Nursery
FACTSHEET

BRITISH COLUMBIA | Ministry of Agriculture

Spring 2017

Production and Pest Management Guide

Table of Contents

Throughout this guide, this symbol ☠ is used to designate very toxic chemicals that need to be used with greater caution.

Chapter 1 - Plant Movement Regulations

British Columbia Plant Protection Regulations

Balsam Woolly Adelgid

Balsam Woolly Adelgid (BWA) is a tiny (less than 1/10 mm), inconspicuous, aphid-like pest that feeds exclusively on true firs (*Abies* species). Despite its small size, it is an extremely destructive pest that can kill a tree after several years of heavy feeding. This is especially true for *Abies lasiocarpa*. There are no known pathogens of the adelgid and attempts to control it with chemicals are usually ineffective. There is tremendous concern it will spread into the Interior and infest the very important and widely distributed *A. lasiocarpa* forests. The movement of *Abies* for use in reforestation, or as an ornamental or a Christmas tree, poses a significant risk of spreading this pest.

Figure 1.1. A fir branch infested with BWA showing the common symptoms, which include needle yellowing and premature needle loss, and swelling of branch nodes and terminal buds.

To reduce this risk, all *Abies* species (Grand Fir, Noble Fir, Fraser Fir, etc.) must be grown under permit. Annual permits expire on December 31st. Permits can be obtained from the Entomologist with the BC Ministry of Agriculture in Abbotsford. When offered for sale or moved from the nursery, plants **no longer** require the tag to verify they were grown under permit. Growers can provide a copy of their *Abies* Permit to verify they were grown under permit.

The area regulated in BC for BWA was expanded in July 2006 (see Figure 1.2). Trees grown outside the quarantine area have free movement within the province. *Abies* grown in the quarantine area cannot be shipped outside the area within BC. There are no restrictions on the domestic movement of *Abies* outside of BC. Sale and movement of cut trees or foliage of *Abies* grown in the quarantine zone is prohibited between January 31 and November 1 anywhere in the province. However, cones and seeds of *Abies* are exempt from this regulation. When moved between November 1 and January 31, cut Christmas trees, boughs for wreaths or decorations, and cones are exempt from area restrictions.

Little Cherry Disease

The Little Cherry Control Regulation prohibits the movement of flowering cherry species (including *Prunus serrulata*, *P. subhirtella*, *P. sieboldii, P. vedoensis* and *P. incisa*) into the Little Cherry Control Area of the southern Interior. Flowering cherries cannot be grown in the landscape in the control areas. With special permission from the Ministry of Agriculture, flowering cherries may be propagated by nurseries in the control area for sale outside of the control area.

The Little Cherry Control Regulation also regulates the movement of cherry stock (*Prunus avium, P. cerasus*) into the Little Cherry Control Areas. No person shall move a cherry tree, rootstock of a cherry tree or the buds of grafting wood for a cherry tree into the Little Cherry control Area without the written permission of the manager of the Crop Protection Program, Ministry of Agriculture.

The Little Cherry Control Regulation was amended in May 1994. The control area now includes the

Creston area (Electoral Districts A, B and C of the Central Kootenay Regional District) in addition to the original control area that covered the Okanagan and Similkameen Valleys.

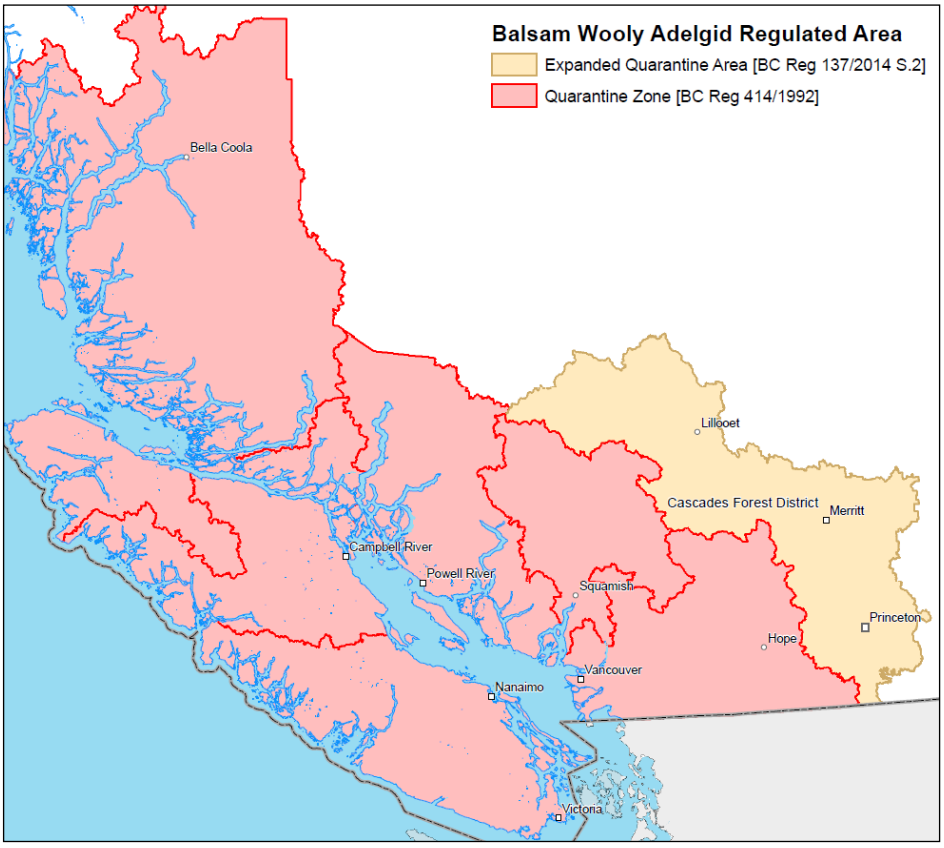


Figure 1.2. Areas within BC that are regulated for Balsam Woolly Adelgid.

Federal Plant Quarantine Regulations

Import Requirements

Imports of nursery stock from all countries must be covered by a Phytosanitary Certificate issued by the exporting country. Domestic Movement Certificates are required for movement of regulated nursery stock within Canada.

Permit to Import

Each shipment of nursery stock from any country other than the continental US must be imported in accordance with a valid import permit. The permit application enables the Canadian Food Inspection Agency (CFIA) to advise an applicant whether the commodity they intend to import is prohibited from entering Canada or is allowed to enter subject to certain restrictions. Permits are required for any nursery stock from the continental US for which there are specific requirements. Permits are required for all material from Hawaii. Information on regulated commodities is available on the Automated Import Reference System (AIRS) website.

A single Permit to Import can be obtained for multiple destinations if specified on the import permit application form. For further information contact your local CFIA office.

The Import Permit application form is available on the CFIA website (form 5256). The site includes information on how to complete the form and fees for permits. The form should be submitted at least 4 weeks prior to the importation date.

Importers are advised to send in their applications outside the peak processing period (i.e., January to April) to avoid delays. Many permits are valid for three years, so always keep track of their expiry date. The CFIA does not advise clients prior to permit expiration and an importer must have a valid permit prior to importation.

Prior to clearance with Canada Customs, entry documents must be presented to the CFIA.

Canadian Plant Protection Regulations

There are plant protection regulations governing the movement of the following nursery stock into BC from other countries and provinces. The CFIA is responsible for the administration and enforcement of the Plant Protection Act and regulations thereunder. Copies of the policy directives that describe the importation prohibitions or restrictions listed below are available on the Agency's web site.

Contact the CFIA for information on quarantine areas, certification requirements, etc. for the importation regulations listed below.

Inspection of Imported Nursery Stock

- It is the responsibility of the importer to provide the labour required to present imported product for inspection, which could include moving or unloading product from the truck.
- Cost of treatment, destruction or return of nursery stock is the responsibility of the importer.

Export Requirements

For first-time exporters, preparing a shipment for export is a daunting task. The following is a general outline for determining plant health requirements for a particular export market. The most common examples are noted, but other conditions and requirements can exist, along with various combinations of the examples shown. When a Phytosanitary Certificate is issued, it indicates that the requirements of the importing country are met.

Research Your Market

Will my product(s) meet the plant health import requirements at my customer's location? When determining export requirements, the product to be exported needs to be adequately described, including:

a) the common and scientific names (Genus, species),

b) whether the plants are shipped as propagative or non-propagative material, and

c) if they are for planting, what form they are in, i.e. cuttings, bareroot, balled & burlapped, pots, dormant, etc.

Sources of Information

a) the customer

b) foreign government or authority

c) CFIA

d) customs brokers – are licensed by the US Customs to transact customs business on behalf of others. For a listing of companies, look up Customs Brokers in the Yellow Pages™.

Results of Market Research

Market research may reveal a variety of documentation requirements, plant protection conditions and certification options. Note that in the case of a country like the US, there may be individual state requirements in addition to national import requirements.

Documents

a) Import permit (usually for importer but sometimes exporter)

b) Phytosanitary Certificate: the original certificate or a copy of the invoice with a CFIA label (Canadian Nursery or Greenhouse Certification Programs only) is required by the US Department of Agriculture. If this is not included with the shipment, it will not clear customs. The invoice and the phytosanitary certificate must be for the same type and number of plants. Nurseries planning to export nursery stock should contact CFIA as early as possible so that certification requirements of the importing country can be met, and growing season inspections can be done if required.

Enquiries may be directed to the Operations Directorate or to your nearest CFIA office.

d) North American Free Trade Agreement Certificate of Origin: under the Agreement, all merchandise manufactured in Canada, as per the Rules of Origin, is duty free. Nursery stock is eligible. A Certificate of Origin form must be completed to insure the product complies with the Agreement. This form can apply to an individual shipment or a one-year period.

d) General Permit and CITES (Convention on International Trade and Endangered Species) (permit &/or certificate): a general permit is required by all US businesses that import, export or re-export endangered and threatened US native plants. The US Endangered and Threatened Plant List (Title 50, Section 17.12) is extensive and is available on the Fish & Wildlife Service web site. The list includes some genera that are widely grown by the industry (e.g. *Arctostaphylos, Clematis* and *Rhododendron*), but the endangered species are different from those commonly propagated in the industry. The CFIA checks whether a General Permit is required for a shipment when they prepare the Phytosanitary Certificate. If a General Permit is required, the inspector will ask the exporting nursery whether the importer has a permit.

   Some plants, for example orchids and cacti, are covered by the Convention on International Trade in Endangered Species of Wild Fauna and Flora and a CITES permit must be obtained before they can be imported or exported. For more information, contact Environment Canada, Canadian Wildlife Service in Ottawa (Phone: 819 997-1840; Fax: 819 953-6283) or refer to the CITES website.

e) Invoice: a proforma invoice is not required, but it is a good format to follow since proper invoicing will reduce delays in processing the shipment. The invoice must be legible and in the English language. US Customs requires three copies of the invoice to move with the shipment. The invoice must include the Internal Revenue Service tax number or social security number of the importer, name of the carrier, country of origin, full description of goods, and the unit price and total value of the shipment.

   If the shipment includes orders for several destinations, it can enter as a single entry if a Proforma Invoice is used and the product enters care-of a customs broker in Blaine, WA.

f) Customs Power of Attorney: only required if a customs broker will be used. This document enables the broker to act as your agent/power of attorney, and permits them to clear your goods and sign documents on your behalf.

Plant Protection Conditions

a) no restrictions

b) general freedom from pests

c) freedom from specific pests

d) production area or province/country free of specific pests

e) specific treatments

f) prohibition of specific plant species (i.e. US - no citrus, prohibited palms, etc.)

Phytosanitary Certification Options

a) no certification required

b) product prohibited (no certification permitted)

c) treatment (and certification)

d) inspection (and certification)

e) post entry quarantine

Arranging for Inspection and Phytosanitary Certification

Make a written request for inspection and certification to one of the addresses shown in this section or to your nearest CFIA inspection office. The Export Application (Form # 3369) is available online. Please note there are fees associated with phytosanitary inspection and certification. The applicable rates are available from the CFIA at your local office or on the Internet. Fees may be paid by cash, approved credit card or on account.

Give as much notice as possible to allow the Agency to schedule your inspection. If a new market is being accessed, up to 2 weeks' notice is required, to allow for research into foreign plant protection import requirements. The process may take longer, if negotiation with the foreign government is required.

Before the inspector arrives:

a) assemble all documents for each shipment;

b) assemble all products to be inspected and certified, and ensure access to all portions of the shipment; and

c) designate a contact person to assist the inspector.

Marking of Goods

It is required that the final consumer of the product must know the country of origin. Therefore, all goods that are capable of being marked must be marked legibly and permanently with the English name of the country of origin, such as "Made in Canada" or "Product of Canada." The outermost container of the goods must be marked, if applicable, in addition to each individual article. The country of origin can be marked directly on the nursery container or on a tag applied to the product.

Shipping

There are eight common types of entry recognized by the US Customs. Nursery stock is most commonly shipped as a consumption entry, temporary importation bond, or as an informal entry.

Consumption (Formal) Entry applies to product that enters for consumption and has a value in excess of $2,000 (Canadian). This is the predominate method of entry. Formal entries require a broker and a customs bond to protect the importer if there is a problem with the entry. You can obtain either a single transaction bond or a continuous bond. The continuous bond is good for numerous transactions for one full year and costs a minimum of $50,000.

Temporary Importation Bond applies to non-consumable products that enter the US on a temporary basis. The products usually must leave the US within one year. Display materials for a trade show should be declared on a temporary importation bond. However, since nursery stock is duty free under the North American Free Trade Agreement, it may be more cost effective to make consumption entry if the US Customs will permit.

Informal Entry applies to most shipments of products with a value equal to or less than $2,000 (Canadian). Informal entries do not require exporting forms, which is where most problems arise when exporting product. The shipment will require a phytosanitary certificate, an invoice, and a CITES permit if there are any endangered plant species in the shipment. Contact a Customs Broker to determine whether or not the product qualifies for informal entry.

Regulations Pertaining to Foreign Vehicles Picking-up Nursery Stock in BC

Out-of-province customers that wish to pick up stock at a nursery in BC need to be licensed under the International Registration Plan or the Canadian Agreement on Vehicle Registration. If their vehicle is not licensed, the importer will need to get a non-resident commercial permit. Permits may be obtained from any weigh scale station, appointed agent, or government agent. The cost of the permit will be based on the gross vehicle weight and the duration of the permit (e.g. single trip or quarterly).

There are additional requirements, including the vehicle's insurance must be on file with the Insurance Corporation of BC (ICBC), and they must either be a member of the International Fuel Tax Agreement or have a Temporary Motive Fuel User Emblem. The temporary emblem can be purchased at provincial weigh scales.

More information on these requirements is available from ICBC or you can contact the Pacific Weigh Station (604 538-1121; 800 559-9688), which is located three blocks north of the Pacific border crossing.

Canadian Nursery Certification Program (CNCP)

Background and Scope

Export certification of nursery plant material is a quarantine requirement of importing countries. The Phytosanitary Certificate, verifying pest freedom is normally issued following pre shipment sampling and inspection. The *Canadian Plant Protection Act* provides the authority for the CFIA to conduct inspections and issue Phytosanitary Certificates.

However, with greater calls for increased efficiencies and a demand by clients to reduce the costs associated with export certification, the Agency has developed a collaborative program with nursery partners. The program certifies qualifying nurseries consistently producing products free of quarantine pests and substantially free of all other injurious pests (the quarantine standard).

Participating producers are required to define in a CNCP Manual the procedures undertaken in the nursery to meet the quarantine standard D-04-01.

The methods must assure the following: the preclusion of specified pests; suggest the means by which the responsible parties within the nursery will inspect and verify that the products are free of pests; and a system by which records attesting to these processes are retained. The Agency will confirm compliance of the standard through regular audits of the nursery's production practices.

Responsibilities of a Canadian Certified Nursery

The producer must ensure that all plants and plant material, within the establishment and those destined for export, are free of quarantine pests and substantially free of all other injurious pests.

The producer must employ a group of individuals that includes a Certification Manager and a Crop Protection Manager.

The Certification Manager will be a member of the facility's management team, and must have a thorough understanding of the CNCP and of the systems approach to mitigating pest risk. The Crop Protection Manager, whose education and training as established by the CFIA, assure(s) a minimum of knowledge of pest management, quarantine principles and regulatory requirements.

The Crop Protection Manager(s) must conduct routine inspections of plant material within the establishment and of plant material being exported to the US. Results of the inspection and any treatments conducted to eliminate pests must be recorded and retained.

The Certification Manager must develop a CNCP Manual that outlines the production practices used by the nursery to preclude pests. The CNCP Manual has two key components: the CNCP Manual and a description of the Phytosanitary Management System, which must include procedures for sourcing plant material, maintaining product identity, shipping certified material, controlling non-conforming product, conducting internal audits, generating corrective action requests, improving and maintaining the Phytosanitary Management System. The CNCP Manual must also have a Pest Management Plan, which is a written description of procedures or processes designed to eradicate, control or suppress pest populations to a level that meets the phytosanitary standard.

The Certification Manager or the Crop Protection Manager(s) must verify that export material meets the import requirements of the US (including freedom from specific state quarantines).

Plant material entering the establishment must be verified free of pests and diseases.

The CNCP facilities will generate CNCP Phytosanitary Certification Labels on site to include with their export documentation for the US border. Copies of the Phytosanitary certificate labels must be retained. Ability to trace the label to all inspection, treatment and origin information is required.

The Certification Manager must agree to inform the Agency of any information regarding the presence of a quarantine pest found in the establishment, or on products entering the establishment or in transit to or at a sale destination.

Responsibilities of the CFIA under the Canadian Nursery Certification Program

The Agency evaluates the Phytosanitary Management System and the Pest Management Plan detailed in the CNCP manual. The qualifications of the Certification Manager and the Crop Protection Manager are evaluated according to the Canadian Nursery Certification Program standard.

CFIA staff conducts audits to confirm adherence to the Phytosanitary Management System and Pest Management Plan, origin requirements and record maintenance as outlined in the CNCP manual.

The Agency provides the results of audits to the Certification Manager and the Crop Protection Manager.

Chapter 2 - Field Culture

This chapter covers the basic principles of soil, water and nutrient management in field nursery production. Some information is relevant to both field culture and container culture. However, it will only be covered in this chapter, and will be referenced to in Chapter 3, *Container Culture*.

Site Selection

When starting an operation to produce field-grown nursery stock, knowledge of the soils and site conditions is essential to success. The location and layout of the operation can also greatly influence profit and even survival. Land suitable for nursery stock production should be devoid of low frost pockets and stones, and should have a layer of loam topsoil at least 60 cm deep. Slightly sloping land is best. Clay loam is required for the production of balled stock and a sandy loam is best for the production of bareroot stock. The optimum soil pH for most woody plants is between 5.0 and 7.2. Sites with soils that have good structure, porosity and pH within or close to the above range are best.

Figure 2.1. Field-grown shade trees.

For established nurseries it is difficult to change the physical nature of the soil. The only tool available is appropriate management. The following sections cover basic management options for both new and established operations.

Soil Preparation

In October of the year proceeding spring planting, soil samples for nutrient and nematode analysis should be taken. A soil analysis is the only accurate guide for fertilizer and lime requirements to correct low pH and nutrient deficiencies. Soil sampling depth will vary based on the nutrient to be analyzed. Soil samples for phosphorus and potassium analyses are best taken to a depth of 15 cm while soil for nitrate-nitrogen analysis are typically sampled to a depth of 30 cm. All soil samples can be collected using a soil probe or spade, from at least 25 locations per hectare. The 25 soil samples should be mixed thoroughly in a clean container and a cupful selected for analysis. Areas of different soil types, or areas of poor drainage, should be sampled separately.

Again, nursery stock grows best in a pH range of 5.0-7.2 because most nutrients held in the soil are available in that range. On the Coast, most soils tend to be acid and require lime. Soil pH is neutral or slightly alkaline in the Interior and quite varied on Vancouver Island. Ground limestone (calcium carbonate) is the most common form of lime used to adjust soil pH. It supplies calcium to the soil and raises soil pH. Dolomitic limestone provides both calcium and magnesium and also raises the pH. Agricultural sulphur is used to lower the pH, but is generally not very effective.

Weeds can damage or make a crop unmarketable. It is recommended to control perennial weeds, such as bindweed and field horsetail, before planting. Apply a systemic, broad-spectrum herbicide to kill existing perennial weeds at least three weeks before turning sod in preparation for planting. The soil should be ploughed, then disced and power harrowed to produce a weed-free surface for planting. Lime and all required nutrients except nitrogen should be incorporated in the top 20 cm of soil during the latter operation to ensure even distribution.

Animal manure can also be incorporated at this time. The addition of manure will improve water-holding capacity in sandy loam, improve the structure of a clay loam (workability) and add nutrients to all soils. The organic matter content of the soil should be at least 3-5% (reported in soil test). Manures continue to supply some plant food in subsequent years. The amount of chemical fertilizer used may be reduced according to the amount and type of manure applied.

More information on the amount and timing of manure and nutrient applications to prevent nutrient leaching and runoff is available in the *Reference Guide: Canada-BC Environmental Farm Plan Program* and the *Nutrient Management Reference Guide*.

Planting

Planting blocks should be laid out in an orderly fashion. Long, straight rows increase maintenance efficiency. Different cultivars of the same species should be planted in different rows, or identification stakes should be placed in partial rows. Skipping a row every 20 or so will provide access for larger equipment.

Spacing within the planting block is important for adequate air circulation and light penetration to the base of the plant throughout the production cycle. Spacing between rows is determined by the size of the equipment to be used in the field (up to 2.0 m). The species grown, the growth habit and the size at which it will be sold will determine the spacing between plants within a row. Bareroot deciduous shrubs and trees are planted 23-46 cm apart within the row, and balled conifers are planted 76-120 cm apart and caliper shade trees are planted 1.5 m or more apart. The number of trees planted per hectare at different spacing is presented in Table 2.1.

Table 2.1. Number of trees planted per acre at different spacing.

Tree Spacing (in feet)	**Trees per Acre**
1 x 4	10,890
3 x 4	3,630
3 x 6	2,420
3 x 8	1,815
5 x 6	1,452
5 x 8	1,089
6 x 6	1,210
6 x 8	908

Spring planting is preferable to fall, as plants not established in their new location before winter are subject to frost heaving and winter kill. Avoid planting during warm, dry periods. Keep root systems moist before planting. Bareroot material can be dipped in a pail of water before planting, but do not let the plants stand in water.

Loosen the root ball of container-grown liners at planting to assist the roots to penetrate the soil. An alternative approach is to shave 2.5 cm of soil from the sides and bottom of the root ball. Shaving the root ball reduces the occurrence of root defects post-planting, which can be a problem with pot-bound transplants. Place the root system in the hole or trench and cover to the same depth at which the plant was grown previously. Irrigate immediately after planting.

Root Pruning

The root system should be pruned of plants that are left in the same spot in the field for more than 2 years. Pruning produces a more fibrous root system and ensures that a larger portion of the root system is taken with the plant when it is dug. Small production areas can be done by hand with a long spade. Half of the roots should be cut just inside of the point where the roots will be cut when dug. This will depend on the ultimate size of the plant when sale is expected. Root pruning should be done in the early fall preferably 2 years before sale. This is essential for plants grown from rooted cuttings or small plugs but is not so important for plants grown from one gallon or larger containers. Irrigate immediately after root pruning to prevent water stress.

Digging

Plants are dug for sale either in early spring or after the fall rains start at the Coast. Conifers and broadleaf evergreens are dug, and balled and burlapped, which means that a quantity of soil is left around the roots and is secured with burlap and twine. It is extremely important to not disturb the root system within the ball of soil. A broken ball usually results in poor or unsuccessful transplant. The size of the ball is related to the size of the plant. Guidelines are available in the Canadian Nursery Stock Standards.

In order to conserve topsoil on the site, efforts should be made to replace soil removed in the root ball by the addition of amendments (e.g. compost) or the use of cover crops. When possible, reduce the size of the root ball to conserve soil.

Deciduous trees and shrubs are dug in the fall if storage is available. Bareroot plants are stored at 2-4^{o}C and 98% relative humidity. On the Coast, it is possible to overwinter some material in a deep bed of sawdust. Rodents must be controlled since they will eat the bark on trees in storage. Dormant plants dug bareroot must be graded to conform to

size standards and bundled. Steps must be taken to prevent the root system from drying out. Heeling in sawdust or holding in a humidified storage area will minimize desiccation.

Soil Management

Good soil management begins before planting. Assess the soil conditions of each field and understand the potential problems as a first step to planting a crop. Land may be inadequately drained, have shallow topsoil, have impermeable subsoil or be too steeply sloped for successful cropping.

Use the following resources to help identify potential problems:

- soil survey reports and maps (some are available online;
- Ministry of Agriculture publications: *Soil Management Handbook for the Lower Fraser Valley* and *Soil Management Handbook for the Okanagan and Similkameen Valleys*;
- specific sections in this guide; and
- professional soil management consultants.

The handbooks discuss general soil management topics including: identification of soil texture and structure, tillage methods, recognition and reversal of soil compaction, and issues related to soil conservation practices. Recommendations in all manuals, including this production guide, are general guidelines only. Qualified soil management consultants are available on a fee-for-service basis to give recommendations specific to each farm. Growers planning to plant a new parcel of land should consult with a professional for recommendations on soil suitability and management. Management includes advice on nutrient management, irrigation and drainage.

Soil management problems are generally related to soil texture, soil structure, drainage and erosion.

Soil Texture

The mineral components in soil are simply small fragments of rock or mineral materials derived from rock that were altered by water and chemical reactions in the soil. Soil particles are grouped into four particle sizes: gravel, sand, silt and clay. In describing soil, "texture" refers to the relative percentages of sand, silt and clay sized particles in the soil material. Soil texture is a permanent characteristic. Texture will not change unless a large quantity of soil material of another texture is added to it, such as might occur during land clearing or very deep plowing into subsoil of a different texture.

Problems related to soil texture are common. Stony soils may reduce the suitability for growing balled nursery stock. Stones can interfere with tillage and digging operations, and will reduce the overall nutrient and water storage capacity when they cover greater than 50% of the surface area or make up more than 75% of the soil volume. Fine-textured soils (silts and clays) are often subject to compaction or drainage issues.

Soil Structure

In soil, individual sand, silt and clay particles become more closely packed and bonded together to form larger particles called aggregates. "Soil structure" refers to the type and arrangement of aggregates found in soils. Aggregates occur in almost all soils, but their strengths, sizes and shapes vary considerably among soil types. Some of these aggregates are in stable forms that are not easily broken down by water or physical forces. In addition to the soil texture, the organic matter content can play a significant role in the development of good soil structure.

The formation of soil structure results from many different processes, including the growth of plant roots, activities of soil organisms, wetting and drying, freezing and thawing, and tillage. Plant roots excrete sugars and resins that bind aggregates or create pores in the soil when they die. Soil organisms also bind aggregates with "glues" or, as in the case of earthworms, create channels that improve drainage and aeration.

Soil structure also affects the internal drainage of the soil, water holding capacity, temperature and the growth of plant roots. In soils under cultivation, most aggregates at the surface tend to break down under the forces of rainfall, irrigation, tillage and traffic. When soils are left exposed to rainfall or are excessively cultivated under less than ideal moisture conditions, the result is the degradation of soil structure. Structure degradation leads to crusting or puddling of the soil surface, or compaction deeper within or below the root zone. This can lead to poor crop growth, poor drainage and soil erosion.

Maintaining Soil Structure - Soil structure is the most important soil characteristic to consider when managing soils as it is most affected by farming practices. It also is one of the most important factors in crop growth, along with water and nutrients. The main objective in soil management is to promote and maintain good soil structure that will be favorable to crop growth.

Soil structure degradation can be reversed by carefully using these cultural practices:

- add organic matter from manure or compost;
- use appropriate and timely tillage;
- protect the soil surface by using cover crops; and
- encourage beneficial soil fauna such as earthworms.

Adding Organic Matter: Managing soil organic matter is integral to sound soil management and is a key to long-term productive field operations, particularly where significant quantities of topsoil are removed over time. Organic matter confers structure to soil, increases water holding capacity and is a major source of phosphorus, sulphur and the primary source of nitrogen. Numerous, readily available soil amendments can be applied to the land. Use of amendments can increase the level of organic matter in the soil. However, the nutrient content of these materials must be considered before use. Added nutrients from manure or compost must match the crop's nutritional requirements.

Rates and times of manure application must be considered, as well as the nutrient requirement of the nursery crop, the soil characteristics (e.g. drainage and slope of land) and the presence of surface and ground waters. Manure should, in most cases, not be applied to bare land due to the potential to leach and/or volatilize. Based on soil test results, a light manure application may be applied in late summer if it is followed (after approximately 1 week) by seeding a winter cover crop, which will act to 'catch' the nutrients. When manure is used, fertilization rates should be reduced. For more information on manure application rates and considerations, contact your local Ministry of Agriculture office.

Compost applications are another option that adds humus to the soil with the advantage of not tying up nutrients. Non-composted materials should not be used, as they will cause nutrient tie-ups (e.g. nitrogen). In order to avoid this, urea or an ammonium salt should be added at the same time at a rate of 20-40 kg/ha. Woodwaste should only be applied in the top 10 cm of the soil.

Appropriate and Timely Tillage: When a tillage operation is carried out, ask the following questions:

- What is the purpose of the tillage operation?
- Is the timing of the tillage operation best for the soil moisture and weather conditions?
- Is the tillage implement the best for the intended purpose?

Tillage is used to:

- prepare a suitable planting bed;
- bury or incorporate crop residues, fertilizers, lime, manure or other soil amendments;
- kill weeds; and
- form raised planting beds.

There are two groups of tillage implements. **Primary tillage** implements such as plows, discs, subsoilers and rotary spaders are used to break soil, reverse compaction and incorporate residues. **Secondary tillage** implements such as cultivators, harrows and rotovators are used to prepare planting beds and incorporate soil amendments. Secondary implements can have a large impact on soil structure by breaking soil aggregates.

The effects of tillage vary with soil type. Medium to fine textured soils are the most susceptible to structural damage. Attention should be paid to the moisture content of such soils prior to plowing, discing and cultivating. Repeated plowing to the same depth may form a compacted layer that can impede water and root penetration. Many nursery operators rely on the conventional rototiller for tillage, residue incorporation and/or for weed control between nursery rows. Too much cultivation with rototiller/rotovators will pulverize the soil and compact the subsoil over time. Avoid slow tractor speeds that result in excessive pulverizing of the soil. An alternative tillage implement that is not as deleterious to soil structure is the spading machine.

Using Cover Crops: Cover crops have many benefits in addition to improving soil structure. Refer to the section on *Cover Crops* on page 12.

Encourage Beneficial Soil Insects: There are many soil insects and other fauna that can assist in maintenance and improvement of soil structure. Worms can create drainage passages that move

water and air through the soil. Bacteria, fungi and worms can improve soil fertility and nutrient availability. The quantity of beneficial fauna in the in the soil can be increased by the addition of organic matter (manure/compost), use of cover crops and crop rotations. Reduced tillage can maintain or improve worm populations and benefit the survival of mycorrhizae colonies that provide nutrients such as phosphorous to plants.

Drainage

Most nursery crops require moderately to well-drained soils with at least 0.5 m unrestricted rooting depth for successful cropping. Many lowland soils in BC have poor natural drainage with a high water table during the fall, winter and spring. These soils often need a subsurface and regional drainage system to remove excess water from the rooting zone for crop production.

Soil in upland areas may have a hardpan within 0.5 m of the surface. In most cases, this hardpan will not allow the soils to drain during the fall, winter and spring. Such soils require a subsurface drainage system to remove excess water from the rooting zone. Hardpan soils may also require deep tillage with a subsoiling implement.

Refer to the *Water Management* section in this chapter for more information on drainage.

Erosion

Topsoil is valuable and very difficult to replace. Sediments entering watercourses can cause negative impacts to fish and to drainage systems.

In the coastal region, all soils are susceptible to water erosion when cultivated and left bare over the winter. Bare or compacted soils are at the greatest risk of soil erosion losses under winter rains. In interior regions, fine textured soils are susceptible to water erosion during peak run off events from storms, snow melt or poor irrigation practices. Water erosion damage is most severe on long (over 100 meters) or steep slopes (over 5 to 10%) where the crop rows run up and down the slope or where cropping practices leave the soil surface exposed to rainfall impact. It can also occur on sites where soil becomes saturated. Valuable topsoil is washed away from the upper slopes and can bury plants on the lower slopes.

Evidence collected from field sites in the Lower Fraser Valley indicates that when crops are planted up and down slopes, soil losses may exceed 10 tonnes per hectare per year. In long duration rainfall events, as much as 55% of the rain runs off the field.

Wind erosion is most serious on light, sandy soils that are left bare over the winter. Wind erosion has been a serious problem on the Sumas Prairie during winter outflow wind conditions. Wind erosion can occur on most soils if the surface soil layer is dry, unprotected and has poor structure.

Erosion Control - Where possible, use the following practices to minimize the loss of soil by water or wind erosion. Although any of the listed practices will help control erosion, the best control is achieved by using as many of the practices together that are appropriate.

Water erosion:

- drainage systems (refer to the section on *Water Management*);
- contour planting (across the slope);
- winter cover cropping; and
- permanent cover cropping on field roads, field margins and water runs.

Wind erosion (these slow the wind speed at the crop or soil surface):

- windbreaks (e.g. tree rows, snow fences or hedges);
- crop residue (should be anchored to the soil); and
- cover cropping.

Cover Crops

Cover crops are grown to protect against soil erosion, to improve soil structure and fertility, to suppress some insect pests and weeds, and to promote some beneficial insects. They are not usually grown for harvest or forage. They are planted when portions of the field, or the entire field, are left bare. Cover crops are also called green manure, living or dead mulches, plow down, companion, relay, double or catch crops depending on their specific use. Cover crops are known to reduce water erosion by over 50% in the South Coastal area.

Before planting a cover crop, it is important to know the soil problem that needs to be addressed. For example, cover crops will not prevent flooding but can improve the movement of rain water into

the soil and to the drains. In addition, planning future crop rotations will assist in choosing the correct cover crop. Some cover crops can harbour beneficial insects such as ladybird beetles or ground beetles. Other cover crops may act as a green bridge for harmful insects or diseases. The risk of pest transmission can be limited by choosing the correct cover crop to fit the desired crop rotation. This will allow the grower to reap the soil conservation benefit of the cover crop.

Choosing a Cover Crop - Once the purpose of sowing a cover crop is established, important factors to be considered are the planting date and subsequent management. Spring cereals sown in late summer or early fall will usually provide good early growth and soil cover. They are often winter-killed, leaving a protective mat on the soil. Spring cereals breakdown early in the spring and will tend to release any trapped nitrogen at a time when it can be used by the subsequent crop.

Winter cereals will usually grow slowly over the winter, producing the majority of their growth in the spring. These crops tend to be more resistant to damage from waterfowl grazing than either spring cereals or any of the legumes or brassicas. Overwintering cereals may require a change in nitrogen management practices as they tend to release any trapped nitrogen late in the summer.

Winter cereals require a spring management program, which may include additional discing or mowing to chop the crop and make it easier to incorporate.

Legume crops, such as hairy vetch or crimson clover, can be used if early planting dates are available. These legume crops are normally grown in a mix with a cereal crop to provide some protection from waterfowl. Hairy vetch is the most reliable. Both crops will provide nitrogen to the subsequent spring crop after they are tilled under in the spring. Hairy vetch exhibits 'hard seededness' and may volunteer in subsequent crop years. Winter peas may also be used.

Brassica crops, such as forage rape or kale, are excellent at tying up soil nitrogen.

Mixes of grasses are recommended for permanent covers along field margins, ditch banks or roadways.

Some specific varieties of cover crops have been reported to suppress pests or increase the population of beneficial insects. Others may be useful for specialized conditions or specific soil management concerns. Table 2.2 lists the best types, seeding rates and planting dates for cover crops used in nursery crop production.

Table 2.2. Recommended seeding rate and planting dates for various cover crops.

Types	Seeding Rate	Recommended Seeding Dates
Spring cereals (barley or oats)	80 - 150 kg/ha (30 - 60 kg/acre)	• before September 10
Winter cereals (winter wheat or fall rye)	80 - 150 kg/ha (30 - 60 kg/acre)	• after August 15 and before September 30 • fall rye better for late seeding
Winter legumes (hairy vetch or winter pea)	15 - 30 kg/ha (6 - 12 kg/acre)	• before September 15 • best seeded in a mix with winter cereals
Legumes (crimson clover)	10 - 20 kg/ha (4 - 8 kg/acre)	• September 10 (later plantings will fail) • need drained conditions
Brassicas (forage rape or kale)	10 - 15 kg/ha (4 – 6 kg/acre)	• after August 15 and before September 30
Annual grasses (annual ryegrass)	20 - 40 kg/ha (8 – 16 kg/acre)	• up to September 15 • can be seeded as in season cover
Grass mixes (containing creeping red fescue, Sheep's fescue, hard fescue or perennial ryegrass)	20 - 40 kg/ha (8 – 16 kg/acre)	• generally recommended for spring seeding or when soil moisture is available in late summer

Spring Management of Cover Crops -

For spring cereal crops, crop residues can be disced, or disced and plowed, depending on the amount of residue. Chop heavy residues first to prevent the formation of a mat of under-decomposed residue.

Winter cereal crops or cover crops that survive the winter should be mowed or killed with a broad spectrum herbicide before plowing down. If large amounts of plant material are to be turned under, apply a light application of manure or 20-30 kg/ha of fertilizer nitrogen to speed decomposition. Chop and incorporate the crop residue with a disc prior to plowing. Rotovating or plowing alone is not recommended.

Water Management

Water management is an essential part of nursery production. Plant growth and yield can potentially be optimum when a reasonable measure of water control is achieved in the soil. Too little or too much water can result in crop losses as natural conditions rarely satisfy crop needs. In some cases, water is also required for pest control or nutrient application. Water quality must be considered because unsuitable water can impact nursery crop growth and quality.

Drainage

Removing excess water in spring, fall and winter is usually necessary in South Coastal BC and, to a lesser degree, in some Interior areas. In the Interior, drainage is frequently required for reclamation and control of soil salinity and alkalinity. Many coastal floodplain areas can also benefit from drainage to reduce or remove saline salts. Drainage systems give the following benefits:

- increased trafficability,
- extended crop season,
- increased crop yields due to improved nutrient uptake,
- improved aeration of the root zone,
- warmer soil temperatures,
- crop protection from "drown-out" and certain seedling and root diseases,
- control of water erosion, and
- increased land values.

Drainage systems usually have a surface and a subsurface component. Both must be well planned, installed and maintained to be effective. Subsurface drainage with a functioning outlet is the best way to control water on most soils. Lightweight, continuous, flexible, perforated plastic drainpipe is used. On sloping land, porous surface or blind inlets may be needed to lead water to the subsurface drains in order to reduce overland flow and erosion. On sandy soils, geotextile filters are needed around the perforated pipe to prevent sand from clogging the drain tube. Filters should not be used on organic soils.

Plastic drain pipe is quickly installed by drainage contractors using specialized equipment.

Installation depth and spacing differs with fields and is mainly based on the climatic conditions and soil type. Pumps are sometimes needed in low-lying areas that lack gravity outlets.

Drainage systems must be maintained. This includes periodic cleaning of drainpipes, outlets and ditches, and careful in-field soil management. Soil conservation and best management practices should be followed to reduce the need for ditch cleaning and to avoid damage to soil tilth.

Agricultural ditches are often connected to channels and streams that contain fish and have good fish habitat. Producers must follow the *Drainage Management Guide* when conducting channel maintenance.

The *BC Agricultural Drainage Manual* provides more information and details on installing a subsurface drainage system.

Irrigation

In almost all parts of the province, the natural rainfall is not sufficient for at least part of the growing season to replace water lost from the soil due to evaporation or crop usage. At these times, irrigation can result in higher yields and, in some cases, prevent crop failure. Irrigation is especially necessary in new plantings where plants have small and shallow root systems.

