become matted together by a fluffy mass of white mycelium. As the grass dries, the mycelium disappears and the dead blades turn yellow and brown. This disease occurs in patches (Figure 5-29, on page 77).

Killed areas often appear as elongated streaks due to spread of spores and mycelium on mowing equipment or in surface water along drainage slopes (Figure 5-30, on page 77). Crowns may be killed and the result is that there may be little or no recovery in dead areas.

Figure 5-29. Pythium blight causes patches very quickly during hot, humid weather. *(Photo: Dr. Tom Hsiang, University of Guelph)*

Figure 5-30. Pythium blight is often seen in streaks following mowing equipment or drainage patterns. *(Photo: Dr. Tom Hsiang, University of Guelph)*

Disease Cycle: *Pythium* species occur widely in soil as saprophytes and overwinter as dormant mycelium in soil, infected plant tissue and in some pond water. During cooler parts of the season, foliar blight is not common, although some species do cause the root rots such as damping-off in cool wet weather. During hot, humid weather, the organism grows extremely rapidly, with infection and blighting occurring in a matter of hours. Outbreaks have been known to devastate stands within 24 hours.

Management: This disease is hard to control curatively because it occurs so quickly and is so damaging. Reduce shade and increase air circulation. Use infrequent deep watering with proper drainage.

Avoid mowing and watering during periods favourable to disease (greater than the upper 20s°C).

Pythium root rot

Pathogen: Species of *Pythium* which are not true fungi, but are more closely related to algae.

Hosts: Creeping bentgrass, annual bluegrass and perennial ryegrass are the most susceptible hosts.

Symptoms: The symptoms are most common during cool wet periods. The grass starts to thin out, and leaves die back as roots are being killed. Roots appear stubby.

Disease Cycle: *Pythium* species occur widely in soil as saprophytes and overwinter as dormant mycelium in soil, infected plant tissue, and some in pond water. During cooler parts of the season, the hyphae infect roots and kill crowns.

Management: This disease is hard to control curatively since it occurs below ground. Improve drainage. Reduce shade and increase air circulation.

Brown ring patch

Pathogen: *Waitea circinata.*

History: This disease first appeared in Ontario in the mid-2000s. It looks similar to yellow patch and brown patch (close relatives) but occurs at a different time of year (usually late spring as weather first starts getting hot).

Hosts: Creeping bentgrass and annual bluegrass are the common hosts.

Symptoms: The symptoms are characterized by a thin yellow-green band that encircles the green area (looks like yellow patch) that are up to 50 cm across (Figure 5-31, on page 78). Inside the band, there are yellow and brown leaves with green leaves. The patch centre often stays green.

Figure 5-31. Brown ring patch on creeping bentgrass occurs as a thin yellow-green ring.

Life Cycle: The fungus survives through the summer and winter as sclerotia or mycelium in thatch or soil.

Under cool wet weather, sclerotia germinate or mycelium grows from thatch and infects leaves.

Management: Minimize thatch and avoid succulent growth going into the late fall by mowing until leaf growth stops. Avoid applying nitrogen (particularly fast-release types) any later than approximately 6 weeks before dormancy. Avoid lush growth too early in spring. Improve drainage and reduce shade and increase air circulation.

Bentgrass dead spot

Pathogen: *Ophiosphaerella agrostis.*

Hosts: Creeping bentgrass is the only host for this disease.

Symptoms: The symptoms start as small dime-size spots that increase to 10 cm across. Spots are reddish-brown and can resemble dollar spot or Fusarium patch. Later the grasses in the centres die back and bleach out, while outer leaves are reddish brown (Figure 5-32, on this page). Spots can form depressions. The disease is most severe in late summer and on younger greens.

Figure 5-32. Bentgrass dead spot on creeping bentgrass in late summer.

Life Cycle: Spores may serve as the initial inoculum. Mycelium in thatch and diseased tissue overwinters and infects more roots starting in spring under wet cool conditions. Summer heat and dryness stop disease progress, but symptoms may become evident due to drought. The fungus becomes active again in the fall with wet cool weather.

Management: A balanced fertility program will help manage this disease. Avoid stress or mechanical injury and excessive traffic. Curative controls can be applied on short intervals

Other Diseases

Fairy ring

Pathogen: *Marasmius oreades* and other mushroom fungi.

Hosts: All turfgrasses are susceptible to fairy ring.

Symptoms: Symptoms can be manifested as a killing ring, a stimulated ring or mushroom ring.

The killing ring starts as a circle or arc of dark-purple wilted turf and grows annually (Figure 5-33, on page 79). The ring of grass then dies off. The circles vary from less than 1 metre to many metres in diameter. The area in the centre of the larger rings is usually occupied by normal grass. In the dead area, roots are commonly overgrown with fungal hyphae.

The hydrophobic zone causes roots to dry and tops to die.

The stimulated ring is more common in Ontario with rings up to a few metres in diameter (Figure 5-34, on this page). Early symptoms consist of a circle or arc of dark-green fast-growing grass without a dead ring. Symptoms are more common in low nitrogen areas. Iron sprays will mask this type of ring.

The last type is an arc or ring of mushrooms and it is most common in areas of infrequent mowing (Figure 5-35, on this page).

Figure 5-33. Killing ring symptom of fairy ring disease on Kentucky bluegrass. *(Photo: Dr. Tom Hsiang, University of Guelph)*

Figure 5-34. Stimulated ring of growth caused by fairy ring fungi as they decompose thatch. *(Photo: Dr. Tom Hsiang, University of Guelph)*

Figure 5-35. Arc of mushrooms forming fairy ring. *(Photo: Dr. Tom Hsiang, University of Guelph)*

Disease Cycle: Mushrooms release spores and spores grow on dead thatch or other organic matter (e.g., tree stumps). A whitish network with a mouldy or musty smell in can be found in wet thatch and soils. (Figure 5-36, on this page). Thatch may decompose leading to ring-shaped depressions. The outer ring stimulation is caused by nutrients released from this decomposition.

Figure 5-36. White mycelium of fairy ring fungi visible in the thatch. *(Photo: Dr. Tom Hsiang, University of Guelph)*

Management: The most drastic option is removal of all fungus-infested soil and replacement with clean soil. Another option is to mix new soil into the ring area and re-seed or re-sod. Mask symptoms by moderate fertility regimes, thorough watering and repeated deep cultivation of affected areas.

The watering and cultivation serve to increase activity of other soil microbes in the infested soil against the fairy ring fungi.

Powdery mildew

Pathogen: *Blumeria graminis* (formerly *Erysiphe graminis*).

Hosts: Nearly all northern grasses can be affected by powdery mildew. It is only a major problem on Kentucky bluegrass.

Symptoms: Turf affected by powdery mildew has a whitish cast and looks thinned out (Figure 5-37, on this page). White powdery masses are visible on upper surfaces of leaves. As the infection of leaves becomes more intense, discoloured lesions develop which gradually enlarge and the whole leaf turns pale yellow. Plants are seldom killed by the powdery mildew, but they become more susceptible to other stresses and diseases.

Figure 5-37. Powdery mildew on Kentucky bluegrass.

Disease Cycle: The pathogen survives winter as small black balls on dead tissue or as mycelium in infected host tissue. Spores are produced in the spring and are spread by wind. Spores germinate and penetrate leaves. New infections produce more spores.

Control: Improve air circulation and reduce shade by pruning of adjacent trees and shrubs. Keep turfgrass vigorous with balanced nutrition. Too much succulence increases susceptibility.

Rusts

Pathogen: *Puccinia* species.

Hosts: Perennial ryegrass and Kentucky bluegrass but other species may have it too.

Symptoms: Symptoms start as small yellow specks on leaves or sheaths (upper or lower surface depending on species). Reddish-brown pustules appear on leaf blades, bearing masses of spores (Figure 5-38, on this page). Rust spores can easily be rubbed off, giving a reddish tinge to shoes and equipment.

Only leaf blades are infected, and severe attacks may result in yellowing and wilt. In late summer and fall, black-brown spots develop in place of the reddish-brown pustules.

Figure 5-38. Reddish brown spots of rust disease on perennial ryegrass.

Disease Cycle: Rusts are obligate parasites, requiring a live host to grow and reproduce. Most rusts have an alternate host, usually a woody or herbaceous species such as barberry and buckthorn. The fungus overwinters on living or dead tissue of the grass host. In the spring, structures on dead grass tissue produce spores which will only infect the alternate host. A few weeks after successful infection of the alternate non-grass host, spores are produced in late spring or early summer (summer spores) which then infect the grass host. Infections on the grass host lead to production of pustules which bear many more spores (summer spores) to re-infect grass. As the grass host tissue dies off, another spore stage (usually black or dark brown winter spores) is produced on the grass tissue and these overwinter.

Management: Mowing and increasing nitrogen fertility will usually control the disease. Water infrequently but thoroughly early in the day. Fertilize sufficiently to avoid nutrient stress, and to improve leaf growth. Increased mowing height with greater frequency will reduce disease incidence and severity. Reduce shade and improve air circulation. Resistant varieties of Kentucky bluegrass and perennial ryegrass are available.

Slime moulds

Pathogens: Myxomycetes (not fungi, but primitive eukaryotes).

Symptoms: These organisms do not cause disease, but they are unsightly. Large masses of the mould may appear suddenly on grass blades in small irregular patches (Figure 5-39, on this page). The masses can be brightly coloured ranging from white, grey, brown or even yellow.

Figure 5-39. Slime mould migrates onto leaf blades but can be easily washed off.

Management: Spore masses may be removed by vigorous raking or washing grass with water.

6. Soil Management and Fertilizer Use

Fertilizing is one of the key components of a good turf management and integrated pest management program. A well balanced fertilizer program will help turf avoid stress, reduce diseases and weed invasion. The best way to determine turf fertilizer needs is to do a soil test, plant analysis or both.

Soil Testing

Soil testing and plant analysis are currently the most accurate tools available to determine how much fertilizer and lime to apply to turf areas. Where possible, use both methods.

Submit turf soil samples to a commercial laboratory accredited by OMAFRA for analysis. All analyses are on a fee-for-service basis. The labs must meet and maintain established levels of proficiency on the basic tests to maintain their accreditation. See Appendix A. *Accredited Soil-Testing Laboratories in Ontario,* on page 103 for a complete list of accredited labs.

Fertilizer guidelines are made on the basis of four types of turfgrass management programs:

- golf course greens and tees
- golf course fairways, sports fields and lawns
- sod
- low-use turf

Soil tests from other labs

Each year there are requests to interpret soil test results from labs other than those listed in Appendix A. *Accredited Soil-Testing Laboratories in Ontario,* on page 103. If the lab uses the identical chemical tests used by the OMAFRA-accredited service and expresses test results in the same units, the OMAFRA fertilizer rates for phosphate and potash can be used.

Only soil tests using chemical extractants that have been calibrated on Ontario soils can provide accurate fertilizer guidelines. A number of labs provide tests such as cation exchange capacity, nitrogen, iron, copper and sulphur. The OMAFRA soil testing service does not do these tests because they do not contribute to better fertilizer guidelines. Research has shown that using cation exchange capacity to adjust guidelines for Ontario soils can lead to less reliable results than are now provided.

Soil sampling

The following steps ensure the quality of the soil sample. Use a soil sampling tube, shovel or a cup changer. Take the core to a depth of 15 cm on all turf except greens and tees. For greens and tees, take a depth of 7.5 cm, which is more closely related to the active root feeding zone of bentgrass. Take at least 20 cores (10–15 on greens) for each sample. Since greens and fields are highly variable, make sure each unit has a separate sample. Sample problem areas separately. Discard the thatch layer of the core, then mix the cores thoroughly in a clean plastic pail. Fill the sample box and fill out an information sheet specifying the type of turf for which you need results.