Irrigation systems include drainage systems used for subirrigation, trickle and drip and various forms of sprinkler irrigation. All have their own merits. The systems must be properly designed, installed and maintained to be effective. Efficient delivery and distribution systems conserve water and save on power and fertilizers. Applying too much water or having leaky pipes may lead to soil

erosion, reduced production and higher operating costs. Over-application of water will also result in leaching of nutrients such as nitrogen and boron. Check and repair or replace pipes, pumps and sprinklers on a regular basis. The Irrigation Industry Association of BC (IIABC) certifies irrigation system designers and companies that can provide efficient plans and products to growers. The Association can be contacted at 604 859-8222 or by email at iiabc@irrigationbc.com.

A water license is required to use irrigation water from surface water sources. Licenses can be obtained from the BC Ministry of Environment. Groundwater is not licensed at the present time. For more information on irrigation system design, operation and maintenance, refer to Ministry of Agriculture factsheets or to the *BC Trickle Irrigation* or *Sprinkler Irrigation* manuals that are available from the IIABC. For information on irrigation system assessments, irrigation scheduling, water and energy conservation, and other beneficial management practices, refer to the *BC Irrigation Management Guide* that is available from the IIABC.

Chemigation

Chemigation refers to the injection and application of pesticides or fertilizers (fertigation) through an irrigation system. Growers who have solid set sprinkler or trickle irrigation systems may use chemigation as a method of applying nutrients. However, pesticides must be registered for application through an irrigation system. Check the label to make sure this method can be used to apply a specific pesticide. Prior to injecting fertilizers or other chemicals into an irrigation system, proper safety procedures must be followed. The booklet *Chemigation Guidelines for British Columbia* provides information on injection rate calculations and safety considerations.

Water Quality for Irrigation

Irrigation water comes from surface or groundwater sources. In many areas, ditch water is used for irrigation. Ditch water may contain high levels of micro-organisms, salts, metals or organic compounds that can affect crop performance or quality. Some groundwater sources may also contain high levels of ions or nutrients that may impact crop performance.

Water quality should be checked at a laboratory before planting a crop. If the crop is established, check the water before applying to the crop. Water tests should assess salt levels (both electrical conductivity and sodium adsorption ratio), pH, metals, nutrients, possible toxic elements and coliforms (see Table 2.3). Also check the levels of bicarbonate (HCO_3), calcium and magnesium. High levels will cause precipitates to form on the crop or possibly plug a drip irrigation system. The *BC Sprinkler Irrigation Manual* and the *BC Trickle Irrigation Manual* provide further information on irrigation water quality guidelines. Table 3.9 shows the acceptable levels of specific elements in irrigation water.

The presence of plant-available nutrients in the greenhouse water supply does not usually present a problem, unless they exceed the amounts normally fed to plants. However, they must be taken into account when formulating nutrient solutions. Certain fertilizer materials, such as phosphoric acid, will react at high concentrations with dissolved calcium, iron and magnesium to form insoluble precipitates that may clog drippers. The risk of precipitates forming is high for water that contains greater than 50 mg/L of calcium and magnesium, or greater than 1.5 mg/L of iron. Water supplies high in calcium and magnesium may not be suited for use in mist systems due to the accumulation of unsightly mineral residues on plant surfaces.

Table 2.3. Water quality evaluation characteristics.

Characteristic	Level that indicates contaminated water	Concern
Biological Oxygen Demand (BOD)	> 40 for small streams or > 60 for larger streams	Danger to fish stocks
Total Iron (Fe)	> 3 mg/L	Crop staining
Nitrate (NO_3-N)	> 5 mg/L	Danger to human health
Total Suspended Solids (TSS)	> 75 mg/L	Danger to fish stocks
Ammonia (NH_4-N)	> 10 – 15 mg/L (depends on pH and temperature)	Danger to fish stocks
Fecal Coliform	a) > 100 CFU/100 mL b) > 0 CFU/100 mL (CFU = colony forming units)	a) Reduced crop quality b) Danger to human health
Tannin and Lignin (resin acids)	> 9 µg/L TRA or > 80 µg/L DHA (TRA = total resin acids) (DHA = dehydroabietic acid)	Danger to fish stocks Crop staining

Protecting Water Quality

Waste products generated during the planting, maintenance and harvesting of nursery crops may have negative impacts on water (see Table 2.3). Growers who operate at the highest environmental standards will be better able to protect themselves from possible challenges to their operations. Proper use and storage of pesticides, fertilizers, manure and woodwaste will help to protect water quality.

Growers are reminded to use best soil management practices in the field and appropriate waste handling techniques during on-farm washing and grading activities. Follow the recommendations in this guide and also refer to the *Reference Guide: Canada-BC Environmental Farm Plan Program*. Growers are encouraged to take advantage of the Canada-BC Environmental Farm Plan Program. Farmers participating in the program will gain more detailed information on a range of environmental issues including water management. For more information, see the section on Environmental Farm Plans at the end of this chapter.

Nutrient Management

Soil Testing

A soil analysis is the most accurate guide to fertilizer and lime requirements. It is especially important before planting to determine soil fertility and pH levels. The necessary lime and fertilizer can then be added when the field is prepared. Soil testing and tissue testing are useful tools for determining fertilizer requirements in established crops. However, sampling must be done accurately and carefully so the samples are representative of soil and crop conditions.

The basic steps for soil sampling are:

- Use the same sampling method and pattern every year.
- Use clean tools (e.g. garden trowel) to collect the sample.
- Use a clean pail (e.g. ice-cream bucket) to hold all samples for one combined analysis.
- Wear disposable gloves when sampling for micronutrients.
- Record relevant information about the location and type of sample.

Table 2.4. Suggested standards of soil fertility for growing woody plants in field production nurseries.

		Available (kg/ha)[a]		Exchangeable (mEq/100 g)[b]	
Group	**CEC [c]**	**P**	**K**	**Ca**	**Mg**
Silt loam to loam	12-16	39-79	169-225	5-10	2
Sandy loam	5-10	28-39	113-169	2.5-4.0	1
Loamy sand to sand	2-4	17-28	68-113	1.5-2.0	0.5

[a] P X 2.3 = P_2O_5; K X 1.2 = K_2O.

[b] 1 mEq/100 g Ca = 450 kg/ha; 1 mEq/100 g Mg = 270 kg/ha.

[c] CEC = cation exchange capacity, which is a measure of the soils ability to hold certain nutrients.

Adapted from: Davidson, Mecklenburg and Peterson (1988)

- Mark the locations on a field map where samples are to be collected. Avoid non-uniform areas.
- Take 10 to 20 individual samples to a depth of 15 cm (6 in) for most nutrients. Sample to 30 cm (12 in) when sampling for nitrate-nitrogen in the fall for 'report card' testing. Try to collect a uniform sample width through the entire 1-15 cm (or 30 cm) profile. Purposefully designed soil samplers remove a core about 2.5 cm (1 in) wide.
- Thoroughly mix the soil in the collecting pail.
- Put about 300 mL (~1 cup) of the mixed soil into a clean plastic bag or box.
- Store the sample in a cooler until it is taken to the laboratory.

Several private laboratories conduct soil testing in BC. Where possible, use local laboratories as they have knowledge of local conditions to conduct the appropriate analyses and give correct recommendations. Use the same laboratory each year for consistent interpretations and recommendations.

Plant Tissue Testing (Foliar Analysis)

Foliar analysis may be the best way to determine if a crop is experiencing a nutritional problem. It measures the nutrient content of plant tissue and, when used to compare "good growth" with "poor growth", can be an excellent diagnostic tool. It can be used for both field and container-grown stock.

Nutrient levels vary widely with age. The best time to take tissue samples is in July and August. Samples may be taken at other times of the year, if nutrient deficiency symptoms appear.

Tissue analysis is a method to determine nutrient imbalances within a plant. Based on the results, corrective actions can be implemented. If nutrient deficiencies are experienced, foliar feeding can be an effective, short-term solution for micronutrient deficiencies. Foliar feeding is not effective for macronutrient deficiencies, since the amount of fertilizer required to correct macronutrient deficiencies is more than can be supplied.

Correct sampling is important. Before collecting a sample, contact the lab for advice on how to collect a good tissue sample. The following is a basic guide to taking plant tissue samples:

- Sample using clean hands or use plastic gloves.
- Select about 50 fully expanded leaves midway along the current years shoot growth for deciduous and broadleaf evergreens.
- Select about 20 (10 cm long) shoots of current year growth for conifers. For pines, spruces and firs remove the needles from the twigs and submit only the needles for analysis.
- Sometimes the damaged portion of the leaf is very small, such as with marginal necrosis. If the entire leaf was analyzed the nutrient deficiency or toxicity in the leaf margins could be masked due to nutrient levels in the rest of the leaf. In such cases, it is recommended to only collect tissue from the damaged portions of the leaf.
- Collect as little woody material as possible. Woody tissue is relatively low in nutrients and therefore will reduce the nutrient levels detected in the sample.
- Rinse foliage in clean water if it is dirty, otherwise submit as is.
- Samples should be kept cool and delivered to the laboratory as soon as possible. If they cannot

be delivered immediately, air-dry the samples and ship in paper bags to avoid spoilage.

- As mentioned above, it is important to submit samples from healthy and affected plants.

Table 2.5. Average nutrient contents in leaves of healthy and nutrient deficient trees.

Nutrient	Healthy Foliage (dry weight)	Nutrient Deficiency Symptoms (dry weight)
Nitrogen	1.5 %	-
Phosphorus	0.12 – 0.15 %	< 0.09 – 0.1 %
Potassium		
conifer	0.4 – 1.0 %	< 0.2 – 0.4 %
broadleaf	1.0 – 1.5 %	< 0.6 – 1.0 %
Calcium	1.5 %	-
Magnesium	0.1 – 0.2 %	< 0.08 %
Sulfur	0.2 %	< 0.15 %
Boron	15 – 100 µg/g	< 15 µg/g
Copper	5 – 15 µg/g	< 4 µg/g
Iron	40 – 100 µg/g	25 – 40 µg/g
Manganese	50+ µg/g	5 – 40 (usually < 20) µg/g
Molybdenum	0.05 – 0.15 µg/g	-
Zinc	12 – 80 µg/g	5 – 20 µg/g

Source: Diseases of Trees and Shrubs, 1987. Sinclair, Lyon and Johnson.

Record Keeping

For the most effective nutrient management program, it is essential to keep track of soil and tissue testing results along with all information about the rates, type and timing of fertilizer, manure or soil amendment applications. Other observations on crop growth, yield, quality and weather during the growing season are also useful.

Use test strips ('checks' or 'control strips') to test changes in a nutrient management program. Then the old practice can be compared to the new practice to see if the crop is affected. This comparison can only be made when the old and new practices are evaluated under the same field and management conditions.

Calculation of Fertilizer Rates

Fertilizers are labelled by percentage according to their guaranteed minimum analysis of nitrogen (N), phosphate (P_2O_5), potash (K_2O), and other nutrients that may be present. Five 20 kg bags (100 kg total) of 12-51-0 contain 12% nitrogen (12 kg N), 51% phosphate (51 kg P_2O_5), and no potash (0 kg K_2O). The rest of the material in the five bags is other elements that are part of the fertilizer compounds carrying the nitrogen, phosphate, and potash. See below for sample fertilizer calculations for field crops.

Sample Fertilizer Calculations

A. The *amount of fertilizer* required = (recommended rate X 100) ÷ fertilizer analysis
Example:

Recommended rate of potash = 135 kg/ha
Fertilizer analysis = 0-0-60

The amount of fertilizer required = (135 kg/ha X 100) ÷ 60 = 225 kg of 0-0-60/ha

B. The ***amount of nutrient*** applied by a fertilizer = (fertilizer applied X fertilizer analysis) ÷ 100
Example:
Amount of fertilizer applied = 225 kg/ha
Fertilizer analysis = 13-16-10
Amount of N supplied = (225 kg/ha X 13) ÷ 100 = 29 kg N/ha

Amount of P_2O_5 supplied = (225 kg/ha X 16) ÷ 100 = 36 kg P_2O_5/ha

Amount of K_2O supplied = (225 kg/ha X 10) ÷ 100 = 22.5 kg K_2O/ha

Methods of Fertilizer Application

Broadcasting and incorporation refers to spreading fertilizer on a soil surface before the crop has been planted, then incorporating the fertilizer into the soil by tillage. Broadcast application is not recommended for most field stock because fertilizer applied between the rows is wasted. Fertilizer can also lodge in the foliage and cause chemical burn. This problem is particularly common in hedging cedar production.

Top-dressing refers to spreading fertilizer on a field when a crop is growing. It is not incorporated, but sprinkler irrigation will wash fertilizer off the leaves and a few centimetres into the soil. For field stock, fertilizer can be dropped around each plant by hand. Hand dropping the fertilizer ensures application to the root zone of the plant. The placement should be 15-30 cm (6-12 in) away from the main stem to prevent chemical burn to the bark.

Banding refers to the application of fertilizer at the time of planting in continuous bands that are 2.5 cm or more to the side of the plant and 5 cm or more deep, depending on the crop.

Side-dressing refers to the banding of fertilizer after plants are established. Care should be taken not to disturb the roots of the plants.

Deep-banding refers to banding fertilizer at a depth of 5 cm or more prior to planting. There is scientific evidence indicating that this results in greater fertilizer efficiency than surface broadcasting for deep-rooted row crops.

Fertigation refers to the application of fertilizer in irrigation water.

Fertilizer Materials

Some basic fertilizer materials are listed in Table 2.6. These materials are used as the basis for many custom fertilizer blends. Please see your local fertilizer supplier for the custom blends available.

Table 2.6. Primary nutrients in common fertilizers.

Nitrogen Materials	Guaranteed Minimum Analysis
Urea	46-0-0
Ammonium Nitrate	34.5-0-0
Ammonium Sulphate	21-0-0 + 24S
Sulphur Coated Urea	37-0-0 + 15S
Calcium Nitrate	15-0-0 + 20Ca
Phosphate Materials	
Diammonium Phosphate	18-46-0
Ammonium Phosphate Sulphate	16-20-0 + 14S
Mono Ammonium Phosphate	12-51-0
Triple Super Phosphate	0-45-0
Potash Materials	
Muriate of Potash	0-0-60
Sulphate of Potash	0-0-50 + 17S
Sulphate of Potash Magnesia	0-0-20 + 20S + 10Mg

Nutrient Reactions in Soils

Nutrients added to the soil may become more or less available depending on the type of fertilizer, the soil moisture, the pH conditions, the nature of the soil, the amount of organic matter and rainfall, and the temperature. Some nutrient elements may be completely lost while others may be 'tied-up'. This section gives information on nutrients from conventional fertilizer sources (i.e., not organic sources such as manure).

Nitrogen (N)

The most common forms of fertilizer nitrogen are nitrate (NO_3), ammonium (NH_4) and urea ($CO[NH_2]_2$). All three forms are highly soluble in water. Urea is converted to the ammonium form by enzymes in the soil. Ammonium nitrogen is adsorbed (chemically bound) to clay minerals and organic matter and is, therefore, retained by the soil. Some ammonium and urea nitrogen may be converted to ammonia gas that escapes into the atmosphere. This usually occurs in dry soil with surface-applied fertilizer. Ammonia losses are

reduced or eliminated by ensuring that the fertilizer is well covered with moist soil. Losses are minimized by banding, immediate incorporation after broadcasting, irrigation following application or broadcasting onto moist soil in cool weather.

Slow release forms of fertilizer have the same reactions in the soil as non-slow release forms, once the nitrogen is released. The slow release mechanism, whether it is a capsule like sulphur coating or a blend like a polymer, is designed to overcome problems with nitrogen losses and availability.

Nitrate nitrogen is not held by the soil and can be leached by water. Leaching losses of nitrate-nitrogen are most severe in sandy soils, in areas with high rainfall, and under intense irrigation. Some nitrate-nitrogen may be converted to gases that escape into the atmosphere. This frequently occurs in wet soils during fall, winter and spring.

Nitrogen should be surface applied in the spring each year. The actual rate of application varies with the amount available in the soil, the soil environment, the plant type and size, and the objective of the grower. A rate of 150 – 200 kg N/ha is suggested but can be modified with experience. Higher rates are used in areas of intensive production, particularly deciduous stock at close spacing. Lower rates are used on more extensive field plantings and slow-growing conifers or first year transplants. The total amount of nitrogen should be divided into 2-3 applications. Apply the first and largest installment in early spring, either before new growth begins or just after planting. Spread the remaining smaller application(s) over the next 3-4 months. Do not apply nitrogen after August 15 on the Coast and July 15 in the Interior, as induced late growth may suffer winter injury. Slow release forms of nitrogen fertilizer can be used. More nitrogen will be required in sandy relative to clay soils.

Phosphorus (P)

All phosphorus fertilizers are phosphate salts. They are water soluble, but tend to form insoluble compounds when incorporated into the soil. Unlike nitrogen and potassium, phosphorus does not readily move in the soil. It tends to remain where it is placed. Therefore, it is important to place phosphorus fertilizer in the rooting zone of the crop before the crop is established, or to band it next to the roots in the established crop. An entire year's phosphorus supply may be applied with one early spring application. Surface application without incorporation is the least efficient way to use phosphorus fertilizer. In some soils, phosphorus becomes "tied-up" if the pH is below 6.0 or above 7.5.

Note: In general, very little phosphorous leaches from the soil, **unless** soil phosphate levels are excessively high. Phosphorous can also be lost in soil sediment during erosion.

Potassium (K)

Potassium fertilizers are all simple potassium salts, such as potassium chloride, potassium sulphate, potassium-magnesium sulphate or potassium nitrate. All are readily water-soluble. Potassium is adsorbed to some extent to organic matter and clay minerals. However, it is subject to leaching, especially in sandy soils. Potassium should be applied in split applications over the season. More potassium will be required in sandy relative to clay soils.

Secondary Nutrients

The level of magnesium (Mg) and sulphur (S) in the soil may be deficient for good crop growth. Soil and tissue testing are the only accurate ways to determine if they are lacking. A number of fertilizers are available that contain sulphur or magnesium. Calcium (Ca) is rarely deficient in soils since it is a component of agricultural lime and many common fertilizers.

Micronutrients

Micronutrients are required only in very small amounts by plants, yet the quantity of iron (Fe), manganese (Mn), copper (Cu), zinc (Zn) and boron (B) in the soil can be insufficient for optimum crop production. It is important to ensure that micronutrient fertilizers are applied at the correct rate. High levels of micronutrients, especially boron and manganese, are toxic to plants. Soil and/or tissue testing are the only accurate ways to determine if these elements are lacking. If they are needed, micronutrients can be added to blended fertilizers and applied along with the routine fertilizer program. Alternatively, micronutrients can be applied in irrigation water (fertigation) or with a crop sprayer (foliar feed). Foliar sprays often give fast response but they should not be applied at higher than recommended concentrations or crop

damage may result. Use enough water to wet the foliage and apply under slow drying weather conditions.

Boron deficiency can cause a wide variety of abnormalities in crops. Fertilizers that include boron can be obtained in most areas. **Caution:** Do not exceed the recommended amount of boron per hectare as it may cause plant injury. If boron-deficiency symptoms occur during the growing season, boron can be applied as a foliar spray. Apply Borospray, Solubor or Borax at manufacturers' directions. In the Interior, boron should be applied in the fall. At the Coast, it should be applied in the spring where a need for it has been shown.

Nutrient Deficiencies

A nutrient deficiency can cause plant growth to be chlorotic (= yellowing), necrotic (= browning) abnormal, stunted, cracked, or a combination of these symptoms. Table 2.7 provides a summary of the typical symptoms associated with specific nutrient deficiencies. When diagnosing nutritional problems it is important to observe whether the symptoms occur on new or old leaves. This will provide evidence to determine whether the deficiency id due to a mobile or non-mobile nutrient. Mobile nutrients can move from older tissues to new growth, and therefore deficiency symptoms will occur first on old growth. In contrast, non-mobile nutrients will not move from old to young growth, and deficiency symptoms develop first on young growth.

The nutrient required may be present in the soil but unavailable to the plants because of weather or soil conditions. Some nutrients will slow down the uptake of other nutrients unless they are present in the correct proportion (Table 3.7 lists nutrient deficiencies that can occur when specific nutrients are available in excess). For example, excess levels of potassium or calcium can lead to symptoms of magnesium deficiency (e.g. interveinal chlorosis of older leaves) because they interfere with magnesium uptake by roots. Excess fertilizer may also cause leaf "burn" or stunted growth.
All nutrients have a pH range at which they are most available to the plants, providing other factors are favourable. If the soil pH is incorrect, it will affect nutrient availability. For example, at a high soil pH iron is less available and will lead to iron deficiency.

Soil pH

Soil pH refers to the acidity or alkalinity of the soil. Soil pH is very important because it affects the availability of nutrients to the plant. Most nursery crops do not respond to fertilization when the pH is very low (extremely acid soils, pH less than 5.0) or very high (extremely alkaline soils, pH above 7.5).

Calcium, phosphorus, magnesium and molybdenum are the nutrients that are most likely to be deficient under acid soil conditions. Test the soil to determine pH before planting and every 2-3 years to monitor changes. Soil pH can usually be modified to obtain a suitable pH for good nursery field production.

Raising Soil pH

Soils in South Coastal BC are typically acidic and modification of soil pH is not required for most acid-loving nursery crops. Lime application to raise soil pH is usually required, however, for species that are not acid-loving. When the soil pH is not known, a soil test should be performed.

Agricultural grade limestone (calcium carbonate, $CaCO_3$) is generally recommended to correct soil acidity. For the Fraser Valley, the general application rate is 1-2 tonnes/ha/yr (400-800 kg/acre) for pH sensitive crops. Rates higher than 2-4 tonnes (800-1,600 kg/acre) are not recommended due to soil reactivity and the difficulty of incorporation. Lime should not be applied within 1 week of applying nitrogen fertilizer or manure, since the high soil pH that occurs shortly after liming will increase the loss of ammonia.

If calcium levels are low, gypsum or fertilizers such as calcium nitrate may also be used to supply calcium, rather than using lime. Gypsum ($CaSO_4$) is not a liming agent and will not increase soil pH.

Table 2.7. Diagnosing plant nutrient deficiency symptoms.

Symptoms		Deficient Nutrient
Stunting of Shoot Tips		
Young leaves are thick, leathery and chlorotic; stems are brittle; "Witch's broom" appearance; poor flowering	⇒	**Boron**
Young leaves chlorotic or distorted (crinkled, strap-like, downward curling of leaf tips); roots may become short, stunted and thick; weakened stems	⇒	**Calcium**
Wilting and dieback of shoot tips; poor pigmentation	⇒	**Copper**
Interveinal Chlorosis		
A. Young leaves		
Veins usually remain distinctly green; chlorosis progresses to older leaves; leaves may appear white; twig dieback	⇒	**Iron**
Gradation of colour from yellow to dark green at the midribs, often not a sharp distinction between yellow and green areas; leaves may develop brown or purple spots, and become necrotic	⇒	**Manganese**
Terminal growth stunted, forming a rosette	⇒	**Zinc**
B. Older leaves		
Upward curling along leaf margins; mid-rib areas remain green	⇒	**Magnesium**
Overall Leaf Chlorosis		
A. Occurs first on young leaves		
Associated with leaf wilting	⇒	**Chlorine**
Stunting and lack of vigour; distorted 'whiptail' leaves or leaf scorch	⇒	**Molybdenum**
Slow, spindly growth; leaves may turn beige	⇒	**Sulphur**
B. Occurs first on older leaves		
Leaves may become necrotic; stunted, slow, spindly growth	⇒	**Nitrogen**
Plants Dark Green With Purple Coloration of Older Leaves		
Slow growth; stunted plants; older leaves turn chlorotic, then necrotic	⇒	**Phosphorus**
Necrotic Spots on Margins or Tips of Older Leaves		
Weak stems and stalks that fall over easily; slow growth; small flowers	⇒	**Potassium**

Effects of Lime

- Corrects soil acidity.
- May improve the physical condition of the soil.
- Dolomitic limestone provides calcium and magnesium.
- Favours bacterial action, hastening the decomposition of organic matter.
- Improves conditions for availability of other nutrients, notably phosphorus and some minor elements.
- Reduces the toxicity of some elements such as manganese and aluminum.
- High rates of lime may help digest organic matter and release nitrogen for a short period after application.
- Above 5 tonnes/ha may tie up some micronutrients such as boron. Magnesium deficiencies may be aggravated, especially in sandy soil. Where this is a problem, some dolomitic lime should be used.
- Excessive use of lime may cause nutrient imbalances, so lime should be used in conjunction with a planned soil testing and fertilizer program.
- Increases rate of organic matter depletion.

Forms of Lime Used

Calcium oxide: quicklime, caustic lime, burnt lime. **Not recommended for use on agricultural land**.

Calcium hydroxide: hydrate or slaked lime should only be used as a spring application for rapid results. Excessive rates above 1,100 kg/ha (450 kg/acre) may be quite caustic and "burn out" organic matter. Only occasional use is recommended on agricultural land.

Ground limestone: calcium carbonate ("agricultural lime") is the most convenient form to handle. It may be applied at any time of the year. Ground limestone dissolves slowly and lasts longer in the soil. (Usually gray lime material, sold in bulk in South Coastal BC.)

Ground dolomite: calcium-magnesium carbonate may be substituted for ordinary limestone.

Notes:

- Fineness of grind is very important. Finer grinds (100 mesh and above) react in soil much quicker than coarse grinds (10-100 mesh). Very coarse limestone (less than 10 mesh) is not recommended. Some coarse material is desirable to facilitate lime handling. Excessively fine material will not flow readily and is subject to wind drift during spreading.
- Lime does not move through the soil – it must be incorporated.
- Gypsum ($CaSO_4$) is not a liming agent. It will not increase soil pH, and under certain conditions it is used to lower pH.

Lowering Soil pH

Sometimes it is advantageous to lower or acidify the soil pH. In Interior areas, alkaline mineral soils may need to be acidified for nursery crop production.

The principal materials used to lower soil pH are elemental sulphur, sulphuric acid, aluminum sulphate and iron sulphate (ferrous sulphate). Ammonium sulphate, ammonium phosphate and other ammonium containing fertilizers are also quite effective when the soil receives sufficient water, though they are primarily sources of plant nutrients.

For large areas, elemental sulphur is probably the most economical product to use. The finer ground the sulphur, the more quickly it will react in the soil to lower the pH. Flower sulphur is very fine (powder) and reacts relatively quickly. Solid sulphur prills (granules) are less finely ground and therefore react more slowly and they are more convenient to apply. Finely ground sulphur is sometimes available in prills that contain a mixture of flower sulphur and bentonite clay that improves the handling, stability and safety of the material.

Soil test laboratories can, by request, determine total soil acid and calculate the sulphur required to attain a desired pH. As a general recommendation apply the equivalent of 2 tonnes/ha (800 kg/acre) in a band where the planting beds will be formed.

Table 2.8. Soil conductivity readings (derived from field soil samples using a 2:1 water and soil paste mixture).

Conductivity Reading (milliSiemens/cm)	Rating	Plant Response
0-0.25	Low	Suitable for most plants when using recommended amounts of fertilizer.
0.26-0.45	Medium	Suitable for most plants when using recommended amounts of fertilizer.
0.46-0.70	High	May reduce emergence and cause slight to severe damage to salt sensitive plants.
0.71-1.00	Excessive	May prevent emergence and cause slight to severe damage to most plants.
1.00	Excessive	Expected to severely damage most plants.

Source: *OMAFRA Nursery & Landscape Plant Production*, Publication 383

Soluble Salts in Soil

Elevated salt levels in soils will interfere with water uptake by plants and eventually crop growth. The effects range from delayed or non-germination of seed to death of new transplants and serious reduction in growth of new or established plants (see Table 2.8). Most soils in BC are low in soluble salts. However, there are regions where salts can accumulate, such as lowland areas adjacent to ocean dykes, areas where salt-water intrusion may affect irrigation water, alkali seep areas in the Interior and areas where road salts or fertilizer salts have accumulated. The problem with soluble salts is most severe when soil moisture is low and salt concentration is high.

Manure and Waste Management

The storage and use of livestock manure and agricultural vegetation wastes is covered by the *Code of Agricultural Practice for Waste Management*. This Code is part of the Agriculture Waste Control Regulation under the *Environmental Management Act*. The Code describes general practices for the use, storage and management of agricultural waste in an environmentally sound manner. Growers are encouraged to take advantage of the Canada-BC Environmental Farm Plan Program. Farmers participating in this program will gain more detailed information on a range of environmental issues including proper use of manure and woodwastes. See the section on *Environmental Farm Plans* at the end of this chapter.

The Code requires that agricultural waste, particularly manures, be kept in a storage facility or covered if not used immediately. The storage must prevent escape of manure to the environment that could cause pollution. Manure may be stored uncovered in the field for up to 2 weeks prior to use. Manure may be stored in the field for up to 9 months if it is kept in a temporary storage facility that prevents the escape of nutrients to the environment, e.g. securely covered with a tarp on a dry site. Areas of the Province, including the Lower Fraser Valley and Vancouver Island regions, that receive total average precipitation greater than 600 mm (24 inches) from October 1 to April 30 inclusive, must cover field stored solid agricultural wastes (except vegetation waste). The field storage facility must be 30 meters from a watercourse or a water source used for domestic purposes.

Table 2.9. Typical nutrient content of various types of manure.

		Nutrient Content[a] kg/tonne (kg/m³)		
Type of Manure	**Moisture %**	**Total Nitrogen**	**P_2O_5**	**K_2O**
Beef (solid)	68	4.2 (2.1)	4.8 (2.4)	8.2 (4.1)
Dairy (solid)	77	3.9 (2.0)	3.4 (1.7)	9.0 (4.5)
Dairy (liquid)	91	2.9 (1.5)	2.1 (1.1)	4.5 (2.3)
Swine (covered pit)	93	6.3 (3.2)	3.3 (1.6)	3.9 (2.0)
Swine (uncovered pit)	98	3.5 (1.8)	1.5 (0.8)	1.7 (0.8)
Horse (with shavings)	72	2.4 (1.2)	1.7 (0.8)	3.2 (1.6)
Spent mushroom compost	70	5.8 (2.9)	2.5 (1.2)	8.5 (4.2)
Poultry (broiler)	25	31.6 (15.8)	22.8 (11.4)	12.2 (6.1)
Poultry (layer)	50	22.8 (11.4)	29.2 (14.6)	11.2 (5.6)

[a] Nutrient values for manure assumes proper storage, handling and application to minimize losses.

Conversions:

1 tonne of liquid manure = approximately 1,000 litres = 1 m^3 = 220 Imp. gallons
1 m^3 = 1.25 yd^3 = 28 bushels
1 tonne of solid manure = approximately 2 m^3 = 2.5 yd^3
To convert kg/tonne to lb./ton, multiply by 2.0
To convert kg/m^3 to lb./yd^3, multiply by 1.7

Nutrient Value of Manure

Manures supply plant food over a period of time. Table 2.9 shows the typical amount of nutrients supplied in various types of livestock manure. Note the moisture and nutrient content varies as a result of storage method, litter content, and/or the age of manure. The nitrogen values given in Table 2.9 are for total nitrogen. For all types of manure, the amount of nitrogen that is available to the crop after it is applied may vary from the value listed in the table. Incorporate all manures (solid or liquid) within 12-24 hours of spreading to reduce ammonia volatilization and to achieve the greatest benefit from the manure nutrients. Nitrogen losses after spreading range from less than 10% if the manure is incorporated soon after spreading, to as much as 50% if the manure is left on the soil surface.

Have the manure tested for nutrient content prior to farm delivery to ensure that the volume (of manure) and nutrient concentrations match your crops' needs. The nutrient content will not change significantly if the manure is kept covered by either a roof or a tarp. If a manure test is unavailable, the table values can be used but they may require adjustment of moisture content for the manure to be used.

Nutrient applications from all sources, including manure and commercial fertilizer, should be balanced to meet the crop requirements for nutrients. The release of nutrients from manure is not consistent. Therefore, in any year manure should only be used to supply up to 75% of the crop's nitrogen requirement. About 50% of the phosphorus in manure is readily available in the year it is applied. Where manure has been used repeatedly, phosphorus is assumed to be 100% available. All potassium from manure is available in the year of application.

The availability of the nitrogen in composted manure is typically lower than raw manure because the nitrogen is held in a more stable form by the organic matter of the compost. Composted manure may be expensive for large-scale field production. The benefits of using composted manure include reduced nitrogen loss through volatilization and its usefulness as a supplement or replacement for other organic matter in plant production.

Using Manure as a Soil Conditioner

Manure is primarily considered a fertilizer as their carbon to nitrogen ratio (C:N) is typically less than 30:1. However, manures with a C:N greater than 30:1 can be used as a soil conditioner if its nutrient content is known and no more is applied than the crop requires for nutrients. Using manure together with cover crops can improve soil structure. The decomposition of the manure in the presence of cover crop roots stimulates biological activity, and increases aeration, permeability and water-holding capacity of the soil. Do not apply manure to bare ground in the fall or winter (mid-September to March 1) or if the field will not be seeded within two weeks. Manure may be applied in February, or later, to fields that have a well-established and actively growing cover crop.

Applying Manure

Under the Code, manure can only be applied to land as a fertilizer or soil conditioner.

In South Coastal BC, apply manure to field crops between mid-March and early July. Be sure that the amount of manure applied is no more than what is needed to fertilize the crop. Manure can be applied to a cover crop between July and October if, based on a soil test, the application rate matches the crop's nutrient requirements.

In the Interior of BC, spread manure only when there is no risk of run-off. Manure should not be applied to frozen or snow-covered ground. Manure may be applied in the fall if the application rate is equivalent to the crop's nutrient requirements and there is a cover crop in place.

Determining the Amount of Manure to Spread on the Field

To spread manure as a fertilizer the following must be known:

- the nitrogen content of the manure,
- the amount of nitrogen supplied by the manure,
- the capacity of the manure spreader,
- the nitrogen needs of the crop, and
- the number of spreader loads of manure per area in the field.

Follow the steps below to calculate the amount of manure to spread.

Note: This is a simplified scenario that may be suitable if soil tests do not show excessive levels of phosphorous (P) and potassium (K). If soil P + K levels are excessive, a nutrient management plan is recommended to help better determine how much manure should be spread on a field.

Additional Precautions

Concerns have been raised over the potential contamination of watercourses with constituents of manure. Water in ditches is often used for irrigation and crop washing, so its quality is important. Nursery growers are encouraged to use best management practices to avoid direct discharge or run-off losses of manure into watercourses. This concern applies not only to the nutrient and solid fractions, but also to the potential pathogens that may exist in animal manure.

Non-Agricultural Wastes (Biosolids, Whey, Yard Waste, Pulp Sludge, Fish Waste, etc.)

Caution: Many wastes generated off-farm are being offered, or sold to farmers for use as a fertilizer or soil conditioner. The use of all agricultural wastes is covered by the *Environmental Management Act* in BC. Use of these materials may be allowed under Regulation or an authorization under the Act. Many of these materials can provide benefits to the soil or crop. However, they come with characteristics or contaminants that can be undesirable to growers.

Woodwaste

"Woodwaste (as defined under the *Code of Agricultural Practice for Waste Management*) includes hog fuel, mill ends, wood chips, bark and sawdust, but does not include demolition waste, construction waste, tree stumps, branches, logs or log ends." Under the Code, woodwaste can be used as a plant mulch, soil conditioner, ground cover, and on-farm access ways as long as the storage or use of the woodwaste does not cause pollution. This means that any leachate or particulate matter from the woodwaste must not enter ground or surface water. Woodwaste must not be used as landfill. It is generally accepted that the depth of woodwaste should be limited to 30 cm. This is the depth that it can be readily incorporated into the soil.

Nursery producers intending to use woodwaste as a soil amendment should have a plan to manage the carbon to nitrogen ratio of the soil after woodwaste application. Smaller particles breakdown more rapidly placing a higher demand on the soil for nitrogen. Large particles are harder to manage from a tillage standpoint.

Composting Nursery Green Wastes

In most cases nursery crop growers will not produce a large amount of compostable material if the operation is solely field-grown stock. Prunings and dead plant material is normally assimilated into the soil during cultivation for weed control or nutrient application. When larger quantities of green waste from prunings or diseased plants are accumulated, then composting may be the best on-site approach to manage these wastes.

Growers who operate container operations or have container stock are more likely to have green wastes from propagation, pruning, dead plants and old or unused media which must be managed. In some cases growers may have agreements with landscape companies to use yard and garden waste generated during landscape maintenance as a substrate for compost at the nursery.

In all cases the material produced is generally characterized as "Yard and Garden Waste" in composting reference material. It can have a wide range of carbon to nitrogen ratios and a wide range of particle sizes and moisture content. Yard waste consists of a variety of different materials, each of which has its own characteristics and requirements. When combining different materials such as leaves, grass clippings, prunings or growing media to make compost, the concept of carbon to nitrogen ratios is critical. The ideal proportion of these two elements is about 30 parts carbon to 1 part nitrogen by weight, although this ratio may need to be adjusted based on the bioavailability of carbon and nitrogen.

Calculating Manure Applications

Step 1. Determine the nitrogen content of the manure.

Refer to Table 2.8 for typical total nitrogen contents of various types of livestock manure. Use these values if a laboratory or quick test value is not available. Nitrogen comes in several forms in manure. The amount of nitrogen in manure also varies and is subject to many management and environmental conditions that can result in nitrogen losses.

Step 2. Calculate the approximate amount of nitrogen supplied by the manure (kg N/yd^3).

Losses of nitrogen upon application of manure can range from less than 20% if manure is incorporated within 24 hours, to over 50% by volatilization if the manure is left on the soil surface. Volatilization of nitrogen increases with increased wind speed, temperature, and ammonia and dry matter concentration of the manure.

$$\frac{\text{N supplied by manure (kg/m}^3\text{) (see Table 2.8) X initial application loss factor*}}{1.31\ \text{m}^3/\text{yd}^3}$$

*Initial application loss factor = 100% - % nitrogen lost

Step 3. Determine the capacity of the manure spreader (yd^3).

$$\frac{\text{Box length (ft) X width (ft) X average depth of manure in spreader (ft)}}{27\ \text{ft}^3/\text{yd}^3}$$

Step 4. Determine the nitrogen needs of the crop (kg/ha).

Refer to specific crop recommendations in the results of a soil test.

Step 5. Calculate the number of spreader loads of manure per area in the field (loads/ha).

$$\frac{\text{Crop N requirements (kg N/ha)} \div \text{spreader capacity (yd}^3\text{/load)}}{\text{N supplied by the manure (kg N/yd}^3\text{)}}$$

Example:

A spreader has a box that is 7.5 feet long and 4 feet wide. It is filled with solid poultry (broiler) manure to an average depth of 2.25 feet. The manure will be spread prior to planting a crop that, based on soil testing, requires about 80 kg/ha (32 kg/acre) of nitrogen. The manure is to be broadcast over the entire area using a conventional spreader. How many loads are needed to supply the crop's nitrogen requirements?

Step 1. Determine the nitrogen content of manure.

From Table 2.8, poultry manure contains 15.8 kg N/m^3

Step 2. Calculate the approximate amount of nitrogen supplied by the manure (kg N/yd^3).

$$= \frac{15.8\ \text{kg N/m}^3\ \text{(from Table 2.8) X } 0.80}{1.31\ \text{m}^3/\text{yd}^3} = 9.6\ \text{kg N/ yd}^3$$

Step 3. Determine the capacity of the manure spreader (yd^3).

$$= \frac{7.5\ \text{ft long X } 4\ \text{ft wide X } 2.25\ \text{ft deep}}{27\ \text{ft}^3/\text{yd}^3} = 2.5\ \text{yd}^3\text{/load}$$

Step 4. Determine the nitrogen needs of the crop (kg/ha).

80 kg N/ha (32 kg N/ac) (based on soil testing)

Step 5. Calculate the number of spreader loads of manure per area in the field (loads/ha).

$$= \frac{80\ \text{kg N/ha} \div 2.5\ \text{yd}^3\text{/load}}{9.6\ \text{kg N/yd}^3} = 3.3\ \text{loads/ha}\ (\div 2.47 = 1.3\ \text{loads/acre})$$

If carbon and nitrogen are too far out of balance, the microbial system will suffer. When there is little nitrogen, the microbial population will not grow to its optimum size, and composting will slow down. In contrast, too much nitrogen allows rapid microbial growth and accelerates decomposition, but this can create serious odour problems as oxygen is used up and anaerobic conditions occur. In addition, some excess nitrogen will be lost as ammonia gas that generates unpleasant odours while allowing valuable nitrogen to escape. Therefore, materials with a high nitrogen content, such as grass clippings, require more careful management, with adequate aeration or frequent turning as well as thorough blending with a high carbon waste.

Waste materials can be blended to improve the carbon to nitrogen balance and hasten decomposition. For example, leaves are typically in a ratio of 40-80 units of carbon to 1 unit of nitrogen. Adding one part grass clippings to three parts leaves will balance these nutrients and help composting proceed in the shortest possible time. See Table 2.10 for estimates of carbon to nitrogen ratios of various compostable materials.

It is very important to know the nutrient availability and salt content of compost, whether the compost is derived from animal manure or plant wastes. Nutrients will be released slowly from compost, but there is often a flush of readily available nutrients and salts from compost that has not been fully cured or slightly weathered prior to use. Checking salt content prior to use as media for seedling or transplant production is critical. Generally less than 50% of growing media by volume should be made up from compost and this may be even lower for composted manure.

When using compost in field stock production growers need to have a manure spreader that can be accurately calibrated and will provide a uniform spread of the compost. Composts can be used along with cover crops to rebuild soils depleted by long term production of balled stock. Composts have also been reported to provide disease suppression or control as well as to inoculate soils with beneficial organisms.

Table 2.10. Estimates of the carbon to nitrogen ratio (C:N) of various compostable materials.

Compostable Material	C:N
High Nitrogen Materials:	
Grass clippings	19:1
Food wastes	15:1
Cow manure	20:1
High Carbon Materials:	
Leaves and foliage	40-80:1
Bark	100-130:1
Wood and sawdust	300-700:1

Chapter 3 - Container Culture

This chapter covers a range of topics related to the propagation and culture of container nursery stock. Information on topics such as drainage, irrigation and compost are covered in more detail in Chapter 2, *Field Culture*.

Site Selection

The area used for container production should be on a slight slope, have no frost pockets and be well drained. A master plan to organize efficient movement of plant material through the propagation, potting up, growing on and shipping stages is important. Road access for vehicles through the container blocks should be at least 7.5 m wide. The irrigation/drainage systems should be installed before planting. Refer to Chapter 2, *Field Culture* for information on problem soils, drainage and erosion control.

Propagation

Many nurseries produce some of their own liners (rooted cuttings) and seedlings. Skill and experience are required to be a successful propagator. Beginners should start on a small scale and increase volume only after successful results have been achieved.

Structures

Propagation facilities range from inexpensive cold frames to elaborate gutter connected polyhouses. The structure should be able to maintain a temperature of at least 4°C in the winter and must have ventilation and 60% shade for the spring to fall period. Beds may be at ground level or raised. For some species the beds should be equipped with plastic tents and removable shade cloth to maintain high humidity with minimal misting. The beds should have a mist system that evenly covers the whole bed. Time clocks are commonly used to automate misting, although other devices are available. The mist interval may need to be adjusted daily to correspond to the temperature and amount of sunlight. Fog systems, although expensive, are used by some nurseries to root cuttings. Fog is used in conjunction with mist to raise the relative humidity and lower the air temperature for summer propagation.

Cuttings must be taken at the appropriate time of year and stuck immediately. Water management is another key to success. Humidity created by the mist or fog system prevents drying before roots are formed. However, too much water can promote rot and death of the cutting. Proper water management takes several years to perfect through trial and error. Keep records of successes and failures so that mistakes are not repeated.

Bottom heat must be supplied for winter propagation. The most common temperature setting is 22°C. For small propagation areas, electric cables can supply bottom heat. A more uniform but somewhat more expensive system is the use of hot water in tubes. Anticorrosive agents must be added to the water to prevent boiler corrosion. It is important to avoid overheating and drying out of the rooting media. This sometimes occurs as a result of faulty placement of heat cables and thermostats. Cover the heat cables with a layer of sand or similar material to provide even heat distribution. It is advised to moisten the sand before placing a crop of cuttings on the bed, since moist sand is better than dry sand at conducting heat and providing uniform heating.

Methods

Some ornamental conifers, rootstock, ground covers and herbaceous perennials are produced from seed. Because of natural genetic diversity, the seedlings will vary in size, shape and colour of foliage. Seeds may require pretreatment, commonly exposure to cool and moist conditions, to ensure a high percentage of germination.

Propagation by cuttings ensures uniform characteristics because each plant is a genetic clone. Plant cultivars should be propagated asexually (cuttings or grafting) to maintain the plant's unique traits. For best results, different plant types may need to be propagated at different times of the year. Deciduous shrubs and trees are often propagated by softwood cuttings taken in July. Broadleaf evergreens are propagated as semi-hardwood cuttings taken from August to October. Dormant conifers and some deciduous shrubs are propagated as hardwood cuttings taken from

December to February. Softwood and semi-hardwood cuttings are rooted in cool houses with bottom heat. Hardwood cuttings are held in cold storage until early spring and stuck in a prepared field.

Propagation by grafting is the process of joining parts of plants together so they will unite and continue their growth as one plant. The top portion of the graft is termed the scion, and the lower portion is termed the rootstock or understock. All methods of joining plants are properly termed grafting, but the operation is termed budding when the scion is a small piece of bark or wood that contains a single bud.

Grafting is used to perpetuate varieties that cannot be reproduced by other means. It is commonly used with fruit trees, shade trees, roses, specific cultivars of coniferous trees and to produce unique and distinctive cultivars such as weeping or pendent forms. Grafting is limited to plants that are closely related and is a highly technical operation.

An excellent source for propagation protocols is the *Combined Proceedings of the International Plant Propagators' Society*. Society members receive a copy of the Proceedings each year. The Proceedings are available online and at some university libraries.

Rooting Media

Seeds are sown in either flats (small seeds) or plug trays. Prepared seedling media are commercially available, or a grower can prepare an in-house mix from peat and vermiculite or peat and sawdust. Seed can also be sown directly into a prepared field bed. It may be beneficial to fumigate the soil before seeding. Dilute liquid fertilizer can be applied after germination. Incorporating controlled-release fertilizer in the media can create a high salt environment and stunt seedling growth, and should be used with caution in propagation media.

Cuttings can be rooted in a variety of media. Washed sand and combinations of peat moss and perlite are used. Premixed rooting media are also commercially available. Cuttings can be inserted straight into the bed (usually sand), or into flats or individual pots. Rooting hormone can be used to accelerate rooting. The strength of the hormone is matched to the woodiness of the stem.

After rooting, the cuttings will require supplemental nutrition. A dilute liquid fertilizer applied twice per week (for example 50 ppm N) will maintain cuttings until transplanting. Slow and controlled-release fertilizers can be incorporated into the mix at one-quarter application rate before sticking. This fertilizer will release continually because of the temperature of the rooting media. Extra misting to leach excess salts from the media may be required once per week.

Sanitation and Fumigation

Sanitation is the simplest and most economical means of controlling insect and disease problems. To prevent introduction and spread of pests, only use plants that are free of pests as propagation stock plants. Clean benches and flats, sterilized media, good quality water, and a preventive fungicide program are important components of propagation. All equipment including houses, benches, tools, flats, containers and soil should be disinfected or sterilized. Use one of the following:

Steam - Items to be steamed should be placed on a bench, or stacked and covered with a tarpaulin, beneath which steam is released to maintain a minimum temperature of 82^{o}C for 30 minutes.

Other Useful Disinfectants - For dipping tools, washing down benches, etc., the following are also effective disinfectants: quaternary ammonium compounds at 1 part in 80; 50% phenol-based lysol at 1 part in 10; and household bleach at 1 part in 10 parts of water.

See the section on *Sanitation* in Chapter 5, *Integrated Pest Management* for additional information on greenhouse sanitation.

Bed Preparation

Containerized plants are arranged by crop type in blocks. The width of the block is determined by the methods used for pest control, fertilizer application and pruning, and is commonly 3-6 m. Plants should be grouped within a block by irrigation demand and by cultivar. Each group should be clearly labeled. Woodwaste or gravel is often used to make nursery beds, since they promote rapid drainage away from the base of the container and provide a clean, weed-free surface. Sometimes beds are covered with ground cloth. An advantage of covering beds with ground cloth is plant debris can be removed with ease from the surface. The existing vegetation should be killed with a nonselective, systemic herbicide before the bed material is applied. Because of environmental considerations, the layer of woodwaste should not exceed 30 cm in depth and should be setback from water courses (ditches included).

Figure 3.1. A gravel nursery bed covered with ground cloth fabric.

Compliance with the *Code of Agricultural Practise for Waste Management (Waste Management Act)* and the *Soil Conservation Act* and *Regulations* is mandatory. Leachate from woodwaste at certain concentrations is toxic to fish.

The number of containers that can be produced in a given area depends on a number of factors, including the container size and spacing. As a general guide, approximately 56,000 #1 containers (30 cm spacing on-center), 13,000 #3 containers (60 cm spacing on-center), and 1,740 #25 containers can be produced per production acre.

Growing Media

Container production differs significantly from field production. First, containers have a very limited volume and, therefore, have a limited capacity to provide the quantity of water, nutrients and oxygen required for plant growth. Second, soilless media are not equal to soil. Relative to mineral soil, soilless media have:

- limited water retention and, depending on the medium used, 30% of the water in the container may not be available to the plant,
- high total porosity, initially somewhere between 65-90% by volume, and
- very low nutrient retention capacity based on volume. Some of the reasons for this are the high porosity of soilless media, their lack of mass to hold nutrients and their lack of fine, colloidal materials. Phosphorus is tightly bound in mineral soils. This is not the case in a standard container media. Research has shown that 76% of soluble super phosphate leaches from a soilless media in 3 weeks.

Growers of container stock must take steps to mitigate the inherent problems of container production systems. One key to success is to use a growing media that sustains healthy and vigorous root growth. The root system has a very important role in overall plant health and growth. Unfortunately, the needs of the root system are at times overlooked. Active root growth and the development of new root hairs is required to optimize plant growth because almost all water and mineral absorption occurs through root hairs, but root hairs only live a matter of days. The needs and health of the plant's root system must be taken into account when developing a container media.

There is tremendous variability in the types of media used in the industry, ranging from 100% bark or other woodwaste material to complex mixes comprised of several components. The cost of media components often plays a role in determining the type of media used. There is equal variability in the quantity and type of inorganic amendments added to the media. The bottom line is there are numerous media formulations that will promote good growth of a given nursery crop.

Whether a nursery prefers to prepare their own media or to have a custom blend prepared for them, growers should be aware that proper selection and management of the media is critical to the success of a crop. This section provides information on the acceptable properties of a media for container production.

Media Components

A wide range of commercial materials are available for use in growing media. Most media used today are soilless or contain only a small fraction of soil. Soil, if not pasteurized, will add weed seeds and pathogens to the media. Soil will also reduce the media's drainage and will significantly increase its bulk density. For these reasons, soilless media are recommended for container production.

A type of woodwaste is a common component of soilless media in British Columbia. The types of woodwaste used include hog fuel, bark mulch, sawdust and wood chips. Other components used include sand, perlite, pumice, vermiculite, several different products made from coconut husks, and various forms of compost. To lessen the quantity of organic wastes that are sent to landfill sites, there is increasing interest in the use of compost in container media. Products being trialed include pulp mill and sewage sludges.

Woodwaste is often the main constituent in soilless media for #1 or larger containers. It will account for 65-100% of the media by volume. In general, chopped bark produces a superior media to a sawdust-based media. Bark should be composted or aged for at least 6 months prior to use, to permit the leaching of excessive salts or organic material that may be toxic to plants. Composting will also reduce the carbon to nitrogen ratio of the material. This is important to reduce the nitrogen demand of the mix. Non-composted woodwaste will have a high nitrogen demand to support the growth of micro-organisms that breakdown the material. If bark is used, hemlock and Douglas fir are recommended. Western red cedar bark is not recommended.

Peat moss is still a common component of soilless media. For small containers, peat may comprise 50-100% of the media. For larger containers, usually not more than 25% peat by volume is used. It is best to use a good quality, fibrous sphagnum peat moss rather than a more decomposed, less fibrous type like hypnum. Fibrous, less decomposed peat provides superior drainage and is better able to support a healthy community of soil micro-organisms. The enhanced microbial growth places pathogens at a competitive disadvantage and gives the media some disease suppressive traits. The level of decomposition of peat moss is measured on a von Post scale (H1 – H10). Peat moss >H4 is finer in texture and more decomposed, and thus has a lower air porosity.

Sand (less than 10% by volume) can be added to the mix to increase weight and water-holding capacity. The addition of sand does not improve drainage. If more than 10% by volume is used, sand will actually reduce water flow through the media.

Perlite and Pumice (up to 30% by volume) are used most frequently in small pots (9-15 cm) to improve drainage and increase air porosity. Pumice is also used to increase bulk density. Perlite and pumice are produced by the rapid cooling of molten rock. Water trapped in the rock turns into vapor which causes the rock to expand, thereby producing many small holes/pores in the material.

Composts are being used increasingly in nursery media as a peat replacement. Research has shown that mixes containing 25-50% compost result in excellent plant growth. Wide acceptance of compost is being curtailed in part due to product inconsistency. The salt level of compost should be tested prior to use and it should be leached if necessary to remove excess salts. If not removed, the excess salts will burn young roots and potentially kill the crop.

Air and Water Porosity

Growing media consist of solid particles as well as pore spaces between and within these particles. These pore spaces are categorized into either large pores that are normally filled with air, or small pores that can be either filled with air or water. It is important to use a media that has a mixture of large and small pores that provides adequate aeration without unduly compromising water-holding capacity. This can be achieved by testing and adjusting the media to achieve the recommended levels of porosity.

Three attributes that are used to define media quality are the total porosity, aeration porosity, and the water-holding capacity. **Total Porosity** is a measure of the total open space in a media that could be filled with either water or air. The total porosity should be equal to or greater than 50%. **Aeration Porosity** is the amount of air space in the media after the free irrigation water has drained out. The optimum aeration porosity for woody plants is 20-30%. **Water-Holding Capacity** is the amount of available water held by the media after watering and drainage. It is directly related to media porosity and the optimum level is 20-25%.

Aeration porosity and water-holding capacity are inversely related. If the aeration porosity is too high, then the water-holding capacity will be low and the media will need to be watered frequently. Likewise, if the water-holding capacity is high, then the media will generally be poorly aerated and the plants will be more susceptible to root death. Thus, a balance needs to be achieved between aeration porosity and water-holding capacity of the media. The climate where the plant is grown and the type of plant (e.g. azaleas require oxygen concentration of at least 20% in the media) are two factors to be considered when deciding upon the most appropriate values for a media.

Increase the aeration porosity of a media by:

- using coarser media components and deeper containers,
- avoiding the use of fine-textured components since they fill the large pore spaces, and
- using components that are stable and that will not readily decompose.

Improper media handling and irrigation practices can reduce the porosity of a soilless media. The porosity of a media will be reduced by over-mixing, which will effectively reduce the particle size of media components. Porosity will also be reduced if the media is compacted by over-packing at filling or if the crop is irrigated with excessive water pressure.

The pattern of root growth in a container can indicate problems related to media porosity and watering practices. A lack of root growth at the bottom of the container is an indicator of poor drainage or over irrigation. In contrast, greater root growth in the bottom as opposed to the top of the container is an indicator of high media porosity or insufficient irrigation.

Calculating Media Porosity and Water-holding Capacity

1. Cover or plug the drain holes in a container. This can be done by lining the pot with a plastic bag of similar size or by putting tape over the drain holes.
2. Fill the container with water to the level it would normally be filled with potting media. Measure and record this volume of water as **A**.
3. Empty the container and fill it to the same level with dry media. Slowly add a pre-measured volume of water until the media is completely saturated. A very thin slick of water will appear on the surface of the media when saturation is reached. This process may take 1-2 hours. Record the volume of water added to the container as **B**.
4. Hold the container over a bucket or catch-basin and carefully open the drain holes. Allow the water to drain freely. It is important to keep the pot level at all times. Allow sufficient time for water to drain completely. Measure and record the volume of water drained as **C**.
5. Use the volumes **A, B** and **C** in the following formulas to evaluate the media's:
   - % **Total Porosity** = **B** / **A** x 100
   - % **Aeration Porosity** = **C** / **A** x 100
   - **Water-Holding Capacity** = Total Porosity - Aeration Porosity

Example:
Pot volume (A) = 6,000 mL

Water added to the media (B) = 3,000 mL

Water drained (C) = 1,250 mL

Total Porosity = 3,000 mL / 6,000 mL x 100 = 50%

Aeration Porosity = 1,250 mL/ 6,000 mL x 100 = 20.8%

Water-holding Capacity = 50% - 20.8% = 29.2%

Perched Water Table

Placing a growing media in a container leads to a "perched" water table or saturation of the media at the bottom of the container. The depth of the saturated zone cannot be reduced by increasing the number or size of drain holes in the container; it is determined by the porosity of the media. A perched water table is usually not a problem in the field, since the water table is relatively deep in comparison to the situation in a container.

One way to reduce the effects of a perched water table is to increase the depth of the container. The percentage of water-saturated media at the bottom of the container is inversely related to container depth. Increasing the depth of the container will increase drainage and media aeration (see Table 3.1).

In many cases it is not practical to use deeper containers. Deeper containers should be considered in cases where saturated media is a problem, such as in propagation. This may make particular sense with difficult-to-root species where excess water is not immediately taken up by roots. The increase in aeration and the concurrent reduction in water, particularly at the surface of the media, can also help to reduce the presence of moisture dependent pests like algae, liverworts, moss and shore flies.

Table 3.1. The effect of container size on media aeration.

	6" Pot	4" Pot	Plug Tray
Aeration Porosity	22%	15%	3%
Water-holding Capacity	49%	56%	68%
Solid Material	29%	29%	29%

Media Temperature

High media temperature can be a serious problem in container stock. The traditional black nursery

container is very effective at absorbing heat from the sun, which leads to the southwest side of the container exceeding 55 °C on a hot day. Since roots start to die at 36°C, this explains why roots on the side of a container exposed to the sun are blackened and dead. Root damage caused by high media temperature can result in a 40-60% reduction in plant growth. Research has shown that the damage can be significantly reduced by using lighter pot colors that reflect (white or silver) versus absorb (black and green) solar radiation. An alternative approach being used by some nurseries is the application of white polyethylene sleeves to containers to reduce solar heating of the media.

Media Stability

The stability of a planting media needs to be considered. It is undesirable to use a media that decomposes quickly, since this will result in a dramatic reduction in media porosity. The need for stable media components is especially important for larger containers, which require more than a growing season for the plant to reach a marketable size. In general, the use of sawdust is not recommended because it breaks down rapidly, and ties up nutrients during decomposition. Peat, composted bark and coconut products tend to be quite stable organic amendments. Inorganic components such as perlite, pumice and vermiculite have the advantage of not being subject to decomposition, although vermiculite can lose much of its porosity through compaction.

Media pH and Electrical Conductivity

Nutritional problems are a primary cause of economic losses associated with poor crop quality and growth. Two media properties that are indicators of nutritional problems are the pH and total soluble salts. Both are relatively easy to measure on container-grown crops. With routine testing of media salts and pH, and occasional complete laboratory analyses, it is possible to eliminate most nutritional problems.

pH

As mentioned previously, soilless growing media are not equal to soil. This is a very important concept to remember when selecting a media pH for container crops. As a general rule, it is recommended that the pH of a container media be one pH unit lower than the crop's optimum pH level when grown in soil. The alkalinity of the irrigation water should also be considered when choosing a media pH. Irrigation water that has a high alkalinity will supply adequate (greater than 5-10 ppm) calcium and magnesium for crop growth and will make liming unnecessary. If the pH of the media is incorrect, it can be raised with the addition of limestone or dolomite, or lowered with the addition of sulphur or iron sulphate (see Table 3.2).

Table 3.2. The quantity of dolomitic limestone[a] or sulphur needed per cubic yard of a peat media to affect the desired pH change.

	Desired Media pH	
Original Media pH	**4.5-5.2[b]**	**5.3-6.2[c]**
3.4-3.9	3.6 kg of limestone	6.3 kg of limestone
4.0-4.4	1.8 kg of limestone	4.5 kg of limestone
4.5-5.2	none	2.25 kg of limestone
5.3-6.2	0.9 kg of sulphur	none
6.3-7.0	1.8 kg of sulphur	0.9 kg of sulphur

[a] A mixture of equal parts of dolomitic and calcic limestone is preferred to using only dolomitic limestone.

[b] Desirable pH for *Euonymus, Pieris, Rhododendron*, many conifers including *Taxus*, and tropical plants.

[c] Desirable pH for bedding plants, *Juniperus, Thuja* and a wide range of other woody nursery plants and most herbaceous perennials.

Media pH should not exceed 7.0. Although *Juniperus* and *Thuja* will grow adequately at a high pH, plants such as *Euonymus, Rhododendron* and *Taxus* will exhibit iron or manganese chlorosis if the pH is above 7.0. With pH-sensitive crops, do not use alkaline sand in the mix.

pH Testing: An electronic pH meter provides the most accurate and practical means of on-site testing. Follow the instructions provided with the meter and be careful to rinse the electrode after use and store the instrument properly. Buffered calibrating solutions are usually supplied with pH meters. The meter should be calibrated before each use.

The level of fertilizer salts in the media will influence the pH. When salt levels are high, hydrogen ions will be displaced from binding sites on the media components. The increase in the concentration of hydrogen ions in the media will lower its pH.

Total Soluble Salts

Fertilizers and other dissolved salts change the ability of a solution to conduct electricity. Pure water is not a particularly good conductor, but as the salinity level increases so does its conductivity. Salt meters (conductivity meters) are used to measure the electrical conductivity of solutions. Since conductivity is directly related to the total level of soluble salts, it thereby provides a rough indication of the fertilizer content in a solution. One factor that must be kept in mind is that not all salts are fertilizers. Some water sources are high in non-fertilizer minerals that tend to increase the overall conductivity. Therefore, while conductivity measurements are a good indicator of relative fertility levels, particularly if measured regularly and tracked over time, it is important to establish the background mineral content of irrigation sources and to have an occasional complete mineral analysis performed to determine the balance of nutrients in the media. Another point to remember is that different fertilizers have different salt indexes.

The rate of nutrient release from some fertilizers is directly related to temperature. This can lead to the accumulation of damaging levels of salts at high media temperatures, which may need to be leached out with additional irrigation. Regular monitoring of soluble salt levels is a simple way to keep track of nutrient release. In addition, media conductivity testing can identify when the fertilizer is exhausted. As the fertilizer becomes exhausted, the salinity of the media will approach that of the irrigation water, indicating the need for fertilization.

Conductivity Testing Methods: An electronic conductivity meter provides the most accurate and practical means of on-site testing. Follow the instructions provided with the meter and be careful to rinse the electrode surface after use and store the instrument properly. Standard salt solutions are available to calibrate conductivity meters. The meter should be calibrated before each use. The moisture content of the media will influence the conductivity measure, since the salinity increases as the media dries. Therefore, the moisture content of the media should be consistent between different sampling periods to enable accurate comparison of test results.

Record Keeping

Growing media should be tested for salts and pH on a routine basis. Testing should begin before the crop is planted and be performed at least every two weeks. It is important to keep records to chart the change in pH and conductivity levels over time. Graphically charting these values will provide a trend of timely information on whether they are rising, falling or staying steady. This is at least as important as the actual reading. It will enable informed decisions to be made about fertilizer concentrations, watering frequencies and leaching rates. Growers that use routine media testing often find they can produce superior crops with less fertilizer and lower leaching rates, thereby reducing waste and the possibility of environmental contamination.

Collecting a Media Sample

There are two strategies available for media sampling. First, several samples can be collected and measured individually. This would provide a good indication of the uniformity of the watering and fertilizing program. If the results are dramatically different between pots or locations, this might provide a clue to uneven growth or other crop problems. However, collecting and measuring individually 10 or more separate samples can be very time consuming, and may not provide information that is any more useful than an average sample. In any case, it is not practical to water and fertilize each plant individually. For these reasons the second or representative sample method is usually the one to use.

Several sub-samples should be combined to obtain a representative sample. Depending on the size of the crop, samples from about 10 or more pots or growing bed locations are required. Combined samples should always be from within one distinct growing unit, environment or irrigation zone. The samples should be obtained from uniform plants that are the same type, age and in the same size container. Try to collect samples at the same time between irrigations (i.e. just before the next watering). Avoid sampling the top 2 cm of media since there is often an accumulation of salts in this zone. Collect samples from the mid-range of the pot, making sure to include more than just the soil at the outside edge of the container. Often 10% of the media can be removed without harming the plant. Fresh, moistened growing media can be used to replace the soil removed for the sample. Follow the same procedure for growing beds, but avoid the top 2 cm and collect the sample from the area of most active root growth. It is very important to be

consistent in sampling methods, so the results will be accurate when tabulated over time. When all the sub-samples have been collected, place them in a clean container or bag and mix thoroughly, taking care not to crush controlled-release fertilizer prills in the sample. The sample can then be sent in for professional analysis, or measured on-site.

Extraction Methods

Over the years, several dilution and extraction methods have been devised. The methods commonly used are the 1:2 extraction, the saturated media extraction and the pour-through method. All have advantages and disadvantages, and all may provide different instrument readings. This often leads to confusion when trying to discuss or compare values obtained from different extraction methods.

For peat-based media, a sample can also be collected by gently squeezing the media. Since water was not added to the media to collect the sample, the conductivity level measured will be higher than for the other methods. Care must be taken to not crush fertilizer prills in the media when collecting a sample, since this will inflate the salt reading.

Table 3.3. Interpretation of soluble salt readings for the saturated paste extraction method.

EC Reading (mmoho/cm) for a "Saturated Paste" Extract	Interpretation
0-0.6	Insufficient fertility.
0.6-2.0	Satisfactory for most nursery crops. The lower range should be used for seedlings.
2.0-3.5	Optimum nutrition.
3.5-4.5	Reduction in growth may occur due to the high level of salts.
4.5+	Very high, injurious salt levels.

Table 3.4. Interpretation of soluble salt readings for the pour through extraction method.

EC Reading (mmoho/cm) for a "Pour Through" Extract[a]	Interpretation
<0.015	Too low, plants are usually starved.
0.015-0.5	Fertilizer addition is required.
0.5-2.5	Satisfactory range for most plants.
2.5-3.5	May slow growth. If conditions are very warm, leaching may be necessary.
>3.5	Leaching of media is necessary. After drainage is complete, application of the liquid feed is required to replenish the growing media.

[a] The procedure to collect an extract: (1) Do not perform the test until 2 hours after an irrigation when the excess water has finished draining from the container and the solution has equilibrated with the media components. (2) Pour 100-200 mL of water through the one gallon pot and collect the drained portion.

Nutrition

To maximize the growth and quality of nursery stock, fertilization is extremely important. All plant health is dependent on proper nutrition. An understanding of fertility management is critical if problems are to be avoided.

This includes knowledge of the essential elements required (see Table 3.6) and the relative nutrient levels needed for optimum plant growth (Table 3.5). A tissue analysis can be used to determine the levels of elements actually present in a plant and, thereby, verify fertilizer imbalances. For more information, see *Plant Tissue Testing* in Chapter 2.

Table 3.5. Suggested nutrient levels for most container crops.

Nutrient Concentration		What to Do
Nitrogen (as water-soluble nitrate N)		
Low	0 - 39 ppm	Add extra nitrogen to the feeding program, especially if using slow-release materials.
Normal	100 – 199 ppm	Continue feeding at high levels and check total salts.
Excess	250+ ppm with high salts	Discontinue feeding nitrogen and check total salts as root damage may occur. Higher rates may be needed for optimum growth in a bark mix and to maintain the same soil test level as in a peat mix.
Phosphorus (as water-soluble P)		
Low	0 – 2 ppm	Add additional phosphorus to the feeding program.
Normal	6 – 9 ppm	Continue feeding at high levels and check total salts.
Excess	50+ ppm	Discontinue feeding phosphorus.
Potassium (as water-soluble K)		
Low	0 – 59 ppm	Add additional potassium to the feeding program.
Normal	150 – 250 ppm	Continue feeding at high levels and check total salts.
Excess	350+ ppm	Discontinue feeding and leach. Plants may tolerate higher levels if the mix contains a high proportion of organic material. (Leaching is ineffective for removing incorporated controlled-release fertilizer.)
Total Salts in mS/cm (mhos x 10^{-3})		
Low	0 – 0.75 ppm	Check for adequate nitrogen and potassium levels.
Normal	2.0 – 3.5 ppm	Continue the feeding program.
Excess	3.5+ ppm	Discontinue feeding. Plants may tolerate higher levels if the mix contains a high proportion of organic material.
Calcium (as water-soluble Ca)		
Low	0 – 79 ppm	Add extra soluble calcium to the feeding program. (Calcium levels are easily raised by adding dolomitic lime or gypsum to the media.)
Normal	200 – 300 ppm	
Excess	400+ ppm	
Magnesium (as water-soluble Mg)		
Low	0 – 29 ppm	Add 0.5 kg/1,000 litres of magnesium sulfate through the irrigation water.
Normal	70 – 200 ppm	
Excess	200+ ppm	

Source: *Nursery & Landscape Plant Production*, 2000. Ontario Ministry of Agriculture, Food and Rural Affairs, Publ. #383.

Table 3.6. Essential elements required for plant growth.

Primary Nutrients	nitrogen, phosphorus, and potassium
Secondary Nutrients	calcium, magnesium, and sulphur
Micronutrients	iron, manganese, boron, copper, zinc, molybdenum, and chlorine. Chlorine is required in minute quantities and is usually available in quantities in excess of plant needs in water and in various fertilizer compounds.
From Air and Water	oxygen, carbon, and hydrogen are not normally considered plant nutrients.

Table 3.7. Nutrient antagonisms that can occur when nutrient levels are high.

Excess Level of:	May Cause Deficiency of:
phosphorus	iron, zinc, copper
potassium	nitrogen, calcium, magnesium
calcium	magnesium, boron
magnesium	calcium, potassium
iron	manganese
manganese	iron, molybdenum
copper	manganese, iron, zinc
nitrogen (especially ammonium-N)	potassium
zinc	manganese, iron
molybdenum	copper

The relative concentration of different nutrients, or nutrient ratios, can be as important to measure as the actual nutrient levels in the media. This is because some nutrients will block or increase the uptake of other nutrients (see Table 3.7). For instance, the ratio of calcium to magnesium should be maintained at 1:0.4 for optimal uptake of both nutrients. In addition, the ratio of some nutrients will influence plant growth. A nitrogen to potassium ratio of 1:1 will generally produce normal growth and height development, whereas a ratio of 5:8 will often produce plants that are darker green and shorter. It is also important to be aware that nutrient demand will differ depending on whether the plant is in a vegetative or reproductive stage of growth. Vegetative plants will require more calcium and nitrogen, while a flowering plant will require more phosphorus and potassium.

Most media components contain little to no available fertilizer, with the exception of some composts. Thus, most soilless media will require some form of chemical supplement to adjust the pH and to augment the available nutrients. In the early years of container production, short-term, water-soluble fertilizers were incorporated into the media, or they were applied as a topdress or in the irrigation water. These fertilizers were low cost but they needed to be reapplied frequently during the growing season. Today, supplemental nutrients are commonly applied by the incorporation of slow or controlled-release fertilizers into the media.

Slow and Controlled-Release Fertilizers

For environmental and efficiency purposes, the incorporation of slow and controlled-release fertilizers in the media is the predominant choice for container stock. Fertigation or the application of water-soluble fertilizers in the irrigation water is infrequently used by the nursery industry. It is used primarily to correct nutritional disorders or for greenhouse crops. The shortcomings of water-soluble fertilizers are:

- they have a short duration and, therefore, must be re-applied frequently during the season,
- they have a high potential for groundwater contamination due to leaching of nitrates and phosphates from the containers,
- they can cause plant damage due to fertilizer salt residues left on the leaves after fertigation,
- they can result in uneven plant growth due to cycles in the amount of fertilizers available in the media, and
- they have low nutrient efficiency.

While the terms "controlled-release" and "slow-release" fertilizer are often used interchangeably, the compounds they describe are quite different.

Slow-release fertilizers can be divided into two groups: 1) naturally occurring organic materials, such as manure, urea, dried blood, and hoof and horn mixtures, and 2) synthetic, low-solubility organic compounds like isobutylidene-diurea (IBDU).

Controlled-release fertilizers are coated with materials like polyethylene, acrylic resins, latex, waxes and sulphur. These materials keep the fertilizer from being immediately soluble and available to plants. An advantage of plastic-coated fertilizers is the rate of fertilizer release is primarily determined by temperature. Since temperature also influences the rate of biochemical reactions involved in plant growth, the release of fertilizers from plastic coated products more closely approximate plant demand.

Figure 3.2. Top-dressed prills of a controlled release fertilizer on a grafted maple.

The period of nutrient release will be stated on the product label. The release period is typically determined under laboratory conditions, not actual plant production. Thus, it is crucial to understand the plant production conditions that affect nutrient release characteristics of different slow and controlled-release fertilizer formulations (see Table 3.8).

Talk to your fertilizer supplier about the range of fertilizer blends that are available for use in container nursery stock.

Micronutrients

A micronutrient source is also incorporated into the growing medium. Micronutrients may be added as either fritted, sulphate-based or controlled-release formulations. Chelated micronutrient formulations are not recommended for incorporation into a media. It is common for growers to use a premix that contains the lime, micronutrients and gypsum, rather than to add each component individually. It is also possible to get custom premixes that include a soluble nitrogen source, humic acid and other nutritional additives. Contact your fertilizer supplier for recommended rates.

Tissue Analysis: A tissue analysis can be used to determine the levels of elements actually present in a plant and verify fertilizer imbalances. It can be an excellent diagnostic tool. For more information, see *Plant Tissue Testing* in Chapter 2.

Table 3.8. Factors that affect the rate of nutrient release from slow and controlled-release fertilizers.

Fertilizer Type[a]	Main Factors Causing Nutrient Release	Comments
Organic Slow-release Fertilizers		
Animal by-products (e.g. hoof and horn mixtures, dried blood, urea, manure)	Microbial activity (fungal and bacterial)	Small particle size. Moderately high temperatures and water content speeds breakdown and could give rise to conditions of ammonia toxicity.
Urea formaldehyde (e.g. Urea Form, Nitroform)	Bacterial activity	Release is unpredictable, can be increased by high temperatures and low pH.
Low Solubility, Slow-release Fertilizers		
Magnesium ammonium phosphate (e.g. MagAmp)	Particle size and moisture	Low pH and high moisture content increase the rate of release.
Isobutylidene-diurea (IBDU)	Particle size, hardness and moisture	Low pH and high moisture content increase the rate of release.
Controlled-release Fertilizers		
Sulphur-coated urea (SCU)	Coating thickness, temperature and moisture	Imperfections in coating may cause a high and sudden release. Micro-organisms may breakdown the coating.
Resin and polymer-coated materials	Coating thickness and temperature	Research indicates that release rates from fertilizer held at 38°C could be up to 60% higher than those from fertilizer held at 27°C.

[a] Some fertilizers may contain a combination of different controlled-release products. Always read the label or associated technical literature before using a product.

Table 3.9. Desirable ranges for specific elements in irrigation water.

Characteristic	Quantity
Set 1 (the minimum list of analyses that should be done regularly)**:**	
pH	5-7
Soluble salts	0-1.5 mmhos/cm
Phosphorus (P)	0.005-5 mg/L
Calcium (Ca)	40-120 mg/L
Sulphate (SO_4)	24-240 mg/L
Alkalinity	0-100 mg/L as $CaCO_3$
Sodium (Na)	0-50 mg/L
Boron (B)	0.2-0.8 mg/L
Fluoride (F)	0-1.0 mg/L
Magnesium (Mg)	6-24 mg/L
Chloride (Cl)	0-140 mg/L
Set 2 (the desirable analyses, but not absolutely necessary)**:**	
Nitrate (NO_3)	0-5 mg/L
Potassium (K)	0.5-10 mg/L
Zinc (Zn)	1-5 mg/L
Molybdenum (Mo)	0-0.02 mg/L
Iron (Fe)	2-5 mg/L
Copper (Cu)	0-0.2 mg/L
Aluminum (Al)	0-5 mg/L
Sodium Absorption Ratio (SAR)[a]	0-4

[a] SAR quantifies the sodium level in relation to the calcium and magnesium levels.
From: *Water Quality Reference Guide for Horticulture*, Aquatrols Corporation of America

Irrigation

Water Quality

Irrigation water quality is an important consideration for a nursery. The water should have a neutral to slightly acid pH and contain low levels of soluble salts (refer to Table 3.9).

The water source should be analyzed before use to determine the level of salinity and the initial pH. It is important to allow tap water to sit for about 60 minutes when measuring pH. This allows any carbon dioxide gas dissolved in the water to come to equilibrium with the air. Dissolved carbon dioxide will tend to lower pH readings. If the water shows any substantial salt content (0.5 mS or above), an irrigation water quality analysis should be performed by a testing laboratory to determine the background mineral content. The report should include the elemental content, including the level of bicarbonates.

The electrical conductivity of the source water should be taken into account when measuring fertilizer content with a salt meter. For instance, if your water has an initial conductivity of 0.8 mS, then you will need to subtract this amount from your fertilizer solution readings to determine the actual fertilizer content of your nutrient solutions. This is important whenever you are checking the accuracy of injectors. Most commercial soluble fertilizers will indicate the conductivity value on the bag for various feeding concentrations. In order to check the calibration of an injector, the background conductivity level must be subtracted from the measured fertilizer conductivity value after injection.

If the pH of the irrigation water is high, it can be acidified with nitric or phosphoric acid, depending on the bicarbonate content of the water. The level of bicarbonate and hydroxyl ions in the water is known as the alkalinity. Alkalinity is a better indicator of the impact the water will have on media pH than the pH measure of the water.

Table 3.10. Suggested liquid feed application rates.

Nutrient	Daily (ppm)	Weekly (ppm)
Nitrogen	28-100	56-300
Phosphorus	1-24	31-250
Potassium	20-126	50-320
Calcium[a]	40-150	75-320
Magnesium	10-50	48-173
Sulphur	20-150	50-280

[a] Calcium should be kept in a separate stock solution to avoid precipitation with sulphates or phosphates.
Note: Applications made between growth flushes have the greatest effect in uptake of nitrogen and subsequent growth of the flush. Intermittent or interrupted applications are more efficient, as a plant will take up more nutrients when slightly "starved" than when constantly fed.

Suggestions:

1. 15-15-18 Soilless Feed
2. 20-20-20 All Purpose Fertilizer + $MgSO_4$ @ 5 mg of magnesium/L
3. 15-15-15 Geranium Special + $MgSO_4$ @ 5 mg of magnesium/L

Trace elements may or may not be included in the formulation. Start with a general fertilizer and fine tune as you gain experience.

Bicarbonates tend to buffer the media and can increase media pH over time. Bicarbonate levels greater than 50 mg/L need to be corrected by acidification or another treatment. Some problems associated with allowing the pH to climb include a greater risk of *Phytophthora* infection and deficiencies of iron, manganese, zinc and boron.

Fertigation: Liquid fertilizer can be applied through the irrigation system during the growing season to either supplement the slow or controlled-release fertilizer or correct a nutrient deficiency. Liquid feed is most efficiently applied on small pots that are tightly spaced. Drainage water must be monitored for nitrates when liquid feed is used. See Table 3.10 for a suggested liquid feed program.

Do not feed after August 15 on the Coast and July 15 in the Interior. The plant must stop growth to enter dormancy before the first frost. A very dilute fertilizer solution could be applied if the plant exhibits signs of nutrient deficiency.

Water Quantity

Overhead sprinkler irrigation is the standard system used for container-grown stock. Overlap of the sprinklers must be complete to ensure all containers receive equal amounts of water. A typical irrigation cycle would apply 1-2 cm of water. Containerized plants use water much more quickly than field-grown plants. The higher porosity and temperature of soilless media contribute to faster water loss.

Plants should be grouped into irrigation zones that have similar water demands. Insert as many shut off valves into a system as possible so that specific areas can be watered more or less often depending on the plants' requirements. A timeclock will assist in timing irrigation cycles. The volume of irrigation applied will depend on the flow rate, pressure and irrigation cycle duration. Early morning irrigation is desirable for plants that are prone to foliar diseases. Drip irrigation is suggested for plants in #5 or larger containers.