When to sample

On well-established turfgrass areas, representative sampling every two to three years may be enough. On newly established areas and on sandy root zones, test annually to monitor the nutrient status more closely. Nitrogen and potash levels can change quickly in sand root zones or if clippings are removed.

Micronutrient tests

Micronutrient deficiencies in turf are rare.

The OMAFRA service provides tests for manganese and zinc. No acceptable soil test for copper or boron is available in Ontario. Plant analysis can give some indication of micronutrient status.

With the exception of some areas in northwestern Ontario, there appear to be adequate supplies of sulphur for plant growth.

Take care to prevent contamination of soil samples. Do not use galvanized (zinc plated) soil sampling tubes to take soil samples for micronutrient tests. Do not use metal containers to collect and mix samples.

Plant Analysis

Plant analysis measures the nutrient content of plant tissue. Compare the analysis results against the "normal" range to determine whether nutrient supply is adequate in your turfgrass. See Table 6-1, *Desirable Nutrient Concentrations in Dried Turfgrass Clippings,* on this page.

Plant analysis is a useful supplement to soil testing in evaluating the fertility status of turfgrass. It is quite independent of soil testing and can provide a valuable second assessment of the nutrient supply, especially for phosphorus, potassium, magnesium and manganese. It is also the only test for nitrogen and the micronutrients. Iron analysis is not likely to be useful.

Plant analysis has limits. Expert help in interpreting the results is often needed since plant analysis does not always show the cause of a deficiency or the amount of fertilizer required to correct it.

Table 6-1. Desirable Nutrient Concentrations in Dried Turfgrass Clippings

Element	Normal range
N	2.5–6.0%
P	0.15–0.55%
K	0.9–4.0%
Ca	0.2–4.5%
Mg	0.15–1.0%
Mn	20–140 ppm
Zn	10–100 ppm
Cu	5–30 ppm
B	3–30 ppm

These are guidelines. Nutrient levels vary depending on species.

Sampling

To collect a proper sample:
- take about 500 grams of clippings from the mower baskets.
- do not contaminate the sample with soil, as even a small amount of soil will make the results invalid, especially for manganese.
- do not topdress, fertilize or apply any chemical sprays before taking the clippings as this will contaminate them.
- dry the samples immediately by placing them in a thin layer on a clean surface, stirring occasionally to help them dry uniformly.
- place samples in a sample bag.
- deliver samples to the lab immediately.

A soil sample taken at the same time as the clipping will provide additional results for comparison.

Nitrogen

There is no satisfactory soil test available for nitrogen (N) under Ontario conditions.

Nitrogen is the element the turf plant uses in the greatest quantities. Nitrogen promotes the dark green colour, leaf and blade development and turf density. Nitrogen plays a role in disease development. Plants deficient in nitrogen are susceptible to diseases such as red thread, dollar spot and anthracnose basal rot. Turf with excess nitrogen is susceptible to other diseases such as Pythium blight and brown patch.

The amount of nitrogen fertilizer used strongly affects the colour, density and vigour of turf. Adjust the amount of nitrogen and the timing of applications to match the growth cycle of the turf and for the desired growth response. Use Table 6-2, *Nitrogen Requirements for Turfgrass,* on page 85 as a guideline.

When to apply nitrogen fertilizer depends on:
- turf species.
- turf use.
- turf conditions.
- soil type.
- desired level of quality.
- weather conditions.
- length of growing season.
- whether or not clippings are removed.
- type of fertilizer used.

Nitrogen equivalency

Fertilizer guidelines are often based on elemental nitrogen. Use the following calculation to determine the application rate of any nitrogen fertilizer formulation.

To apply 0.5 kg N/100 m²

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

Another method is to use Table 6-3, *Nitrogen Equivalency,* on page 85, to determine the amount of fertilizer (with any given per cent nitrogen) needed for an application rate of 0.5 kg N/100 m².

Table 6-2. Nitrogen Requirements for Turfgrass

Turf Use	Nitrogen Requirements
greens, tees	Consult a turf specialist to determine nitrogen guidelines for turf. Rates are usually not more than 4 kg N/100 m^2 in 6–8 applications. Established greens will not usually require more than 2.5 kg N/100 m^2. Do not apply more than 0.5 kg N/100 m^2 per application.
lawns, fairways, athletic fields	Consult a turf specialist to determine nitrogen guidelines for turf. Rates are usually not more than 2 kg N/100 m^2 in 4 applications if clippings are left on. Do not apply more than 0.5 kg N/100 m^2 per application.
low-use turf	Consult a turf specialist to determine nitrogen guidelines. Usually 0.5 kg N/100 m^2 applied once per season will suffice.
sod	Prior to final cultivation before seed bed preparation and where the soil is a coarse texture, apply 90 kg N/ha. Where soil is medium or fine texture, is high in organic matter, or has a history of luxuriant growth, reduce the initial application to 50 kg N/ha. On turf with less than 85% groundcover, apply 70 kg N/ha as early as feasible in the spring after seeding. Reduce the rate to 35 kg N/ha where vigorous growth is evident. In mid or late June apply 50 kg N/ha. Withhold further applications until 3 weeks prior to harvesting, then apply 35 kg N/ha. Where sod is held over a second winter, apply 45 kg N/ha in September, late May and every 10 weeks until harvest.

Nitrogen sources

Quick-release sources of nitrogen fertilizers are generally less expensive than slow-release. However, they are also more prone to leaching and have a higher burn potential. Therefore, if used, apply these sources of nitrogen more frequently but at lower rates and water the turf after application.

Slow-release sources of nitrogen are generally more expensive but less prone to leaching, have a lower burn potential and are available more slowly.

A large selection of nitrogen sources is available. They can be divided into two categories, inorganic and organic. The organic category is subdivided into synthetic organic (quick release and slow release) and natural organic.

Inorganic nitrogen

Inorganic nitrogen sources contain no carbon. These nitrogen materials include ammonium nitrate, ammonium sulphate, and potassium nitrate. Inorganic nitrogen is water soluble and releases quickly. It has high burn and high leaching potential and is relatively inexpensive.

Synthetic organic nitrogen

Synthetic organic fertilizers are chemically based and originate from atmospheric nitrogen. They are classed as organic because they contain carbon. This category is available in quick-release and slow-release forms. Urea is the only turf fertilizer that is a synthetic organic and a quick-release source of nitrogen. Urea is also inexpensive, has a low burn potential and can be used as a liquid fertilizer.

Table 6-3. Nitrogen Equivalency

To obtain 0.5 kg N/100 m^2	
N% in fertilizer	**kg/100m²**
5	10.00
6	8.33
7	7.14
8	6.25
9	5.55
10	5.00
11	4.55
12	4.16
13	3.84
14	3.57
15	3.33
16	3.12
17	2.94
18	2.77
19	2.63
20	2.50
21	2.38
22	2.27
23	2.17
24	2.08
25	2.00
26	1.92
27	1.85
28	1.79
29	1.72
30	1.67
31	1.61
32	1.56
33	1.50
34	1.47
35	1.43
46	1.09

Slow-release synthetic organic nitrogen

Slow-release forms of synthetic organic nitrogen are manufactured using two technologies, either a chemical reaction with urea or by encapsulating urea. These sources of nitrogen are slow release, have a low burn potential and low leaching potential. They are expensive relative to urea.

The products that result from a chemical reaction with urea are urea formaldehyde (UF), also called methylene urea (MU), isobutylidine diurea (IBDU), and triazones.

Methylene ureas combine urea with carbon and hydrogen and forms chains of molecules. Short chains have faster nitrogen release and higher burn potential. Longer chains have slower nitrogen release and lower burn potential. This type of fertilizer requires microbial activity to release the nitrogen.

Isobutylidine diurea is formed by the reaction between isobutylaldehyde and urea. The nitrogen is released by hydrolysis. The size of the particles controls the nitrogen release rate. Smaller particles have quicker release rates.

Triazone is produced by the reaction between urea and formaldehyde, which forms a cyclic methylene urea. Triazone is released through microbial degradation.

Coated ureas

Coated ureas are urea pellets surrounded by a less soluble sulphur or polymer coat. Water penetrates and cracks the coating to release the nitrogen in sulphur-coated urea (SCU). Some SCU products are coated with a wax sealant that requires microbial activity to break it down. The coating thickness controls the release rate of nitrogen. SCU fertilizers are relatively inexpensive. Polymer-coated ureas (PCU) are more expensive than SCU but provide a more controlled nitrogen release.

Natural organic nitrogen sources

The use of natural organic sources of nitrogen has increased over the last decade. Natural organics have a low burn potential, a slow release rate, low leaching potential and rely on microbial activity for nitrogen release. The drawback for natural organic fertilizers is low nitrogen content and high cost. The three categories of organic nitrogen fertilizers are derived from sewage sludge, animal products and plant products.

Phosphorus and Potassium

Apply phosphorus and potassium to turf areas based on a soil test. The requirements for these nutrients are found in Table 6-4, *Phosphorus Requirements for Turfgrass* and Table 6-5, *Potassium Requirements for Turfgrass,* on page 87. Rates in Table 6-4 are expressed as kg of P_2O_5 (phosphate) and rates in Table 6-5 are expressed as kg of K_2O (potash). The amount of nutrient contained in a fertilizer is expressed as the weight, in per cent, of the nutrient element in the fertilizer, with two exceptions. A list of phosphorus sources can be found in Table 6-6, *Phosphorus Sources* and a list of potassium sources can be found in Table 6-7, *Potassium Sources,* on page 87.

Phosphorus and potassium are both expressed as the weight of the oxide (phosphorus pentoxide, P_2O_5, and potassium oxide, K_2O), rather than the element. This convention was established in the early days of chemical analysis, when an organic material like wood would be burned to remove the carbon and hydrogen, and the remaining ash (mostly oxides of the nutrient) would be weighed to determine the nutrient concentration. These oxides are not stable under natural conditions and do not represent the forms of the nutrients that are absorbed by plants, but they are engrained in the fertilizer labelling requirements.

To convert from elemental phosphorus (P) to P_2O_5, multiply the per cent P by 2.29. This accounts for the additional weight of oxygen in the compound.

To convert from elemental postassium (K) to K_2O, multiply the per cent K by 1.20.

Do not use this table with soil test results from labs not listed in Appendix A. *Accredited Soil-Testing Laboratories in Ontario,* on page 103, unless their methods are identical to those used by the OMAFRA-accredited labs.

Phosphorus is important in establishing turfgrasses. Where a soil test is not available, use the following guidelines to obtain a rough estimate of requirements:

- Where the turf has been fertilized regularly for a number of years or heavily in recent years, use the rates of phosphate and potash listed for the high soil test rating.
- If the field has received little fertilizer in the past, use one of the rates listed for a low soil test rating.

Table 6-4. Phosphorus Requirements for Turfgrass

Rates are total yearly applications. Not more than 90 kg/ha should be applied in any one application except for sod, which may receive the total yearly amount in one application before seeding.

Soil phosphorus (0.5 M sodium bicarbonate) Extractant used for OMAFRA-accredited soil test	Phosphate (P_2O_5) required — kg/ha		
(ppm P)	Greens, tees, fairways, lawns, athletic fields	Low-use turf	Sod
0–3	370 HR	90 HR	230 HR
4–5	360 HR	80 HR	210 HR
6–7	350 HR	70 HR	200 HR
8–9	340 HR	60 HR	190 HR
10–12	320 HR	40 MR	170 HR
13–15	300 HR	30 MR	150 HR
16–20	260 HR	20 MR	130 MR
21–25	220 MR	0 LR	110 MR
26–30	170 MR	0 LR	90 MR
31–40	120 MR	0 RR	70 LR
41–50	70 LR	0 RR	50 LR
51–60	40 LR	0 RR	40 LR
61–80	0 NR	0 NR	30 LR
Greater than 80	0 NR	0 NR	0 NR

Legend: HR = high response; MR = medium response; LR = low response; RR = rare response; NR =no or negative response.