Run-off water from irrigation can be contaminated with fertilizer, woodwaste leachates and pesticides. This run-off can cause possible contamination in both surface and ground-water. It is critical that run-off is minimized by the efficient use of irrigation systems. See the *Environmental Guidelines for the Nursery and Turf Industry in British Columbia* and the irrigation discussion in Chapter 2, *Field Culture* for additional details.

General Crop Maintenance

Maintenance schedules are as varied as the plant material produced. In general, pruning, pot spacing, and pesticide and fertilizer applications are normal activities during the growing season.

To produce compact, well-shaped, high quality plants in containers, pruning is necessary after

each flush of growth (one to three times per season). Sharp hedging shears are used to lightly shape the plant. Do not cut back into woody stems unless a drastic change in shape is required. Newly extended growth of rhododendrons can be pinched. Larger deciduous shrubs may require pruning to remove unwanted branches or suckers.

Plant debris should be removed from the growing area to control pest problems. This is a mandatory best management practice for container-grown high risk host plants (e.g. *Camellia, Rhododendron,* and *Viburnum*) in the Canadian *P. ramorum* Nursery Certification Program. Infected leaves are a source of inoculum that must be cleared from beds on a regular schedule to minimize the risk of *P. ramorum* infection.

Plants must be monitored for disease and insect pests throughout the season. Regular inspection and spot spraying will decrease the amount of pesticide required. Consult Chapter 5, *Integrated Pest Management* for more detailed information on crop monitoring and nursery sanitation.

Controlled release fertilizer can be applied as a topdress in mid-season to ensure continued growth to the end of the season. Plants carried over the winter to be grown on in the same pot should be top-dressed early in the spring, just before growth commences. Talk to your fertilizer supplier for detailed recommendations.

During the second year of growth many fast-growing shrubs must be spaced to ensure quality. Prearranged spacings that are equal in all directions from the pot will result in even growth and orderly blocks.

Overwintering

The main emphasis when overwintering container stock is to protect the crop's root system, since it is more susceptible to low temperature injury than above ground parts of the plant. The winter protection system also protects against desiccation injury. Several systems of protection are used including to cover or consolidate stock, or to move stock into an overwintering polyhouse. A factsheet on *Reducing Low Temperature Winter Injury to Containerized Nursery Stock* is available from the BC Ministry of Agriculture.

Stock consolidation involves placing containers pot-to-pot tight. This creates a large mass of heat from the containers and the soil beneath them, which will protect the inner plants from the cold. However, the plants on the perimeter have no protection and will be the first to be damaged with cold weather. Perimeter plastic wraps can be applied around the consolidated stock to provide additional protection. The plastic does not provide any insulation, but it does help to trap warmer air within the stock and thereby provides additional winter protection. The main benefit of the wrap is to be a windbreak. Since the plastic has no insulation value, the pots on the perimeter likely get minimal protection from this approach. Some growers instead have used insulated microfoam wraps.

For sensitive crops, additional protection can be provided by placing peat bales, sawdust, or 1-2 rows of pots filled with growing media around the perimeter of the stock. The stock can also be mulched with a loose material, such as sawdust.

Covers can be pulled over entire beds of consolidated containers in advance of cold weather. The covers trap ground heat and block airflow out of the crop, and provide a greenhouse effect. It is important to use polyethylene that allows some light penetration to increase the temperature under the cover. However, do not use clear polyethylene because it will lead to a sharp temperature rise under the cover on clear days and will dry out the stock more quickly. Thermal microfoam blankets can also be used as a cover.

Disease spread can be a problem underneath covers and can lead to crop failure. A preventive fungicide should be applied prior to covering the stock to reduce disease development. Also, structureless covers can lead to physical crop damage if snow accumulates on them. Mice are always a problem in covered stock.

Holding stock in an unheated polyhouse provides the greatest level of protection and is commonly used for broadleaf evergreens and all marginally hardy plants. The sensitivity of a crop's root system to cold temperatures, the potential for disease problems and susceptibility to desiccation injury are factors to consider when determining which plant types to protect.

Polyhouses covered with a double layer of plastic are the best overwintering structures. Clear or white plastic can be used. White plastic reduces heat buildup in the house on sunny winter days. It is recommended to use 6 mL, 3-year plastic to reduce tearing in high winds, at least for the outside layer. Ventilation is required during sunny

or bright weather, to prevent heat buildup and to reduce the humidity and the occurrence of *Botrytis*.

Due to the higher temperatures that occur in a polyhouse or under a cover, fertilizer salts may accumulate in the media. If salts are allowed to accumulate in the media, they will draw water away from or out of fine roots. Dried roots cannot absorb nutrients or be a passage way for water to the foliage. As a result, the foliage dries or 'burns' and the plants stop growing. Excessive root damage can result in plant death. Also, injured roots provide an easy route into the plant for root rot organisms. Therefore, the level of soluble salts in the media should be tested periodically (see the section on *Conductivity Testing Methods* in this chapter). If the soluble salt levels get too high, the stock should be irrigated to remove the excess salts. Alternatively, the stock can be watered about once per month to prevent excess salts from accumulating in the container.

Environmental Considerations

The production of nursery crops can have a negative impact on the environment. The *Environmental Guidelines for the Nursery & Turf Industry in British Columbia* provides growers with options for managing a nursery in an environmentally sound manner, without contravening federal or provincial environmental laws or regulations. Some steps growers can take to protect the environment include:

- When used for a container bed, woodwaste should be less than 30 cm deep and should be placed back from any waterway including a drainage ditch. The use of woodwaste products, such as sawdust, chips or hog fuel is controlled under the *Waste Management Act* because leachates from these materials can be toxic to fish.
- To minimize the quantity of fertilizer leached from a container, fertilizer should be applied as a topdress just before a major growth flush. Application after August 15 is not recommended in the Lower Mainland region, because a late-season fertilizer application can trigger a late flush of growth, which is susceptible to frost damage. Application after July 15 is not recommended for the Interior.
- Irrigate only in the early morning to reduce the incidence of foliar diseases and the need to apply fungicides.
- Test and adjust the uniformity of the irrigation system. An overhead sprinkler system, which is the standard system used for container-grown nursery stock, has an efficiency of 75% at best. The efficiency will depend on many factors, including crop type and spacing, wind speed, water pressure and system design (e.g. nozzle size and height). System efficiency should be measured and the system modified to improve uniformity. Wind and inadequate water pressure have been found to be the two major factors that reduce the efficiency of overhead sprinkler systems.
- Good water management reduces plant stress and susceptibility to insect and disease problems.
- Recycling of irrigation run-off should be accompanied with a water treatment program to prevent the build-up of disease causing organisms and algae.

Chapter 4 - Integrated Weed Management

Weed control is critical for the production of high quality trees and shrubs. Weeds compete, often successfully, with plants for water, nutrients and light. They also harbour insects, disease and rodents that can damage nursery crops and increase the need for pesticide applications. Nursery stock that contains hard-to-control perennial weeds can be unmarketable, too. No one wants to purchase a plant that is infested with field horsetail (*Equisetum arvense*). Yellow nutsedge (*Cyperus esculentus*) is another creeping perennial weed that is being spread in nursery stock. It reportedly is present in about 5% of all container-grown stock in the Southeast US. Some US states have expressed a desire to designate both yellow and purple nutsedge as quarantine pests. Weed control must not be taken lightly and should be implemented on the entire site to be successful.

There is increasing interest in non-herbicide methods of weed control in the industry, due to:

- growers' concerns of herbicide phytotoxicity,
- a lack of effective herbicides registered in Canada,
- environmental concerns associated with herbicide run-off, and
- concerns of herbicide residues getting into irrigation ponds.

Herbicide use in the nursery and landscape can be reduced by adopting an integrated approach to weed management. This program should include prevention, and physical, cultural and chemical control methods.

Prevention

Prevention is the most important but least used weed management method. Two keys to weed prevention are to limit the introduction of weeds and weed parts, and to prevent weeds from going to seed.

Limit the introduction of weeds and weed parts. Weeds have evolved very effective mechanisms of dispersal and survival. For these reasons, weed managers must adopt the philosophy that it is easier to prevent or exclude weeds in the first place than to treat them once established. Weeds or weed parts are often brought into a nursery or landscape inadvertently on nursery stock or in soil or growing media. Weeds are also spread in improperly managed compost and manures, on machinery, and in contaminated seed.

Media and plants brought onto a site should be visually inspected for weeds prior to use. If weeds are present, quarantine (if possible) the plants until the problem is corrected.

Hand pulling established weeds often will not be sufficient. The soil will likely still contain seeds and/or weed parts that will permit them to re-establish. Follow-up treatments will be required to prevent the weeds from spreading at the site.

Before purchasing soil and media from a new supplier, investigate the steps they take to keep the product clean. If the quality of the media is questionable, check it for weed germinants with a germination test. Growing media is often blamed as the source of weed problems. However, a trial conducted at seven nurseries in North Carolina found the immediate nursery environment, not the media components, to serve as the major source of weed problems (*Journal of Environmental Horticulture*, 10:159-161. September 1992).

It is important to take steps to keep media clean once it arrives at the site. The media should not be stored outdoors where it will be exposed to contaminants. It is preferable to use an enclosed structure where the media will be kept dry and clean.

If storage outdoors is the only option, then it is recommended to store it on an impermeable pad and to cover it with a tarp. It is important to not allow surface water run-off to contact the pile, since this water could contain weed seeds and plant pathogens. It is also important to control weeds before they go to seed on the entire site to prevent cross contamination.

Never let weeds go to seed. Seed production, particularly for annual weeds, is very high and these seeds can lie dormant in the soil for many years. For example, lamb's-quarters and pigweed can produce up to 72,000 and 117,000 seeds per plant, respectively. Their seeds can also remain viable for 20 to 40 years. Perennial weeds are equally insidious, since a new plant can arise from small root fragments. It is recommended to spray creeping, perennial weeds with a systemic herbicide to kill their roots before cultivating the field. Using cultivation alone will be inadequate and will only spread the weed. There is no disputing that weeds have evolved very effective mechanisms of self-preservation.

Some weeds also have highly effective seed dispersal mechanisms. The slightest touch of a mature seed pod of bittercress (*Cardamine oligosperma*) will result in their seeds being shot up to 0.6 m away. Dandelion and groundsel seeds are attached to "parachutes" that are spread great distances with the slightest breeze. Therefore it is even important to control weeds on the perimeter of the site to prevent spread into the growing area. Such weeds can be controlled by mowing, cultivation or chemicals.

Cultural Weed Control

Attempts should be made to modify the habitat to make it more favorable for growth of the crop rather than the weeds. This is one of the most effective, but often overlooked methods for weed control. Weeds have evolved particular adaptations to environmental conditions (See Table 4.1). Changing soil conditions (e.g. correct drainage, pH or compaction problems) and cultural practices (e.g. fertilization, irrigation and pest control) can provide a more effective and longer lasting solution to a weed problem, since healthy and vigorous plants are better able to compete against weeds. When planting ground covers, it is imperative to use competitive plants and to plant them close together so they will fill in the area within a few years. An advantage of cultural methods, relative to herbicides, is they provide a longer term solution to weed problems.

Table 4.1. Preferred site conditions for the growth of weeds.

Scientific Name	Common Name	Preferred Site Conditions
Achillea millefolium	Yarrow	Drought, low fertility
Bellis perennis	English daisy	Low fertility, low pH, excessive moisture
Glechoma hederacea	Ground ivy	Excessive moisture and shade
Medicago lupulina	Black medic	Drought, low fertility
Plantago spp.	Plantain	Low fertility, compacted
Poa annua	Annual bluegrass	Low fertility, compacted, high moisture
Polygonum aviculare	Prostrate knotweed	Compacted, drought
Ranunculus spp.	Buttercup	Excessive moisture
Stellaria media	Chickweed	Excessive shade and moisture
Taraxacum officinale	Dandelion	Thin grass, low mowing, low fertility, drought
Trifolium repens	Clover (white)	Low nitrogen, drought, compacted
various genera	Moss	Heavy shade, poor drainage, low pH
Veronica spp.	Speedwell	Poor drainage, shade

Physical Weed Control

Mechanical Removal: Cultivation practices such as rototilling or hoeing are common and effective means of controlling weeds. Entire plants or plant parts may be buried, or weeds may be severely stressed by cultivation. Periodic cultivation should be carried out about 2 weeks after shoot emergence when the shoots have taken up food reserves from the root system, but before significant levels of photosynthates have been translocated down to the root system. For this strategy, cultivation can simply consist of chopping off the tops with a hoe, or using a line trimmer to cut the weed as low as possible. By repeating this throughout the season, food reserves in the root system are eventually depleted, or the weed is sufficiently stressed to succumb to pests, diseases or environmental stresses (Figure 4.1).

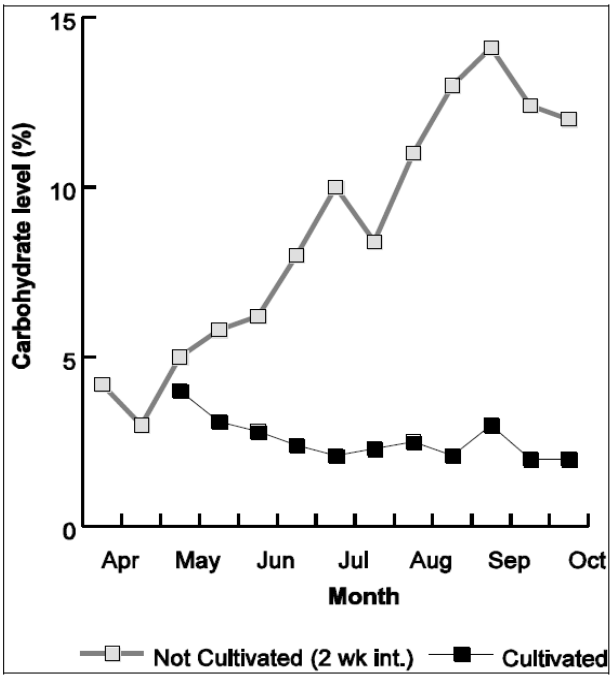


Figure 4.1. Effect of cultivation on morning glory root reserves.

Extreme caution must be applied when cultivating around crops to minimize injury to their surface roots and lower stems. Avoid cultivating soil when it is very wet or dry. Cultivating wet soil will lead to soil compaction, and cultivating dry soil will damage the soil's structure. Poor cultivation practices and frequent cultivation or rototilling will reduce soil tilth and usefulness.

Hand pulling, burning and even steaming of emerged weeds can be effective but must be done when weeds are young (prior to flowering and seeding).

Mulches: There are numerous benefits to using plant mulches. They can moderate soil temperature and retain soil moisture, and organic mulches can provide nutrients and organic matter to the soil. Another benefit is weed control. Mulches control weeds by smothering small weeds, by excluding light that is required for seed germination, and by creating a relatively dry surface that is inhospitable for germination. If the mulch is fine-textured or highly decomposed, it will stay too wet and will allow weed seeds to germinate. Therefore, it is recommended to use a coarse mulch that has a low water holding capacity.

Two organic mulches commonly used in the landscape are bark mulch and leaf compost. Sawdust is not used in the landscape, but is used at times as a mulch for field and container-grown nursery stock. Organic mulches will tie up some nitrogen as they decompose. Therefore, it is recommended to add extra nitrogen to the mulch, otherwise plant growth may be reduced. For sawdust, it is recommended to add about 0.5 kg N/m^3.

Figure 4.2. Sawdust mulch on one gallon pot.

Inorganic mulches are also used. Mulches of decorative stones and lava rock actually create a more difficult weed control situation in the landscape, since they impede physical cultivation.

If mulches are applied incorrectly, they can kill newly-planted and established trees. When applying mulch, two rules of thumb to keep in mind are do not apply it against a tree's trunk, and do not apply more than a 10 cm deep layer. When mulch is placed against a tree, it keeps the trunk moist and makes it susceptible to attack by pests. In addition, it restricts the ability of the bark to breath. Always remember that plant roots and the inner bark are living, respiring tissues. Anything that restricts gas exchange from these tissues will stress and perhaps kill them. For this reason, the use of black plastic as a weed barrier is also not recommended. Weeds invariably establish through breaks in the plastic, as well it depresses the growth of landscape plants by impeding the infiltration of air and water into the soil.

Mulches are being used to control weed growth in container-grown ornamentals, too. Forest seedling nurseries in BC routinely apply a thin layer of fine gravel to container-grown seedlings for weed control. Similarly, some ornamental nursery growers are using pumice or sawdust mulches. A 1 cm layer of sawdust mulch can provide 99% weed control for 2 months. Geotextile weed discs and plastic lids (Enviro Lids) are other options. The industry's interest in mulches has resulted in an explosion in the number of products available. There are several new organic mulches being tested that are made from coconut fibres (AW-disk), straw (BioTop), wood fiber (Corrudisc), or pelletized sweepings from sheep shearing operations (Wulpack). The results with the latter products have been mixed.

Figure 4.3. Liverwort growth occurs where soilless media is exposed due to lifting and curling of the fabric weed disc.

There are drawbacks that limit the use of mulches in containers. Mulches can be difficult and expensive to apply uniformly and efficiently, they do not all hold up well with heavy irrigation, and their effectiveness is dramatically reduced if the integrity of the layer is disrupted by shrinkage or shifting of the layer (Figure 4.3). At times the mulch can even be phytotoxic. This occurred in tests with ProScape at Spring Meadow Nursery Inc. in Grand Haven, MI (*American Nurseryman*, February 15, 2001). The toxicity was discovered to be due to high levels of boron in the mulch.

Living mulches can also be used. Sowing a fall crop of spring barley between rows of nursery stock will reduce the need to control winter annuals. This cover crop will also provide erosion control and increased trafficability. The cover crop can be cultivated the following spring.

Chemical Weed Control

Chemical control should be used only when other methods have not provided satisfactory results. This is particularly true in a landscape situation where the public may be directly impacted by pesticide application, and where guidelines for pesticide application may require that people be informed about pesticide use. In general, if an herbicide needs to be used, select a product that has low toxicity to humans and non-target organisms, and that has low residual activity and minimal adverse effects on the environment.

Herbicides must be applied accurately, at the right time and at the right stage of weed growth for maximum effect. Always read and follow the label instructions. If the material is used contrary to the label, the warranty is null and void. Proper equipment must be used and adjusted correctly to make accurate and thorough applications. The spray pattern must be even and uniform. Make sure granular materials are uniformly spread. Check the calibration of the spreader occasionally, and always recalibrate it before using different sized granules. More detailed information on calibration is presented in Chapter 10.

Liquid applicators include hand sprayers as well as large power sprayers. Chemicals which dissolve readily may be adequately mixed by using hydraulic agitation of a pump bypass. Oil-water emulsions and wettable powders usually require constant vigorous mechanical agitation.

Always use clean water. Salty or hard water may result in gumminess or precipitates that can plug nozzles. Test a small amount of chemical with water before mixing in the tank. This should be done the evening before spraying. If a precipitate forms, determine the cause and a solution before applying. Have screens on hose lines and nozzles to prevent plugging or back pressure. Replace worn nozzles. Wettable powders are especially hard on brass nozzles.

Case Study – Controlling Liverwort (*Marchantia* species) in Containers

Liverwort is one of the most prevalent and troublesome weeds in container-grown nursery stock. Liverwort thrives under moist conditions. This is a reason why it often gets established during propagation and overwintering.

Liverwort produces a green, spreading thallus that clings to the soil by fine roots that are produced on almost the entire lower surface of the thallus. Heavy infestations can compete with the crop, restrict water infiltration, and can make a crop unmarketable. Shipments of nursery stock have been rejected due to the presence of liverwort.

There are no effective herbicides registered in Canada to control established liverwort. In addition, even dead liverwort on nursery stock is undesirable to some clients. For these reasons, growers need to strive to prevent its growth. This can only be accomplished by using a combination of physical, cultural, and chemical controls.

Physical Methods:

Since the prostrate thallus of liverwort is tightly attached to the growing medium, it is very difficult to remove by hand. Liverwort removal is usually accomplished by scraping it off with a layer of medium. This method is expensive, potentially damaging to surface roots of the crop, and relatively ineffective since liverwort will quickly re-establish from thallus fragments, vegetative propagules (gemmae), or spores left behind. In contrast, mulches that are quick-drying can be very effective (Figure 4.4).

Cultural Methods:

- wash and disinfest cuttings, and sanitize the cutting preparation area and the propagation beds before sticking cuttings
- allow the surface of the medium to dry between irrigations; for this reason, subirrigation systems are generally effective at reducing the incidence of liverwort
- incorporate macronutrients, since topdress applications promote liverwort growth
- apply slow release micronutrients as a topdress (use sulfur forms preferably), since some micronutients are quite effective at suppressing liverwort growth (e.g. copper, iron oxide, and zinc) (*Proceedings of SNA Research Conference*, 1998, Vol. 43:396-402).

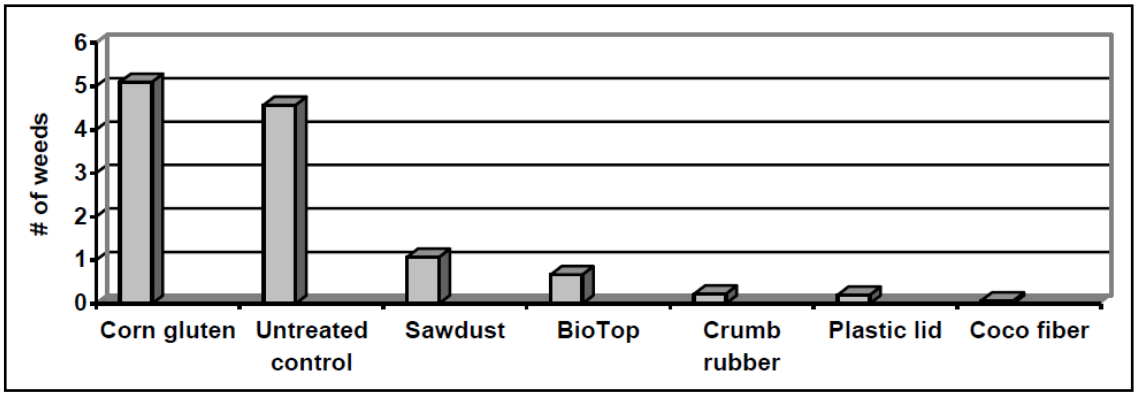


Figure 4.4. The results of a 12-month study on the effectiveness of mulches to control weed growth in container nursery stock. The data presented is the average number of weeds removed per container each month during the growing season. All of the mulches, with the exception of corn gluten meal, significantly reduced weed growth relative to the untreated control. **Adapted from:** *Alternative Weed Control for Container Nursery Production*, 2004, Canadian Nursery Landscape Association Project # 2003-03.

Chemical Methods:

a. **Preemergent –** BroadStar (flumioxazin) is registered to control liverwort on outdoor container-grown woody ornamentals. Ronstar (oxadiazon) is also registered for preemergence weed control in some container-grown nursery crops. The Ronstar label does not make any claim about liverwort control, however research has shown it to be moderately effective (see Table 4.2). Similar results were found in research conducted at Cornell University (*Perennial Plants*, Vol 5(4):7). Uniform herbicide coverage is critical for success.

b. **Postemergent –** over the years, the efficacy has been tested of a wide range of products on liverwort established in container stock. None of these products can be recommended for use because of phytotoxicity problems and, more importantly, they are not registered for this use. Dr. Sven Svenson presented an excellent review of these products at the 1997 International Plant Propagators Society Meeting, Southern Region (*IPPS Combined Proceedings*, 1997, Vol 47:414-422).

c. **Liverwort control on non-crop land –** To be successful, a weed control program must include steps to reduce weed growth on non-crop land. SureGuard (flumioxazin) is registered for application to non-crop areas in and around ornamental nurseries. Although the label does not state that it controls liverwort, flumioxazin is known to control liverwort. EcoClear 25% (acetic acid) is also registered for weed control in non-crop areas at nurseries, which includes in and around greenhouses. The label for EcoClear does not claim to control liverwort, but research has demonstrated efficacy against this weed. Safer's De-Moss 40% (soap) has a domestic registration for use in greenhouses to control moss, algae, lichens and liverwort. **Warning:** All of these products caution against spraying desirable plants due to the risk of plant injury.

Table 4.2. The influence of irrigation and surface treatment on the percent cover of liverwort in container-grown *Picea glauca* 'Albertiana Conica'. The low irrigation treatment was watered every 3 days, and the high irrigation treatment was watered daily. The Ronstar treatment was not part of the mulch experiment, but was added for comparison purposes. **Adapted from**: S. Svenson, *Proceedings of SNA Research Conference*, 1998, Vol. 43:396-402.

Irrigation Frequency	Treatment	Weeks after Treatment	
		3	6
Low	No Mulch (control)	16%	55%
	Hazelnut Shells	0%	4%
	Pumice	0%	37%
	Geotextile	0%	20%
	Ronstar	0%	12%
High	No Mulch (control)	22%	100%
	Hazelnut Shells	0%	8%
	Pumice	15%	85%
	Geotextile	9%	32%
	Ronstar	14%	45%

Chapter 5 - Integrated Pest Management

Integrated pest management (IPM) is a decision-making process that uses all available techniques to suppress pests effectively, economically and in an environmentally sound manner. IPM is a process for managing pest populations that includes the following elements:

a. to plan and manage ecosystems to prevent organisms from becoming pests,
b. to identify pest problems and potential pest organisms,
c. to monitor populations of pests and beneficial organisms, and damage caused by pests and environmental conditions,
d. to use injury thresholds in making treatment decisions,
e. to suppress pest populations to acceptable levels using a combination of biological, physical, cultural, mechanical, behavioural and chemical controls, and
f. to evaluate the effectiveness of treatments.

In practical terms this means having a plan that lists all possible plant host/pest problems and appropriate control methods to selectively reduce a pest population, while not harming beneficial organisms.

An IPM program takes into account factors that influence plant health and vigour as well as those that affect the health and reproductive capacity of pests. The program will attempt to optimize growing conditions for the crop while making the conditions less favourable for pest development. Key aspects of a nursery IPM program are:

- sanitation,
- optimizing crop growth,
- monitoring crops for pests,
- knowledge of pest life cycles, and
- timely use of control tools, such as biological, chemical, cultural and mechanical controls.

Sanitation

Nursery and landscape sanitation includes the removal or exclusion of factors that allow pests to gain access to crops, to spread between plants, or to survive between crops. Good crop hygiene focuses on starting clean and preventing the introduction of pests. Prevention is often easier and less expensive than to manage an established pest population.

Start with Healthy, Pest-Free Plants

Closely inspect all plant material introduced to a nursery or landscape for pests. Plants with pest problems should be 'quarantined' while the problem is rectified.

Strict sanitation also applies to propagation stock. The moist, warm conditions that favour propagation also favour disease development (e.g. botrytis and downy mildew). Cuttings and scion material should only be collected from healthy and pest-free stock plants. Washing in a detergent will help to remove soil, weed seeds, pathogens, or insect eggs or other life stages from the surface of cuttings.

Cutting and pruning tools should be frequently sanitized on all crops to prevent the spread of diseases. Table 5.1 lists products and treatment times to disinfect cutting knives.

Sanitation of Production Areas

Between crops all production beds, greenhouses, benches, walkways and containers should be cleaned. It is very important to remove organic debris before treatment with an oxidizing disinfectant (e.g. bleach, hydrogen peroxide), since the debris will significantly reduce the efficacy of the disinfectant.

It is also important to follow a sanitation program during crop production. Sanitize cutting tools periodically when pruning crops.

Table 5.1. Disinfectant treatments for cutting knives used by the greenhouse floriculture industry. Do not dip cuttings in the disinfectants. No evaluation was made of the phytoxicity of disinfectant-treated knives on the cutting. Use these treatments with CAUTION.

Disease	Best Disinfectant	Treatment Time
Bacterial blight of geranium	5% Virkon	Quick Dip
	10% Bleach[1]	Quick Dip
	DCD Floralife (16 mL/L)	Quick Dip
	70% Ethanol[2]	20 seconds
Penicillium	10% Bleach[1]	10 seconds
	70% Ethanol[2]	10 seconds
Fusarium wilt of cyclamen	5% Virkon	Quick Dip
	10% Bleach[1]	Quick Dip
	70% Ethanol[2]	Quick Dip
	DCD Floralife (16 mL/L)	20 seconds

[1] Household strength bleach containing 5.25% sodium hypochlorite. Bleach is very corrosive and may damage cutting tools over time.
[2] Keep ethanol containers away from flames.

The management of weeds must also be a priority. Weeds in production areas can spread to crops and are a feeding and breeding site for many pests. For example, common groundsel (*Senecio vulgaris*) is known to harbour whiteflies, leafminers, aphids and western flower thrips.

Another route for pests to enter production areas is on dirty footwear and clothing. To put this in perspective, a pinch of soil can contain over 10,000 *Fusarium* spores, and only one spore is needed for infection (Jarvis, 1997). One option to reduce the spread of pests on footwear is to install footbaths at the entrance of sensitive greenhouses, such as propagation houses. A container with a foam mat is effective. Use a disinfectant such as BioSentry, KleenGrow or Hyperox. Change the solution every day or when it becomes soiled, and ensure staff and visitors use the footbath. Post signage about your policy regarding the use of footbaths.

Avoid wearing bright-colored clothing (e.g. blue and yellow) since it is attractive to insects.

Handling Media and Plant Residues

The movement of soil and inadequately composted organic mulches on machinery or in bulk can introduce pests to an area. New media should be visually inspected for pests prior to use. Germination tests should also be performed to detect weed germinants.

Figure 5.1. Footbath signage and mat used at the entrance to a nursery.

Plant residues and sick plants harbour pests and should be quickly removed from production areas. For instance, rose blackspot and apple scab will overwinter on fallen leaves. Therefore, it is recommended that fallen leaves be collected and removed from the area to reduce inoculum levels.

Plant debris should be buried, pasteurized or burned. An open refuse pile near a production area is a recipe for disaster, since it will be a source of reinfestation for a variety of pests.

If you must have a cull pile, locate it far away and downwind from the production area and the source of irrigation water. The pile should be covered with a plastic sheet or a soil layer after each deposit to prevent the release of spores and the buildup of insects on plant debris. The best solution is to remove all cull material from the site. Recycling is fine, but do not recycle your pests.

Screening

Pests that fly such as thrips, aphids and moths can be excluded from a greenhouse by covering vents with screens. Several materials of various mesh sizes are available. Screens reduce airflow into greenhouses, which is usually compensated for by increasing the surface area of the vent opening or by installing pleated screens into the vent opening. The surface area of the screened vent should be 2-5 times larger than the unscreened vent area.

Algae Control

The buildup of algae on surfaces, floors and in pipes should be minimized because it encourages and harbours shore flies and, can pose a safety hazard due to its slippery nature. Avoid over-watering and provide good drainage. Disinfectants can also be used to manage algae.

Optimizing Crop Growth

Plants that are vigorous and are not under stress are better able to resist pests. To maximize crop growth, the level of all factors that control plant growth must be optimal. If too much or too little of any factor is supplied, the crop will have reduced growth and will be more susceptible to diseases. The rate of crop growth will be determined by the level of the growth factor that is in most limited supply. This concept is commonly referred to as the principle of limiting factors.

Some factors that influence crop growth are light, temperature, water, air and soil tilth (fertility, drainage and aeration). For many of these the quantity and quality of the factor must be taken into account. Steps to optimize crop growth include:

- Improve soil drainage through the installation of drain tiles to reduce the risk of root rot on susceptible hosts. Waterlogged soil results in the depletion of oxygen. Oxygen content below 10% will injure roots, and levels below 3% will result in the cessation of root growth in many plants. Roots injured by a lack of oxygen will leak nutrients, which attract various root rot organisms.
- Increase plant spacing, or change pruning practices to produce a less dense plant canopy, to improve air movement and reduce problems with foliar diseases.
- Moderate greenhouse temperatures, since large swings in temperature can produce an environment that is ideal for pest development.

Remember that strong and healthy plants have the best chance to fight pests and resist infections.

Monitoring Crops for Insect Pests

Monitoring is the regular inspection of plants to detect the presence of pests or adverse environmental conditions. Crop monitoring is essential for pest management, since it enables pests to be detected when at low levels and at a susceptible stage of development. Monitoring will also provide information on the presence and activity of beneficial organisms, and the effectiveness of previous treatments.

Monitoring provides the information to make sound pest management decisions. It is accomplished by inspecting plants and by the use of a variety of trapping devices. In addition, environmental data may be recorded, such as temperature, rainfall and humidity. (See Tables 5.2, 5.3, 5.4 and 5.5 for monitoring and scouting methods for use in greenhouses and the field.)

It is usually best to have one person assigned to maintain a scouting and monitoring program. However, every staff person should be trained to look for and report signs and symptoms of pests.

Table 5.2. Monitoring methods for insects in polyhouses and greenhouses.

Monitoring Method	Aphids	Fungus Gnats	Leafhoppers	Leafminers	Mites	Moths	Plant Bugs	Shore Flies	Thrips	Whiteflies
Yellow sticky cards at top of plant canopy	✓	✓	✓	✓			✓	✓	✓	✓
Blue sticky cards at top of plant canopy									✓	
Trap crops/catch plants	✓								✓	✓
Potato sections on soil surface		✓								
Light traps						✓				
Visual Inspection	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 5.3. Monitoring methods for insects in the field.

Monitoring Method	Aphids & Adelgids	Caterpillars	Leafhoppers	Mites	Moths and Borers	Thrips	Weevils	Wireworms
Board traps							✓	
Sticky traps and bands	✓		✓			✓	✓	
Tap foliage over a white surface	✓	✓	✓	✓		✓	✓	
Blacklight traps					✓			
Visual inspections	✓	✓	✓	✓	✓	✓	✓	
Trap crops				✓				
Flour baits								✓
Pheromone traps		✓			✓			✓

Table 5.4. Scouting methods for insects in polyhouses.

Scouting Methods (Visual Inspection)	**Aphid**	**Caterpillar**	**Fungus Gnat**	**Lacebug**	**Leafhopper**	**Leafminer**	**Mealybug**	**Gall Midge**	**Spider Mite**	**Plant Bug**	**Scale**	**Shorefly**	**Slug, Snail**	**Thrips**	**Weevil**	**Whitefly**
Flower/Shoot Tip Damage	✓	✓							✓	✓				✓		
Leaf/Stem Damage																
Galls								✓								
Holes		✓								✓			✓			
Lineal mines						✓										
Notches on margins															✓	
Skeletonization		✓											✓			
Speckling				✓	✓				✓					✓		
Signs of a Pest																
Dark fecal spots on leaf		✓		✓								✓	✓	✓		
Honeydew/sooty mould	✓						✓				✓					✓
Insects clustered on stems	✓						✓				✓					
Insects fall out of flowers when tapped										✓				✓		
Insects seen to move in flowers when blown on														✓		
Insects or eggs on underside of leaf	✓	✓							✓					✓		✓
Insect skins on leaf	✓				✓											
Pests hide under objects													✓		✓	
Slime trails													✓			
Small black flies			✓									✓				
Webbing									✓							

Table 5.5. Scouting methods for insects in the field.

Scouting Method (Visual Inspection)	**Adelgid**	**Aphid**	**Boring Beetle or Caterpillar**	**Bud Moth, Spruce Budworm**	**Tent Caterpillar, Webworm, Tortrix Larva**	**Rose Curculio**	**Cutworm, Looper, Sawfly, Winter Moth**	**Leafhopper**	**Leafminer**	**Plant Bug**	**Mealybug**	**Spider Mite**	**Scale (Oyster/cottony)**	**Slug, Snail**	**Pear/Rose "Slug" (Sawfly)**	**Thrips**	**Cypress Tip Moth, Pine Shoot Moth**	**Gall Wasp, Midge**	**Weevil**	**Whitefly**
Flower/Shoot Tip Damage		✓		✓	✓	✓				✓		✓				✓				
Leaf/Stem Damage																				
Galls	✓																	✓		
Holes, defoliation					✓		✓							✓						
Lineal mines									✓								✓			
Notches on margins																			✓	
Pitch or gum, sap flow			✓		✓															
Shoot dieback			✓	✓									✓				✓			
Skeletonization					✓										✓					
Speckling								✓				✓				✓				
Yellow, curled leaf		✓			✓			✓												✓
Signs of a Pest																				
Dark fecal spots on leaf					✓		✓							✓		✓				
Honeydew/sooty mould		✓									✓		✓							✓
Insect clusters on stem		✓									✓		✓							
Insects fall out of flowers when tapped										✓						✓				
Insects move in flowers when blown on																✓				
Insects or eggs on underside of leaf		✓										✓				✓				✓
Insect skins on leaf		✓						✓												
Slime trails														✓						
Webbing					✓							✓								
White wax deposits	✓	✓									✓		✓							

Insect traps and sticky cards can be used to detect flying pests (e.g. fungus gnats, moths, thrips and whiteflies), but they have to be monitored on a regular basis. In the greenhouse, it is recommended to use sticky traps at the rate of 1 per 100 m^2. The cards should be located above the crop canopy and be checked twice a week. More traps should be placed close to doorways and vents. In general, 6-8 cards will be required per monitoring area.

Evaluate the stickiness of traps after 3-4 weeks and replace if necessary. Keep an on-going record of trap-catch numbers. When a pest is detected, have it accurately identified and begin control measures as soon as possible.

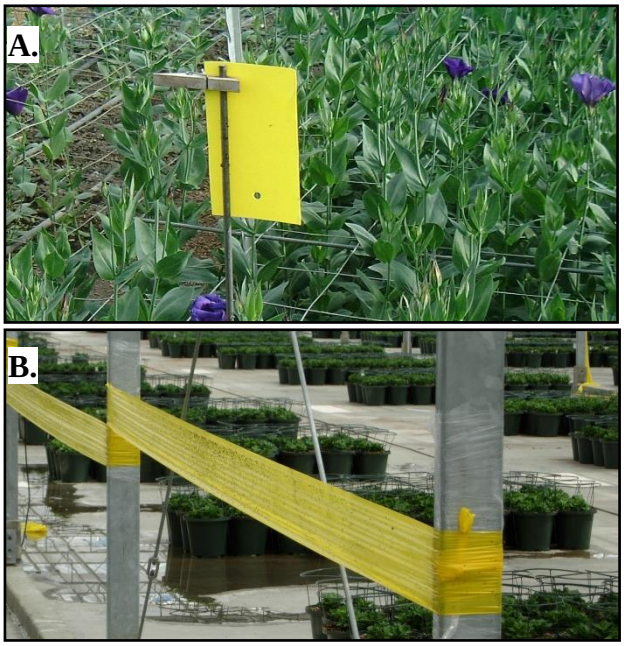


Figure 5.2. The use of a yellow sticky card (A) and tape (B) to trap flying insects.

Another detection method commonly used is to tap the foliage to dislodge pests onto a catch tray, such as a piece of white paper. This technique is useful for counting elm leaf beetles, some caterpillars, leafhoppers, mites, thrips and weevils.

Plant Phenology

When monitoring, the stage of development of landscape plants in the area should be recorded. Since plant and insect development are both dependent on temperature, the development of certain plants can be correlated with the developmental stage of specific pests. For example, egg hatch of eastern tent caterpillars coincides with bloom of saucer magnolia.

Plant phenology can be used to determine the time of year to monitor for a pest and is more precise than relying on calendar dates. But it needs to be constantly verified under local conditions. The pest manager should be aware that the environment can differ inside polyhouses and around buildings, and should take this into account when selecting appropriate indicator plants.

A list of indicator plants for insects commonly found on ornamentals in BC is provided in Table 5.6. When an indicator plant reaches a particular stage of development, it is time to monitor for certain insects. The information is adapted from the publication *Coincide: The Orton System of Pest Management*, and is based on twenty years of data from Illinois. Since the development for plants and insects is based on temperature, the same rates of development probably occur in BC, but at different calendar dates.

Scheduling Crop Monitoring

Work done in a similar climatic zone to the Lower Mainland has concluded that an effective landscape IPM program requires a minimum of 10 monitoring visits each season. There should be at least two visits each month from May through August, plus one in late winter or early spring, and one in the fall. This schedule is best suited to a landscape in which deciduous plants prevail.