Table 6-5. Potassium Requirements for Turfgrass

Rates **(ppm K)** are total yearly applications. Not more than 90 kg/ha should be applied in any one application except for sod which may receive the total yearly amount in one application before seeding.

	Potash (K_2O) required — kg/ha			
Soil potassium (1.0 M ammonium acetate) Extractant used for OMAFRA-accredited soil test	Greens, tees	Fairways, lawns, athletic fields	Low-use turf	Sod
0–15	400 HR	200 HR	90 HR	140 HR
16–30	360 HR	180 HR	80 HR	120 HR
31–45	320 HR	160 HR	70 HR	80 HR
46–60	280 HR	140 HR	50 HR	60 HR
61–80	200 HR	100 HR	30 MR	50 MR
81–100	160 HR	80 MR	20 MR	40 MR
101–120	120 MR	60 MR	20 MR	30 MR
121–150	80 MR	40 MR	0 MR	30 MR
151–180	40 MR	40 MR	0 RR	0 LR
181–210	0 LR	0 LR	0 RR	0 RR
211–250	0 RR	0 RR	0 RR	0 RR
Greater than 250	0 NR	0 NR	0 NR	0 NR

Legend: HR = high response; MR = medium response; LR = low response; RR = rare response; NR =no or negative response.

Table 6-6. Phosphorus Sources

Sources	P_2O_5 %
triple superphosphate	46
monoammonium phosphate (11-52-0)	52
diammonium phosphate (18-46-0)	46

Table 6-7. Potassium Sources

Sources	K_2O %
potassium chloride (muriate)	60–62
potassium sulphate	50
sulphate of potash magnesia (11% of Mg)	22
potassium nitrate	44

Phosphorus, along with nitrogen, is one of the major nutrient sources contributing to surface and groundwater pollution in Ontario. Although phosphorus is not readily leached from turf soils into groundwater, it can enter surface waters through erosion and runoff.

- Avoid applying phosphorus fertilizer where runoff is likely such as on frozen soils and paved surfaces.
- On established home lawn turf, apply phosphorus-free fertilizers unless a soil test indicates phosphorus is needed.

Many turf fertilizer companies have removed phosphorus from their blended turf fertilizers to help minimize the potential for phosphorus contamination of surface water.

Phosphorus does not leach readily from the soil and may accumulate to very high levels. Potassium leaches to some degree from sandy and organic soils. In contrast, nitrogen leaches quite readily.

Applying Fertilizer

Turf use, conditions and soil type

Areas that are subject to high levels of traffic (sports fields and golf course turf) and areas that are irrigated frequently need more nutrients. Nitrogen and potassium are the most important. Older turf needs less nitrogen than younger turf. Do not apply more than 0.5 kg N/100 m² per application (see Table 6-2, *Nitrogen Requirements for Turfgrass,* on page 85).

It is better to apply fertilizer more frequently and at lower rates because this minimizes the chances of leaching and/or runoff. This is especially true in the summer. Sandy, light textured soils may require more frequent fertilizer applications because nitrogen can easily leach from them. Home lawns with a very shallow layer of poor quality topsoil may also require more frequent fertilizer applications.

Type of fertilizer

Nitrogen may be obtained from a complete fertilizer or by using ammonium nitrate, urea or slow-release nitrogen materials. Where water-soluble ammonium nitrate or urea is used, water it in to avoid foliar burn.

Timing of application

Avoid fertilizing during periods of heat, drought stress or when conditions favour active disease development.

Early spring fertilization is not recommended as this tends to promote excessive shoot growth. Delay applying nitrogen until late May or early June. Apply fertilizer during the summer on irrigated turf only. Apply fertilizer high in nitrogen between mid-Aug to mid-Sept. to help turf recover from any issues during the growing season. Apply fertilizer to low-use turf once per year in the early fall. Rates should be kept low enough to prevent lush growth late in the fall. Additional information on nitrogen fertilizer rates and timing can be found in Chapter 1, *Integrated Pest Management for Turf,* on page 11.

Environmental considerations

Fertilizer that gets into ground water or surface water can have a negative impact on water quality. To minimize the possibility of this happening, always apply fertilizer with a properly calibrated spreader. Remove fertilizer from hard surfaces where it may run off into surface water. Avoid applying fertilizer if a heavy rain is in the forecast to minimize nutrient runoff.

Information on spreader calibration can be found in OMAFRA Publication 384, *Protection Guide for Turfgrass.*

Municipal Sewage Biosolids

Municipal sewage biosolids are a source of nitrogen, phosphorus and organic matter that can be used to produce sod. A site receiving sewage biosolids must have a certificate of approval issued by the Ontario Ministry of the Environment and Climate Change.

Before sewage biosolids can be applied to land, the site must qualify under the *Environmental Protection Act* Regulation 347 and the *Nutrient Management Act* Regulation 267/03. These regulations set site and application criteria and the waiting period between applying sewage biosolids and harvest. The period between applying sewage biosolids and harvesting sod is 12 months.

For more information on municipal sewage biosolids, see the OMAFRA website at *www.ontario.ca/omafra*.

For more information on sod production visit the Turf section of the OMAFRA website at *www.ontario.ca/crops*.

Adjusting soil pH

Soil pH is a measure of acidity or alkalinity on a scale from 0–14. The middle of the scale (7.0) is neutral, with values below 7.0 being increasingly acid and values above 7.0 increasingly alkaline. Most Ontario soils have pH values between 5.0 and 8.0. As soil acidity increases, the solubility of elements such as iron and manganese also increases. Most turf species grow well in soils with a pH of 5.5–7.5.

Raising pH

Lime is used to raise pH. General lime applications for most crops, based on buffer pH, are listed in Table 6-8, *Lime Requirements to Correct Soil Acidity Based on Soil pH and Soil Buffer pH,* on this page.

Buffer pH

Different soils may have the same soil pH value, for example 5.2, but require different amounts of lime to bring the pH to a particular desired level, for example, 6.0. This difference depends chiefly on the clay and organic matter content of each soil.

The soil pH determines if a soil should be limed, but a separate soil test, the buffer pH, determines the amount of lime required. Buffer pH is the measure of how much lime is needed to neutralize the acidity in a particular soil. Use Table 6-8 to determine the amount of lime needed to reach the different target soil pH values required for different crops.

Table 6-8. Lime Requirements to Correct Soil Acidity Based on Soil pH and Soil Buffer pH

Buffer pH	Target soil pH = 6.5 Lime if soil pH is less than 6.1	Target soil pH = 6.0 Lime if soil pH is less than 5.6
	Ground limestone required — t/ha (Based on Agricultural Index of 75*)	
7.0	2	0
6.5	3	2
6.0	9	6
5.5	17	12
5.0	20	20

* The agriculture index is an indication of limestone quality that combines the neutralizing value (see section below) and the fineness rating into a single value. The average agricultural index of limestone sold in Ontario has been about 75.

Limestone quality

Calcitic limestone consists largely of calcium carbonate. Dolomitic limestone is a mixture of calcium and magnesium carbonates. Use dolomitic limestone on soils with a magnesium soil test of 100 or less as it is an excellent, inexpensive source of magnesium. On soils with magnesium tests greater than 100, either calcitic or dolomitic limestone may be used to increase soil pH.

Two main factors affect the value of limestone for soil applications. One is the amount of acid a given quantity of limestone will neutralize when it is totally dissolved. This is called the "neutralizing value" and is expressed as a percentage of the neutralizing value of pure calcium carbonate. A limestone that will neutralize 90% as much acid as pure calcium carbonate is said to have a neutralizing value of 90. In general, limestone higher in calcium and magnesium content will have a higher neutralizing value.

The second factor that affects the value of limestone as a neutralizer of acidity is the particle size. Limestone rock has much less surface area to react with acid soil than finely powdered limestone, hence it neutralizes acidity so slowly that it is of little value.

Lowering pH

Sulphur can be used to lower pH. See Table 6-9, *Soil Acidification to pH 5.0 with Sulphur,* on this page. Do not apply more than 2 kg sulphur per 100 m² on established turf. Lower rates should be used on high-sand-content soils such as putting greens. Soils with pH above 7.0 frequently contain too much lime to use sulphur to lower the pH.

Table 6-9. Soil Acidification to pH 5.0 with Sulphur

Initial pH	Soil type: Sand (kg/100m²)	Soil type: Loam (kg/100 m²)
	kg of elemental sulphur per 100 m² for each of 2 successive years	
7.0	7.4	22.6
6.5	6.0	17.5
6.0	4.0	12.0
5.5	2.0	6.0

Temperature, moisture and aeration conditions affect the rate of pH change. The best time to apply materials to adjust the pH is spring, late fall or after cultivation practices such as coring. Perform major pH adjustments before turf is established. This will allow the soil amendments to be incorporated into the root zone by tillage.

Soluble Salts in Soil

High concentrations of water-soluble salts in soils can prevent or delay germination of seeds and can kill established plants or seriously retard their growth.

Ontario soils are naturally low in soluble salts. Soluble salts therefore rarely cause a problem in crop production and are not routinely measured in soil tests.

Excessive applications of fertilizers, run-off of salts applied to roads and chemical spills are some reasons soluble salts may be found in Ontario soils. If the amount of water is small, a given amount of salt in a soil creates a higher soil-water-salt concentration. Soluble salts also interfere with the uptake of water by plants. For these reasons, plant growth is most affected by soluble salts in periods of low moisture supply.

Soluble salts can be measured readily in the lab by measuring the electrical conductivity of a soil-water slurry. The higher the concentration of water soluble salts, the higher the conductivity. Table 6-10, *Soil Conductivity Reading Interpretation,* on this page, provides an interpretation of soil conductivity readings in Ontario field soils in a 2:1 water-soil-paste mixture. This is the procedure used by the OMAFRA-accredited labs.

Table 6-10. Soil Conductivity Reading Interpretation

Conductivity "salt" reading (millisiemens/cm)	Rating	Plant response
0–0.25	L	Suitable for most plants if OMAFRA-accredited soil test reports are followed.
0.26–0.45	M	Suitable for most plants if OMAFRA-accredited soil test reports are followed.
0.46–0.70	H	May reduce emergence and cause slight to severe damage to salt-sensitive plants.
0.71–1.00	E	May prevent emergence and cause slight to severe damage to most plants
1.00	E	Expected to cause severe damage to most plants.

Legend: L = low; M = medium; H = high; E = extremely high.

For more in-depth information on soil management and soil fertility, see OMAFRA Publication 611, *Soil Fertility Handbook*.

7. Turfgrass Species

Many turfgrass species are available for use in Ontario. The right choice depends on the desired appearance, intended use, level of maintenance and site conditions. Selecting the appropriate turfgrass species is also an important part of an IPM program. Turf is rarely seeded as a monoculture. Turf is either seeded as a blend (a combination of different cultivars of the same species) or a mixture (combination of two or more turfgrass species). A summary of turf species and mixtures based on intended use is shown in Table 7-1, *Turfgrass Selection,* on this page. A summary of turfgrass species characteristics can be found in Table 7-2, *Turfgrass Species Characteristics and Uses,* on page 94. Seed suppliers also have information about the varieties available.

Kentucky bluegrass *(Poa pratensis)*

Kentucky bluegrass is used extensively for home lawns, sports fields, parks and sod farms. This species produces a high-quality, dark green, dense turf with low-growth habit of medium-to-fine texture. Most varieties have good cold tolerance, good recuperative potential from turf injury, good tolerance to traffic and resistance to diseases such as leaf spot.

Kentucky bluegrass adapts to a wide range of soil and management conditions but performs best with moderate fertility, well-drained soil and full sun. Although not very drought resistant, Kentucky bluegrass can survive long, dry periods in a dormant state.

Canada bluegrass *(Poa compressa)*

Canada bluegrass may be used in areas that are too dry, acidic, or infertile for other grasses. It does not recover well from mowing but will produce a thin, low-quality turf for low-maintenance areas. It is well adapted to all cool-season areas but will not produce a high-quality lawn.

Rough bluegrass *(Poa trivialis)*

Rough bluegrass is a fine-textured turfgrass best suited for areas that tend to stay moist and shady. It is often a component of seed mixes. Seeded areas germinate rapidly, and the grass blends well with other common lawn species. It has poor high-temperature and drought tolerance, and its yellowish green leaf blades turn brown under the stress of high temperature and low soil moisture.

Table 7-1. Turfgrass Selection

Lawns	Species (percentages are expressed as a percent of the seed mixture)
medium to high maintenance — sun	Kentucky bluegrass (80–100%), turf-type perennial ryegrass (0–20%)
medium maintenance	Kentucky bluegrass (50–60%), fine fescue (20–30%), perennial ryegrass (20%)
low maintenance, dry and shady	fine fescue blend (100%) or suitable mixture with fine fescue (30%), perennial ryegrasses (20%) and shade-tolerant Kentucky bluegrasses (50%)
wet	rough bluegrass
Athletic fields	
new fields	Kentucky bluegrass blends (100%) or Kentucky bluegrass-perennial ryegrass mixture (Kentucky bluegrass 80% and perennial ryegrass 20%)
overseeding	turf-type perennial ryegrasses (100%)
Golf courses	
greens	creeping bentgrass, velvet bentgrass, red fescue
tees	creeping bentgrass, velvet bentgrass, Kentucky bluegrass, turf-type perennial ryegrass
fairways	creeping bentgrass, velvet bentgrass, Kentucky bluegrass, fine fescues

Supina bluegrass *(Poa supina)*

Poa supina was selected in Germany in the 1960s. It is currently used there on lawns, sports fields and golf courses. It is shade tolerant, wear tolerant and can tolerate low mowing height. It performs poorly under hot, dry conditions and does well if irrigated. It is very aggressive and is used for the goal mouth areas of sports fields and shaded areas on greens. It is marketed in seed mixtures with perennial ryegrass, fine fescue and Kentucky bluegrass for use on sports fields and golf courses.

Weeping alkaligrass *(Puccinellia distans)*

Weeping alkaligrass is a low-growing bunch-type grass with excellent tolerance of alkaline soils. It is both drought-tolerant and winter-hardy and looks similar to fine fescue. Weeping alkaligrass establishes rapidly but does not compete well on fertile soils. It is especially suited to areas where road salt kills the existing turf species. Weeping alkaligrass is also well suited for turf areas where effluent or reclaimed water is used.

Fine fescue (creeping red fescue, chewings fescue, hard fescue) *(Festuca spp.)*

Fine fescues produce a fine-textured turf that is medium green in colour and has a low-growth habit. These species grow well under low moisture. Most varieties perform well in moderate shade. They require very little fertilizer and are slow growing, which makes them a good choice in low-maintenance situations. If over fertilized they have a tendency to produce excessive amounts of thatch. They are also very cold tolerant.

Varieties containing endophytic fungi (beneficial fungi that live inside the turfgrass plant) have exhibited increased resistance to many common turf insects, including bluegrass billbug, sod webworms and chinch bugs, offering an alternative to chemical insect control. Endophyte-enhanced varieties may also exhibit increased tolerance of stress conditions. Perennial ryegrasses and tall fescue varieties may also contain endophytes. For more information on endophytes see Chapter 4, *IPM for Turf Insects,* on page 33.

Turf-type perennial ryegrass *(Lolium perenne)*

Turf-type perennial ryegrasses are being used more often for home lawns, sports fields and tees on golf courses. Perennial ryegrass is a wear-tolerant, bunch-type grass with a rapid growth rate. It does not form thatch. Improved turf-type perennial ryegrass cultivars are medium textured and medium to dark green in colour. One of the most significant improvements in turf-type perennial ryegrass cultivars is the incorporation of endophytes. Endophytes provide the grass with resistance to leaf-feeding insects such as bluegrass billbug, sod webworm and hairy chinch bugs.

Perennial ryegrass is quick to germinate and establish. Establishment can take as little as 4–6 days at temperatures of 15–18°C. Because of this, perennial ryegrass is the preferred species for overseeding lawns and sports fields. It requires moderate fertility, tolerates moderate salinity and grows well in sunny to partially shady locations. It is seldom planted alone and is commonly used in seed mixtures to provide a rapid turf cover, acting as a nurse grass for the more slowly germinating Kentucky bluegrass and fine fescues.

Ryegrass should not comprise more than 20%–25% of the seed blend (based on weight), or its rapid germination and growth will cause excessive competition for the other species.

Perennial ryegrass can be seeded alone to provide a high-quality sports turf. Because perennial ryegrass does not have rhizomes (underground horizontal stems), frequent overseeding is needed to maintain a dense stand of turf.

Perennial ryegrass has the poorest low-temperature tolerance of all the perennial cool-season turfgrasses. It is not winter-hardy in all areas of Ontario. It does not tolerate poorly-drained soils where standing water may occur in the spring and is best suited to the southern part of Ontario.

Spreading turf-type perennial ryegrass

Turf breeders from a variety of companies have released a subspecies of perennial ryegrass that produces pseudo-stolons. They were bred and selected under traffic stress for strong recuperative ability. These spreading perennial ryegrasses contain endophytes. They have been evaluated for winter-hardiness, drought tolerance, ability to resist weed and insect invasion.

Research trials to date have shown that these spreading types have the ability to out-compete weeds, are weak spreaders (intermediate between bunch type perennial ryegrass and Kentucky bluegrass), have poor drought tolerance and winter-hardiness but will fill in after a drought or winter injury unlike conventional turf type perennial ryegrasses.

Creeping bentgrass *(Agrostis stolonifera)*

Creeping bentgrass produces a fine-textured, high-quality turf but requires intensive maintenance, including close, frequent mowing and good disease management. It is one of the most cold-hardy turfgrasses. It grows best in full sun but tolerates partial shade, and it has poor drought tolerance, requiring frequent irrigation during dry weather. Creeping bentgrass has a medium establishment rate and low-to-medium nitrogen requirements. It is very tolerant of close mowing and can develop excessive thatch under a high maintenance regime. Creeping bentgrass is susceptible to a wide range of diseases including dollar spot, brown patch, Pythium blight, and take-all patch.

Creeping bentgrass is most commonly used for putting and lawn bowling greens where a uniform playing surface is required. Creeping bentgrass also provides an excellent turf for golf course tees and fairways if mowed at or less than 1.2 cm.

Colonial bentgrass *(Agrostis tenuis)*

Colonial bentgrass can be used as an alternative to creeping bentgrass.

Velvet bentgrass *(Agrostis canina)*

Velvet bentgrass has the finest leaf texture, highest shoot density and smoothest playing surface of all turfgrasses. There is much diversity of colour within the velvet bentgrasses, ranging from very light to a bright, lime green and often darker. Velvet bentgrass possesses exceptional drought, shade and disease tolerance (especially to dollar spot and brown patch) while requiring very low levels of nitrogen. It is adapted to relatively low soil pH levels (5.0–5.5), but performs better at slightly acidic levels of 6.0–6.5. In neutral soils (7.0) or soils near to neutral (6.5–7.5), acidifying fertilizers such as ammonium sulphate improve the performance of velvet bentgrass. It also has good wear and low temperature tolerance. A major limitation is its lack of high temperature tolerance. It can be used as an alternative to creeping bentgrass, especially in shady situations or where reduced fertilizer and pesticide use is desirable.

If over fertilized, it tends to produce excess thatch. Frequent, light topdressing coupled with light vertical mowing will help maintain a firm, smooth surface. Aggressive, deep verticutting may be needed once a year to remove hydrophobic thatch, and deep-tine aerification may be necessary to relieve compaction.

Velvet bentgrasses can stand low mowing heights. Heights as low as 3 mm are fairly common on tournament-grade velvet bentgrass greens. It can be mown at comparatively higher heights of cut while retaining extremely smooth putting surfaces and performs very well at fairway heights to 14 mm.

Tall fescue *(Festuca arundinacea)*

This medium-to-coarse-textured turf species tolerates heat, drought, shade and salt. It is suitable for a wide range of soils and requires low-to-moderate fertility. It is best when seeded on its own. It requires warmer soils to germinate than the other cool-season grass species and should be seeded earlier (mid-July to mid-Aug).

Many tall fescue varieties contain endophytes, which provide the grass with resistance to leaf-feeding insects such as bluegrass billbug, sod webworm and hairy chinch bugs.

Spreading tall fescue

Turf breeders from a variety of companies have released rhizomatous selections of tall fescue. These selections are reported to grow better in summer and late fall than tall fescue, and require less water because of their deep roots. They also have endophytes that are different from other tall fescue.

Research trials to date have shown that these spreading types of tall fescue have the ability to spread. They are weaker spreaders than the spreading perennial ryegrasses. They retain their green colour longer during a drought period. They are not as good as the spreading perennial ryegrasses at out-competing weeds but have superior winter-hardiness compared to the creeping perennial ryegrass types.

See Table 7-2. *Turfgrass Species Characteristics and Uses,* on page 94, for a summary of the characteristics of each species.

Table 7–2. Turfgrass Species Characteristics and Uses

Species	Growth Type	Mowing Frequency	Establishment Rate *(days)*	Nitrogen Req't kgN/100m²/month	Wear Tolerance	Drought Tolerance	Water Usage	Competitiveness	Thatch Formation	Shade Tolerance	Cold Tolerance	Endophytes	Seeding Rate (kg/100m²)	Uses
Kentucky bluegrass *Poa pratensis*	C	M	21	0.2–0.7	G	G	H	M	M–H	F–G	VG	N	1.0–1.5	Home lawns, sports fields, parks and sod farms
Supine bluegrass *Poa supina*	C	M	21	0.2–0.4	E	P	H	H	M–H	VG	VG	N	0.75–1.0	Sports fields and shaded greens. Seed in a mixture with Kentucky bluegrass (10%–50% supine bluegrass, 50%–90% Kentucky bluegrass)
Perennial ryegrass *Lolium perenne*	B	H	4–6	0.2–0.5	E	F	M	H	None	F-G	P	Y	2.5	Home lawns (as part of a mixture with Kentucky bluegrass and fine fescues), sports fields, tees on golf courses and overseeding
Spreading perennial ryegrass	C	H	4–6	0.2–0.5	E	F	M	H	L	F-G	P	Y	2.5	Home lawns and sports fields. More research is needed on the suitabilitly of this type of perennial ryegrass for Ontario.
Red fescue *Festuca rubra*	C	L-M	Medium	0.1–0.3	G	G	M	M	L–M	VG	G	Y	2.0	Shady areas and low-maintenance areas on home lawns, golf course greens and out-of-play areas
Chewings fescue *Festuca rubra* var *commutata*	B	L-M	Excellent	0.1–0.3	E	G	L	H	M–H	VG	G	Y	2.0	Shady areas and low-maintenance areas on home lawns and golf course out-of-play areas
Hard fescue *Festuca longifolia*	B	L	Slow to medium	0-0.1	G	E	L	M	M	VG	G	Y	2.0–2.5	Shady areas and low-maintenance areas on home lawns and golf course out-of-play areas
Sheep fescue *Festuca ovina*	B	L	Slow to medium	0	G	E	Best if not irrig.	M	M	VG	G	Y	2.0–2.5	Shady areas and low-maintenance areas on home lawns and golf course out-of-play areas
Tall fescue *Festuca arundinacea*	B	H	Quite good	0.2–0.5	G	E	H	M	None	G	F	Y	3.0–4.0	Sports fields, highways and boulevards
Spreading tall fescue	C	H	Quite good	0.2–0.5	G	E	H	M	L	G	F	Y	3.0–4.0	Home lawns and sports fields. More research is needed on the suitabilitly of this type of tall fescue for Ontario.
Creeping bentgrass *Agrostis palustris*	C	H	Medium	0.15–0.35	G	P	H	H	H	F	E	N	0.3–0.5	Golf course greens, tees, fairways and lawn bowling greens
Velvet bentgrass *Agrostis canina*	C	M	Medium	0.1–0.2	E	VG	M	H	VH	VG	E	N	0.3–0.5	Low-maintenance golf course greens and fairways

Legend: (C = creeping, B = bunch)
(VH = very high, H = high, M = medium, L = low)
(E = excellent, VG = very good, G = good, F = fair, P = poor)
(Y = Yes, N = No)

A list of Ontario turfgrass seed distributors can be found in Table 7-3, *Ontario Distributors of Turfgrass Seed,* on this page.