On sites where conifers are most abundant, a few extra early season and late season monitoring visits are advised, as these plants are attacked by several species of cold-tolerant pests. The fall visit should include observations for pest overwintering stages. The late winter visit is needed to look for scale insects on deciduous branches before foliage obscures them. Dormant oil sprays can be applied at this time.

For most BC nursery sites, which contain some coniferous stock, a minimum of 18 plant-monitoring visits each season are required. At least two monitoring visits should be done in February to March, three each in April and May, two each in June through August and two in November to December. Tables 5.7 and 5.8 list common pests to look for at different times of the year.

The number of random plant samples per area (observations) and the location of these plants within the area should be decided in advance. This should avoid the temptation to always sample the end of the row closest to the road.

The insect threshold number that will render a plant unsalable will have to be assessed. Several years of meticulous record keeping will be necessary to predict with confidence when or when not to control. There is no published information that lists threshold levels for insect pests in nursery crops.

Table 5.6. Using plant phenology as an indicator of insect development (Adapted from the publication *Coincide: The Orton System of Pest Management*).

Insect Pest	Vulnerable Insect Stage to Monitor	Indicator Plant Stage of Development that Coincides with Insect Stage
Adelgid, Cooley spruce gall	Overwintering insect	*Magnolia X soulangiana* - pink bud
Adelgid, Cooley spruce gall	Overwintering nymph	*Acer saccharum* - leaves in full colour
Aphid, honeysuckle	First aphid	*Aesculus hippocastanum* – blooming
Aphid, pine bark	Overwintering female	*Syringa vulgaris* - green bud
Aphid, willow	Newly-hatched nymph	*Magnolia X soulangiana* – dropping petals
Aphid, woolly apple	When aphids are present	*Catalpa speciosa* – blooming
Bagworm	Newly-hatched larva	*Catalpa speciosa* – blooming
Beetle, elm leaf	Young larva	*Aesculus hippocastanum* – late bloom
Borer, bronze birch	Newly-hatched larva	*Aesculus hippocastanum* – late bloom
Borer, peach tree	Start of egg hatch	*Philadelphus coronaries* – blooming
Borer, peach tree	End of egg hatch	*Solidago canadensis* – blooming
Budworm, spruce	Young larva	*Magnolia X soulangiana* – dropping petals
Caterpillar, Eastern tent	Young larva	*Magnolia X soulangiana* – early bloom
Eriophyid mite, spruce	Newly-hatched immature	*Magnolia X soulangiana* - pink bud
Gall midge, honeylocust pod	Newly-hatched larva	*Gleditsia triacanthos* – bud break
Leafminer, birch	Young larva	*Syringa vulgaris* - late bloom
Mite, spruce spider	Newly-hatched nymph (1st flush)	*Magnolia X soulangiana* - pink bud
Mite, spruce spider	Newly-hatched nymph (2nd flush)	*Solidago canadensis* – blooming
Mite, two-spotted spider	Immature stage and adult	*Yucca filamentosa* - early bloom
Moth, European pine shoot	Overwintering larva	*Magnolia X soulangiana* - pink bud
Moth, European pine shoot	Newly-hatched larva	*Catalpa speciosa* – blooming
Moth, tussock	Young immature larva	*Crataegus crus-galli* – blooming
Needle miner, spruce	Young feeding larva	*Magnolia X soulangiana* - pink bud
Root weevil, Black vine	Overwintering adult	*Aesculus hippocastanum* – late bloom
Root weevil, Black vine	New adult	*Catalpa speciosa* – blooming
Sawfly, European pine	Newly-hatched larva	*Magnolia X soulangiana* – dropping petals
Scale, cottony maple	Newly-hatched crawler	*Yucca filamentosa* – blooming
Scale, European elm	Overwintering nymph	*Prunus X cistena* – blooming
Scale, European elm	Newly-hatched nymph	*Yucca filamentosa* – blooming
Scale, Fletcher	Overwintering female	*Magnolia X soulangiana* – blooming
Scale, Fletcher	Newly-hatched crawler	*Yucca filamentosa* – blooming
Scale, lecanium	Newly-hatched crawler	*Yucca filamentosa* – blooming
Scale, oystershell	Newly-hatched crawler	*Syringa vulgaris* - late bloom
Scale, pine needle	First instar nymph	*Aesculus hippocastanum* – blooming
Scale, San Jose	Newly-hatched crawler	*Catalpa speciosa* – blooming
Scale, spruce bud	Newly-hatched crawler	*Sorbus aucuparia* - fruit turning orange
Webworm, fall	Young larva	*Sorbus aucuparia* - fruit is orange

Table 5.7. The life cycles of some important nursery and landscape pests in the coastal region of BC. Shaded areas designate when to monitor for a pest and, if required, when to implement a control program.

Developmental Stage Symbols: **A** = adult **E** = egg **L** = larva **N** = nymph **P** = pupa	**February-March**	**April**	**May**	**June**	**July**	**August**	**September-October**	**November-December**
Adelgids	ENA	ENA	ENA	ENA	ENA	ENA	ENA	ENA
Aphids	E	NA	NA	ENA	ENA	ENA	E	E
Bark beetle, Douglas fir, fir engraver & Mt. pine	L	L	LA	ELA	ELA	ELA	L	L
Bark beetle, European elm	L	L	LP	EA	EA	L	L	L
Bark tortrix, cherry	LP	LP	A	LA	LA	L	L	L
Borer, bronze birch	L	L	L	LA	LA	LA	L	L
Borer, poplar & willow	LA	LA	LA	LA	LA	LA	LA	LA
Budmoth, eyespotted	L	L	P	EA	EA	L	L	L
Budworm, holly	E	L	L	L	P	A	A	E
Budworm, western spruce	L	L	LP	P	EA	L	L	L
Bug, boxelder	A	EA	ENA	ENA	ENA	ENA	ENA	A
Cutworm, climbing	LP	LP	LPA	LPA	LPA	LPA	LP	LP
Flea beetle, alder	A	ELPA	ELP	ELP	A	A	A	A
Lacebug	E	E	N	ENA	ENA	ENA	E	E
Leafhopper	E	E	N	ENA	ENA	ENA	E	E
Leafminer, arbutus & serpentine	L	LP	A	ELA	L	L	L	L
Leafminer, birch	P	P	LA	LA	LA	LA	P	P
Leafminer, boxwood	L	LP	EA	ELA	L	L	L	L
Leafminer, cypress	L	LA	EA	EA	L	L	L	L
Leafminer, holly	L	L	A	EA	L	L	L	L
Leafminer, lilac	P	LA	LA	LA	LA	L	L	L
Mite, European red	E	E	NA	NA	NA	NA	E	E
Mite, two-spotted spider	A	NA	NA	NA	NA	NA	A	A
Moth, apple & cherry ermine	L	L	LP	A	A	E	L	L
Moth, cypress tip	LP	PA	EA	EA	L	L	L	L
Moth, Douglas-fir & tussock	E	E	L	L	LP	A	A	E
Moth, European pine shoot	L	L	P	A	EA	L	L	L
Moth, winter	E	L	L	P	P	P	P	A
Needle miner, spruce	L	P	LA	LA	L	L	L	L
Plant bugs (lygus)	A	A	NA	NA	NA	NA	A	A
Psyllid, boxwood	A	ENA	ENA	ENA	ENA	ENA	A	A
Sawfly, curled rose	P	LP	LA	LA	LA	LP	P	P
Scale, brown soft & cotton camellia	N	EA	EA	EA	N	N	N	N
Scale, cottony maple	N	N	EA	N	N	N	N	N
Scale, lecanium	N	N	EA	ENA	N	N	N	N
Scale, oystershell	E	E	N	N	A	A	EA	E
Scale, pine needle	EA	EA	N	N	N	A	EA	EA
Scale, San Jose	N	N	EA	ENA	ENA	ENA	N	N

Table 5.7. The life cycles of some important nursery and landscape pests in the coastal region of BC. (Cont'd)

Developmental Stage Symbols: **A** = adult **E** = egg **L** = larva **N** = nymph **P** = pupa	**February-March**	**April**	**May**	**June**	**July**	**August**	**September-October**	**November-December**
Skeletonizer, apple & thorn	A	EA	ELA	ELA	ELA	ELA	A	A
Spanworm, Bruce	E	L	L	P	P	P	P	A
Tent caterpillar, western	E	L	L	L	A	A	E	E
Thrips	N	N	NA	NA	NA	NA	N	N
Webworm, cotoneaster	L	L	P	LA	LA	LA	L	L
Webworm, fall	P	P	P	A	L	L	L	P
Webworm, juniper	L	L	P	LA	LA	L	L	L
Weevil, black vine	LA	LA	PA	LA	LA	LA	LA	LA
Weevil, sitka spruce	A	A	L	L	L	LP	P	A
Whiteflies	N	NA	NA	NA	NA	NA	N	N

Table 5.8. Monitoring schedule for insect pests of trees and shrubs (by month of occurrence) in the South Interior. The data is from 10 years of field reports collected in the Okanagan by CropHealth Advising & Research.

MARCH	Stage to Monitor	Host Plants to Monitor
Sucking Insects		
Aphids	Nymph	*Viburnum*
Mite, rust	Nymph	*Pyrus*
Scale, cottony maple	Immature female	*Acer*
Scale, European elm	Immature female	*Ulmus*
Psyllid, pear	Egg	*Pyrus*
Chewing Insects		
Bug, boxelder	Adult	*Acer*
Gall Formers		
Adelgids	Immature female	*Picea*
Mite, blister	Nymph	*Acer, Juglans*
APRIL		
Sucking Insects		
Aphids	Egg, nymph	*Acer, Betula, Cornus, Cotoneaster, Crataegus, Malus, Prunus* (flowering plum), *Ribes, Rosa, Tilia, Ulmus, Viburnum*
Aphid, Bark	Nymph	*Pinus*
Aphid, green ash	Nymph	*Fraxinus* (green ash)
Mite, European red	Egg	*Malus, Sorbus*
Mite, spruce spider	Egg	*Abies, Juniperus, Picea, Pseudotsuga menziesii, Taxus, Thuja*
Psyllids	Egg, nymph	*Crataegus*
Psyllid, boxwood	Egg, nymph	*Buxus*
Psyllid, pear	Egg, nymph	*Pyrus*
Scale, European elm	Nymph	*Ulmus*
Scale, juniper	Mature female	*Juniperus*
Scale, lecanium	Immature female	*Carpinus, Fraxinus* (green ash), *Malus, Prunus* (flowering plum), *Quercus, Tilia*
Scale, oystershell	Immature female	*Crataegus, Fraxinus, Prunus* (flowering plum), *Quercus, Tilia*
Scale, pine needle	Immature female	*Pinus*
Chewing Insects		
Budworm, spruce	Larva	*Abies, Picea, Pseudotsuga menziesii*
Bug, boxelder	Adult	*Acer*
Caterpillars	Egg	*Malus, Prunus* (flowering plum), *Rosa, Tilia*
Curculio, rose	Adult	*Rosa*
Leafminer, birch	Adult	*Betula*
Leafminer, lilac	Adult	*Syringa*
Root weevils	Adult	azalea, *Rhododendron, Taxus, Thuja*
Gall Formers		
Adelgids	Adult	*Abies, Picea, Pinus, Pseudotsuga menziesii*
Gall midge, honeylocust pod	Adult, egg	*Gleditsia*
Mite, blister	Nymph	*Sorbus*
Borers		
Weevil, white pine	Adult	*Picea*

Table 5.8. Monitoring table for insect pests of trees and shrubs (by month of occurrence) in the South Interior. (Cont'd)

MAY		
Sucking Insects		
Aphids	Nymph	*Acer, Betula, Caragana, Cornus, Cotoneaster, Crataegus, Fagus, Juglans, Lonicera, Malus, Picea, Potentilla, Prunus* (flowering plum), *Quercus, Ribes, Rosa, Salix, Spiraea, Tilia, Ulmus*
Aphid, bark	Egg, nymph	*Pinus*
Aphid, green ash leafcurling	Nymph	*Fraxinus* (green ash)
Leafhoppers	Adult	*Rosa*
Mites, spruce spider	Adult, nymph	*Abies, Juniperus, Picea, Pseudotsuga menziesii, Taxus, Thuja*
Phylloxera, oak leaf	Adult, egg, nymph	*Quercus*
Psyllids	Nymph	*Crataegus*
Psyllid, boxwood	Nymph	*Buxus*
Psyllid, pear	Nymph	*Pyrus*
Spittlebugs	Nymph	*Forsythia, Potentilla, Rosa, Spiraea, Junipers, Pinus*
Chewing Insects		
Budworm, spruce	Larva	*Abies, Picea, Pinus, Pseudotsuga menziesii*
Bug, boxelder	Adult	*Acer*
Caterpillars	Larva	*Malus, Prunus* (flowering plum), *Rosa, Sambucus, Spiraea, Syringa, Tilia*
Caterpillar, tent	Larva	*Acer, Malus*
Curculio, rose	Adult	*Rosa*
Lacebug	Nymph	azalea, *Rhododendron*
Leafminer, birch	Larva	*Betula*
Leafminer, lilac	Larva	*Syringa*
Leafminer, poplar	Larva	*Populus*
Looper, barberry	Larva	*Mahonia*
Moth, tussock	Larva	*Abies, Pseudotsuga menziesii*
Root weevils	Adult	azalea, *Rhododendron, Taxus, Thuja*
Sawflies	Larva	*Ribes, Rosa*
Thrips	Adult	*Prunus* (flowering plum), *Rosa*
Gall Formers		
Adelgids	Egg, nymph	*Abies, Picea, Pinus, Pseudotsuga menziesii*
Gall midge, honeylocust pod	Adult, egg	*Gleditsia*
Borers		
Bark beetle, pine	Adult	*Pinus*
Borer, shothole	Adult	*Sorbus*
Weevil, white pine	Adult, larva	*Picea*

Table 5.8. Monitoring table for insect pests of trees and shrubs (by month of occurrence) in the South Interior. (Cont'd)

JUNE		
Sucking Insects		
Aphids	Nymph	*Acer, Betula, Caragana, Cornus, Cotoneaster, Crataegus, Fagus,* flowering plum, *Juglans, Lonicera, Malus, Picea, Potentilla, Quercus, Ribes, Rosa, Salix, Spiraea, Tilia, Ulmus*
Aphid, green ash leafcurling	Nymph	*Fraxinus* (green ash)
Aphid, petiole gall	Nymph	
Leafhoppers	Adult	*Malus, Parthenocissus, Rosa*
Mite, rust	Adult, nymph	*Pyrus*
Mites, spruce spider	Nymph, adult	*Abies, Juniperus, Picea, Pseudotsuga menziesii, Taxus, Thuja*
Mites, two-spotted spider	Adult, nymph	*Caragana, Robinia, Rosa, Salix, Spiraea*
Phylloxera, oak leaf	Adult, egg, nymph	*Quercus*
Psyllid, pear	Adult, nymph	*Pyrus*
Scale, juniper	Adult, nymph	*Juniperus*
Scale, pine needle	Adult, nymph	*Pinus*
Scale, Fletcher	Adult, nymph	*Taxus, Thuja*
Scale, European elm	Adult, nymph	*Ulmus*
Spittlebugs	Nymph	*Forsythia, Potentilla, Rosa, Spiraea, Junipers, Pinus*
Chewing Insects		
Beetle, cottonwood leaf	Larva	
Beetle, elm leaf	Larva	*Ulmus*
Caterpillars	Larva	flowering plum, *Malus, Rosa, Sambucus, Spiraea, Syringa, Tilia*
Caterpillar, tent	Larva	*Acer, Malus*
Lacebug	Adult, nymph	azalea, *Rhododendron*
Leafminer, poplar	Larva	
Looper, barberry	Larva	*Mahonia*
Moth, codling	Larva	*Malus*
Moth, tussock	Adult, larva	*Abies, Pseudotsuga menziesii*
Needle miners, spruce	Larva	*Picea*
Root weevils	Adult, larva	azalea, *Rhododendron, Taxus, Thuja*
Sawflies	Larva	*Picea, Populus, Ribes, Rosa*
Skeletonizer, apple & thorn	Larva	*Malus*
"Slugs" (sawfly larva)	Larva	*Cotoneaster, Crataegus, Pyrus, Rosa*
Thrips	Adult	*Prunus* (flowering plum), *Rosa*
Gall Formers		
Gall midge, honeylocust pod	Adult, egg	*Gleditsia*
Mite, blister	Nymph	*Juglans*
Borers		
Bark beetle, pine	Adult, nymph	*Pinus*
Borer, bronze birch	Adult, nymph	*Betula*
Borer, maple twig	Adult, nymph	*Acer*
Borer, shothole	Adult, nymph	*Sorbus*
Moth, pine shoot	Adult, nymph	*Pinus*
Pitch moth, sequoia	Adult, nymph	*Pinus*
Weevil, white pine	Larva	*Picea*

Table 5.8. Monitoring table for insect pests of trees and shrubs (by month of occurrence) in the South Interior. (Cont'd)

JULY		
Sucking Insects		
Aphids	Nymph	*Acer, Betula, Cotoneaster, Crataegus, Fagus, Juglans, Lonicera, Populus, Potentilla, Prunus* (flowering plum), *Quercus, Robinia, Rosa, Salix, Spiraea, Tilia, Ulmus*
Aphid, petiole gall	Nymph	*Populus*
Psyllid, pear	Adult, nymph	*Pyrus*
Leafhoppers	Adult	*Rosa*
Lacebug	Adult, nymph	azalea, *Rhododendron*
Phylloxera, oak leaf	Adult, egg, nymph	*Quercus*
Scale, juniper	Adult, nymph	*Juniperus*
Scale, Fletcher	Adult, nymph	*Taxus, Thuja*
Scale, spruce bud	Adult, nymph	*Picea*
Scale, European elm	Adult, nymph	*Ulmus*
Scale, cottony maple	Adult, nymph	*Acer*
Scale, lecanium	Adult, nymph	*Carpinus, Fraxinus* (green ash), *Quercus, Tilia*
Scale, oystershell	Adult, nymph	*Crataegus, Fraxinus* (green ash), *Quercus, Tilia*
Mite, rust	Adult, nymph	*Pyrus*
Mite, spruce spider	Adult, nymph	*Abies, Juniperus, Picea, Pseudotsuga menziesii, Taxus, Thuja*
Mite, two-spotted spider	Adult, nymph	*Caragana, Malus, Populus, Potentilla, Prunus* (flowering plum), *Robinia, Rosa, Salix, Spiraea, Viburnum*
Chewing Insects		
Beetle, cottonwood leaf	Larva	*Populus, Salix*
Beetle, elm leaf	Larva	*Ulmus*
Caterpillars	Larva	*Rosa, Sambucus*
Fly, walnut husk	Adult, larva	*Juglans*
Moth, codling	Adult, larva	*Malus*
Root weevils	Adult	azalea, *Rhododendron*
Sawflies	Larva	*Picea, Populus, Ribes*
"Slugs" (sawfly larva)	Larva	*Cotoneaster, Crataegus, Prunus* (flowering plum), *Pyrus*
Webworm, fall	Larva	*Acer, Betula, Crataegus, Fraxinus* (green ash), *Juglans, Malus, Populus, Prunus* (flowering plum), *Quercus, Sorbus, Syringa, Tilia, Ulmus*
Gall Formers		
Gall midge, honeylocust pod	Adult, egg	*Gleditsia*
Borers		
Bark beetle, pine	Adult	*Pinus*
Borer, bronze birch	Adult	*Betula*
Borer, maple twig	Adult, larva	*Acer*
Borer, peach tree	Adult, larva	*Prunus* (flowering plum)
Borer, poplar	Adult, larva	*Populus*
Borer, shothole	Adult	*Sorbus*
Moth, pine shoot	Adult, larva	*Pinus*
Pitch moth, sequoia	Adult, larva	*Pinus*

Table 5.8. Monitoring table for insect pests of trees and shrubs (by month of occurrence) in the South Interior. (Cont'd)

AUGUST		
Sucking Insects		
Aphids	Nymph	*Acer, Potentilla, Prunus* (flowering plum), *Quercus, Robinia, Rosa, Salix, Spiraea, Tilia*
Lacebug	Adult, nymph	*Salix*
Leafhoppers	Adult, nymph	*Salix*
Mite, rust	Adult, nymph	*Malus, Picea, Prunus* (flowering plum), *Pyrus*
Mites, two-spotted spider	Adult, nymph	*Caragana, Carpinus, Cotoneaster, Gleditsia, Malus, Populus, Potentilla, Prunus* (flowering plum), *Robinia, Rosa, Salix, Sorbus, Spiraea, Viburnum*
Phylloxera, oak leaf	Adult, nymph	*Quercus*
Psyllid, pear	Adult, nymph	*Pyrus*
Scale, cottony maple	Nymph	*Acer*
Chewing Insects		
Beetle, cottonwood leaf	Adult, nymph	*Populus, Salix*
Beetle, elm leaf	Adult, nymph	*Ulmus*
Bug, boxelder	Adult, nymph	*Acer*
Fly, walnut husk	Adult, nymph	*Juglans*
Moth, codling	Adult, larva	*Malus*
Skeletonizers, apple & thorn	Larva	*Malus*
"Slugs" (sawfly larva)	Nymph	*Prunus* (flowering plum), *Pyrus*
Webworm, fall	Larva	*Acer, Betula, Crataegus, Fraxinus* (green ash), *Juglans, Malus, Populus, Prunus* (flowering plum), *Quercus, Sorbus, Syringa, Tilia, Ulmus*
Borers		
Bark beetle, pine	Adult, larva	*Pinus*
Borer, peach tree	Adult, larva	*Prunus* (flowering plum)
Borer, poplar	Adult, larva	*Populus*
SEPTEMBER – OCTOBER		
Sucking Insects		
Adelgids	Adult, nymph	*Picea, Pseudotsuga menziesii*
Aphids	Adult, nymph	*Acer, Cornus, Fraxinus* (green ash), *Picea, Spiraea, Viburnum*
Mite, rust	Adult, nymph	*Picea*
Mites, spider	Adult, nymph	*Malus, Sorbus, Spiraea*
Mites, spruce spider	Adult, nymph	*Abies, Juniperus, Picea, Pseudotsuga menziesii, Taxus, Thuja*
Chewing Insects		
Fly, walnut husk	Adult, nymph	*Juglans*
Webworm, fall	Larva	*Populus, Prunus* (flowering plum), *Sorbus, Syringa*

Diagnosing Crop Disorders

Monitoring is a very useful technique to identify crop disorders. However, it takes an experienced pest manager to be able to know what type of information to collect to accurately identify the cause of a disorder. Correct identification of the cause(s) of a disorder is essential to develop a control strategy. For instance, caterpillars (larvae of butterflies and moths; order Lepidoptera) and sawfly larvae (order Hymenoptera) are very similar in appearance. However, pesticides containing *Bacillus thuringiensis* (e.g. Dipel, Foray) are only effective on Lepidopteran caterpillars. The pest manager needs to be able to differentiate these two pests to select an effective insecticide. Sawfly larvae have 6 or more pairs of prolegs without crochets and Lepidopteran larvae have 5 or fewer pairs of prolegs with crochets (Figure 5.3).

Figure 5.3. The larvae of the Pine sawfly have 8 prolegs.

Diagnosing crop disorders requires a logical thought process that includes several distinct steps.

1. Identify the host plant. Many insects and diseases are host-specific; therefore knowing the host plant will allow you to quickly limit the number of suspected causes.
2. Identify the location and extent of damage on individual plants and in the plant population. This information can be used to differentiate between damage caused by living (biotic) and non-living (abiotic) factors. Damage caused by pests usually has a random, non-uniform distribution on a plant and within a plant population, and often occurs on one crop. Damage caused by abiotic factors is often uniform in distribution, and occurs on more than one type of plant and at one point in time. Abiotic disorders are caused by environmental stress, mechanical damage and chemical factors. Abiotic disorders cannot be corrected by the application of pesticides.
3. Collect information on any excavation work, herbicide applications, etc. that may have recently occurred in the area. Look for patterns of damage associated with changes in soil texture or grade.
4. Note signs and symptoms of damage on the host plants and use this information to determine the cause. Ensure that you observe the plant's root system, too. Root injury often leads to foliar damage.

   Insects can be divided into two groups based on the type of plant damage caused by their feeding activities. These groups are the piercing and sucking insects, and the chewing insects. Chewing damage is caused by a broad group of insects, and the symptoms can vary from small, irregular notches, to large chewed areas or leaf skeletonization. It is very difficult to identify the cause of leaf chewing from the symptoms alone, with perhaps the exception of leaf notching by root weevils. Signs of the causal agent are required. Chewing-like damage can also be caused by abiotic factors (e.g. freezing damage during the bud stage). A diagnostic symptom of insect chewing is the presence of necrotic tissue on the perimeter of the damaged area, which is a result of the cells being ruptured by chewing.

   Piercing and sucking mouthparts can produce a range of damage symptoms, including:

   - leaf and growing tip distortion (e.g. curling, crinkling, stunted internodes) is common after feeding from true bugs, aphids and thrips;
   - toxic reaction of leaf leading to yellowing and premature leaf fall; and
   - the formation of galls and bladders – galls can be produced in response to disease and insect pests. Galls are often solid if caused by a pathogen and are compartmentalized if they are associated with insect activity.

   Remember that insect damage can remain long after the causal pest is gone.
5. Sometimes specialized lab skills are required to identify the causal agent and the services of a plant diagnostic lab may have to be used.

Knowledge of Insect Life Cycles

Knowledge of pest life cycles is critical for making pest management recommendations. Insecticide and miticide applications must be timed to occur when the majority of the pest population is vulnerable to chemical control. Often the egg and pupal stages are resistant to pesticides.

Precise timing is even more important when releasing biological control agents or using specific, non-residual pesticides, such as soap or horticultural oils. Published information can help pinpoint each pest's susceptible stage to a part of a month, but to narrow the ideal application time to a few days, crop monitoring must be done.

After a pest control treatment is applied, always monitor its effect afterwards. Keep dated records of pest problems and the stages of crops attacked, since this information can be used to predict future pest problems.

Timely Use of Control Tools

Chemical control should be used only if the other methods are shown to be inadequate. This is particularly true in a landscape situation where the public may be directly impacted by the application of pesticides, and where guidelines for pesticide application in public areas requires that people be informed about pesticide use. In general, if a pesticide needs to be used, select one that has low toxicity to humans and non-target organisms, and that has low residual carry over and minimal adverse effects to the environment. Pesticide recommendations for ornamental crops are provided elsewhere in this guide and will not be discussed in any detail in this section.

Biocontrol agents can be a viable alternative to pesticide use for some pests. There is increasing interest in their use in landscapes and nurseries.

Biological Control

The term "biological control" refers to the use of natural enemies to suppress pests. Biological control tactics include both conserving naturally occurring beneficial organisms and introducing commercially reared beneficials. Pest control based on the release of biological controls was pioneered by the greenhouse sectors. It has been proven effective at maintaining pest levels below their economic threshold.

The release of beneficials is best suited to enclosed structures.

The successful use of introduced biological control agents in ornamental crops is dependent on a number of factors. The pest level that can be tolerated in a crop is important because a biological control program seldom eliminates every pest. The range of insects, mites and diseases that a crop is susceptible to must be considered, as compatible control methods must be available for all potential problems. The use of biological control is best suited to long-term crops because the predator and the parasitoids must go through at least one generation to buildup to effective levels and establish a dynamic equilibrium between pests and beneficials over time.

Biological control is not a "silver bullet" that will solve all pest management problems. The method may need to be restricted to certain stages (e.g. propagation) or areas of production. Some advantages of applying a biological control program are the corresponding reduction or elimination of pesticide use, improved worker safety, the lack of re-entry intervals with beneficials, and the potential to use the program as a public relations tool.

Some reasons why the use of beneficial organisms may result in inadequate pest control are:

- the pest was incorrectly identified, which resulted in the use of the incorrect biological agent,
- the environmental conditions were not suitable for the biological agent,
- host plant interference (the biological did not like the taste of the crop),
- pesticide residues on plants negatively affected the beneficial organisms,
- the beneficial organisms were released too late or in too low numbers,
- biologicals were sick or dead upon arrival,
- unexpected pests interfered with control, and
- the goals and expectations of the program were not realistic.

Beneficial insects are a valuable addition to many pest control programs. The following information is a review of practices to increase the positive impact of beneficials in nurseries and landscape settings, and a description of the most common beneficials found in British Columbia.

Building a Resident Population of Beneficial Insects

A favourable environment will attract beneficial insects to a nursery or a landscape setting. For most predators the immature stages feed only on pests. The adults often feed on flower pollen. For example, the female syrphid fly requires flower nectar to produce eggs. Thus, the fly will be attracted to a site with flowers and will feed before searching for an aphid colony to lay eggs.

Techniques that can be used to build a resident population of beneficial insects include diversifying the garden landscape, planting appropriate flowers, retaining banker plants and releasing commercially reared beneficial organisms.

Diversifying the garden landscape: Crops or landscapes that have little plant diversity are less desirable to beneficial insects. A diverse landscape with a variety of flowers, shrubs and trees, and small sources of water will provide shelter, alternative food sources, overwintering sites and water for predator insects. A succession of flowers over the season will provide a continuous supply of pollen and nectar for feeding adults.

Planting appropriate flowers: Many researchers have examined the value of different flowers to attract predator insects. For example, clover, buckwheat and yarrow are excellent flowers to attract minute pirate bugs, an important predator of nursery and flower production. Dill, fennel and yarrow attract lady beetles, syrphid flies and parasitic wasps. Table 5.9 provides a list of flowers that attract beneficial organisms.

Retaining banker plants in the nursery: Plants already colonized by aphids, thrips or spider mites will attract beneficial insects. Keeping a few infested plants will allow the predator population to increase and disperse over the rest of the site. If two adjacent areas are infested with the same pest problem and a pesticide application is planned, the manager can treat one area first and wait 1-2 weeks to treat the second area to preserve the resident beneficial insect population.

It is important to be patient and allow nature to do its work. The goal of sound pest management is to keep the situation under control and prevent plant damage, not to wipe out all insects.

Table 5.9. Flowers and shrubs that attract beneficial insects.

Alyssum	*Lobelia*
Achillea	*Lobularia maritima*
Anthemis tinctoria	*Monardia*
Aster	*Phacelia*
Aurinia saxatilis	*Potentilla*
Calendula	*Reseda odorate*
Ceanothus	*Rudbeckia*
Chrysanthemum maximum	*Schizanthus*
Chrysanthemum parthenium	*Sedum*
Coreopsis	*Tagetes*
Cosmos	*Thymus*
Heliotropium arborescens	*Verbena*
Iberis	*Veronica*

Source: *Integrated Pest Management Manual for Landscape Pests in British Columbia*

Releasing commercially-raised beneficial insects: Purchasing beneficial insects is a good method to augment the resident population of predators and parasites. This practice is commonly used for greenhouse crops and in specific landscape situations. However, not all situations are favourable to this practice. For instance, many species of lady beetles sold by insectaries, such as the convergent lady beetle (*Hippodamia convergens*), will instinctively fly away upon release and will provide little benefit to a small outdoor landscape. The aphid midge is another predator of aphids. It requires open soil that is not disturbed at the base of the plant to complete its life cycle. Use of aphid midges is most appropriate in greenhouses or rose gardens, rather than in field production or street plantings, although it is effective outdoors during the warmer summer months.

Using Pesticides Selectively

Pesticides are important in pest management programs, but they can be harmful to naturally occurring predators and parasites. In many situations, an outbreak of aphids or spider mites can be traced back to a pesticide application that destroyed the population of beneficials.

At times a pesticide application will be required to control a pest. The pest manager should use strategies that minimize the impact of pesticides on beneficial organisms. This includes treating problems early in the season and using pesticides with short residual activity or low toxicity to beneficials.

Treating problems early in the season: Some pests become active many weeks before their predators. To prevent pests from causing injury to crops, it can be important to treat them early in the season. For example, aphids emerge from overwintering eggs at bud break on *Cornus* and *Viburnum*. Aphid feeding early in the spring will cause deformed leaves that will be present for the rest of the year. For these crops, therefore, it is necessary to apply a knockdown product at bud break to control the early flush of aphids. Later in the season, native aphid predators and parasites can be effective, season-long controls, provided they are not disrupted by a mid-summer pesticide application.

Aphids appear during summer months on plants such as *Potentilla* and *Spiraea*, which is a time when large numbers of predators are present. A pesticide application may not be necessary during this period.

Using pesticides with low residual periods: Careful selection of pesticides is required to minimize their impact on beneficials. Select a pesticide that is systemic or has a short residual period. Dormant oil and insecticidal soap are relatively compatible with an integrated pest management program. These two pesticides have short residual activity, allowing the population of beneficials to re-establish soon after the treatment. Applying a pesticide as a spot treatment is another approach to reduce the quantity of pesticide used on a crop. This can also be achieved by applying a systemic pesticide as a trunk band or as a soil drench treatment.

Using pesticides of low toxicity to beneficials: Pesticides vary in their toxicity to predators and parasites. Generally, broad-spectrum products, which control a large variety of pest problems, will kill predators and parasites whereas narrow-spectrum products are less harmful.

Native Beneficial Organisms

(Adapted From: Lanthier and Jensen, 2001, *Nursery IPM Project*, #300050)

Pest managers should strive to preserve and enhance populations of beneficial organisms when designing pest management programs. In order to accomplish this goal, the pest manager must be able to recognize different stages in the life cycle of beneficials.

There are numerous native beneficial organisms that help to reduce pest outbreaks on nursery crops. Information on a few of the more common and effective native beneficial insects is presented below. There are also many books and pamphlets available that show the life stages of beneficial insects.

Aphid Midges (*Aphidoletes* spp.)

Identification: The adult is a small (2-3 mm), night-flying fly that resembles a mosquito. It has long, slender legs and beaded antennae, which are often curled back over their heads. The bright-orange larvae are legless and very small, less than 3 mm in length. The tiny eggs are orange and oval. *Aphidoletes* eggs and larvae are always found amid an aphid colony, whereas a similar insect, the apple leaf midge, is usually found inside rolled leaf edges and is a pest of *Malus* trees.

Figure 5.4. Aphid midge larvae (left, orange insect) feeding on an aphid.

Preferred Food: The larvae are predaceous and feed on over sixty species of aphids. *Aphidoletes aphidimyza* is particularly effective on the green peach aphid, whereas *A. colemani* provides better control of the melon aphid. The larvae puncture the leg joint of aphids and inject a paralyzing poison before sucking the body fluids, leaving only a shriveled, black corpse. They are voracious, eating up to fifty aphids per day and often killing more aphids than they eat. The adults do not prey on insects but feed on honeydew and nectar. The adults require nectar or honeydew to lay eggs.

Life Cycle: *Aphidoletes* overwinter as pupae in soil or debris and emerge in early June when daylight is longer. The adult is very efficient at locating aphid-infested plants. *Aphidoletes* prefers large aphid colonies for egg-laying. The number of eggs deposited is directly related to the size of the aphid colony. It will lay between 150-200 eggs over a 10 day lifespan. The eggs incubate for 2-5 days and larvae feed for 7-14 days before dropping to the ground to pupate. High mortality of the larvae will occur if they land on a dry, clean surface (e.g. plastic). Pupation requires 7-21 days. The duration from egg to adult is approximately 20 days. There are 3-5 generations per year.

Status in Ornamental Plants: *Aphidoletes* are very effective predators that can bring an aphid problem under control within a few days. When present on a plant, they should be allowed to do their work without interference from toxic pesticides.

For nursery and landscape managers, it is challenging to see them. The adults fly mainly at night, and the young larvae are so tiny they are often hidden beneath aphids.

Aphidoletes are available from commercial insectaries. They are sold in the pupal stage in a carrier. Since they require open soil at the base of the plant for pupation, they are well-suited for use in greenhouses and landscape beds. When used in a greenhouse, sprinkle the carrier on the soil in a shaded, moist area. It is recommended to release adult flies in the landscape, which can be done as follows:

- Store the container in a cool location to allow adult flies to emerge from the pupae.
- In early morning or late afternoon, release the flies by placing the opened container in a shaded location at a plant infested with aphids.
- Once the release is complete, store the closed container in a cool location.

This procedure can be repeated daily as more adults emerge. It may take 7-10 days for all adults to emerge. The impact of *Aphidoletes* can take up to one year to manifest but is sustained for many years once they are established in a landscape.

Carabid Ground Beetles (*Pterostichus* spp., *Carabus* spp., etc.)

Identification: There are about 20 different species of carabid ground beetles. They range in length from 2-30 mm. Their larvae are hairless and have pincer-like jaws.

Figure 5.5. An adult carabid ground beetle. (Photo: D. Raworth, AAFC)

Preferred Food: The diet of some species consists of 90% animal matter and they consume 3 to 4 times their body weight each day. Both the adults and larvae attack a wide range of pests, such as aphids, caterpillars, mites, slugs and weevils. Since they emerge in summer, they cannot be relied on to control weevils early in the season.

Life Cycle: Many are nocturnal and often live in the soil. They breed in the spring or fall. Adults emerge in July and August, and live 2-4 years. Leaving some weeds between rows (e.g. white clover and pigweed) will help to attract and conserve ground beetles in the field.

Green and Brown Lacewings (*Chrysoperla carnea, Chrysopa oculata, Hemerobius pacificus*)

Identification: There are three common species of lacewings in British Columbia, two green and one brown.

The adult green lacewing is bright green with a long, thin body that is 10-20 mm in length. The eyes are golden or red incandescent, the antennae are long and delicate, and the wings are large, green and lacy. The adult brown lacewing has a brown body with pale brown wings. It is typically smaller and less common than the green lacewing.

The eggs of all species are white and laid singly or in groups. Those of the green lacewing are typically attached by a stem that is 8 mm long to the underside of a leaf, whereas the eggs of the brown lacewing are not.

The larvae have an alligator-shape with distinctive legs and mandibles, and a long, pointed head. When mature, the larvae are 6-10 mm in length, and are pinkish brown to cream in colour with darker markings.

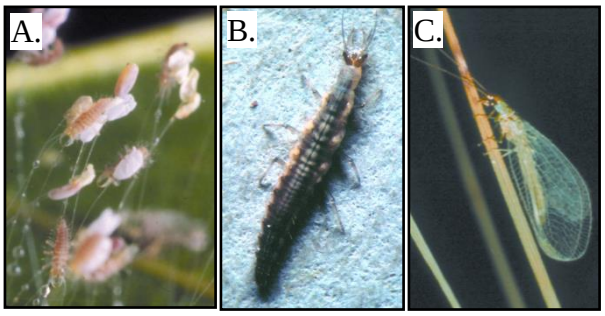


Figure 5.6. Lacewing eggs (A), larva (B), and adult (C). (Photo (right): D. Gillespie AAFC)

Preferred Food: Although aphids and mealybugs are their preferred source of nourishment, both green and brown lacewings will also feed on mites, scale, thrips, leafhoppers, psylla and small caterpillars. When prey is scarce, the adult *Chrysopa* species can feed on honeydew, nectar and pollen. Lacewing larvae puncture their prey and suck out the internal fluids. Green lacewing larvae are capable of consuming 20-100 aphids per day.

Life Cycle: Lacewings overwinter as pupae or adults. They are usually seen during the summer months, more often at night, as they are attracted to light. The females can lay 100-200 eggs, with development time from egg to adult being approximately one month. Some lacewing adults can live for many months.

The larvae are sometimes seen as early as April, being one of the first active predators in the spring. However, this insect is more common in August and September.

Status in Ornamental Plants: The adult green lacewing is among the prettiest insects of nature. The delicate, transparent green wings stand up high above the insect body. Many field workers will recognize the cluster of eggs hanging on threads on the underside of leaves. This predator is usually found in low numbers and cannot provide a stand-alone control of aphids or mites.

Lacewings are available from insectaries for commercial releases. Cannibalism is a problem, as the larvae are generalist feeders and the first to emerge will happily consume the other larvae in the shipment. Many field experiments indicate that releasing adults is not a practical option as they immediately fly away before depositing eggs.

Jumping Spiders (Salticidae)

Identification: There are several types of jumping spiders. They range in size from 3-15 mm, and are hairy and often brightly coloured. They are excellent jumpers and retreat when disturbed. Jumping spiders are active during the day, especially when warm and sunny. They produce silk shelters under objects or in crevices, but do not produce webs.