Table 7-3. Ontario Distributors of Turfgrass Seed

Distributor Address	Contact Information
Bishop Seeds Ltd. Box 171, 99 John St. Harriston, ON N0G 1Z0	519-338-3840 519-338-2510 fax *info@bishopseeds.ca* *www.bishopseeds.ca*
Direct Solutions (Agrium Advanced Technologies) 10 Craig St. Brantford, ON N3R 7J1	519-770-3157 519-757.0800 fax *www.aatdirectsolutions.com*
Graham Turf Seeds Ltd. 1702 Elm Tree Rd., R.R. #1, Lindsay, ON K9V 4R1	1-877-247-1082 705-878-8822 705-878-1978 fax *www.grahamturf.com*
Lawn Life 935023 Airport Rd. Mono, ON L9W 6C6	519-942-9333 519-942-9333 fax *info@lawnlifenaturalturfproducts.com* *www.lawnlifenaturalturfproducts.com*
Master's Turf Supply Ltd. 80 William St. W. Harriston, ON N0G 1Z0	519-510-8873 519-510-8875 fax *mastersturf@wightman.ca*
Ontario Seed Company 330 Phillip St., Box 7, Waterloo, ON N2J 3Z9	1-800-465-5849 519-886-0557 519-886-0605 fax *www.oscturf.com*
Pickseed Canada Ltd. 1 Greenfield Rd., Box 304, Lindsay, ON K9V 4S3	705-878-9240 705-878-9249 fax *www.pickseed.com*
Quality Seeds R.R. #1 8400 Huntington Rd., Woodbridge, ON L4L 1A5	877- 856-7333 905-856-7509 fax *www.qualityseeds.ca*
Speare Seeds Ltd. P.O. Box 171, Harriston, ON N0G 1Z0	519-338-3840 519-338-2510 fax *www.speareseeds.ca*

Time of seeding

Seeding can be done mid-April to early June, mid-July to end of September, or as a dormant seeding. Mid-August to mid-September is preferred as soil moisture and temperature conditions are best for germination, and there is less competition from germinating weeds, with the exception of tall fescue.

Weed control

Broadleaf weeds can be a problem in newly seeded turf. Mowing can control weeds such as mustard, ragweed and lamb's quarters. See OMAFRA Publication 384, *Protection Guide for Turfgrass* for herbicides and bio-pesticides allowed under the *Pesticides Act* and Regulation 63/09 or visit *www.ontario.ca/pesticideban.*

Mowing newly seeded turf

For Kentucky bluegrasses, fine fescues, perennial ryegrasses and tall fescues, allow about 4 cm growth before first mowing. For bentgrasses, mow after 10–12.5 mm of growth. For the next two to three mowings, cut at 12.5 mm, gradually reducing it to the desired mowing height.

Maintain all species at mowing heights as listed in Table 7-4, *Mowing Heights,* on this page.

Table 7-4. Mowing Heights

Clippings contain nutrients the soil can use. If they are removed, additional nutrients, in particular nitrogen and potassium, should be increased. If turf is mowed regularly, clippings do not contribute to thatch accumulation.

Grass Type	Mowing height	Clippings
Greens	4.8–7.5 mm	remove
Tees	7.5–15 mm	remove
Fairways	13–23 mm	return or remove
Athletic Fields	2.5–5.0 cm	return
Lawns	4.0–6.0 cm	return

8. Water Management

Throughout the summer, turf water requirements often exceed average rainfall. The result is a water deficit. This includes home lawns, commercial turf, sod farms, sports fields and golf course turf. To make up the water deficit, turf must be irrigated. There are many things to consider, including:

- laws and regulations
- irrigation scheduling and amount
- dormancy
- water quality
- water conservation

Laws and Regulations

If using more than 50,000 L per day from a surface or groundwater source, a Permit to Take Water is required. For an application and guide, visit *www.ontario.ca* and search on 'permits to take water'. One acre irrigated with 13 mm of water is equal to 50,000 L. The permit ensures that all water users and water resources are protected. To apply for a permit, contact a local Ministry of the Environment and Climate Change (MOECC) office. See Appendix D, *Ministry of the Environment and Climate Change Regional Contact Information,* on page 106 for a list of MOECC contacts.

If taking water from a surface water source, the following information is required:

- the flow rate of the river, creek or stream (measured during summer)
- a map
- GPS co-ordinates if available
- estimated daily rate of water to be used
- volume of water required for irrigation
- a completed Permit to Take Water application

If taking water from a well, a pond replenished from a well or an excavated pond replenished by a well, the following may be required:

- a map
- GPS co-ordinates if available
- a completed Permit to Take Water application
- water well records within the survey area
- details of pumping equipment and intake levels
- information on sub-surface conditions, e.g. pits, drill holes or other excavations
- pumping test report to show water level before and after taking the maximum amount of water applied for and the time it took the water level to recover

To build a dugout pond or by-pass pond, in addition to a Permit to Take Water, you may need construction permits from:

- the conservation authority if the site is in a designated flood plain
- the Ministry of Natural Resources and Forestry
- the Niagara Escarpment Commission

Irrigation Scheduling for Golf Courses, Irrigated Sports Fields and Sod

Irrigation scheduling is influenced by many factors, including soil infiltration rates, water holding capacity, rooting depth, and evapotranspiration rates.

Evapotranspiration (ET) is a measure of the amount of water transpired by plants and evaporated from soil. ET is expressed in mm per day. ET is affected by temperature, light intensity, wind, humidity and the type of crop. ETs can be estimated from local weather data or on-site weather instruments. Table 8-1, *Average Maximum Daily Evapotranspiration Values,* on page 98 lists ETs for areas throughout the province.

Measuring soil moisture

One way to schedule irrigation is by measuring soil moisture.

To start, estimate the maximum amount of crop-available soil water in the root zone. The available water-holding capacity is the maximum amount of water available for plant growth that a soil can hold. It varies with soil texture.

A sandy soil may have less water-holding capacity, but all of the water is available for plant growth. A clay soil has more water-holding capacity, but some of it is so tightly bound to the soil that it is not available for plant growth. Each soil texture has a characteristic amount of water-holding capacity. Table 8-2. *Available Water Based on Soil Type*, on page 98, lists the per cent volume of water per volume of soil for different soil textures.

Table 8-1. Average Maximum Daily Evapotranspiration (ET) Values (mm)

Month	Date	Windsor	Ridge-town	London	Simcoe	Vine-land	Toronto	Mt. Forest	Trenton	Ottawa	North Bay	Thunder Bay
May	7	2.1	2.2	2.4	2.8	2.0	2.3	3.0	2.1	3.0	2.7	2.4
	14	3.5	3.7	3.7	3.7	3.6	3.6	3.6	3.5	3.7	3.1	3.1
	21	3.6	3.8	3.9	4.6	3.2	3.9	4.0	3.6	4.2	3.3	3.3
	28	4.1	4.0	3.7	4.9	3.3	3.8	3.3	3.3	3.5	2.9	3.7
June	4	4.2	4.3	4.1	4.8	3.9	4.3	4.5	4.3	4.6	3.9	4.0
	11	4.3	4.2	4.2	5.2	4.4	4.2	3.8	4.1	4.6	4.1	4.1
	18	4.2	4.3	4.1	5.4	4.3	4.4	4.5	4.0	4.6	3.9	4.1
	25	4.9	4.7	4.5	5.5	5.3	4.6	5.2	4.8	4.5	4.0	4.9
July	2	4.6	4.7	4.9	5.3	4.7	4.5	5.3	4.5	4.7	4.1	4.3
	9	5.4	5.2	4.5	5.5	5.2	4.9	5.1	5.1	5.0	4.2	4.7
	16	4.9	4.9	4.4	5.0	4.8	4.7	4.8	4.4	4.3	4.0	4.8
	23	4.7	4.6	4.4	5.6	4.4	4.8	4.5	4.5	4.9	4.0	5.1
	30	4.8	4.2	4.3	5.1	3.3	3.9	4.7	4.2	4.5	3.7	4.5
Aug	6	4.8	4.7	4.2	4.6	4.3	4.5	4.8	4.1	4.3	3.6	4.0
	13	3.6	3.8	3.5	4.5	3.3	3.6	3.2	3.3	3.2	2.6	4.2
	20	3.4	3.0	3.6	3.5	3.2	3.2	3.7	3.4	3.4	2.6	2.8
	27	3.5	3.3	3.5	4.3	3.3	3.4	3.5	3.0	3.1	2.4	2.7
Sept	3	3.5	3.2	3.4	4.5	3.2	3.3	3.3	3.2	3.5	2.7	2.8
	10	3.3	3.4	2.8	3.9	2.7	3.0	3.4	2.6	2.4	2.5	2.3
	17	2.4	2.4	2.3	3.0	2.5	2.7	2.2	1.7	1.3	1.0	1.6
	24	2.3	2.4	2.3	2.9	2.2	1.6	1.7	1.7	1.9	0.7	1.1

Source: OMAFRA/Agriculture and Agri-Food Canada Best Management Practices booklet, *Irrigation Management,* Order No. BMP08

Table 8-2. Available Water Based on Soil Type

Soil type	Percent available water	Volume of water in a 300 mm rooting depth
sandy loam	10%	30 mm
loam	13%	39 mm
clay	6%	18 mm

To calculate the depth of water available in the root zone, multiply the per cent of available water by the effective rooting depth, which is 300 mm for turf.

Total crop-available soil water in the root zone at field capacity is the available water capacity of the soil texture multiplied by crop rooting depth.

Choose the limit of soil moisture depletion before irrigation should be added. For turf this is estimated at 50% crop-available soil water. Measure this by using a tensiometer, electrical resistance blocks, time-domain reflectometer or frequency-domain reflectometer. All these technologies have strengths and weaknesses. Consult your irrigation supply company. For more information, see Irrigation Best Management Practices on the OMAFRA website at *www.ontario.ca/crops*.

Water budget

Another way to schedule irrigation is to develop a water budget. A water budget is based on the premise that the soil is a reservoir for available water. Available-water capacity is reached when the soil reservoir is full. Rainfall and irrigation add water to the reservoir, and crop water use and evapotranspiration take water out of the reservoir.

First, determine the available-water-holding capacity of the soil. Then, measure or estimate the incoming water (rain and irrigation) and the outgoing water (evapotranspiration, run-off and drainage).

Rain and irrigation vs. evapotranspiration

The incoming water is the amount of precipitation or irrigation applied to a site. To measure this you will need a rain gauge and a knowledge of your irrigation system delivery rate in mm/hour.

The outgoing water is the water lost through evapotranspiration from plants and soil and from runoff and drainage. Table 8-3, *Estimate of Turf*

Evapotranspiration From 1 p.m. Weather Observation in July and August, on this page, shows how to estimate the ET.

Table 8-3. Estimate of Turf Evapotranspiration From 1 p.m. Weather Observation in July and August

Sky	Temperature	Humidity	Wind	Turf ET (mm)
sunny	above 23°C	low	high	6.0
sunny	above 23°C	low	low	5.5
sunny	above 23°C	high	high	5.0
sunny	above 23°C	high	low	4.5
sunny	below 23°C	low	high	4.5
sunny	below 23°C	low	low	4.0
sunny	below 23°C	high	high	3.8
sunny	below 23°C	high	low	3.5
cloudy	above 23°C	low	high	3.5
cloudy	above 23°C	low	low	3.0
cloudy	above 23°C	high	high	2.8
cloudy	above 23°C	high	low	2.5
cloudy	below 23°C	low	high	2.5
cloudy	below 23°C	low	low	2.0
cloudy	below 23°C	high	high	1.8
cloudy	below 23°C	high	low	1.5

Source: *Understanding Turf Management,* R.W. Sheard. 2005

Crop factor

The values in Table 8-3 are for turf growing during July and August. An adjustment factor is needed to account for differences in seasonal growth. For turf, the adjustment factors are:

- May: 0.75
- June: 0.85
- July: 1.00
- August: 1.00
- September: 0.75
- October: 0.6

Water budget example

To avoid turf stress, irrigate when the available-water reserve is at 50% (available-water reserve is half empty). Irrigate to fill the available-water reserve. If turf is over-irrigated the result will be run-off or leaching.

For example, for a sandy loam with 30 cm of rooting zone, Table 8-2 on page 98 shows the available-water reservoir is 30 mm. In July there is no need for a seasonal correction. Rain a few days ago filled up the reservoir and the weather since has been sunny. Therefore the reservoir will be about 70% full. Table 8-4, *Water Budget Example,* on this page, shows how the water budget is calculated daily. The available water each day is the amount available from the day before plus any rain or irrigation minus the ET for that day. The per cent available water is the water available in mm divided by the water-holding capacity for that soil. In the example this is 30 mm.

On day 4 the starting available water is 27.5 mm. Ten mm of rain fell and only 1.8 mm of ET was lost from the system (27.5 + 10 – 1.8 = 35.7). The soil only holds 30 mm, so the excess water would run off or, more likely, leach below the root zone and therefore be unavailable to the plant. The difference between 35.7 and 30 is 5.7 and is reported in the run-off or leach column.

The water budget method can significantly reduce the amount of water used on sports fields, golf course turf and sod.

Water budgeting should be used with care on sand-based root zones. There is a tendency to underwater at times. Also, during periods of high evapotranspiration, localized dry spots may form.

Table 8-4. Water Budget Example

Day	1 p.m. temp	Weather	Rain (mm)	ET (mm)	Irrigation (mm)	Available (mm)	% available	Run-off/ leach
1		–	–	–	–	21	70	-
2	26	sunny, dry, light wind	0	5.5	0	(21 – 5.5) = 15.5	15.5/30 = 52%	0
3	28	sunny, dry, windy	0	6.0	18	15.5 + 18 – 6 = 27.5	27.5/30 = 92%	0
4	15	cloudy, fog, windy	10	1.8	0	27.5 + 10 – 1.8 = 35.7	100%	5.7
5	18	cloudy, low humidity, high wind	0	3.5	0	30 – 3.5 = 26.5	26.5/30 = 88%	0
6	24	sunny, low humidity, low wind	4	7.5	0	25.5 – 7.5 = 18	18/30 = 60%	0
7	30	sunny, low humidity, windy	0	8.0	20	18 – 8 + 20 = 30	30/30 = 100%	0

Scheduling home lawn irrigation

Water deeply and infrequently. Avoid shallow watering, which promotes shallow rooting and the accumulation of thatch.

Most home lawns need 2.5–4.0 cm of water a week to prevent dormancy. This is best applied in the early morning to prevent long periods of leaf wetness. Most compacted topsoils on home lawns will not accept this much water in one application. The option then is to cycle the irrigation through all the stations twice. The sporadic rest period gives that area some time to allow the water to infiltrate the root zone.

Dormant turf

Home lawns and other turf that does not receive adequate rainfall and is not irrigated will turn brown in the summer. When this happens the turf is not dead, it is dormant. The grass plants may appear dead to the naked eye, but deep inside the plant there is a small area (called the crown) which is still alive. Once this crown gets rain again, it will start growing and the turf will green up in 10–14 days.

Turf can remain dormant for up to six weeks without any adverse effects. There may be some turf loss if the dry period continues much longer. For every week after the six week mark, expect a loss of about 25% of the turf. It is important when lawns are dormant to minimize traffic.

If the lawns receive excessive traffic while in a dormant state, irreparable damage will result. Another factor that could affect how well a lawn will rebound is whether or not there are insects such as hairy chinch bugs feeding on the turf. For more information on hairy chinch bugs see Chapter 4, *IPM for Turf Insects*.

Weed invasion

Another result of having dormant turf for several weeks in the summer is broadleaf weed invasion. When turf is dormant, it is not thick, lush and green. If the weed seeds in the top of the soil get light and some moisture, they will germinate and become established in dormant turf.

For more information on home lawn irrigation, see OMAFRA Factsheets, *Lawn Maintenance* and *Is a Brown Lawn a Dead Lawn?* These factsheets can be found on the OMAFRA website at *www.ontario.ca/crops*.

Quality of Irrigation Water

Irrigation water quality is one of the most important aspects of a turf irrigation system. Irrigation water has a significant influence on the characteristics of the turf root zone. Over successive irrigation cycles, the chemicals present in the water affect the pH, soluble salts, bicarbonate level and other chemical properties of the root zone.

Problems with irrigation water quality become more important in turf management as water resources become limited, forcing the use of non-potable sources. Common symptoms of water quality problems include nutrient deficiency symptoms (e.g. as a result of high or low pH), reduced growth, discolouration, wilting, leaf curling and desiccation (e.g. accumulation of salts).

Solids can be present, clogging the irrigation delivery system. Biological and chemical components can affect turfgrass performance and dissolved minerals and salts can cause problems. Some salts are nutrients, but others are toxic to plants if they are present in excessive amounts. The rate at which undesirable salts accumulate depends on the amount of soluble salts in the water, the amount of irrigation applied annually, and the physical and chemical properties of the soil.

Major water quality problems include:

- high or low water pH.
- high total soluble salt concentration.
- high sodium (Na) concentration.
- the wrong proportion of Na.
- high levels of carbonate (CO_3), bicarbonate (HCO_3), calcium (Ca), magnesium (Mg), chloride (Cl) or boron (B).

Testing irrigation water

Test irrigation water throughout the growing season. Quality is highest in the spring, when water volumes are at their highest. There are fewer dissolved salts, giving lower electrical conductivity (EC) values. Bicarbonate levels are also lower. For these reasons, test irrigation water in the spring and compare it with subsequent tests done in the summer and early fall.

A number of chemical attributes can be tested. See Table 8-5, *Acceptable Ranges for Chemical Properties of Irrigation Water for Most Turf Species,* on page 101. Collect samples from below the surface, around the level where the intake line sits. Do this when the bottom sediment has not recently been disturbed. Collect about 500 ml (about the size of a bottle of spring water) and refrigerate it until it is sent to the lab.

Where lab results show some chemical properties beyond the acceptable range, a few options are available. Find an alternative source of irrigation water with chemical properties within the acceptable ranges. Use more water from a good source to leach excess solutes. Treat the water to remove salts (e.g. reverse osmosis), which is effective but costly.

Much of the soil in southern Ontario has a limestone base, giving soils and groundwater their alkalinity. Although pH is a good indicator of the acidity or alkalinity, the level of bicarbonate is a more accurate indication. The higher the level of bicarbonate, the more difficult it is to bring the pH down. It is possible to correct water pH problems with the injection of nitric or phosphoric acid, depending on the bicarbonate content of the water.

Table 8-5. Acceptable Ranges for Chemical Properties of Irrigation Water for Most Turf Species

	Units of measurement	Acceptable range
salinity (TDS)	mg/L	450–2,000
salinity (EC)	dS/m	0.7–3.0
pH		6–7
bicarbonates (HCO_3)	mg/L	90–500
sodium (Na)	SAR	3–9
chloride (Cl)	mg/L	70–355
boron (B)	mg/L	1.0–2.0

TDS: total dissolved salts; EC: electrical conductivitySAR: sodium absorption rate

Salinity

The acceptable range for dissolved salts in irrigation water is 200–800 parts per million (ppm) or 200–800 mg/L. When dissolved salts rise above 2,000 ppm, the irrigation water may injure turf. The degree of tolerance of high-salt irrigation water depends on the turf species and the root zone mix. Cool-season turfgrass species and their tolerances are listed in Table 8-6, *Relative Tolerances of Cool-season Turf Species to Soil Salinity,* on this page. If the soil has good permeability and drainage, it can tolerate poor-quality irrigation water. Periodic heavy irrigation can leach excess salts. Electrical conductivity (EC) is the measure of the total of salts and is expressed in decisiemens/metre (dS/m). It can also be expressed as millimhos per centimetre (mmhos/cm), which is equivalent to dS/m. To convert EC to ppm, multiply by 640.

Table 8-6. Relative Tolerances of Cool-season Turf Species to Soil Salinity

Grass Type	Tolerance to Soil Salinity
alkali grass	T
annual bluegrass	S
annual ryegrass	MS
colonial bluegrass	S
creeping bentgrass	MS
fine fescues	MS
Kentucky bluegrass	S
perennial ryegrass	MT
rough bluegrass	S
tall fescue	MT

Legend: S = Sensitive (less than 3 dS/m); MS = Moderately sensitive (3-6 dS/m); MT = Moderately tolerant (6-10 dS/m) T = Tolerant (greater than 10 dS/m)

Sodium

Sodium in turf irrigation water can decrease soil aeration, water infiltration and soil water percolation. The rate at which soils adsorb sodium from water is called the sodium adsorption ratio (SAR). SAR is expressed as:

$$SAR = \frac{Na^{+}}{\sqrt{\dfrac{(Ca^{2+} + Mg^{2+})}{2}}}$$

The sodium, calcium and magnesium are expressed in mmoles/L.

SAR is used to classify the sodium hazard of water sources. A SAR above 6.0 may result in a sodium build-up in certain soils.

Bicarbonate

Reduced soil permeability can also occur when water is high in bicarbonate. High bicarbonates allow calcium and magnesium in the soil to precipitate and form calcium carbonate and magnesium carbonate. Calcium and magnesium carbonates in the presence of sodium may reduce soil permeability. The bicarbonate risk is expressed as the residual sodium carbonate (RSC) and is calculated in meq/L:

$$RSC = (CO_3^{2-} + HCO^{3-}) - (Ca^{2+} + Mg^{2+})$$

At RSC levels above 2.5 there is a danger of the soil becoming impermeable.

Chlorides

Excessive concentrations of chlorides may cause turfgrass tip-burn and can kill shoots. Concentrations greater than 355 ppm are undesirable for salt-sensitive species.

Boron

Boron is an essential micronutrient needed in very small amounts. It may become toxic if irrigation water contains more than 2 ppm.

Management Strategies for Low-Quality Irrigation Water

During years where rainfall is abundant, irrigation with poor quality water is usually not a problem. The high-quality rain water leaches any salts that may accumulate. Turf problems resulting from the use of poor-quality irrigation water are usually evident during dry years.

If a soil-water test shows that soluble salts are a problem, soil cultivation and good irrigation scheduling to ensure there is enough water to cause leaching will help.

The infiltration rate, percolation rate and drainage can affect the success of these management strategies.

Irrigation water quality issues can be complex. For a complete discussion consult *Understanding Water Quality and Guidelines to Management* by Duncan et. al., 2000.