Preferred Food: Jumping spiders stalk and attack prey. They feed on a range of insects, including beetles and treehoppers.

Lady Beetles

Lady beetles are also called "lady bugs" and "ladybird beetles". There are many species of predaceous lady beetles. This section covers the common, twice-stabbed and *Stethorus* lady beetles.

Common Lady Beetle

Identification: The adults are oval, rounded beetles, with more than 500 species known to occur in the United States and Canada. They vary in length from 4-10 mm and display a variety of colours, including black, red, orange-red and yellow. Many species have a characteristic wing colour and number of black spots on their wings, but other species show a large variation in the colour and number of spots.

The larvae have an alligator-like shape. At first they are black, have short hairs and spines on their backs, and have well-developed legs. The later instars are grey to blue-black with orange markings. The pupae are often found hanging from leaves and bark and are orange-red with black markings.

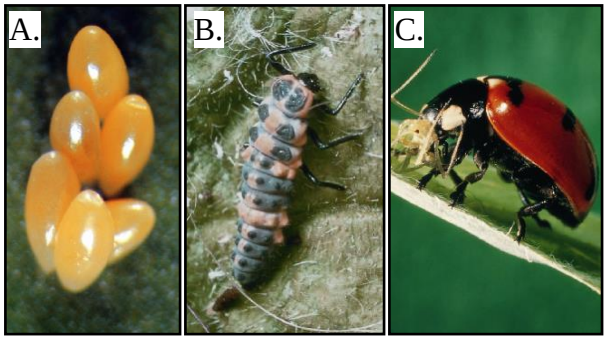


Figure 5.7. Lady beetle eggs (A), larva (B), and adult (C). (Photos: D. Raworth, AAFC)

Preferred Food: Both adults and larvae feed on aphids, spider mites, scales and mealybugs. Adults chew the body parts and can eat up to 3,000 aphids in their lifespan. Full-grown larvae can suck the body fluids of approximately fifty aphids per day. When prey is in short supply, the adults can

survive for a short period on pollen and nectar.

Life cycle: Lady beetles overwinter as adults and become active early in the spring. An adult female will lay 10-50 yellow to orange elongated eggs in a cluster, often on the underside of a leaf. The time span from egg to adult is usually 20-35 days. The adults can live one to two months and under ideal outdoor conditions, there may be up to six generations per year.

Status in Ornamental Plants: The lady beetle adult is the first predator of the season and can be seen in early April. They can multiply to large numbers in a short time and continue to forage for aphids all through the summer. The public easily recognizes this predator.

Nursery and landscape managers should learn to recognize the larval stage of lady beetles. The alligator-shape, blue to black with orange markings, is typical of this predator. There are many situations where toxic pesticides are applied to control "bugs" that turn out to be lady beetle larvae.

Different species are available from insectaries for commercial release. The species collected in the mountains of California often fly away from the point of release before searching for food, making them less useful in open areas. Recently, the Asian lady beetle (*Harmonia axyridis*) became available through some suppliers and is said to remain at the site of release.

Twice-stabbed Lady Beetle (*Chilocorus stigma*)

Identification: The twice-stabbed lady beetle exhibits the standard lady beetle body shape and is 5 mm in size, but has a characteristic shiny black body with two red spots on the wings. The larvae are alligator-shaped with prominent spines and often go unnoticed as they hide under the body of their prey.

Preferred Food: *Chilocorus* spp. commonly feed on scale insects. They will also prey on aphids, adelgids and other soft-bodied insects.

Life Cycle: The twice-stabbed lady beetle overwinters as an adult and appears very early in the spring, often in early April. It is commonly seen on plants with a high population of overwintering scale.

Status in Ornamental Plants: This pretty lady beetle is a joy for landscape managers. It is a common sight in juniper plantings affected by juniper scale. Feeding by adults and larvae can provide reasonable control of scale crawlers.

Stethorus Lady Beetle (*Stethorus picipes, S. punctum, S. punctillum*)

Identification: The *Stethorus* lady beetle, also called "the spider mite destroyer", is up to 1.5 mm long. It exhibits the standard lady beetle body shape but has a shiny black body with pale, tiny hairs.

The larvae are dark grey to brown and covered with a plentitude of fine hairs. The pupae are dark orange to black and are covered with fine hairs.

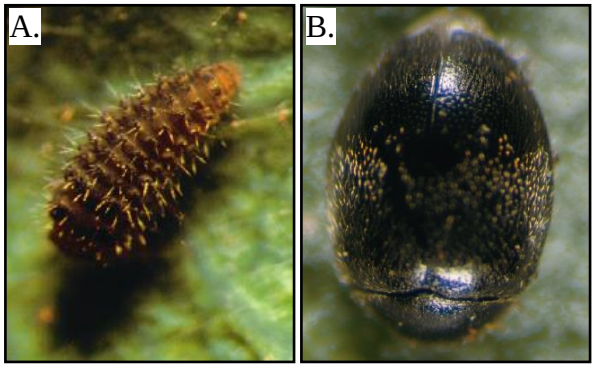


Figure 5.8. *Stethorus* larva (A) and adult (B). (Photos: D. Raworth, AAFC)

Preferred Food: *Stethorus* lady beetle adults and larvae prey almost exclusively on spider mites. An adult may consume 20-60 spider mites and lay up to ten eggs per day over a three-month period. The older larvae can eat up to 250 mites per day.

Life Cycle: *Stethorus* beetles overwinter as adults in leaf litter. The females will lay their eggs in a spider mite colony. Development from egg to adult is 2-4 weeks, depending on temperature, resulting in a number of generations per year.

Status in Ornamental Plants: The species is very common on plants with a high population of spider mites. It provides relatively good control on mature plants in landscape areas, but it usually does not appear in adequate numbers early enough in the season to prevent damage on young nursery plants.

Pirate Bugs (*Orius tristicolor, O. insidiosus, O. minutus*)

Identification: The *Orius* adult is oval, flat and has a narrow, pointed head. The wings are held flat on the body at rest and they are black with white diamond marks vaguely resembling a typical pirate flag. Adults are small and range in size from 2-3 mm. They tend to move rapidly.

The nymphs are pear-shape and orange or yellow in colour. With a size range of 1.8-3.7 mm, they are tiny insects but are visible to the naked eye.

Preferred Food: Both the adults and nymphs are predaceous insects. The nymphs can feed on thrips, whiteflies, small caterpillars, insect eggs, aphids and adelgids. They can consume up to 30 spider mites per day. When prey is abundant, the nymphs will kill more thrips than it needs to consume.

Life Cycle: The adults overwinter under bark or in ground litter. Emerging in late spring, the female adult can live for 3-4 weeks and lays her eggs into plant tissue. Development time from egg to adult is 3-6 weeks, resulting in 3-4 generations per year.

Status in Ornamental Plants: *Orius* are the unsung heroes of nursery production, both in the field and in containers. Both the adults and nymphs can be very abundant on plants that have thrips, spider mites or aphids. It can survive on flower pollen when there is no prey.

Pirate bugs are available from insectaries for commercial release. They have proven to be effective for greenhouse release to control thrips. They should not be used deliberately in conjunction with predatory mites, on which they can feed.

Deraeocoris and *Anthocoris* Species

Identification: The adult has an oval-shaped, flat body that is 4-6 mm in length. They have a black head and body and a tan wing pattern. The adult *Deraeocoris* is twice as large as and stouter than the adult *Anthocoris*. Nymphs are pinkish-grey when they first emerge and turn to a light grey with darker marking as they grow. They resemble pirate bug larvae but are larger, roughly 4 mm in length.

Preferred Food: They can consume aphids and other soft-bodied insects, but their preferred diet includes mites (30 or more a day) and pear psylla (especially the eggs).

Life Cycle: Species of *Deraeocoris* and *Anthocoris* overwinter as adults and become active when daily temperatures exceed 10°C. Egg incubation usually takes three days, and development from egg to adult requires approximately 20 days. Nymphs can be present in late spring and late summer as two overlapping generations can occur during the year.

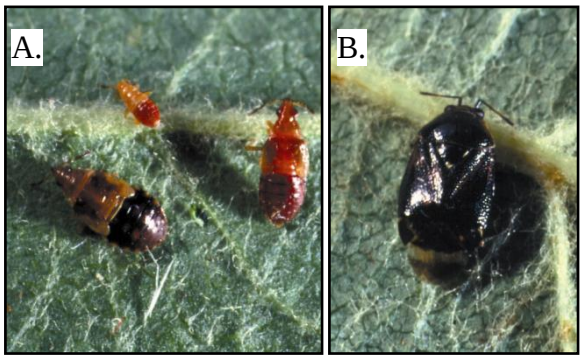


Figure 5.9. Three *Anthocoris* nymphal instars (A) and adult *Deraeocoris brevis* (B). (Photo: ICMI)

Status in Ornamental Plants: They are occasionally seen in landscapes and nurseries. However, they are far more common in tree fruit orchards and are an important predator of pear pests.

Parasitic Wasps (Braconids, Chalcids, Ichneumonids)

Identification: There are thousands of parasitic wasp species, which differ in biology, host and appearance. Some are endoparasitic, developing within their host, while others are exoparasitic, developing on the outside of the host.

Adult wasps range in size from 1-35 mm long. The small species are difficult to see with the naked eye. The damage done by the larvae or emerging wasp is usually more obvious than the adult.

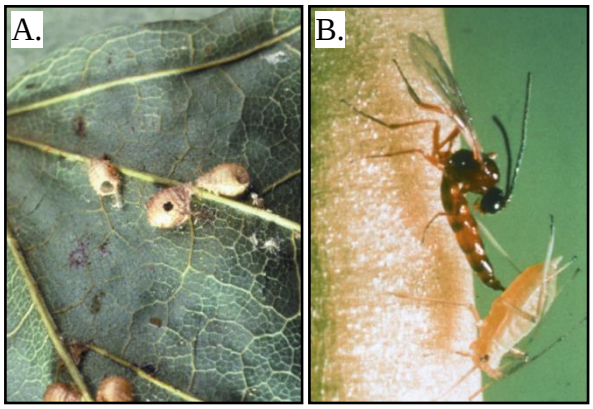


Figure 5.10. Aphid mummies parasitized by a *Trichogramma* wasp (A) and a parasitic wasp laying its eggs in an aphid (B).

Preferred Food: Parasitic wasps are grouped in three insect families.

The Ichneumonid wasps are parasitic to the egg and larvae of caterpillars and beetles. The female adult has a long, needle-like egg-laying structure at the back of the abdomen (ovipositor).

The Braconid wasps inject their eggs into a broad host range, including caterpillars, flies, beetles and aphids. In some cases, they emerge early to pupate in cocoons adjacent to the host carcass. Infected or parasitized aphids ("mummies") appear swollen, tan or black in colour and shell-like. An exit hole will be present if the adult wasp has already emerged or the larva has left to make a cocoon. The presence of mummies amidst an aphid colony is an indicator that other "healthy" aphids may also be parasitized and will soon die.

The Chalcid wasps are very small and parasitize a wide range of caterpillars, flies and some beetles. A well-known member of this family is the *Trichogramma* wasp, which lays its eggs inside the eggs of many moths and butterflies.

Life Cycle: The life cycle and number of generations per season varies depending on the parasite species.

In general, the female deposits one or more eggs into the body of a host insect, be it an aphid or a caterpillar. Upon hatching, the larva feeds on the internal organs of the host in such a way that the host remains alive during parasite development. In some cases, the dead host serves as a house for pupation. The adult parasite emerges later, leaving behind a mummified host carcass or a cocoon.

Status in Ornamental Plants: Parasites are efficient warriors that can devastate an aphid colony within days. The presence of a few mummified aphids is a sign of doom and gloom for the colony. Unfortunately, the parasitic wasps tend to arrive after the aphid population has built to large numbers. Landscape and nursery managers must show patience to allow the parasites to establish. Most pesticides kill parasitic wasps. Using a toxic product to control an aphid outbreak will destroy the resident parasite population and may trigger future flare-ups of aphids.

Predatory Mites (*Amblyseius/Neoseiulus* spp., *Hypoaspis* spp., *Phytoseiulus persimilis*, *Typhlodromus* spp., *Zetzerllia mali* and others)

Identification: Most predaceous mites have a pear-shaped body and a reddish or translucent colour, although they can also be opaque white when they are not feeding. They are larger than their prey, the adult being 0.25-0.4 mm in length, and are typically more active and shinier than the pest mites. Predatory mite eggs are shiny, oval and colourless to opaque white.

Figure 5.11. A predatory mite. (Photo: D. Raworth, AAFC)

Preferred Food: Predatory mites feed on all stages of plant-feeding mites, including rust mites, two-spotted spider mites, McDaniel mites and European red mites. Some species feed on fungus gnats and thrips.

Life Cycle: Predatory mites overwinter as adults under the bark and other refuges. They emerge early in the spring and feed on early-season rust mites and two-spotted spider mites. The development time from egg to adult is 7-21 days depending on temperature, allowing for 6-10 generations over the course of the year.

Status in Ornamental Plants: Predatory mites are very common in all nursery and landscape settings and provide more benefits than most managers realize. Many outbreaks of spider mites can be traced back to an application of a pesticide that eliminated the predatory mites, allowing pest mites to cause damage in the absence of natural control.

The population of predatory mites can build to large numbers when there is an abundant supply of prey. A ratio of 1 predator mite to 30 or 40 spider mites is often sufficient to obtain effective control within a few days.

Various species of predatory mites are available from insectaries for commercial release. Each species has a preferred range of relative humidity, temperature, and prey. The supplier can suggest the predatory mite that would be the most effective for each situation.

Neoseiulus fallacis has been shown to be an effective biological control agent of multiple spider mite species on shrubs and perennials in a study conducted in Oregon (*J. Econ. Entomology*, 2002,

95:1135-1141). It was less effective on conifers and shade trees, especially on tall plants with a sparse canopy. Control by *N. fallacis* is also known to be reduced on widely spaced plants, and on rhododendron cultivars that have sticky new growth. A threshold of 1 mite per 5 leaves is sufficient to feed the predator and to not cause significant plant damage (Rosetta, 2004 CanWest Horticulture Show).

Syrphid Flies (*Syphidae* spp.)

Identification: Adult syrphid flies resemble bees or wasps in their colour pattern but are usually smaller and have only one set of wings. They are also referred to as "hover flies", because of their ability to hover in flight. Their body length ranges from 8-15 mm. Hundreds of species have been identified in North America.

The white, elongated eggs are normally laid singly among aphid colonies. The larvae are legless, have a tapered and flattened body that is 10-15 mm in length at full size, and exhibit varying colours of white, yellow, green and brown. These maggots sway their pointed heads from side to side to search for prey or when disturbed.

The pupal stage is smooth, cigar-shaped and light to dark brown in colour.

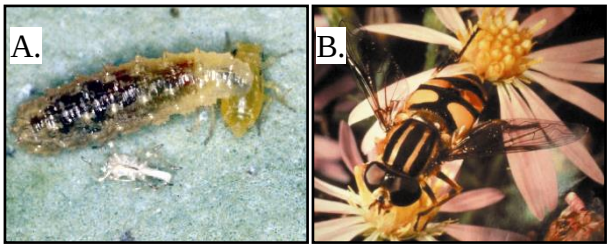


Figure 5.12. Syrphid fly larva (A) and adult (B). (Photo (right): AAFC)

Preferred Food: Syrphid adults feed strictly on flower pollen and nectar but the larvae are voracious aphid feeders. Despite being legless, the larva is very efficient at finding its prey and can consume 200-800 aphids in a 10-day period. When aphids are in short supply, some species can survive on flower pollen. The syrphid larvae can also feed on caterpillars, thrips and sawfly larvae.

Life Cycle: Syrphid flies overwinter as mature larvae, pupae or adults. The adults can be seen as early as April and both adults and larvae are found in large numbers in May. The females require pollen to produce eggs, laying 400-1,000 single eggs amid aphid colonies over a lifespan. The eggs require only a few days to hatch and the larval stage last 7-10 days. Pupation occurs in a dark place such as a rolled leaf or in the soil litter and takes about one week.

The total duration from egg to adult is 2-4 weeks with approximately 4 generations per year.

Status in Ornamental Plants: Syrphid flies are one of the most effective aphid predators of ornamental plants, both in nurseries and in landscape settings. They can be found in large numbers throughout the province at all times between April and October. When they are present on a plant, they can provide control of an aphid problem within a few days.

Larvae can be mistaken for caterpillars, but they are legless, usually in the middle of an aphid colony, and have a characteristic tapered body shape.

Having plants in bloom is a good method to increase the resident population of this predator, as the adult females feed on the flower pollen before laying eggs. Plants such as yarrow, flowering buckwheat, and members of the carrot and dill family have shallow nectarines that provide accessible food sources for the adults.

Building a Nursery IPM Program

(Adapted From: Lanthier and Jensen, 2001, *Nursery IPM Project*, #300050)

Every nursery should have an integrated pest management (IPM) program. When introducing a program into their operation, the nursery should keep it simple, only focusing on a few plants and their associated problems. This will allow the nursery management to become familiar with the process without introducing too many changes simultaneously. A nursery IPM program can be implemented in the following stages: have a crop monitoring and recording program; correctly identify the problems; make use of biological control; and, if needed, select the least-toxic pesticide to treat the problem.

This section is designed to be a step-by-step process to start and develop a program that is successful and adaptable to the special needs of each nursery.

Crop Monitoring

Monitoring is the regular inspection of plants to detect problems caused by pests or environmental disorders, and without it an IPM program does not exist. For general information about monitoring, see *Monitoring Crops for Pests* in this chapter.

The aim of monitoring is to detect plant problems early and to gather information to assist the site manager to make sound pest management decisions. If successful, the plant problems will be found at the nursery, not by the customer receiving a shipment. The following steps are useful when developing a monitoring procedure.

Dedicate one person to monitor the nursery: The most effective way to build a successful IPM program is for nursery management to assign one person the task of crop inspection. This person, often called a "scout", must be given enough time to tour the facility and look for plant problems. This time must be dedicated exclusively to monitoring. The scout should not be expected to perform other duties such as shipping, pruning or weeding during the inspection.

Allocate the required amount of time for monitoring: Each nursery must determine how much time is necessary to conduct adequate monitoring. Some nurseries require one day every second week, while others need two days per week. The length of time required will depend on the number of potential pest problems, which will be related to the number of crops grown and the season of the year. Typically, a nursery growing many different crops will have more pest problems than a nursery growing few crops. Also, since there are more pests in the spring than summer, monitoring in the spring can take twice as long as in the summer.

Learn to recognize "normal" from "not normal" plant growth: The scout must be able to recognize plant problems at their early stages of development, which requires the ability to differentiate "normal" from "not normal" growth. Many problems first appear on the newest foliage. Damage symptoms to look for are pierced, deformed or discoloured leaves. The pest symptoms and signs listed in Tables 5.4 and 5.5 can assist in diagnosing crop disorders.

Use a variety of monitoring methods: There are many different ways to monitor plants and different problems require different monitoring methods. Some of the most common monitoring methods are to:

- visually inspect plants for damaged leaves or other plant parts, and the presence of insects or disease,
- tap branches to dislodge insects above a white sheet of paper attached to a clipboard,
- use sticky or pheromone traps to capture the adult stage of many insects,
- use indicator plants to monitor specific insect pests at the most appropriate times, and
- watch for weather conditions that favour the development of certain diseases.

More monitoring methods for use in the field and greenhouse are presented in Tables 5.2 and 5.3.

Seek the observations of field supervisors: Most nurseries have field personnel and supervisors dedicated to specific production areas. They look at the plants on a daily basis and will notice when a pest infestation is starting or when a plant is becoming "not normal". The scout should regularly discuss crop conditions with field staff, as their observations are a time-saving method to identify potential pest problems.

Examine plants with many predator insects: In their adult stage, many predator insects are very efficient at finding small infestations of aphids, spider mites and thrips. An abundance of predators in a bed of plants is a warning signal that a pest problem may be developing.

Use appropriate field equipment: The following tools are useful for field monitoring:

- A hand lens (16x) to examine insects and disease structures in the field,
- Sharp and clean hand pruners to collect samples,
- Containers and bags to store samples,
- A trowel and a shovel to examine the soil at the base of the plants, and
- A notebook and a pen to record observations and counts.

Identification of Plant Problems

Different problems require different solutions. The proper identification of the problem is the first step before selecting a treatment that will be effective. For example, spraying for insects will not solve a plant problem caused by a disease.

Proper identification serves many purposes. If the

problem is caused by an insect, the site manager can examine the life cycle of the pest and apply a treatment at the most vulnerable growth stage of the pest. If the problem is caused by a disease, the site manager can modify growing practices to reduce the conditions that favour disease development.

The following are useful approaches for identifying plant disorders (for additional information, see *Diagnosing Crop Disorders* in this chapter).

Look at the whole plant, not just the top growth: A thorough examination of the plant is often the only way to obtain an accurate diagnosis of the underlying problem. Many plant problems are caused by environmental factors that cannot be fixed by spraying pesticides. For example, a plant that is wilting may suffer from the lack of water in the soil, or may have root rot from excess water, or may have root damage caused by rodent feeding.

There are many other reasons to examine a plant thoroughly. Insects such as leafhoppers and sawflies hide on the underside of the leaves during their young stages and are normally not detected until they have caused serious damage.

Make counts of plants with pest problems: Counts are a written record of the type and number of pests found and the number of plants affected. They also make a useful permanent record to verify whether a problem is increasing or disappearing, or whether a pesticide application has been effective.

The monitoring scout should check enough samples to have data that is reasonably accurate in order to justify any treatments. The number of samples will vary with each problem and the expertise of a scout. Twenty samples may be sufficient in some situations, whereas five hundred samples may be required in others.

Use appropriate laboratory equipment: Have a work area that includes a table, shelves and a refrigerator. This space is used to examine plant parts more closely and to store samples. Have a dissecting microscope to assist with pest examination and identification. Build a library of books and articles that have colour pictures, technical descriptions or control recommendations.

Seek professional help with difficult problems: A person observing a plant problem for the first time may find it strange and mysterious, but a more experienced individual will provide a rapid diagnosis and suggest effective control options. Seeking this expertise can be a time-saving process. The scout should develop a list of contacts in the area that can help with specific problems. The Ministry's Plant Diagnostic Lab, based in Abbotsford, provides a fee-for-service to industry professionals for diagnosis of plant problems.

Treatment of Plant Problems

When pest levels justify it, a treatment may be necessary to aid in fixing a plant problem. There are many situations where non-chemical approaches can be effective and adequate. For example, pruning out infected plant parts can successfully control some diseases. With insect pests such as aphids and spider mites, naturally-occurring predators can provide acceptable control when the pests are in low numbers.

Pesticides should be used as a last resort when other methods are not practical in an IPM program. Pesticide treatment is more common in commercial nurseries than in landscapes, as the cost of application is spread over hundreds of plants.

Below are a few useful steps when using pesticides to treat pest problems.

Use pesticides only when justified: There are three common situations that justify the use of pesticides in a nursery.

1. Apply a pesticide to control a pest problem that can seriously damage a plant. Insects such as bark borers, sawflies and root weevils can kill an affected plant. In most cases, the only effective control is to apply pesticides at the proper time in their life cycle.
2. Apply a pesticide when the pest problem is present on plants ready for sale. Some insect problems that may be minor in nursery production can trigger complaints by customers. Aphids and thrips are examples of minor pests that should be controlled before the plants are shipped.
3. It may be necessary to apply a pesticide to manage a pest problem that bothers nursery workers. Aphids on the new growth of field-grown trees will cause little damage to the plants but will annoy the workers who walk through the plants for routine activities such as pruning or tying.

Use pesticides in the safest possible way: Pesticides are chemical products that may be toxic to people and the environment. It is important to use pesticides in a safe way. Follow label instructions for application rates and safety precautions. When a pesticide is applied, ensure the area is clear of people, and follow provincial regulations for restricted re-entry intervals. Generally, the re-entry interval is 24 hours for most herbicides and fungicides, and 24-48 hours for many insecticides (WorkSafeBC Regulations). Note that the re-entry interval may be different on the pesticide label. Use the re-entry interval on the label if it is longer than the WorkSafeBC interval.

Whenever possible, select a pesticide of low toxicity to preserve naturally-occurring predators and parasites. These insects help control many common pests such as aphids, spider mites and thrips, and are easily killed by pesticide products of moderate or high toxicity.

Verify the treatment was successful: An IPM program will be adopted by nursery management if pest problems are properly controlled. It is important to examine the plants following a pesticide application to verify the effectiveness of the treatment.

A pesticide application that was not successful can often be traced back to a faulty application. Common errors include driving the tractor too rapidly, not getting thorough coverage of the plants or plugged nozzles.

Build a calendar of pest problems: Each nursery has its particular set of pest problems and pest problems change with the seasons. Some pest problems return every year during the same period. By keeping a record of the date of treatment applications, a monitoring scout can inspect the plants only when seasonal pest problems are present and have a program in place before the pests arrive.

In this publication, you will find examples of seasonal pest problems for plants in the Lower Mainland (Table 5.7) and the Southern Interior (Table 5.8) of British Columbia.

Ask the question: Can the problem be controlled in the future without pesticides? In some cases, pest problems come back every year and the only option is to apply a pesticide at the proper time. In other cases, the production practices can be modified, for example, by dropping a plant variety that is very susceptible to aphids, or by changing the irrigation scheduling to prevent leaf spot infections.

Chapter 6 - General Disease Management

This chapter contains a description of and management recommendations for common diseases of ornamental plants. Refer to the publication *Crop Protection Guide for Nursery and Landscape Plants* for a listing of the pesticides registered to control bacterial and fungal diseases.

BACTERIAL DISEASES

Bacterial Blight/Canker

Hosts: This bacterial disease is caused by *Pseudomonas syringae* pv. *syringae* under cool and wet conditions. It attacks at least 40 species of woody deciduous nursery plants. It is a major problem on ornamental maples, lilacs, flowering cherries and oriental pears in the Lower Mainland, but rarely occurs in the Interior.

Symptoms: Blackening (or browning) of new shoots and tip dieback are the most common symptoms on *Acer, Cotoneaster, Euonymus, Forsythia, Magnolia, Populus, Prunus, Pyrus, Rosa, Rubus, Syringa* and *Vaccinium*. Other symptoms include blossom blast on pear and leaf spots and vein blackening on *Acer, Cornus, Magnolia, Tilia,* and *Populus*. *Malus* is less susceptible. Blossom blight, blackening of buds, leaf shot-hole and stem or trunk cankers with gum exudation are common on *Prunus*.

Disease Cycle: In Coastal British Columbia, symptoms appear on new growth from March to June under cool, wet conditions. The pathogen spreads in water and enters young buds, wounds and leaf openings. Once the weather turns hot and dry, the pathogen ceases to cause new infections, although the disease remains "latent" in previously infected plant tissues. Leaf abscission scars can be infected in the fall on some hosts, such as *Acer palmatum*, although symptoms may not be apparent until spring.

The pathogen passes the summer and winter on and inside twigs and buds. Ice-nucleating strains of the bacterium have been shown to increase susceptibility of plants to frost injury. On the other hand, damage from bacterial blight is often worse following a late spring frost or cold period.

Disease Management: Chemical control is more often needed on young trees and shrubs rather than on older, established plants. Pseudomonas blight can often be controlled on mature trees and shrubs with timely pruning and by maintaining good plant health. Leaf spotting and even some shoot dieback in the spring do not usually cause long-term damage to mature plants and rarely requires chemical control. Mature trees may require treatment if shoot damage has been severe the previous year, to prevent recurring blossom blast, if larger branches are dying back, and if the trees are growing under other stressful conditions that increase their susceptibility.

Management options for bacterial blight and canker include:

1. **Freezing:** Protect frost-sensitive plants from cold temperatures and ice formation in early spring and fall.
2. **Weeds:** Control weeds around susceptible nursery stock. Weedy areas become frost pockets. *Pseudomonas syringae* has also been shown to survive on many weeds.
3. **Pruning:** Minimize pruning wounds because they provide an entry point for bacteria. Pruning tools can spread bacteria. Make sharp cuts and disinfect pruning tools between cuts, especially when working with symptomatic trees. Use a 10% solution of household bleach (corrosive to metal objects), or Lysol, or other disinfectant. Prune back to green tissue below the cankered or dead area of the limb.
4. **Timing of Pruning:** Prune trees in January or February, or in mid-summer when weather is dry. Peach trees pruned in fall/early winter have been shown to have more damage from bacterial blight than trees pruned in January or February (*Hortscience*, 1976, 11:103-104). The number of *Pseudomonas* bacteria on plants is highest in the spring, so pruning in March/April has the greatest risk of spreading infection.

5. **Nutrition and Management:** Provide optimum nutrition, good drainage and growing conditions and add lime to increase soil pH if necessary. Weak, poorly growing trees sustain more bacterial blight damage. Do not fertilize after July, as this will result in overly succulent growth in the fall, which is more susceptible to blight and cold damage. Space plants for good air circulation. Remove and destroy dead twigs and fallen leaves.
6. **Cauterization:** On orchard-grown stone fruit trees in New Zealand, burning *Pseudomonas* cankers with a hand-held propane burner has been shown to limit spread of cankers and prevent girdling of cankered branches. The tissue around the burned area callused quickly and, 2 years later, showed no signs of infection (*Plant Disease Reporter*, 1976, 60:60-61). This might be a useful treatment option for larger landscape trees.
7. **Resistance:** Rootstocks and varieties of some flowering cherry and oriental pear species have shown resistance to *Pseudomonas syringae*. 'Kwanzan' cherry is susceptible when young but often develops resistance as the tree matures.

Crown Gall

Hosts: Crown gall disease is caused by a soil-borne bacterium called *Agrobacterium tumefaciens*. Over 600 plant species in more than 90 families can be infected. Common hosts include *Aster*, blueberry, *Chrysanthemum, Cydonia,* daisy, *Euonymus*, *Juglans, Juniperus, Malus*, marigold, *Prunus, Pyrus*, raspberry, *Rosa, Salix* and *Vitis*.

Symptoms: Galls develop on the crown and roots, or in some cases on the shoots and branches. Galls are usually soft, spongy and white at first, but later turn hard and brown. They range in diameter from a few millimeters to several centimeters. Infected plants often show symptoms of nutrient deficiency, such as yellowing of leaves, followed by a general decline and stunting. A large gall at the crown may be more damaging than several smaller galls on roots or stems, since it interferes with the main vascular system of the plant.

Disease Cycle: The bacterium can survive for at least 2 years in soil. They spread on diseased nursery stock, in irrigation or ground water and on cultivation and pruning equipment. The bacteria infect roots and crowns, often entering through wounds caused by pruning tools, insects, freezing or pathogenic nematodes.

Rain splash can move bacteria from soil to stems and leaves where they can infect through wounds or stomata. Upon infection, the bacterium inserts specific bacterial genes into the genome of plant cells, which stimulate the cells to divide rapidly, producing a tumour-like growth that contains more bacteria. As galls break down in the soil, the bacteria are released.

Diagnosing crown gall is difficult because some plants that are susceptible to infection can also produce gall-like plant growths due to other factors. If in doubt as to the cause of galling, it is best to obtain a laboratory analysis to confirm crown gall. It may not be possible to recover *Agrobacterium tumefaciens* in laboratory culture from older galls. There are also saprophytic strains of this bacterium in soil that do not cause disease.

The Ministry's Plant Health Lab can confirm the presence of *A. tumefaciens* using a PCR–based molecular diagnosis.

If a definite diagnosis is not possible, the grower must decide whether or not to remove the plants, keeping in mind:

- the potential market or outcome for the plants - in a landscape situation, it may depend on the severity of symptoms expressed by the plants,
- whether there was a previous crown gall problem in that soil,
- the fact that large galls not due to *Agrobacterium* can also be damaging to plants, but won't spread to other plants,
- the risk of disease spread to other nearby susceptible plants through ground water, soil particles or plant maintenance activities, and
- as a general rule, if the galls appear only on the branches, main trunk, or only at the graft unions, and not on roots or crown, the cause is most likely not crown gall.

Disease Management:

1. Purchase new stock only from a reputable supplier. Plants grown in soil infested with crown gall may appear clean but can carry latent infections that will produce galling in subsequent years.
2. Inspect new stock for crown gall before planting and do not plant any with gall symptoms.
3. Avoid injury to roots and bark in the crown area when planting or cultivating, as this creates potential entry-sites for the bacterium.
4. If only a few plants are affected, remove and destroy these to prevent spread of infection. Remove all roots and soil from around infected plants and take to a landfill. Do not compost infected plant debris or soil.
5. If only a few branches are affected prune off the the infected branches. Sterilize pruners in 10% bleach (corrosive to metals), Lysol, 70% alcohol (2 minute exposure) or other disinfectant between cuts.
6. Do not take cuttings or propagate from diseased plants.
7. Do not re-plant susceptible species into previously infected soil for at least 2 years.
8. Rotate with grasses or small grains. Grasses do not develop crown gall disease, although they may harbour the bacterium.

Soil solarization has been successful in some areas on light, sandy soils, but it is doubtful whether the temperature would reach a high enough level in most British Columbia soils to kill the bacterium.

Galls Caused by Other Factors

Galls caused by factors other than crown gall can cause decline and weakening of plants. Roses can produce a gall-like growth at the graft that is a physiological reaction to an incomplete graft. Rhododendrons produce "tissue proliferation" galls on branches, roots, or at the base of the plant, which are believed to be caused by a genetic disorder and perhaps other environmental factors. Apples also produce various galls and burr-knots that are physiological or environmental in origin.

Forsythia commonly has small galls along stems and twigs caused by a fungus, *Phomopsis.* Leaf and bud galls on azalea, *Cotoneaster* and *Prunus* spp. may be caused by fungi such as *Exobasidium* and *Taphrina*. Trees and shrubs of the Legume family have nitrogen-fixing galls (nodules) on roots caused by a beneficial bacterium, *Rhizobium*. Root knot nematodes also produce small white galls on roots. Insects, such as midges, wasps and gall mites are a common cause of galls on stems and leaves.

Fire Blight

Hosts: Fire blight is caused by the bacterium *Erwinia amylovora.* It occurs only on members of the Rosaceae family. Common hosts in British Columbia include *Amelanchier, Cotoneaster, Cydonia, Crataegus, Malus, Photinia, Potentilla, Pyracantha, Prunus, Pyrus, Rosa, Sorbus* and *Spiraea*.

Fire blight rarely occurs in the cool and wet Lower Mainland region of British Columbia, but is common in the Interior.

Symptoms: The bacterium causes foliar and blossom blight, twig dieback and branch cankers. The succulent tips of blighted shoots often droop, forming a "shepherd's crook", and turn brown to black. Leaves remain attached to dead twigs. A cream or tan coloured ooze may be present at the edge of cankers and on young infected shoots.

Entire trees can sometimes be killed and rootstocks can also be infected. In rootstocks, *Erwinia amylovora* causes a crown necrosis that resembles Phytophthora crown rot.

Disease Cycle: *Erwinia* prefers warm, wet weather. New infections occur in late spring during periods of rain or high humidity when temperatures are greater than 18°C. The bacterium overwinters in infected wood. New infections occur through blossoms, shoot tips, young leaves and wounds. The bacterium can be spread to healthy blossoms by insects, such as aphids, flies, leafhoppers and bees, as well as splashing rain.

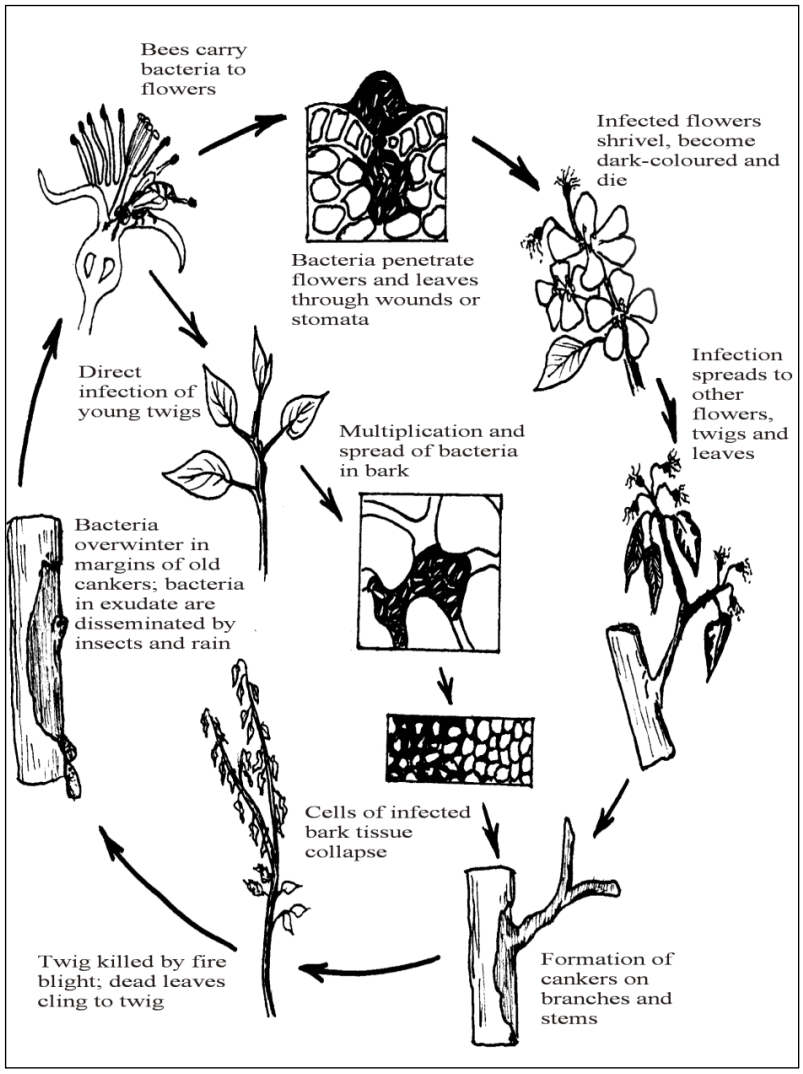


Figure 6.1. *Erwinia amylovora* disease cycle.

Disease Management: The Agriculture and Agri-Food Canada (AAFC) publication *Integrated Management of Fire Blight on Apple and Pear in Canada*, 2006 (AAFC No.: 10124E), provides current information on the management of fire blight.

1. **Blight Removal:** Cut out and burn or bury infected foliage and branches as soon as symptoms are noticed in late spring and throughout the summer. Do not combine with pruning. Make sharp cuts 15-30 cm or more below discoloured wood. Disinfect pruning tools between cuts with 10% household bleach (corrosive to metals), lysol, or other disinfectant. Disinfectant should also be applied to large cuts. Once weather turns cool in fall, inspect and cut out any infections missed earlier.
2. **Sanitation:** Eliminate old infected trees from the vicinity of new plantings and nursery stock.
3. **Plant Management:** Space nursery stock to provide good air circulation. Provide good drainage. Avoid overhead irrigation as much as possible or water early in the morning so foliage can dry off quickly. Use moderate amounts of nitrogen and do not fertilize after mid-summer to prevent excessive succulent shoot growth.
4. **Insect Management:** Control aphid, leafhopper and other insect infestations if this can be done without harming bees.
5. **Resistance:** Resistant varieties and cultivars are available. The publication *Integrated Management of Fire Blight on Apple and Pear in Canada* (2006) ranks apple and pear cultivars and rootstocks for their susceptibility to fire blight.

FUNGAL DISEASES

Botrytis Blight (Grey Mould) and Storage Moulds

Botrytis cinerea is a fungus that occurs wherever there is high humidity and soft plant material. The disease first becomes established on dying or dead tissue and then spreads to healthy leaves, petioles, stems, blossoms, buds, twig tips, fruit or seedlings. Infection first appears as water-soaked areas on soft or senescent foliage, flower parts or young stems. These areas turn tan to brown or greyish-white as they dry out. Fuzzy grey spore masses develop on infected tissues under cool, moist conditions. Spores are air-borne and can infect healthy plant tissues.

This disease is often a problem in overwintering polyhouses where stagnant moist air and day/night temperature fluctuations result in condensation on the plant. *Botrytis* can carry over on old plant debris and as sclerotia in the soil. Sclerotia can survive in soil for several years.

The disease is primarily a problem in container stock. However, dense seedling beds and closely planted landscape plants may also be affected. Because conifer seedling stock may be stored for a considerable period, *Botrytis* and other storage moulds are of major importance.

Symptoms initially develop on lower needles of bundled conifer seedlings, especially around the tie strings. Damage can quite often develop without conspicuous surface mould. The disease progresses to the shoots and stems, and the needles become watery and decayed. Affected needles normally fall off. Branches may have water soaked lesions from which the bark easily strips exposing the dead, butterscotch-coloured cambium. When cartons are opened there tends to be a musty odour.

Commonly affected woody plants include: *Alnus,* azalea, *Camellia, Cedrus, Cornus, Crataegus,* cypress, *Hibiscus, Hydrangea, Ilex, Juniperus, Prunus, Pseudotsuga, Pyrus, Rhododendron, Rosa, Syringa* and *Viburnum.*

Commonly affected flowering perennials include: *Aster, Chrysanthemum, Convallaria majalis*, *Dahlia, Dianthus, Paeonia*, statice, *Tulipa* and many herbs. The disease is called "fire" on *Tulipa* and *Narcissus*.

Disease Management:

1. Quickly remove infected plants or plant parts from production areas to reduce the spread of *Botrytis* spores. All dead leaves should also be removed.
2. Improve air movement around plants with good weed control and plant spacing/pruning.
3. Lower the humidity in greenhouses by increasing ventilation and air movement. *Botrytis* is favored by humidity levels of ≥ 95% for at least 3 hours; germination of conidia can be prevented by maintaining a humidity level of ≤ 80% (FlowerTech, 2003, Vol: 6: 15-17).
4. If practical, water only in the morning so plants dry off quickly.
5. The use of plastic mulch on containers has been shown to reduce the relative humidity around plants and to significantly reduce infection by *Botrytis* (FlowerTech, 2003, Vol: 6: 15-17).
6. Alternate fungicides with different chemistry and limit the application of any one product to two or three per growing season to prevent the development of resistant *Botrytis*.
7. Do not re-use soil or planting mix from plants that were infected with *Botrytis*.
8. Remove, burn or bury cull piles upon which the fungus can sporulate.

For conifer seedlings, a protective spray may be applied early in the season for bareroot stock. Daconil (chlorothalonil) or Rovral (iprodione) sprays may be necessary throughout the growing season for container stock. To help reduce the incidence of mould during cold storage, the crop should be treated before the lift with a spray of Rovral (iprodione). Do not harvest until seven days after fungicide application. It is especially important to treat any stock that has been infected with *Botrytis* during the growing season and stock that will not be frozen during storage.

Other recommended pre-storage treatments include:

1. Store stock for the shortest possible time.
2. Monitor stock regularly on a seedlot basis, particularly stock with frost or other damage.
3. Immediately ship and out-plant stock showing damage.
4. Coastal stock should be stored at 1°C while stock of Interior provenances can be stored at −2°C. This prevents mould growth

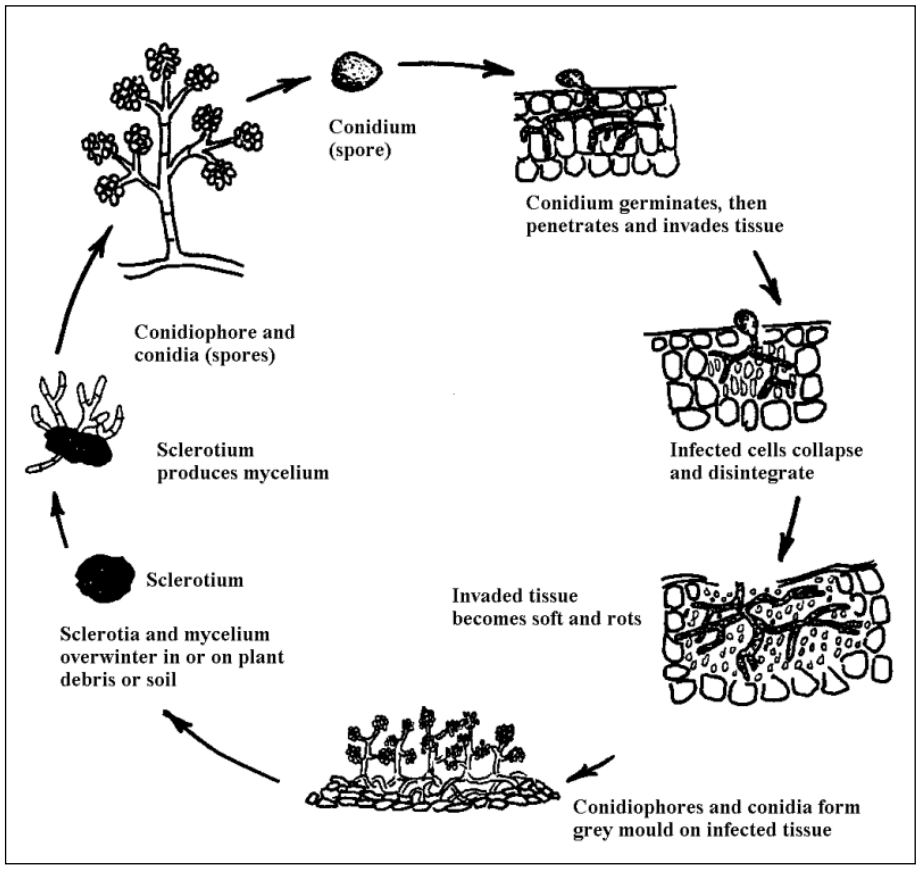


Figure 6.2. *Botrytis* life cycle.

Damping-Off of Seedlings

The pre-emergence form of this disease causes rotting of ungerminated seeds or germinants before they emerge, while the post-emergence form causes rotting of seedlings slightly above and below the soil surface causing them to topple over.

Many fungi are involved, including species of *Cylindrocarpon*, *Fusarium, Rhizoctonia, Pythium, Phytophthora* and other fungi.

Disease Management for Conifer Seedlings:

1. Sow stratified seed.
2. Sow at optimum temperature and apply a sterile sand cover.
3. Irrigate in the morning.
4. In severe cases, a captan treatment may be necessary.

Downy Mildew

Downy mildew diseases are caused by species within the Family Peronsporaceae. These are "oomycetes" or "protists", and are closely related to *Pythium* and *Phytophthora*. They are obligate pathogens and, as such, can only exist in an active form on a live host. They have no saprophytic ability; they cannot survive on dead plant tissue or other organic matter.

Hosts: Most downy mildews are specific to one host plant, but some can infect plants in several genera. Commonly affected ornamental plants include *Buddleia*, foxglove, *Hebe, Hellebore, Phlox*, *Rosa*, *Rubus*, snapdragon and many others. The disease has recently been found to infect basil and *Impatiens walleriana*, but not *Impatiens x hawkeri* (New Guinea impatiens), and is causing serious damage to both crops in regions of North America. In BC, the first detection of downy mildew occurred in 2012 on basil and in 2013 on impatiens.

Symptoms: Symptoms are variable and can include a downy, felt-like or powdery, white to gray growth on the underside of leaves; leaf and growing tip distortion; stunting and yellowing of plants; yellowing of leaves and early leaf drop; and/or purple spotting of leaves along the veins or mid-vein blotches. The symptoms can resemble nutrient deficiencies or soil/root problems caused by other factors. The pathogen may not sporulate on Rosa in the laboratory, so diagnosis can be uncertain. Cuttings from infected roses typically root poorly and die-off. Infected plants may not show symptoms when first planted, but do not thrive and gradually die out or continue to grow poorly after the first or second year.

Disease Cycle: Peronospora infect plants via air-borne sporangia that germinate and enter through leaves and stem buds, but then grow systemically, progressing down into the stems, crowns and even the roots. Infected mother plants that do not show serious symptoms can thus transmit the infection to cuttings, which die off after transplanting or continue to grow poorly. The disease is not known to be seed-borne. Optimum conditions for sporangial infection are cool temperatures (about 16^{o}C) and several hours of leaf wetness.

Many downy mildews also produce hardy oospores that can carry over in soil and plant debris for several years and provide a long-term source of inoculum.

Figure 6.3. Impatiens infected with downy mildew may appear off-color with a white mildew coating on the underside of the leaves (arrow); the leaves may turn yellow and then abscise.

Disease Management:

1. Avoid overhead watering in the evening when temperatures are cool. Use drip irrigation or water only in the morning so that leaves will dry off quickly when air temperatures are warmer.
2. Propagate only from seed or disease-free mother plants.
3. Remove perennial ornamental plants from the nursery that may harbour and spread the pathogen, or strictly isolate new production plants from the suspected plants.
4. Remove plant debris, including fallen leaves, in the fall that can harbour the pathogen, and put down new ground covers under containers. Relocate new plantings away from areas that have had downy mildew infected plants in the past.
5. Practice good plant sanitation practices in the nursery and polyhouse. Bury, burn or remove infected plants to a landfill. Do not allow cull piles or clippings to remain around the nursery. Practice good weed control and space plants to provide good air circulation.
6. There is little or no information on resistant varieties.

Keithia Blight

Keithia Blight, which is caused by the fungus *Didymascella thujin*a, is a foliar disease of western red cedar. Individual leaflets dieback and toxins produced by the fungus may kill heavily infected trees.

The fungus forms slightly swollen, circular, red-brown to olive-green or black spore-producing fruiting bodies on infected leaf scales. The fruiting bodies later drop out leaving shot-holes on the dead, white scales. The disease is most commonly found on two-year-old seedlings and usually starts on the lower foliage.

Disease Management: For conifer seedlings, cedar carried over from one year to the next is a prime source of the disease. Production of one-year-old rather than two-year-old stock may reduce disease incidence. Conditions of low density, low succulence, high light intensity and low humidity discourage infection and spread.

Nematodes

Nematodes are microscopic, worm-like organisms that are invisible to the naked eye. Nematodes are commonly thought of as solely a soil-borne pest. However, there are several foliar nematodes that damage ornamental plants, especially herbaceous perennials. Both types of nematodes have a wide host range.

Soil-borne Nematodes: They interfere with plant growth by feeding on plant juices from roots, migrating through root tissue, creating infection sites for root rots or wilt diseases, and transmitting viruses. Reduced plant vigour associated with high nematode levels is frequently blamed on other causes such as poor soil fertility, lack of moisture, insects, diseases or even soil exhaustion. The foliage of an infected plant may be chlorotic (yellow) and the plant may be stunted.

When soil-borne pathogens such as *Cylindrocarpon, Fusarium, Phytophthora, Pythium, Rhizoctonia* and *Verticillium* are present along with nematodes, the impact on the plant may be much greater.

Corky root disease is caused by a soil-borne nematode, *Xiphinema bakeri*. The nematode is confined to coastal bareroot seedling nurseries and the problem often occurs in nurseries established on recently-cleared forest lands. Nematode populations rarely reach damaging levels on the first crop, however subsequent production may be severely damaged if the land is continuously cropped.

Symptoms of corky root become apparent on Douglas fir midway through the first growing season, when secondary needles of random seedlings become chlorotic and shoots are stunted. Taproots have few if any laterals and are dark, swollen and often club-tipped, but not rotted.

If soil-borne nematodes are suspected of causing a problem, a soil and root nematode count should be done. Since nematodes tend to be spotty in their distribution, careful soil and root sampling is necessary in order to collect a representative sample. In general, nematodes tend to be located where the majority of roots are in the soil.

It must also be kept in mind when collecting a sample that more pathogenic nematodes may be inside root tissues than in surrounding soil in mid-summer. Nematodes move into roots in summer to reproduce and to escape dry soil conditions. The Ministry's Plant Health Lab can process root and soil samples for nematode count and identification.

Foliar Nematodes: There are several species of nematodes (*Aphelenchoides* spp.) that infect foliar and stem tissue of ornamental plants. Foliar nematodes enter plants through stomata and other openings. Once inside the plant, they pierce plant cells and feed on the contents. When there is a high population of nematodes in the tissue, they will migrate out of the leaf to search for another host.

The common symptoms of foliar nematode feeding are numerous, yellow to black, water-soaked lesions on a leaf. The lesions often have sharp borders that are restricted by main leaf veins. The patchwork appearance to the damage occurs because nematodes cannot get through large leaf veins, and are, therefore, confined to the space between veins.

Figure 6.4. The patchwork appearance of symptoms of foliar nematodes in a leaf of *Anemone* species.

Nematode Management: Soil-borne nematodes are not highly mobile pests. In general, they will only move about 15 cm per year on their own in the soil. Their primary mode of movement and spread is by physical movement of infested soil. Irrigation runoff and flood waters can spread nematodes. To reduce their spread, remove soil from equipment before moving it between fields.

Research in Ontario has shown that a cover crop of 'Crackerjack' or 'Creole' marigolds or Canadian Forage Pearly Millet '101' can significantly reduce the population of root lesion nematodes in soil (*Horticulture Review*, March 2001). The efficacy of the treatment does depend on soil and weather conditions during cover crop establishment.

Foliar nematodes can only move between plants when there is free moisture or high humidity, and when there is physical contact between the plants, which includes workers handling them.

1. Take steps to reduce greenhouse humidity.
2. Space plants to prevent contact between neighboring plants.
3. If the infestation is recognized early, removal of damaged leaves and stems may be sufficient, otherwise infested plants should be discarded.
4. Sanitation is critical since nematodes can survive in a dehydrated state in dead plant tissue for two years. Remove and destroy plant debris and have workers wash their hands before handling a clean crop.

For conifer seedlings, follow a three-year crop rotation with two years crop and one fallow to manage Corky Root. Thoroughly cultivate infested fallow areas during the hot dry period of August and September. Sample the fallow fields in early summer for nematodes. Preplant nematicide or soil fumigant may be applied. Do not transfer diseased stock among nurseries.

Powdery Mildew

Hosts: Almost every plant species, except conifers, is susceptible to a powdery mildew. With few exceptions, most powdery mildew fungi are very host specific. For example, the powdery mildew that infects rhododendrons will not infect roses. Under favourable environmental conditions, powdery mildew can cause significant plant damage. They are obligate pathogens and, as such, can only exist in an active form on a live host. They have no saprophytic ability; they cannot survive on dead plant tissue or other organic matter.

Commonly affected ornamental plants include *Acer*, azalea, *Betula, Ceanothus, Clematis, Cornus, Corylus, Gaultheria, Hydrangea, Kalmia, Lonicera, Malus, Nandina, Quercus, Rhododendron, Rosa, Syringa, Vaccinium* and *Viburnum*.

Symptoms: A powdery, chalky, white-coloured growth appears on the leaves that can resemble spray residue. The spores are usually seen on either the lower or upper leaf surface, but in some cases can appear on both leaf surfaces. Symptoms may appear first as only mild, diffuse yellow spotting on the upper side of the leaves.

The underside of these spots will show the typical white, powdery sporulation. In more severe cases, dwarfing, leaf and growing tip distortion, overall yellowing and severe browning of the foliage may occur. The fungus does not usually infect stems or cause twig or stem dieback.

Disease Cycle: High humidity, rather than free water, favours spore production and low humidity favours spore maturation and release. Warm days and cool nights are ideal for disease development.

In Coastal British Columbia, the disease can occur as early as January on some plants, such as rhododendron.

The spores spread mainly by wind and carry over on leaf debris and perennial foliage from year to year. When a powdery mildew spore lands on a susceptible leaf, it enters the leaf cells via a germ tube and then grows inside the leaf. About 5 to 10 days later, the fungus produces numerous propagules (spores) on the surface of the leaf, which is the chalky coating that is visible to the eye.

Spores can infect susceptible leaves whenever they land on them, so protectant fungicide sprays are often necessary to protect new spring growth before infection occurs.

Some powdery mildew fungi produce overwintering bodies that can survive on dead leaves.

Disease Management:

1. Plant disease-resistant hybrids or cultivars.
2. Prune out and burn or bury infected plant parts, if practical.
3. Rake up and burn or bury fallen leaves. In most cases, composting will destroy powdery mildew spores.
4. Reduce humidity by spacing plants for good air circulation and by adjusting irrigation practices.
5. Avoid planting host plants in shaded areas.
6. For roses, disease severity can be reduced by using a high-pressure hose to thoroughly wet all leaves and canes on a sunny afternoon, to permit quick drying of the leaves afterwards.
7. On severely affected plants, preventive fungicide sprays may be necessary. On landscape plants, 4% liquid sulphur (DOMESTIC) is effective.

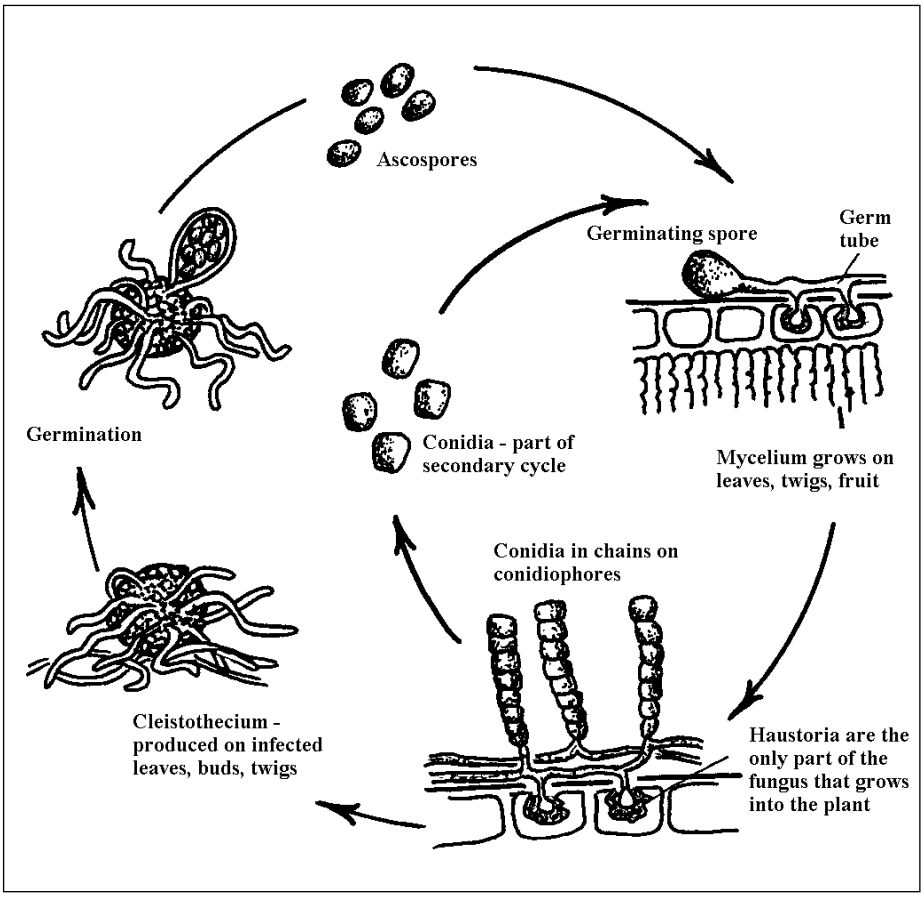


Figure 6.5. Powdery mildew life cycle.

Root Rot Caused by *Armillaria*

Hosts: Armillaria root rot occurs on over 700 species of conifers and cedars, hardwood trees, shrubs and berries. *Armillaria* is a native fungus in British Columbia soils and most often infects plants on newly cleared land. *Armillaria ostoyae* is the common species found in infected conifers in British Columbia, but other species may also attack berries, hardwood and fruit trees. (In older literature, the name *Armillaria mellea* was often used to refer to all species.) In landscape plants, the disease is most commonly found on conifers, *Malus, Quercus*, *Rubus* (blackberry, raspberry) and *Thuja*.

Symptoms: The first symptoms are leaf yellowing and wilting, and plant decline and dieback. Only one side of the plant may be affected. Cutting away the bark at or just below ground level reveals a white mat of fungal mycelium. Dark brown to black, shoestring-like strands of fungal mycelium called "rhizomorphs" may be visible in the mat or scattered around the base of the plant.

Rhizomorphs look more like plant roots when found in the soil. In the fall, a cluster of honey-coloured mushrooms may appear at the base of infected trees.

The pattern of disease can vary. Sometimes only one or two mature trees will die in a hedgerow, or a larger planting may be affected in a field.

Disease Cycle: The fungus spreads from plant to plant by means of the rhizomorph strands, which can grow for several meters through the soil. In the fall, the fungus may produce clumps of honey-coloured mushrooms at the base of the tree. The mushrooms produce air-borne spores that also spread the disease.

Armillaria can survive for many years on dead roots and old cane stubs. It is usually a disease of mature trees that are suffering environmental stress. Healthy, vigorous trees can often out-grow the infection until other factors, such as flooding, soil compaction, etc., inhibit root growth.

Other wood-rotting fungi can produce a white fungal growth at the base of dead or declining fruit trees, cane berries, roses and cedars. When rhizomorphs are not seen, these fungi are often mistaken for *Armillaria*. A laboratory analysis may be needed to identify *Armillaria*.

Figure 6.6. White mat of *Armillaria* mycelium underneath the bark of a blueberry plant.

Disease Management:

1. Water deeply when needed. Avoid surface watering around the crown and main trunk.
2. Remove infected trees, including roots, and soil in the root zone and re-plant with resistant species.
3. For oak and mature shade trees with early decline symptoms, it may help to remove any grass or ground cover and expose the soil in a 1-meter radius around the base of the tree. This will help keep the soil warm and dry and provide a less favourable environment for fungal growth.
4. When new sites are being cleared, avoid *Armillaria* root rot by:
    - Girdling large trees before removal so roots will decay.
    - Removing all roots greater than 2.5 cm (1 inch) in diameter.
    - Leaving the prepared site fallow for at least one year.

Root, Stem and Crown Rot Caused by *Fusarium* and *Rhizoctonia*

Fusarium species are a cosmopolitan group of fungi that can cause a wide range of disease symptoms. They cause root and crown rots, and stem cankers in ornamentals (see *Damping-Off*). Stem cankers caused by *F. lateritium* often produce a characteristic orange-colored mass of spores, but this is uncommon for *F. solani*.

Some species of *Fusarium* are primary invaders of healthy plants, whereas other species are weak pathogens or saprophytes, invading plants that are weakened by other causes.

As facultative parasites, they are very persistent. They can survive adverse conditions by entering dormancy as chlamydospores or in a saprophytic state on dead root fragments. In many conifer species, *Fusarium* can be seed-borne causing both pre- and post-emergence damping-off. As the disease proceeds, the xylem tissues in the plant are compromised resulting in their inability to move water and nutrients.

Some of the common hosts of *Fusarium* include: *Acer, Carpinus caroliniana, Cotoneaster, Euonymus alatus, Ficus, Fraxinus pennsylvanica, Hibiscus syriacus, Juglans nigra, Laburnum anagyroides, Liriodendron, Malus, Populus, Prunus, Quercus, Robinia pseudoacacia, Salix* and *Sorbus americana.*

Rhizoctonia is a soil-borne, cosmopolitan fungus that is primarily known as a root pathogen but that can also cause damping-off, foliar lesions, and stem cankers. It produces small (1 mm), black sclerotia that can survive adverse conditions. Infected roots typically have a reddish-brown "dry" rot. Cool, moderately wet conditions encourage *Rhizoctonia*. Infected plants may be stunted and chlorotic, and the stem may become constricted at the crown, which is referred to as wire stem. Azaleas are very susceptible to *Rhizoctonia*.

Disease Management: For conifer seedlings, a seed source can be screened for potential levels of *Fusarium* by measuring the level of inoculum on the exterior seed coat. If greater than 5% of the seed in a source test positive for *Fusarium*, then a number of actions are recommended: imbibe the seed in running water, sanitize all seeding equipment and growing containers, reduce early heat and water stress, and encourage rapid germination.

Root Rots Caused by *Phytophthora* and *Pythium* and Foliar Blight by *Phytophthora*

Phytophthora and *Pythium* are members of the "oomycete" group of protists, commonly called water moulds. There are many species of *Phytophthora* and *Pythium* that attack a wide range of plants.

Hosts: Woody plants are more commonly attacked by *Phytophthora* species and herbaceous plants by *Pythium*, but there are many exceptions. *Pythium* species can be present in dead roots and crowns of woody plants as secondary invaders, following Phytophthora root rot, other diseases or environmental damage.

Commonly affected plants include: azalea, *Calluna, Cedrus, Chamaecyparis, Cornus, Cotoneaster, Erica, Ilex, Gaultheria, Juniperus, Larix, Malus, Pieris, Pinus mugo mughus, Pseudotsuga, Rhododendron, Taxus* and *Thuja occidentalis* ('Smaragd').

In warm soils (>15°C), *Phytophthora cinnamomi* is a common cause of root, crown and foliar blight on a wide range of woody plants. At cooler soil temperatures, species such as *P. cactorum, P. megasperma, P. syringae* and *P. cryptogea* also have a wide host range. Other species have very specific hosts, such as *P. ilicis* on *Ilex* and *P. lateralis* on *Chamaecyparis lawsoniana*.

Symptoms: Root, crown and even foliar and branch or stem infections can be caused by these organisms. Plants with root rot typically exhibit drought or nutrient deficiency symptoms including yellowing, leaf drop, wilting and general decline. Infected leaves and shoots are often black and soft. Infection often spreads from roots up into the crown or base of the stem or trunk. Cutting into this area reveals a dark brown to black rot with a distinct margin between rotted and healthy tissue.

Ilex, Pieris and *Rhododendron* often develop foliar and stem blight. On *Cotoneaster* and *Ilex*, *Phytophthora* also causes a black fruit rot.

Disease Cycle: *Phytophthora* and *Pythium* spread via infected plants or through movement of zoospores or sporangia in contaminated soil, water and in wind-blown rain. Sporangia produce zoospores that infect roots and other plant tissues.

Phytophthora and *Pythium* produce thick-walled oospores that can survive in soil for many years. Infection is favoured by wet conditions in poorly drained soils and either in or under container-grown plants. In the landscape, root rot is also common in locations subject to drought in summer and excessive moisture in winter. Drought-stressed plants seem to be more susceptible to root rot infection when moisture is restored.

Phytophthora ramorum: This quarantine pathogen deserves special attention because of the negative impact it has had on West Coast nurseries. *P. ramorum*, the causal agent of Ramorum Blight and Dieback, causes foliar blights, stem lesions, trunk cankers, or shoot dieback on more than 70 plant genera. The California Oak Mortality Task Force web site is a good source of information on the disease.

P. ramorum is established in only a few counties in California and in Curry County, Oregon, but it is annually detected at nurseries in British Columbia, and California, Oregon, Washington and a few other US states. If the pathogen is detected at a nursery, retail or landscape site, federal regulatory officers implement harsh steps to eradicate the pathogen, which will include implementing site quarantine actions, including plant destruction.

The economic impacts of these actions are significant to the impacted site. To protect the sector from the pathogen, the industry developed a nursery certification program for *P. ramorum* in 2004. The program included nursery sampling, testing, record keeping, best management practices, and third-party auditing. The program no longer operates as a stand-alone program and has been integrated as a module of the Clean Plants Program, which is a broader nursery certification program. Information on the program is available on the Canadian Nursery Certification Institute website.

Nurseries are encouraged to be certified for *P. ramorum*, and purchasers of nursery stock are encouraged to buy from certified nurseries.

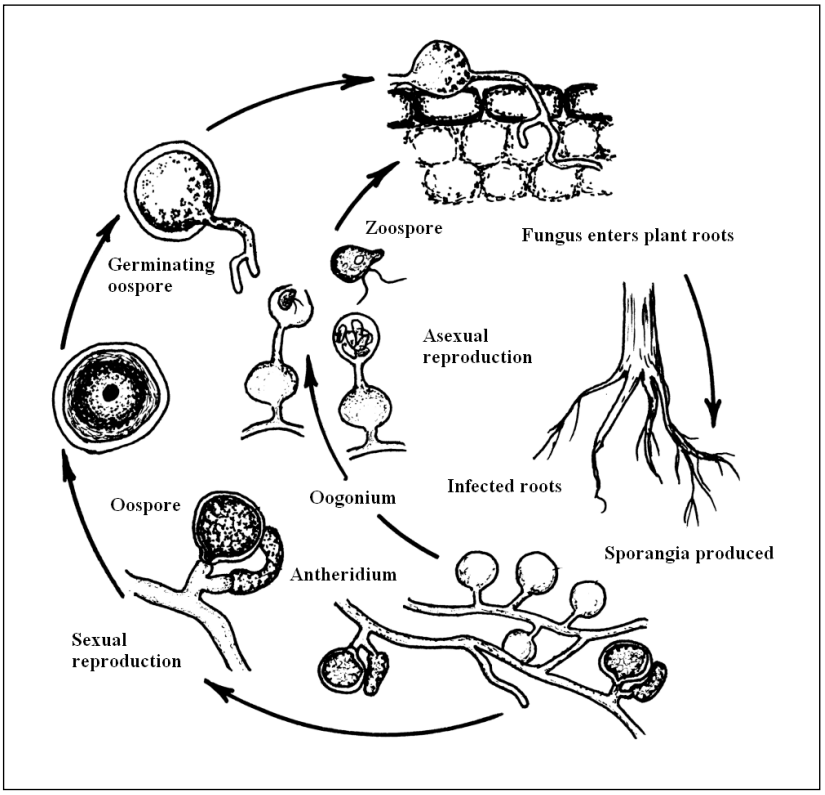


Figure 6.7. Pythium root rot life cycle.

Disease Management:

Nursery:

1. Participate in the Clean Plants Program. Information on the program is available on the Canadian Nursery Certification Institute website.
2. Disease-free stock plants should be used for propagation at all times.
3. Use strict hygiene in propagation, media preparation and potting.
4. Good drainage within and underneath the container is essential.
5. If plants become infected, do not move plants that are susceptible to *Phytophthora* into that bed until the drainage has been improved and fresh ground cloth has been put down.
6. Do not plant susceptible genera in soil contaminated with *Phytophthora*.

Landscape: Foliar Blights

1. Prune and space plants for good air circulation.
2. Control weeds and grasses around plants to reduce humidity.
3. Remove and destroy fallen leaves and dead twigs during summer.

Landscape: Crown and Root Rot

1. If crowns are not damaged, improving drainage at the site can sometimes allow plants with root rot to recover.
2. Replacing plants:
   - Remove all contaminated soil and roots beyond the root zone of the dead plant.
   - Replace with clean soil.
   - Replant with healthy stock or resistant varieties/species. Late spring or early fall are the best times to plant to avoid both heavy rains and summer drought.
   - Do not apply excessive fertilizer, which can burn new roots.
3. Water or irrigate to prevent both long periods of soil wetness and drought stress. Watering in the morning is better than evening, as it allows excess water to evaporate more quickly. Giving plants a thorough soaking every few days is better than watering every day. Drip irrigation, if run for several hours at a time, is very conducive to root and crown rot.

Rusts

Rusts are a highly specialized group of fungi. They have complex life cycles with several spore stages. Some can continually infect one host plant species from year to year, while others must complete their life cycle on different host plant species each year, in order to cause infection.

Rust fungi appear as white, yellow, orange, red or brown raised pustules on leaves, buds, fruits and stems. The pustules often have a powdery appearance and are easily visible to the naked eye. Identification of rust fungi to species usually requires a laboratory examination. Even then, a definite identification to species may not be possible if only one spore stage is present.

There are two foliage rusts (*Melampsora medusae* and *M. occidentalis*) that commonly occur in forest nurseries. They attack Douglas fir, western larch, tamarack, ponderosa pine and lodgepole pine. Both rusts have yellow-orange spore-producing pustules on the needles in late spring to August. They require the alternate host *Populus* and occur predominantly in bareroot nurseries located in forested areas.

Western gall rust is caused by the fungus *Endocronartium harknessii*. It affects two or three-needle pines, primarily in bareroot nurseries. On seedlings, the rust causes globose galls or swellings on the stem or branches. Because there is an interval between infection and development of conspicuous galls, the disease is rarely noticed until late in the second growing season or until the seedlings are lifted, graded or outplanted. Stock leaving the nursery should be disease-free to prevent spread to disease-free forests.

Table 6.1. Common rusts of ornamental plants.

Rust	Host(s)
Alder rust (*Melampsoridium betulinum*)	*Alnus*, *Betula, Larix*
Black stem rust (*Puccinia graminis*)	wheat, *Berberis*
Cedar-apple rust (not known to be present in BC) (*Gymnosporangium juniperi-virginianae*)	*Malus, Juniperus*
Clavariform rust (*Gymnosporangium* spp.)	*Amelanchier, Crataegus,* Rosaceae species, *Juniperus*
Daylily Rust (*Puccinia hemerocallidis*)	*Hemerocallis*
Douglas fir needle rust (*Melampsora* spp.)	*Pseudotsuga, Populus, Larix, Picea, Pinus, Tsuga*
Heuchera rust (*Puccinia heucherae*)	*Heuchera,* other Saxifragaceae species
Hollyhock rust (*Puccinia malvarearum*)	*Althea,* other Malvaceae species
Hypericum rust (*Uromyces triquetrus*)	*Hypericum*
Juniper rusts (*Gymnosporangium* spp.)	*Amelanchier, Chaenomeles, Juniperus, Crateagus*, *Sorbus*
Mahonia rust (*Cumminsiella mirabilissima, Puccinia graminis* and *P. brachypodii*)	*Mahonia*
Pear trellis rust (*Gymnosporangium fuscum*)	*Pyrus, Juniperus*
Rose rust (*Phragmidium* spp.)	*Rosa*
Rhododendron rust (*Chrysomyxa* sp.)	*Rhododendron, Picea*
Western gall rust (*Endocronartium harknessii*)	hard pine
White pine blister rust (*Cronartium ribicola*)	5-needle pine, *Ribes*

Disease Management:

1. Plant disease-resistant hybrids or cultivars.
2. For rusts that continually re-infect the same host plant species, a dormant season cleanup of all diseased leaves is very important.
3. For rusts with two hosts, control usually involves removing the less important host from the vicinity of the more economically important one (the one which is being grown as a crop). Junipers and ornamental pears should not be planted within 300 meters of each other in Coastal British Columbia.
4. White pine blister rust kills eastern white pine (*Pinus strobus*) and western white pine (*Pinus monticola*) and other 5-needle pines. Wind-blown spores can spread for several kilometers. *Ribes* spp. should never be grown within 1,000 metres of white pines, or in white pine forest areas such as northern Vancouver Island and Interior valleys.
5. Use a surfactant to improve fungicide penetration into the rust pustules, unless the pesticide label states to **not** add a surfactant.

For conifer seedlings, eliminate the alternate hosts in the immediate vicinity of the forest nursery. If practical, rake and burn the fallen leaves of *Populus* trees.

For Western gall rust, remove all infected pines for 300 metres around the nursery. Cull and destroy all gall-bearing seedlings. Fungicide treatments are usually not practical.

Sirococcus Blight

This disease is caused by *Sirococcus conigenus.* It affects Sitka, white and Englemann spruce; lodgepole and yellow pine; and rarely western hemlock. It is often seed-borne in spruce. It has also been associated with tip dieback of *Cedrus* spp. in landscape plants in Coastal British Columbia.

The symptoms and time of appearance differ for container and bareroot seedlings. In containers, it is randomly distributed affecting young seedlings and killing the primary needles from the base upwards. Depending on the state of progress, the upper needles may be green. Affected tissues are light to reddish brown and seedlings remain upright.

In bareroot and Interior container nurseries, the symptoms usually appear in late summer through fall in one-year-old stock or in rising two-year-old stock. Fall symptoms may be confused with early frost damage, but the pattern of development on the shoot is the same as in container seedlings.

Disease Management: For landscape and nursery plants, prune out infected branch tips and apply a protectant fungicide in early spring, where practical. For conifer seedlings, check that the seed from a given seedlot has been assayed for *Sirococcus*. Keep a close watch on emerged seedlings and when the disease appears, remove and burn diseased plants and inform the seed source of the disease outbreak in the seedlot. Reduce humidity and if practical increase illumination.

Verticillium Wilt

Hosts: Two species of *Verticillium* fungus (*V. dahliae* and *V. albo-atrum*) cause wilting on woody plants. Of these, *V. dahliae* is the most common. This species produces microsclerotia that can carry over in soil for up to 10 years. *V. albo-atrum* persists in the soil for 1-2 years, and is most commonly found on alfalfa. These fungi attack many deciduous trees, herbaceous perennials, berries, weeds and vegetables, but do not infect conifers, cedars or grasses.

Other hosts of the *Verticillium* fungi include potatoes, peppers, tomatoes, raspberries and strawberries. Nursery or landscape trees planted on land previously cropped with these plants have a high risk of developing the disease.

Verticillium wilt is not a problem in container production unless infested soil, compost or wood chips have been used for potting or mulching.

Commonly affected woody plants in British Columbia include *Acer, Aesculus,* azalea (rhododendrons are generally resistant), *Catalpa, Ceanothus, Cercis, Liriodendron tulipifera, Magnolia, Paeonia, Photinia, Prunus, Rosa,* sea buckthorn, *Syringa, Tilia* (it has been found infected in British Columbia, although some lists identify it as resistant), *Viburnum* and *Weigela.*

Symptoms: The fungus enters the roots and moves upward in the plant, plugging up the plant's vascular system. Often the first symptoms seen are nutrient deficiencies, yellowing, wilting and dieback of young twigs and branches, often on one side of the plant or tree. These symptoms are easily mistaken for root rot, frost damage, soil fertility, drought stress or other problems. Diseases such as bacterial blight and cankers caused by fungi often attack weakened twigs, so *Verticillium* can be easily overlooked as a primary cause. However, with Verticillium wilt, the dieback becomes progressively more severe from year to year. Cutting into woody stems with a knife reveals black or brown streaks in the wood or vascular cambium, often in nodes where branches or stems diverge, but these are not always visible.

Disease Cycle: *V. dahliae* produces black "microsclerotia" that survive for up to 10 years in soil. *V. albo-atrum* does not produce sclerotia so soil is usually infested for only one or 2 years with this species. Both fungi also produce spores (conidia) in and on infected plant tissue. These tiny spores spread through air and in ground and drainage water and cause new infections through roots.

Infection can also be spread through grafting. Spores, mycelium and microsclerotia can survive in debris from infected plants, such as chipped branches used for mulching or incorporated in planting media.

Mature landscape trees with Verticillium wilt will sometimes "wall-off" the infected branches and survive for many years. Other trees may totally succumb within a year or two of the first twig dieback.

Disease Management:

It can be impossible to eliminate all *Verticillium* microsclerotia from infested soil.

1. Remove the infested roots and soil and replant with a tolerant or resistant species.
2. Avoid drought stress or flooding on mature landscape trees, as stress will accelerate *Verticillium* damage.
3. Mature trees where dieback is just starting can be pruned to remove dead wood and may show only intermittent symptoms for many years. Pruners should be disinfected with 10% bleach before being used on other trees.
4. Purchase propagating stock only from reliable sources.

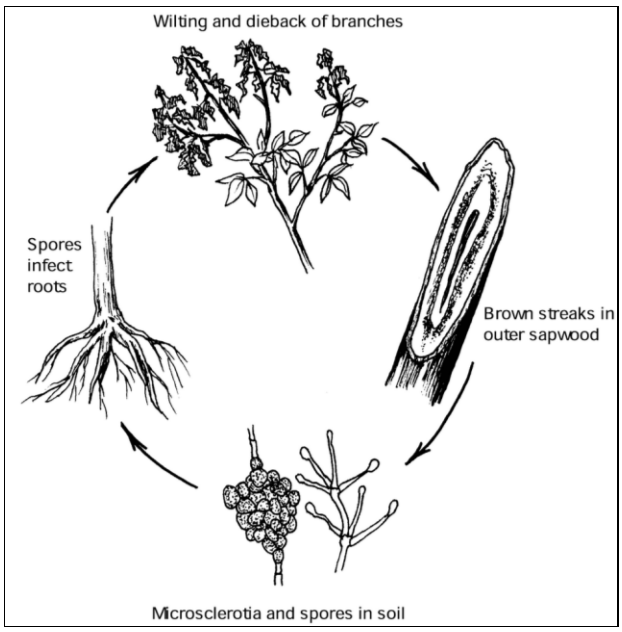


Figure 6.8. *Verticillium dahliae* disease cycle.