Conserving Water

To conserve water:

- Choose species that have good drought tolerance, such as velvet bentgrass for fairways, greens and tees or fine fescues on home lawns.
- Have an efficient irrigation system design that reduces run-off, meets site-specific irrigation needs, matches application rates to infiltration rates and uses multiple applications.
- Check that all sprinkler heads are functioning properly, are level and are operating at the correct pressure.
- Do a system test to calculate the precipitation rate and distribution uniformity and use this information to calculate an irrigation schedule.
- Improve irrigation scheduling by using water budget information, experience and knowledge of the site.
- Design irrigation zones that include only areas of similar soil types, slopes and climatic conditions.
- Use a good cultivation program on sports fields, golf courses or home lawns that promotes deeper root growth and enhances water infiltration rates.
- Educate turf managers about water management and conservation. Also educate policy makers, club officials and members, sod farmers and home owners.
- Catch and use run-off. Some golf courses collect drainage and run-off from parking lots and hard surfaces and store and use this water for irrigation.
- Use effluent water on high-sand-profile root zones or on sod farms with high percolation rates.
- Design a golf course that uses mulch materials, drought-resistant grasses, native grasses and ground covers, rocks and non-irrigated mounds.
- Test for moisture requirements rather than relying on automatically timed intervals. Relate irrigation cycles to the local evapo-transpiration rates, soil type, drainage characteristics and species of turfgrass. Have manual overrides on automatic watering systems that are easy to adjust for unusually wet or dry conditions or use automatic rain delays to shut off irrigation during rainy periods.

References

Duncan, R.R.; Carrow, R.N. and Huck, M. *Understanding Water Quality and Guidelines to Management*. USGA Green Section Record. 38 (5):14-24, 2000

Sheard, R.W. *Understanding Turf Management*. Sports Turf Association, 2000

9. Appendices

APPENDIX A: Accredited Soil-Testing Laboratories in Ontario

The following labs are accredited to perform soil tests for pH, buffer pH, P, K, Mg and Nitrate-N on Ontario soils.

Laboratory Name	Address	Telephone/Fax/E-mail		Contact
A & L Canada Laboratories Inc. *www.alcanada.com*	2136 Jetstream Rd. London, ON N5V 3P5	Tel: Fax: E-mail:	519-457-2575 519-457-2664 *alcanadalabs@alcanada.com*	Greg Patterson Ian McLachlin
Activation Laboratories *www.actlabsag.com*	9-1480 Sandhill Dr. Ancaster, ON L9G 4V5	Tel: Fax: E-mail:	289-204-0515, Ext. 102/104 289-204-0514 *Laboratory@ActLabsAg.com*	Rob Deakin Dr. Steve Jenkins
Brookside Laboratories, Inc. *www.blinc.com*	200 White Mountain Dr. New Bremen, OH 45869 United States	Tel: Fax: E-mail:	419-753-2448 419-753-2949 *mflock@blinc.com*	Mark Flock
Exova Accutest Laboratory Exova Canada Inc. *www.exova.com*	8-146 Colonnade Rd. Ottawa, ON K2E 7Y1	Tel: Fax: E-mail:	613-727-5692, ext. 317 613-727-5222 *lorna.wilson@exova.com*	Lorna Wilson
FoReST Laboratory *lucas.lakeheadu.ca/forest/*	955 Oliver Rd. BB1005D Thunder Bay, ON P7B 5E1	Tel: Fax: E-mail:	807-343-8639 807-343-8116 *soilslab@lakeheadu.ca*	Breanne Neufield Joel Symonds
University of Guelph Laboratory Services *www.guelphlabservices.com*	University of Guelph P.O. Box 3650 95 Stone Rd. W. Guelph, ON N1H 8J7	Tel: Fax: E-mail:	519-767-6299 519-767-6240 *aflinfo@uoguelph.ca*	Nick Schrier
SGS Agri-Food Laboratories *www.agtest.com*	503 Imperial Rd. Unit #1 Guelph, ON N1H 6T9	Tel: Fax: E-mail:	519-837-1600 1-800-265-7175 519-837-1242 *ca.agri.guelph.lab@sgs.com*	Jack Legg Papken Bedirian
Stratford Agri Analysis *www.stratfordagri.ca*	1131 Erie St. Box 760 Stratford, ON N5A 6W1	Tel: Fax: E-mail:	519-273-4411 1-800-323-9089 519-273-2163 *info@stratfordagri.ca*	Keith Lemp Mark Aikman

There is no official accreditation in Ontario for tissue analysis, but all the accredited soil-testing labs are monitored for proficiency on tissue analyses.

APPENDIX B: Diagnostic Services

Weed identification

Pest Diagnostic Clinic
Laboratory Services Division
University of Guelph
95 Stone Rd. West
Guelph, ON
N1H 8J7
519-767-6256
519-767-6240 fax
www.guelphlabservices.com
Email: *aflinfo@uoguelph.ca*

Turf disease and insect diagnosis and nematode counts

Turf Diagnostics
The Guelph Turfgrass Institute
519-824-4120 x 58873
519-766-1704 fax
www.guelphturfgrass.ca
Email: *diagnostics@guelphturfgrass.ca*

Sample submission forms can be obtained at *www.guelphturfgrass.ca*

Collecting and submitting samples for disease, weed or plant identification

Disease diagnosis
Choose a 10–15 cm square piece of turfgrass (a cup changer plug works well) including thatch and 5 cm of soil.

Take a sample from the outside edge of a ring or patch and include healthy and unhealthy turf as well as the interface between. If symptoms are general, collect the sample from an area where they are of intermediate severity.

Plant identification
The entire plant (including root) is preferable. It should include lateral buds, leaves, and flowers or fruits.

Specify where the plant came from, i.e., cultivated field, waste area, yard, etc. Also include the county of origin, if available.

Shipping plant material
Do not add moisture when packing turf samples, plants or plant parts. Wrap in newspaper, tying roots and soil off separately to reduce contamination, and put in a plastic container. Avoid shipping over the weekend.

Insect specimens
Send dead, hard-bodied insects cushioned in a sturdy container. Preserve soft-bodied insects such as caterpillars in alcohol.

Hints for shipping insects
- Do not send insects in water.
- Do not tape insects to paper or send them loose in an envelope.
- Live insects should have enough food to survive until arrival. Clearly label the package with "live insects."

Sampling for nematodes
Only living nematodes can be counted. Accurate counts depend on proper handling of samples.

When to sample
Take soil and root samples at any time when the soil is not frozen. In Ontario nematode soil population levels are generally highest in May-June and again in September-October.

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 dripline).

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.

Sampling soil
Take samples using a soil-sampling tube, trowel or narrow-bladed shovel. Sample soil to a depth of 20–25 cm. If the soil is bare, remove the top 2 cm before sampling. Combine 10 or more subsamples in a clean pail or plastic bag. Mix them well. Take 0.5–1 L from this to create a sample. No one sample should represent more than 2.5 ha.

Number of subsamples
The number of subsamples is based on the total area sampled:
- for 500 m^2 take 10 subsamples
- for 500 m^2–0.5 ha take 25 subsamples
- for 0.5 ha–2.5 ha take 50 subsamples

Sampling roots
From small plants, take the entire root system plus adhering soil. For large plants, dig 10–20 g fresh weight from the feeder root zone and submit it.

Handling soil samples
Place in plastic bags as soon as possible after collecting.

Handling root samples
Place in plastic bags and cover with moist soil from the sample area.

Storage
Store samples at 5–10°C and do not expose them to direct sun or extreme heat or cold.

APPENDIX C: Turf Scouting Record

Date: ____________________ Scout name: ______________________ Site location : ________________________

Green or tee: ______________ Playing field: _____________________ Home lawns : ________________________

Turf species

- ❍ Kentucky blue
- ❍ tall fescue
- ❍ bentgrass
- ❍ annual bluegrass
- ❍ fine fescue
- ❍ perennial ryegrass

Comment

____

____

____

Contact info

Name: ________________________________

Address: ______________________________

____

Phone: ________________________________

	H	*M*	*L*
Compaction			
Thatch layer			
Soil type			

Site evaluation

Age of turf: ____________ Seed or sod: ____________ Sun or shade: ________________

Abbreviations

Disease	***Abb.***
anthracnose	A
brown patch	BP
dollar spot	DS
fairy ring	FR
fusarium patch	FP
grey snow mould	GSM
leaf spot	LS
patch disease	PD
pink snow mould	PSM
powdery mildew	PM
red thread	RT
rust	R
unknown/other disease	OD

Insect	***Abb.***
annual bluegrass weevil	ABW
black cutworm	BCW
black turfgrass ataenius	BTA
bluegrass billbug	BB
European chafer	EC
European cranefly	ECF
hairy chinch bug	HCB
Japanese beetle	JB
June beetle	JuB
sod webworm	SW
unknown/other insect	O

Pest management unit map

Pest management unit map instructions

- Use a separate data sheet each time a specific pest management unit is scouted.
- Record the date, name of scout, site location and type of pest management unit: golf hole, sports field, home lawn.
- Include a contact name and phone number.
- Note the turf specie or species present.
- Document as much information about the site as possible: age of turf, seed vs. sod, shade vs. sun, compaction, soil texture and thatch.
- Add comments on prevailing weather that may have influenced pest development.
- Draw a diagram of the pest management unit in the box. (See sample)
- As you walk or ride in a serpentine pattern across the unit, mark the areas of disease by drawing the perimeter of the affected area. Use the abbreviations to indicate which disease or insect is present. Estimate the percentage of area affected and mark it on the map.
- When using specific insect monitoring teachniques, record the technique and the results on the map.

APPENDIX D: Ministry of the Environment and Climate Change Regional Contact Information

Region/County/Branch	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 P.O. 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. Suite 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. Suite 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 E: Glossary

Antenna — a segmented sensory organ borne on an insect head, found in pairs.

Anthracnose — a disease that appears as black sunken lesions caused by fungi that produce their asexual spores in a structure called an acervulus.

Ascomycetes — a group of fungi that produce their sexual spores in a sack called an ascus. Most foliar and canker pathogens are ascomycetes.

Bacterium (bacteria, plural) — minute unicellular organisms which lack chlorophyll, and are the chief agents of fermentation, putrefaction and decay. Many are pathogenic on plants or animals.

Basidiomycetes — a group of fungi that produce their sexual spores on a club call a basidium. The rusts and wood-rotting fungi are basidiomycetes.

Biological control — use of other organisms to control pests.

Blight — a disease characterized by general and rapid killing of tissue.

Blotch — a disease characterized by large, irregularly shaped, spots or blots.

Callow — an immature adult insect.

Canker — a necrotic often sunken lesion on a stem, branch or twig of a plant.

Causal agent — biotic or abiotic source of disease.

Chitin — is a tough, translucent material found in the exoskeleton of insects.

Chlorotic — yellowing of normally green tissue due to chlorophyll destruction or failure of chlorophyll formation.

Claw — of an insect leg, a hollow, sharp end of an insect leg.

Conidium (conidia, plural) — an asexual fungus spore.

Cuticle — the outer covering of an insect formed by a layer of chitin.

Damping off — destruction of seedlings near the soil line, resulting in the seedlings falling over on the ground.

Degree-day accumulation — an estimate of heat accumulation using the average daily temperature minus the threshold temperature for a given organism.

Diagnosis — the recognition or determination of the existence of a disease.

Dieback — progressive death of shoots, branches and roots generally starting at the shoot tip.

Disease — a condition in which a plant or a part of it is affected by some factor which interferes with normal growth or development or the normal functioning of its organs and tissues.

Disease cycle — the chain of events involved in disease development: inoculation, penetration, infection, dissemination.

Disease triangle — composed of host, pathogen, environment which together dictate the amount of disease.

Elytra — the outer leathery of chitinous wings of beetles that cover the hindwings.

Endophyte — any organism growing inside a plant.

Eradication — control of plant disease by eliminating the pathogen after it is established or by eliminating the plants that carry the pathogen.

Frass — solid larval insect excrement.

Forewing — a pair of wings of a four winged insect that are closest to the head.

Fungus (fungi, plural) — a large group of organisms which do not have chlorophyll, such as moulds, mildews, mushrooms, rusts and smuts. Most have a filamentous body (called a mycelium, individual strands are called hyphae) and subsist on organic matter as saprophytes or parasites. Many are pathogenic. The Kingdom Fungi is divided into classes: Oomycetes - water moulds, damping-off, root-rots; Ascomycetes - leaf spots, cankers, etc.; and Basidiomycetes - rots, rusts.

Fungicide — a compound toxic to fungi.

Gall — a swelling or overgrowth produced on a plant as a result of infection by certain pathogens.

Grub — the larval stage of a beetle.

Hindwing — the pair of wings of a four-winged insect farthest from the head.

Host — a plant that can be invaded by a pathogen and from which the pathogen obtains its nutrients.

Host range — the various species or varieties of host plants that may be attacked by a pathogen.

Hypha (hyphae, plural) — a fungal strand, a filamentous branch of a mycelium.

Infection — the establishment of a pathogen within a host plant.

Infection court — a site or condition on a plant favourable to infection e.g. a wound.

Infectious disease — a disease that is caused by a pathogen which can spread from a diseased to a healthy plant.

Inoculation — the coming in contact of a pathogen with a plant.

Inoculum — the pathogen or its parts that can cause infection. That portion of individual pathogens that are brought into contact with the host. Inoculum which causes the first infections in the season is called primary inoculum; and inoculum produced from primary infections which lead to subsequent secondary infections are called secondary inoculum.

Instar — a stage between molts.

Integrated control — an approach that attempts to use all available methods of control of a disease of all the diseases and pests of a crop plant for best control results but with the least cost and the least damage to the environment.

Larva — a young insect that has thatched and is in an immature form.

Latent infections — the state in which a host is infected with a pathogen but does not show any symptoms.

Leaf spot — a lesion on a leaf.

Lesion — a localized area of discoloured, diseased tissue.

Mandibles — are the first pair of jaws in an insect's mouth.

Metamorphosis — a series of changes that an insect passes through in its growth from egg to adult.

Mildew — a fungal disease of plants in which the mycelium and spores of the fungus are seen as a whitish growth on the host surface.

Molt — to cast off or shed the outer skin at certain intervals to replace it with new skin.

Mosaic — plant disease symptoms characterized by light-green, yellow or white areas intermingled with the normal green tissue, or of whitish areas intermingled with areas of normal colour. Depending on the intensity or pattern of discoloration, mosaic-type symptoms may be described as mottling, streak, ring pattern, line pattern, veinclearing, veinbanding, or chlorotic spotting.

Mould — any profuse or woolly fungus growth on damp or decaying matter or on surfaces of plant tissue.

Mycelium (mycelia, plural) — the mass of filamentous strands of hyphae that make up the body of a fungus.

Mycoplasmas — pleomorphic prokaryotic microorganisms that lack a cell wall (like a bacterium but without a cell wall).

Necrotic — dead and discoloured.

Nematodes — generally microscopic, wormlike animals that live saprophytically in water or soil or as parasites of plants and animals, threadworms, or eelworms.

Nymph — sexually immature form of insect usually similar to the adult found with incomplete metamorphosis.

Obligate parasite — see parasite.

Oomycete — a class of fungi that produce oospores, the water moulds.

Ozone — a highly reactive form of oxygen that injures plants in high concentrations. Formed naturally by sunlight and oxidative processes.

Parasite — an organism which lives in or on another live organism from which it derives it nourishment. Obligate parasites require living hosts for growth and reproduction. (Compare this to a saprophyte which is an organism obtaining its nourishment from dead organic matter). Obligate parasites absolutely require live hosts to grow and multiply.

Pathogen — a disease causing organism.

Pest — any organism which is troublesome, disturbing, noxious or destructive.

Phenology — a branch of science dealing with the relationship between climate and periodic biological phenomena.

Phytotoxic — toxic to plants.

Plant Pathology — the study of agents and environmental conditions that cause disease in plants, of the mechanisms and processes by which these factors produce disease in plants, of the interactions between disease causing agents and diseased plants, and of the methods of preventing and managing plant disease.

Prolegs — rounded fleshy usually paired tubercles on the prothorax of a caterpillar.

Prothorax — the first segment of the thorax closest to the insects head.

Protectant — a substance that protects an organism against infection by a pathogen.

Puparium — a rigid outer shell formed from larval skin that covers some pupae (as in European Crane Fly).

Quarantine — control of import and export of plants to prevent spread of diseases and pests.

Resistance — the ability of an organism to exclude or overcome the effects of a pathogen or other damaging factor.

Ringspot — a circular area of chlorosis with a green center; a symptom of many virus diseases.

Rot — the softening, discoloration, and often disintegration of a succulent plant tissue as a result of fungal or bacterial infection.

Rust — a disease giving a rusty appearance to a plant and caused by one of the rust fungi.

Sanitation — the removal and burning or disposal of infected plant parts, decontamination of instruments & hands etc.

Sclerotium (sclerotia, plural) — a compact mass of hyphae usually with a darkened rind capable of surviving under unfavourable environmental conditions.

Scorch — burning of leaf margins as a result of infection, pesticide injury or unfavourable environmental conditions.

Spatulate — round and broad at the top and slender at the base.

Stomata (stomates, plural) — is a tiny opening or pore that is used for gas exchange found mostly on the under-surface of plant leaves.

Tarsus — the foot of the insect leg.

Thorax — the second region of an insect body.

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 ha	=	1 square kilometre (km^2)

Cubic measures (volume)

Dry measure

1,000 cubic millimetres (mm^3)	=	1 cubic centimetre (cm^3)
1,000,000 cm^3	=	1 cubic metre (m^3)

Liquid measure

1,000 millilitres (mL)	=	1 litre (L)
100 L	=	1 hectolitre (hL)

Weight-volume equivalents (for water)

(1.00 kg) 1,000 grams	=	1 litre (1.00 L)
(0.50 kg) 500 g	=	500 mL (0.50 L)
(0.10 kg) 100 g	=	100 mL (0.10 L)
(0.01 kg) 10 g	=	10 mL (0.01 L)
(0.001 kg) 1 g	=	1 mL (0.001 L)

Weight measures

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

Dry liquid equivalents

1 cm^3	=	1 mL
1 m^3	=	1000 L

Metric conversions (approximate)

5 mL	=	1 tsp
15 mL	=	1 tbsp
28.5 mL	=	1 fl. oz

Application rate conversions

Metric to imperial or U.S. (approximate)

litres per hectare × 0.09	=	Imp. gallons per acre
litres per hectare × 0.11	=	U.S. gallons per acre
litres per hectare × 0.36	=	Imp. quarts per acre
litres per hectare × 0.43	=	U.S. quarts per acre
litres per hectare × 0.71	=	Imp. pints per acre
litres per hectare × 0.86	=	U.S. pints per acre
millilitres per hectare × 0.014	=	U.S. fluid ounces per acre
grams per hectare × 0.014	=	ounces per acre
kilograms per hectare × 0.89	=	pounds per acre
tonnes per hectare × 0.45	=	tons per acre

Imperial or U.S. to metric (approximate)

Imp. gallons per acre × 11.23	=	litres per hectare (L/ha)
U.S. gallons per acre × 9.35	=	litres per hectare (L/ha)
Imp. quarts per acre × 2.8	=	litres per hectare (L/ha)
U.S. quarts per acre × 2.34	=	litres per hectare (L/ha)
Imp. pints per acre × 1.4	=	litres per hectare (L/ha)
U.S. pins 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)

Liquid equivalents

litres/hectare		**approximate gallons/acre**
50	=	5
100	=	10
150	=	15
200	=	20
250	=	25
300	=	30

Dry weight conversions (approximate)

grams/hectare		**ounces/acre**
100 grams	=	1 ½ ounces
200 grams	=	3 ounces
300 grams	=	4 ¼ ounces
500 grams	=	7 ounces
700 grams	=	10 ounces
kilograms/hectare		**pounds/acre**
1.10 kilograms	=	1 pound
1.50 kilograms	=	1 ¼ pounds
2.00 kilograms	=	1 ¾ pounds
2.50 kilograms	=	2 ¼ pounds
3.25 kilograms	=	3 pounds
4.00 kilograms	=	3 ½ pounds
5.00 kilograms	=	4 ½ pounds
6.00 kilograms	=	5 ¼ pounds
7.50 kilograms	=	6 ¾ pounds
9.00 kilograms	=	8 pounds
11.00 kilograms	=	10 pounds
13.00 kilograms	=	11 ½ pounds
15.00 kilograms	=	13 ½ pounds

Conversion Tables — Metric to Imperial (approximate)

Length

1 millimetre (mm)	=	0.04 inch
1 centimetre (cm)	=	0.40 inch
1 metre (m)	=	39.40 inches
1 metre (m)	=	3.28 feet
1 metre (m)	=	1.09 yards
1 kilometre (km)	=	0.62 mile

Area

1 square centimetre (cm^2)	=	0.16 square inch
1 square metre (m^2)	=	10.77 square feet
1 square metre (m^2)	=	1.20 square yards
1 square kilometre (km^2)	=	0.39 square mile
1 hectare (ha)	=	107,636 square feet
1 hectare (ha)	=	2.5 acres

Volume (dry)

1 cubic centimetre (cm^3)	=	0.061 cubic inch
1 cubic metre (m^3)	=	1.31 cubic yards
1 cubic metre (m^3)	=	35.31 cubic feet
1,000 cubic metres (m^3)	=	0.81 acre-foot
1 hectolitre (hL)	=	2.8 bushels

Volume (liquid)

1 millilitre (mL)	=	0.035 fluid ounce
1 litre (L)	=	1.76 pints
1 litre (L)	=	0.88 quart
1 litre (L)	=	0.22 gallon (Imp.)
1 litre (L)	=	0.26 gallon (U.S.)

Weight

1 gram (g)	=	0.035 ounce
1 kilogram (kg)	=	2.21 pounds
1 tonne (t)	=	1.10 short tons
1 tonne (t)	=	2,205 pounds

Pressure

1 kilopascal (kPa)	=	0.15 pounds/in^2

Speed

1 metre per second	=	3.28 feet per second
1 metre per second	=	2.24 miles per hour
1 kilometre per hour	=	0.62 mile per hour

Temperature

°F	=	(°C × 9/5) + 32

Conversion Tables — Imperial to Metric (approximate)

Length

1 inch	=	2.54 cm
1 foot	=	0.30 m
1 yard	=	0.91 m
1 mile	=	1.61 km

Area

1 square foot	=	0.09 m^2
1 square yard	=	0.84 m^2
1 acre	=	0.40 ha

Volume (dry)

1 cubic yard	=	0.76 m^3
1 bushel	=	36.37 L

Volume (liquid)

1 fluid ounce (Imp.)	=	28.41 mL
1 pint (Imp.)	=	0.57 L
1 gallon (Imp.)	=	4.55 L
1 gallon (U.S.)	=	3.79 L

Weight

1 ounce	=	28.35 g
1 pound	=	453.6 g
1 ton	=	0.91 tonne

Pressure

1 pound per square inch	=	6.90 kPa

Temperature

°C	=	(°F – 32) × 5/9

Abbreviations

% = per cent (by weight)
ai = active ingredient
AP = agricultural powder
cm = centimetre
cm^2 = square centimetre
DG = dispersible granular
DP = dispersible powder
E = emulsifiable
e.g. = for example
EC = emulsifiable concentrate
F = flowable
g = gram
Gr = granules, granular
ha = hectare
kg = kilogram
km/h = kilometres per hour
kPa = kilopascal
L = litre
m = metre
m/s = metres per second
m^2 = square metre
mL = millilitre
mm = millimetre
SC = sprayable concentrate
SP = soluble powder
t = tonne
W = wettable (powder)
WDG = water dispersible granular
WP = wettable powder

www.ontario.ca/crops