Chapter 7 - General Insect and Mite Management

This section contains a description of and management recommendations for common insects and mites that damage a wide range of ornamentals. Refer to the publication *Crop Protection Guide for Nursery and Landscape Plants* for a listing of the pesticides registered to control insects and mites.

Aphids and Adelgids

Aphids and adelgids both feed by piercing and sucking mouthparts. Their feeding can stunt plant growth, or induce the formation of galls and witches broom. They have complex life cycles that often involve alternate hosts. One way of differentiating them is to look for the pair of cornicles (=tail pipes) on the posterior end of the insect. Aphids have tail pipes, although they may be quite short at times and only visible as dark spots. Adelgids do not have tail pipes.

Aphids: Aphids are small, soft-bodied, bulb-shaped, sap-sucking insects that vary in colour from pinkish white to green and black. They may be winged or wingless and vary in length from 1.8-3 mm. They reproduce continuously during the growing season and most species overwinter on plants as eggs. Nearly all plants, including conifers are attacked by aphids. Different stages of many species alternate between woody plants in the fall and winter, and herbaceous plants in the spring and summer.

The Green Peach Aphid (*Myzus persicae*) overwinters as eggs on some deciduous trees and as adults on the underside of rosette leaves of a number of winter annuals, including common mallow, flixweed, tumble mustard, stork's-bill and shepherd's-purse (*Potato Progress*, 2002, Vol 2(3):1). The adults will reproduce asexually (only females are present) if the temperature is mild. Winged aphids (sexual cycle) are generally produced if the colonies are stressed (ie. temperature or crowding).

Aphids suck plant sap from the underside of leaves and needles, and prefer to feed on new growth. Symptoms of feeding include mottling and distortion of foliage. Black sooty mold can grow in the sugary honeydew excreted. Ornamentals frequently attacked are *Picea* (spruce aphid); *Euonymus, Hedera, Prunus, Rosa* (green peach aphid); *Prunus* (black cherry aphid); and *Rosa* (rose aphid, potato aphid).

The giant conifer and spruce aphids feed on conifers. Giant conifer aphids attack all species of conifer seedlings grown in nurseries. Great numbers of these large, dark-coloured, long-legged, aphids feed gregariously on twigs or branches and may cause foliage chlorosis. The small, dull-green spruce aphid is usually found on older needles, and causes mottling followed by chlorosis and needle drop.

A conifer root aphid, *Pachypappa tremulae*, has infested stock at several nurseries in British Columbia. To date most infestations have occurred on container spruce but related root aphid species also infest pine, larch and Douglas fir. These aphids are often discovered during the lift by their secretions of white waxy filaments and are often mistaken for ectomycorrhizae. Infestations are usually on the surface of the plug between the roots and the container wall, closer to the top of the plug than the bottom.

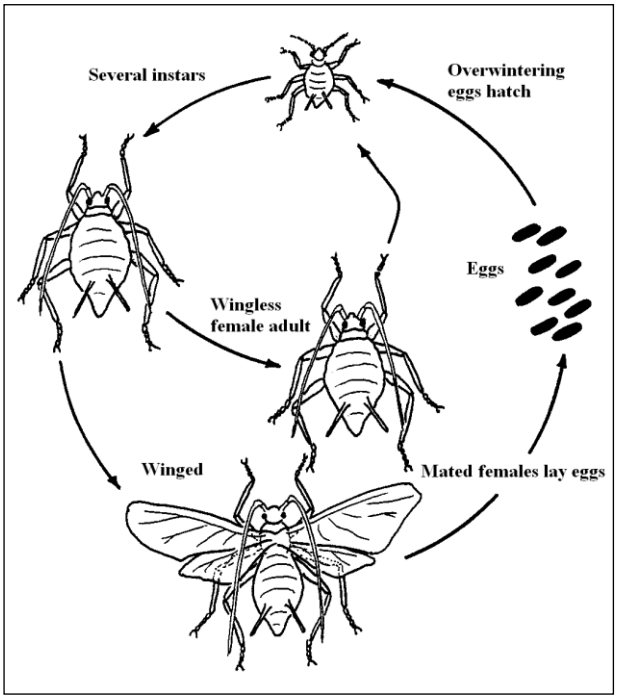


Figure 7.1 Aphid life cycle (6-14 days).

Most nurseries that have sustained infestations of conifer root aphid have not reported any damage. Outplanting studies have shown that they have no measurable effect on seedling performance and as such no control strategies are recommended.

Aphid Management: Aphid infestations are often detected by the presence of wasps or ants. Both will feed on the honeydew as well as re-distribute aphids throughout the nursery crop. Aphid populations can increase rapidly under favourable conditions and control may be necessary to protect plants.

A strong spray of water will dislodge aphids, thereby damaging their mouthparts, and often control light infestations. Many natural enemies such as lady beetles, lacewings, syrphid larvae and Hymenoptera wasp parasites help reduce aphid populations. However, populations of natural enemies often become abundant only when the aphid population is high and may not reduce the aphid population below damaging numbers early in the growing season.

Monitor plants regularly, starting in early spring. If aphid levels become damaging before natural enemies appear, apply a registered pesticide. If possible, delay spraying until June when natural enemies will have an effect. Good coverage of the foliage is essential if spraying is considered necessary.

Preventive dormant oil sprays applied just prior to bud break will help control overwintering aphid eggs.

Woolly Adelgids: Woolly adelgids attack both evergreen and deciduous trees. Genera known to be susceptible include *Abies, Chaenomeles, Cotoneaster, Crataegus, Fagus, Larix, Lonicera, Malus, Picea, Pinus, Pseudotsuga, Pyrus, Sorbus* and *Tsuga*. Woolly adelgids appear as tiny, white, woolly spots on trunks, limbs or leaves. They are difficult to control because sprays will not penetrate their wool-like wax covering. Systemic insecticides give good control on deciduous trees. Control is also provided by applications of dormant oil between October and April, and of insecticidal soap. A spreader-sticker should be added to sprays when treating conifers. The species of primary concern are the Cooley Spruce Gall Adelgid, Balsam Woolly Adelgid, and the Hemlock Woolly Adeglid.

Balsam Woolly Adelgid is a regulated pest within BC. A permit is required to grow *Abies*, and growers in the quarantine zone (Coastal BC) cannot ship outside the area within BC. The restrictions are in place to protect native *Abies* species in the interior of BC (for more information, see *BC Plant Protection Regulations*, Chapter 1).

Cooley Spruce Gall Adelgid is present in both coastal and interior nursery areas. Sitka, white and Englemann spruce, and Douglas fir are the hosts. In the nursery, damage is most severe on Douglas fir where the adelgids feed on new needles. In older spruce trees, the adelgids cause large cone-shaped galls. This damage is rarely visible in the nursery although older adjacent trees may be affected.

Hemlock Woolly Adelgid (HWA) was first reported in BC in 1922. It is known to also inhabit many areas of the US Pacific Northwest. In BC, HWA usually causes minor damage to the native hemlocks (e.g. Western and Mountain hemlocks). In the Eastern US, however, large areas of native hemlocks have been killed or severely damaged by this pest, resulting in serious environmental consequences.

Figure 7.2. Woolly ovisacs and black nymphs (circled) of hemlock woolly adelgid.

HWA is a federally regulated pest and BC is the only regulated region in the country. The restrictions were imposed to reduce the spread of HWA into Eastern North America Nurseries in BC must be registered with the CFIA's HWA Nursery Program to ship these crops to another province.

Woolly Adelgid Management: For Douglas fir seedlings, nurseries are encouraged to remove mature spruce trees in and around the nursery site that serve as the alternate host for the gall forming stage of Cooley spruce gall adelgid.

Bark Beetles and Wood Borers

A diverse group of insects are classed as wood borers. They affect most shade trees, conifers and some fruit trees. They are difficult to control chemically because they reside within a host tree for a large part of their life cycle.

For the Elm Bark Beetle, see *British Columbia Plant Protection Regulations* in Chapter 1.

Clearwing borers: There are a few species of concern in this group of stem boring caterpillars. Clearwing borers are all moths (Sesiidae) that look similar to wasps. They have one generation per year. Moths fly in spring or summer and lay eggs in host plants. Larvae hatch and bore into stems and branches, causing pitch flow and/or branch death. Major species include: Sequoia Pitch Moth, Douglas Fir Pitch Moth, Apple Clearwing Moth, Greater Peach Tree Borer, and a new pest to BC, the Lilac Borer. Hosts include *Fraxinus, Malus, Picea, Pinus*, *Prunus,* and *Pseudotsuga*.

Management of bark beetles and wood borers: To reduce the risk of **wood borers**, burn all plant debris and prunings, keep trees growing vigorously and avoid transplant shock. Remove and burn damaged limbs and plants. Borers generally attack only weakened trees. Healed-in, balled and burlapped trees are under stress and can be attacked.

Management of **clearwing borers** includes mechanically digging out larvae from pitch pockets in bigger trees with wire or another implement, and pruning out and destroying infested stems if possible. A mating disruption product is available for Greater Peach Tree Borer and Apple Clearwing Moth. Utility in nursery will be limited due to the normally small size of the planting. Pheromone lures are available for some species and can be useful in determining species present. Mass trapping may have some impact. Trunk and stem sprays may be useful on trees/saplings during moth flight.

Caterpillars and Moths

Caterpillars are the immature stages of moths or butterflies. Some form tents; some do not. All are defoliators of deciduous or coniferous trees and shrubs, and some feed in colonies.

Bruce Spanworm and Winter Moth: These drab, grey or grey-brown moths are almost identical in appearance and habits. The Bruce spanworm is native to North America. The winter moth is a European species that was introduced to Vancouver Island and now occurs throughout the Fraser Valley.

These insects attack a wide variety of deciduous ornamentals. Young larvae drift on silken threads, so nursery trees can become infested from neglected backyard trees in the area.

From early spring to late May or early June, the caterpillars feed on buds, foliage, flowers and fruit. Defoliation occurs when infestations are severe. Full-grown larvae are about 2 cm long. They are bright green with three narrow whitish stripes on each side of the body.

The moths occur from late October to the end of December. The male moths fly in the evening. The flightless females climb up the tree trunks to lay eggs.

Genera known to be susceptible to Bruce Spanworm include *Acer, Fagus, Quercus* and *Populus.* Genera known to be susceptible to Winter Moth are *Acer, Betula, Malus, Populus, Quercus* and *Vaccinium*.

Management of Bruce spanworm and winter moth: The application of sticky bands to the trunk and larger limbs of a tree is an excellent physical barrier to winter moths. Apply two 15 cm wide sticky bands at 30 and 60 cm above ground in late October. The bands will trap female moths as they crawl up the tree to deposit eggs. The lower band should be replaced when it becomes dry, filled with moths or debris, or when wingless female moths begin to be trapped on the upper band. All bands can be removed and burned in February and March. To avoid possible damage, the material can be put on plastic strips wrapped around the tree. For trees with rough bark, cotton batting can be used beneath the plastic to fill in gaps in the bark and reduce the chance of a moth crawling underneath the sticky band.

Cranberry Girdler / Sod Webworm: This moth has been found at nurseries throughout the province. Adult girdlers are small, delicate moths about 1.2 cm long with protruding snouts. The forewings are a pale straw colour with touches of brown, silver and black. The hindwings are silvery-grey. The larvae girdle seedlings in the root collar area. Damage has a ragged appearance and occurs from August to November depending on the nursery location and season. In bareroot, 2+0 true firs and Douglas fir are the preferred host. In containers, spruce and Douglas fir have been attacked and larger stock types are preferred. Seedlings may become chlorotic, but most damage is detected during the lift. This pest will also colonize turf and cranberry, as the common names suggest.

Management of the cranberry girdler/sod webworm: As this pest readily feeds on grass, remove or reduce grassy areas in and around the nursery site that could harbour populations. Frequent mowing can help to reduce endemic populations. Pheromone traps available from Pherotech can be used to monitor moth populations during the summer. An average of three moths per trap indicates that damage from larvae in the fall will be significant. If moth flight is high enough, an insecticide should be applied during moth flight to reduce oviposition by the adults.

Cutworms: Adult cutworm moths are thick-bodied, dull-coloured, mostly nocturnal moths, which are about 18-25 mm long and fold their wings tent-fashion when at rest. The larvae are large, soft, fat, worm-like, dull-coloured caterpillars up to 4 cm long with hairless bodies and shiny heads.

Larvae of several cutworm species have been pests in forest nurseries. All species of seedlings and stock types can be attacked.

There are probably populations at all nurseries in every growing season, but the severity of infestations varies greatly. Damage is usually confined to very young succulent seedlings. Foliage, roots or stems may also be affected. Feeding usually takes place at night.

Management of cutworms: Crop and non-crop areas should be kept weed-free. The use of light traps in greenhouses can reduce adult populations, however these catch many non-target and beneficial insects as well. Moths can be excluded from greenhouses and shelterhouses by keeping the doors closed and placing screens over the fan intakes and vents. For small outbreaks, remove and destroy cutworms from the growing media.

European Pine Shoot Moth: The larvae can damage most species of pines by boring into the buds and shoots, and injuring or killing them. They overwinter in the bud and emerge the following June.

Adults fly from June to July. They have a wingspan of about 2 cm, orange forewings marked with irregular silvery lines and grey hindwings. This pest is largely controlled by natural enemies.

Management of European pine shoot moth: For conifer seedlings, pheromone traps can be used to indicate if moths are present. Traps are available from Pherotech or the nursery pest management specialist, Ministry of Forests. When moths are found, pesticide treatment is recommended. Inspect pine stock at the end of September. An excess of resin around the buds will indicate the presence of larvae. Cull out and burn infested seedlings.

Tent Caterpillars and Skeletonizers: Forest and Western Tent caterpillars overwinter as hardened egg masses, 1.2 to 2.5 cm wide, which encircle a twig. The eggs hatch in spring (May). The caterpillars feed in colonies and consume flowers, buds and foliage over the next six weeks.

The Forest Tent caterpillars are bluish-grey and have a prominent row of whitish, diamond-shaped dots along the back. They spin silken mats for travelling. The adult moths are reddish to pale fawn, with two narrow, pale, oblique, transverse lines separating off a dark wide band of the forewings. Genera known to be susceptible are *Acer, Betula, Crataegus, Fraxinus, Populus, Prunus, Quercus, Rosa, Salix, Tilia* and *Ulmus*.

The Western Tent caterpillar is hairy, yellowish-brown, with a row of blue spots flanked by orange spots along the back and can be up to 5 cm in length. The larvae stay in colonies and form tent-like webs for protection. The moths emerge in June and July and are light to dark brown. Genera known to be susceptible are *Arbutus, Betula, Ceanothus, Corylus, Crataegus, Ilex, Malus, Populus, Prunus, Quercus* and *Salix*.

Apple and Thorn Skeletonizers overwinter as pupa, emerging in the spring to lay small green eggs under leaves. The caterpillars are yellowish to greenish with many black dots.

Feeding takes place inside a rolled-up leaf. There can be up to four generations per year. Genera known to be susceptible are *Betula, Malus, Prunus, Pyrus* and *Sorbus*.

Management of forest tent and western tent caterpillars, and apple and thorn skeletonizers: During the dormant season peel or prune off the egg masses from the twigs. In the spring, if tents are not numerous, they should be pruned off with the young caterpillars and destroyed.

Spruce Budworm: The spruce budworm can be a serious problem in nurseries located in areas where forest infestations occur. Between May and July, nursery stock can become infested by larvae that have overwintered in mature trees in and around the nursery site. Larvae are voracious feeders, and can cause significant damage to small seedlings.

They prefer true firs and Douglas fir. Spruces can also be damaged if grown in an area where infestations are heavy in surrounding trees. Adult moths lay their eggs on nursery stock during their flight in mid-July. The resulting larvae overwinter in small, silken cocoons. They are difficult to find and control; and may accompany nursery stock to the reforestation sites.

Management of spruce budworm: For conifer seedling nurseries, nursery personnel should carefully monitor in the spring and control larvae that blow onto the seedlings. Pheromones and light traps can be used to monitor adult populations. Significant infestations of larvae warrant a pesticide application. For Dipel, treat when there are five or more larvae per branch. Treatment should occur at the beginning of moth emergence and be repeated at 2 week intervals as long as adults are present.

Tussock Moth: Larvae of tussock moths can be chronic pests in nurseries. The adult male is a rusty brown with a white dot and light brown band on each forewing. The adult females are flightless, sedentary, with light tan hairs covering the body. The females cement their white egg masses to the styrofoam containers in reforestation nurseries. When the blocks are re-used in the spring, the larvae emerge to infest container stock. Larvae are brightly coloured with yellow and black tufts of hair, and will attack all species of conifer seedlings.

Management of tussock moth: For conifer seedlings nurseries, larvae are often easily detected by nursery staff and can be removed manually. In some people, the hundreds of hairs on the caterpillars can cause a rash. When infestations become too large for manual control, insecticide sprays can be used.

Fungus Gnats

Fungus gnats are primarily pests of container stock. Adults are delicate, dark grey or black flies about 3 mm long. They are often seen running or flying near the soil surface, especially in wet areas. The slender white larvae have shiny black heads and are sometimes found in the plugs. Most species feed on decaying organic matter and algae. They are commonly found in compost. Some species may damage seedling roots although they are not normally attracted to healthy plants.

Fungus gnats are often confused with shore flies. Although similar in appearance to fungus gnats, shore flies are not thought of as a plant pest. Therefore, it is important to be able to differentiate these two flies (refer to Figure 7.3).

Adult shore flies have shorter antennae, stouter bodies, and are stronger fliers than fungus gnats, and their larvae lack the distinctive black head of fungus gnat larvae.

Management of fungus gnats: The best form of control is sanitation. The flies are attracted to areas of moss and algae, which is where they lay their eggs. Good drainage is important, including removal of puddles of water from the greenhouse floors. Good cultural practices that produce vigorous, healthy stock and proper irrigation to avoid overwatering will make plants less attractive.

There are two types of biological control agents that are currently used for fungus gnat control. They are a soil-inhabiting mite, *Hypoaspis miles*, and entomopathogenic nematodes.

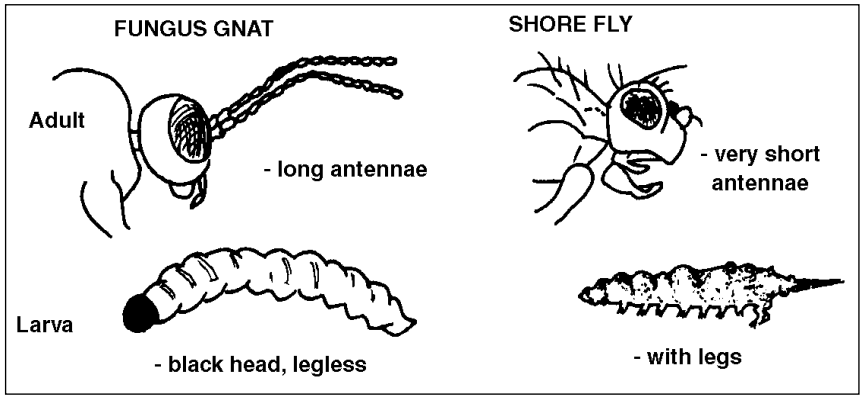


Figure 7.3. Distinguishing characteristics of fungus gnats and shore flies.

Lace Bugs

Lace bugs are serious pests of both deciduous and broad-leaved evergreen ornamentals. Most lace bugs have very specific plant preferences. Genera known to be susceptible to lace bugs include *Acer,* azalea, *Betula, Cotoneaster, Crataegus, Fagus grandiflora, Leucothoe, Pieris, Pyracantha, Quince, Rhododendron, Salix and Sorbus*.

Lace bugs have sucking mouthparts and feed on the underside of foliage. Feeding results in the production of chlorotic flecks on the foliage, which are most visible from above.

These symptoms are very similar to those produced by leafhopper and mite feeding. A distinguishing sign of lace bugs is dark, varnish-like spots of excrement on the underside of damaged leaves.

Figure 7.4. A lace bug on the underside of a rhododendron leaf.

Lace bugs have 2-3 generations per year. Lace bugs that feed on broadleaf ornamentals overwinter as eggs, which are either inserted into or cemented onto leaves. Lace bugs that feed on deciduous ornamentals overwinter on the plant or in the leaf litter as adults. In the spring, the overwintering adults lay their eggs on the foliage of a host plant.

Figure 7.5. Leaf stippling (top) and dark excrement on the underside of a pieris leaf (bottom) caused by the andromeda lace bug.

Leafhoppers

There are hundreds of different leafhoppers that feed on woody ornamentals. All leafhoppers have sucking mouthparts and feed on shoots and the underside of leaves. A characteristic symptom of feeding is the presence of white flecks or stipple spots on the foliage. Under low magnification the stipples can appear to have a snowflake appearance. Individual stipples coalesce together. Other symptoms include overall stunting, reduced vigour, tissue swelling, leaf curling and distortion, premature leaf fall, the development of multiple leaders and increased winterkill of damaged shoots. In addition, leafhopper saliva is toxic to some plants and can produce a condition called "hopperburn", which is characterized by browning of leaf margins.

A distinguishing sign of leafhopper damage is the presence of cast "skins" on the underside of leaves. When the nymphs molt, they shed their skin. The skin at times remains attached to the leaf because the mouthparts are partially embedded in the leaf.

There is considerable diversity in the lifecycle of different species of leafhoppers. They can have one to several generations per year, and overwinter as either eggs or adults. The eggs are inserted into leaves, shoots or bark. Adults overwinter in leaf litter or in bark crevices. Nymphs almost always remain on the plant where the eggs were laid. In contrast, adult leafhoppers are very capable fliers. Leafhoppers can be spread considerable distances in air currents.

Leafhoppers can transmit diseases, such as Elm Yellows Disease and Pierce's Disease of grapes.

Genera of plants that are known to be susceptible to leafhoppers include *Acer, Alnus,* azalea*, Betula, Cornus, Crataegus, Gleditsia, Malus, Populus, Prunus, Quercus, Rhododendron, Rosa* and *Ulmus*.

Leafminers and Needle Miners

The larvae of some wasps, flies, moths and beetles live and feed within plant foliage. They feed on the soft internal tissue of foliage, but not on the upper or lower epidermal layers. The symptoms of their feeding are white blotches or lineal mines in the foliage. The larvae and/or their excrement can often be seen inside the mined areas. Mined foliage often turns yellow or brown, and may droop and drop prematurely.

Pests that mine the foliage of conifers are referred to as needle miners, and those that mine broadleaf ornamentals are called leafminers. All of the economically important needle miners are Lepidopterans. Most miners have quite specific host preferences. Genera known to be susceptible include *Abies, Alnus, Arbutus, Betula, Crataegus, Cupressus, Ilex, Juniperus, Picea, Pinus, Platanus,* privet, *Pseudotsuga menziesii, Thuja, Tsuga and Ulmus*.

Miners that can be pests of ornamentals in British Columbia include the aspen blotchminer, the spruce needle miner, and the aspen, birch, boxwood, cypress (tip moth), holly, lilac and the Madrone serpentine leafminers.

Most needle and leafminers overwinter as larvae. In general, larvae overwinter in the foliage of evergreens, and in the leaf litter of deciduous plants. The larvae pupate in the early spring and the adult insect begins to lay eggs on the underside of newly developing foliage of a preferred host. The larva mine into the foliage upon hatching. Most have only one generation per year, although some can have up to 4 generations.

Leatherjackets

Leatherjackets, the larvae of crane flies, have been seen as pests only in coastal nurseries. Adults fly from summer through fall resemble large greyish-brown mosquitoes with bodies about 2.5 cm long, two wings and long spindly legs. Adults lay eggs in late summer and fall that hatch quickly. The overwintering larvae girdle seedlings from March to May. The greyish coloured, legless larvae have tough leather-like skin, no distinctive head, and can reach 4 cm in length. Any stock present in the nursery in the spring can be attacked, although most damage has occurred on early sown 1+0, 2+0 transplants and bareroot stock.

They will feed on almost any species of nursery stock. The damage consists of girdling just below the soil surface. Damaged stock appears off-coloured and dried out.

When infesting container plugs, the leatherjackets often remain with the seedling during the harvest. Although they do limited damage to the seedlings while growing in the nursery or during cold storage, they may girdle the seedling when outplanted in the spring.

Management of leatherjackets: The best approach is to monitor for adults. A large number of adults flying around indicate a potential leatherjacket problem in current stock. The best control is achieved by drenching to kill the young larvae during the second week in October after all eggs have hatched. Remove or reduce grassy areas in and around the nursery site that could harbour populations.

Lygus Bug

Lygus bug adults, usually 7 mm long and half as wide, are broad, flattened, and oval-shaped with a small projecting head. They range in colour from yellowish-green to reddish-brown and are covered with small, irregular, yellow, reddish-brown and black splotches. Lygus populations overwinter as adults, becoming active with warm spring weather. They can start feeding on seedlings when the true or secondary needles develop after seedling emergence.

Feeding by the adults and nymphs initially causes distortion of seedling terminal shoots, which later become multiple-leaders. Damage has been found on 1-year-old seedlings of all species, but pine, larch and spruce are preferred, while older stock is only attacked during the period of leader elongation. Lygus bugs are also referred to as tarnished plant bugs.

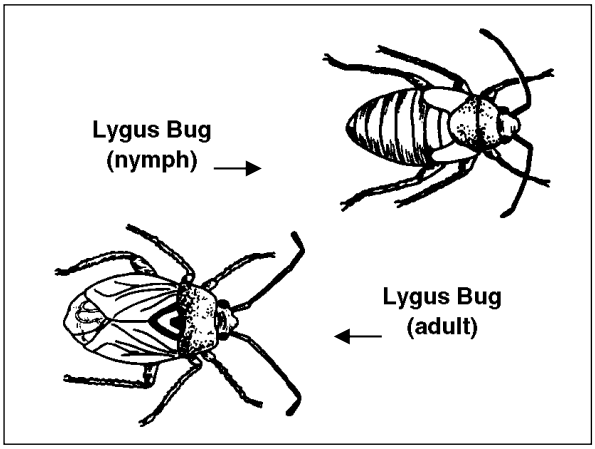


Figure 7.6. Nymph and adult tarnished plant bug.

Management of Lygus bugs: Nurseries can incorporate a preliminary monitoring plan using yellow sticky cards to better time insecticide applications. Monitor the surrounding vegetation to predict the arrival of lygus bugs within the crop. Fringe monitoring should start when mean daily temperatures stay above 5^0C and continue until peak of flight of the first generation.

Mites

Mites are spider-like arthropods that are almost invisible without magnification. They vary in colour from pale yellow or green, to red and reddish-brown. Many species of mites can be present in nursery stock. These mites may be harmful, harmless, or beneficial. Mites feed on evergreens and deciduous plants. Speckling, bleaching, or bronzing of the foliage typifies damage. Some species such as McDaniel and two-spotted spider mites produce webbing on needles or leaves. Mite populations increase rapidly during hot, dry weather. Heavily infested foliage may drop prematurely.

Blister and rust mites are yellowish-white in colour, extremely small (0.3 mm long), and slow moving. Blister mites, as the name suggests, cause discoloured blisters on leaves, and russeting and deformity of fruit. Rust mites cause bronzing, browning or silvering of the leaf surface. These types of mites (eriophyids) can also infest conifers, causing needles to turn yellow and become stunted or twisted. Galls can form at the terminals of *Juniperus* and *Cedrus*. Infested needles may drop prematurely.

The spruce spider mite has been the most damaging species to date of conifer seedlings. The mites feed on needles causing them to become dry, mottled and bleached. Severely affected foliage turns yellow to dull, rusty-brown and the needles drop off. Fine silk webbing will be found among the needles of infested twigs. Spruce mites survive as red eggs during the hottest periods of midsummer and the winter.

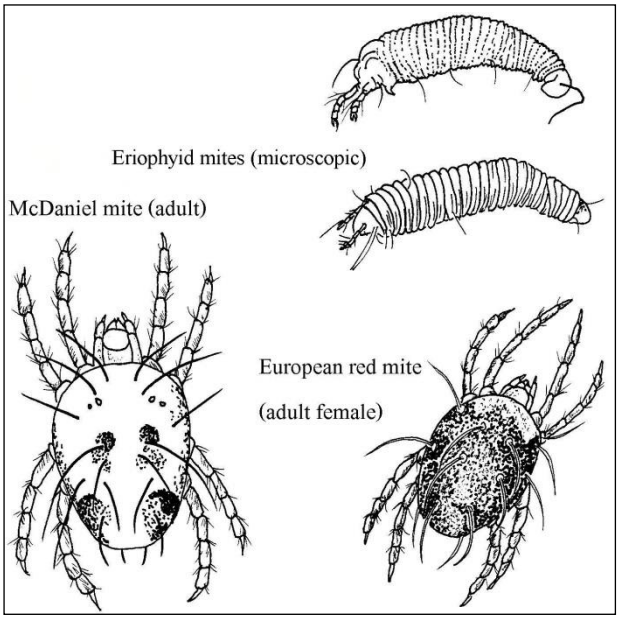


Figure 7.7. Eriophyid, European red and McDaniel mites.

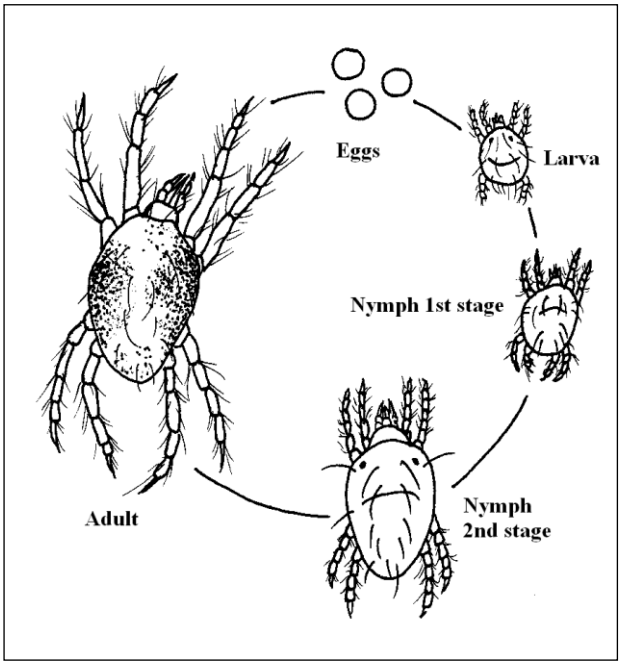


Figure 7.8. Two-spotted spider mite life cycle.

Table 7.1. Plant genera that are susceptible to different mites.

Mites	Susceptible Genera
Eriophyid (Bladder Gall, Blister, Rust mites)	*Acer, Carya, Cedrus, Chamaecyparis, Cotoneaster, Fagus, Juglans, Juniperus, Malus, Picea, Pinus, Populus, Pseudolarix, Pseudotsuga, Pyrus, Quercus, Rhus, Sorbus, Taxus, Tilia, Tsuga, Ulmus*
European Red	*Chamaecyparis, Crataegus, Juglans, Malus, Prunus, Robinia, Rosa, Sorbus* and *Ulmus*
Spruce Spider	*Abies, Juniperus, Larix, Picea, Pinus, Pseudotsuga, Thuja* and *Tsuga*
Two-spotted	*Chamaecyparis, Crataegus, Hedera, Hydrangea, Juniperus, Pieris, Rhododendron, Rosa, Thuja, Tsuga*

Management mites: Monitor twigs and needles in early spring for reddish-orange overwintering spider mite eggs to determine if sprays are needed. Native predatory mites usually keep pest mites under control. Before spraying, examine plants for beneficial mites. If beneficial mites are present, delay or avoid spraying.

Dormant sprays destroy overwintering eggs, nymphs and adult mites. Predaceous mites are available from several suppliers. Two-spotted mites thrive under hot, dry conditions, so regular foliage wetting will help suppress this pest.

Root Weevils

Several different root weevils are found in the Pacific Northwest, including the clay-colored, black vine, obscure, strawberry, rough strawberry, and the woods weevil. Adult weevils feed on leaf margins and cause a characteristic notching pattern. Adults are elusive, feeding at night and hiding during the day. As a result, populations often go undetected until damage occurs.

Larvae can be even more damaging than adult weevils, since they are present in the soil for 9-10 months of the year, where they feed on plant roots. The larvae can completely girdle the stems of rhododendrons and camellias at the soil line. Black vine weevil larvae can girdle the lower stem to 2 cm above the soil line. Weevil larvae girdle container-grown stock often just below the point at which foliage begins. They feed throughout the fall and during warm periods in winter. The woods weevil will feed all winter.

Adult weevils vary in colour from grey to black and range in length from 9-13 mm. They cannot fly and only a couple of species have males. A female weevil can lay between 200-400 eggs per year, and some species can even lay eggs at refrigeration temperatures. The eggs are layed in the soil near plants. There is one generation per year.

The larvae are soil-dwelling, white, C-shaped, legless grubs with brown head capsules. Both adults and larvae overwinter. Between 10-15% of some weevil species will overwinter.

Overwintering adults become active in the spring. They have mature ovaries and can immediately begin to lay eggs. The reproductive capacity of overwintering weevils is often double that of first year weevils. Adult emergence time varies between different weevil species. For instance, adult clay coloured weevils appear in late March and feed on new buds and girdle stems. Adult black vine weevils begin to emerge in late May or early June, after pupating for approximately 4 weeks in earthen cells.

Newly emerged adults must feed for about 4 weeks before they can lay eggs. It is best to control adult weevils before they begin to lay eggs.

Genera known to be susceptible include *Camellia, Juniperus, Kalmia, Picea, Rhododendron, Pinus, Rubus, Rosa, Thuja, Taxus, Vaccinium, Tsuga, Yucca* and *Viburnum*.

Management of root weevils: Control is most often directed at the adults. Spraying at dusk or after dark will increase the efficiency of the application, because adults leave the soil at night to feed on the foliage. Because they are wingless, a band of sticky material can trap them as they climb plants. However, they can walk over traps that are not adequately sticky. Spray plants either in early morning or late evening when fresh notching of leaves or girdling of twigs is noticed (late June to early July). Since newly emerged adults are not reproductively mature for about 4 weeks, it is best to delay spraying to allow more adults to emerge.

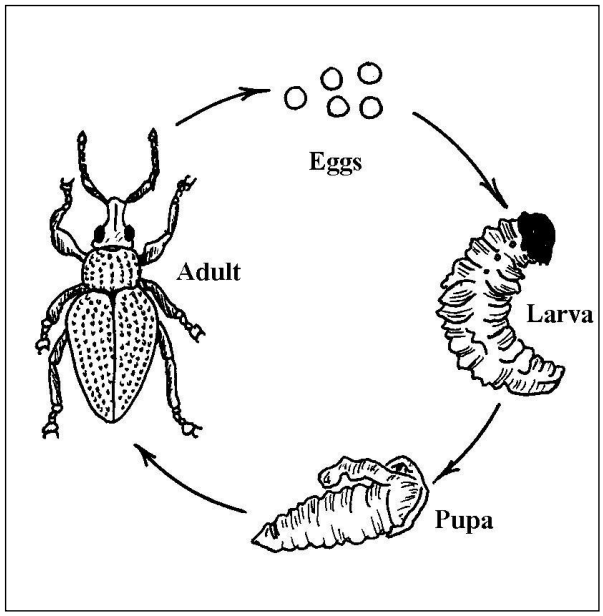


Figure 7.9. Root weevil life cycle.

It is recommended to spray three weeks after the first adults emerge, which should be at peak adult emergence. You can test whether an adult is reproductively mature by squeezing them between your thumb and forefinger, with their head pointing down. If they are mature, you will be able to squeeze eggs out of their ovipositor.

One cultural method to lessen damage caused by root weevils is to remove all thatch/grass from around the root collar of the plant.

For bareroot conifer seedlings, ensure that fallow panels are kept clear of weeds and cull material. Set out traps and monitor frequently for adults in the summer. Traps consist of 30 cm lengths of 2" X 4" lumber placed flat on the soil, which weevils hide under during daylight hours. Trapping as a tool is highly variable, and should only be used as an indicator of weevil presence. Trapping should not be relied on for the time of first emergence or any indication of quantity of weevils in an area. Adult emergence usually occurs in the first half of June. Spray infested areas two weeks after emergence. Apply a second spray three weeks after the first. Continue trapping and repeat treatment as necessary. Roadways and waste areas adjoining infested production areas should also be treated.

For container-grown conifer seedlings, ensure that areas adjoining greenhouses and compounds are kept clear of weeds and cull material. Spray infested greenhouses to control adult weevils as per bareroot. To kill larvae in plugs, apply a drench of entomopathogenic nematodes around the beginning of September while larvae are young.

Sawflies

Pear and rose "slugs" are not slugs; they are the larval stage of a group of sawflies. The larvae appear slimy and non-segmented, and therefore resemble slugs. The pear slug has two generations per year, whereas the rose slug has only one. Both overwinter in the soil as mature larva and pupate in the early spring. The adults lay their eggs on the underside of host leaves. The larva skeletonize the upper side of the leaf, at times leaving only the lower epidermal layer intact. Damaged areas turn brown and the leaves may drop prematurely. A fully-grown larva is about 13 mm long.

Genera that are known to be susceptible to either the pear or rose slugs include *Cotoneaster, Crataegus, Malus, Prunus, Pyrus*, *Rosa* and *Sorbus*.

Conifer sawflies can cause serious defoliation of pines and a few other conifers. There are 6 different conifer sawflies (*Neodiprion* species) in BC. Four feed exclusively on pines. The other two sawflies include the Balsam fir sawfly, which feeds on *Abies amabilis*, *A. lasiocarpa*, *Picea engelmannii*, *P. glauca*, *P. sitchensis*, and *Pseudotsuga menziesii*, and the Hemlock sawfly, which feeds primarily on *Tsuga heterophylla*.

Figure 7.10. Pine sawfly larvae are gregarious pests that can cause significant damage in the spring to the previous year's needles.

All of the conifer sawflies overwinter as eggs that are inserted into niches cut into current season needles. The larvae reach a maximum length of 18 to 25 mm, depending on species. They are present for about 2 months beginning in either May or June.

Larvae feed gregariously on 1- to 2-year-old needles, and migrate from a branch only after devouring all of the needles, with the exception of the current season's growth. Damaged branches have a bottle-brush appearance.

Depending on the species, the larvae will spin a cocoon in the foliage or in the duff, and the adults will emerge in August or September.

Scales

Scales are sap-sucking insects that attack many shrubs and trees, including evergreens and fruit trees. They produce a protective, waxy shell. Oyster shell and San Jose scales are armoured scales. They have a hard shell and do not produce honeydew. The soft body of armoured scales can be separated from the scale. Lecanium and soft brown scales are soft scales and they do produce large quantities of honeydew. The body of the soft scale insect is firmly attached to the scale. Dead scales can even affect the appearance of a plant, therefore it is often best to discard heavily infested plants.

Figure 7.11. Ovisacs of a soft scale, the cottony camellia scale, on the underside of a viburnum leaf.

The **Euonymus scale** is orange at the crawler stage. Adults are either white (male) or brown (female) and about 2 mm long. They are found on the protected parts of the plant, close to the ground. There are 2-3 generations per year.

Genera known to be susceptible include *Buxus, Camellia, Daphne, Euonymus, Hedera, Hibiscus, Ilex, Ligustrum, Lonicera, Pachysandra, Paxistima* and *Prunus*.

The **Lecanium scale** is a family of a dozen species of scales. They vary in colour from reddish black to black and range in length from 3-12 mm. The females lay eggs in late June that hatch within a few weeks.

Crawlers migrate to the underside of the foliage to feed for the summer. They crawl back to the twig and small branches in late summer to overwinter. The overwintering nymphs are exposed, relative to armoured scales, and are susceptible to dormant season treatments.

Genera known to be susceptible include *Acer, Betula, Carya, Celtis, Cercis, Crataegus, Fagus, Gleditsia, Juglans, Malus, Morus, Platanus, Populus, Prunus, Pyrus, Quercus, Salix* and *Tilia.*

The **Oyster shell scale** resembles a seashell in shape and is about 3 mm in length. In large numbers, they can reduce vigour to the point of killing the tree. About 40-150 eggs overwinter underneath each female scale. The eggs hatch in mid-May and the crawlers move out to the twigs to feed. A scale forms to cover them in about six weeks.

Genera known to be susceptible include *Acer, Cornus, Fraxinus, Malus, Populus, Rosa, Salix* and *Syringa.*

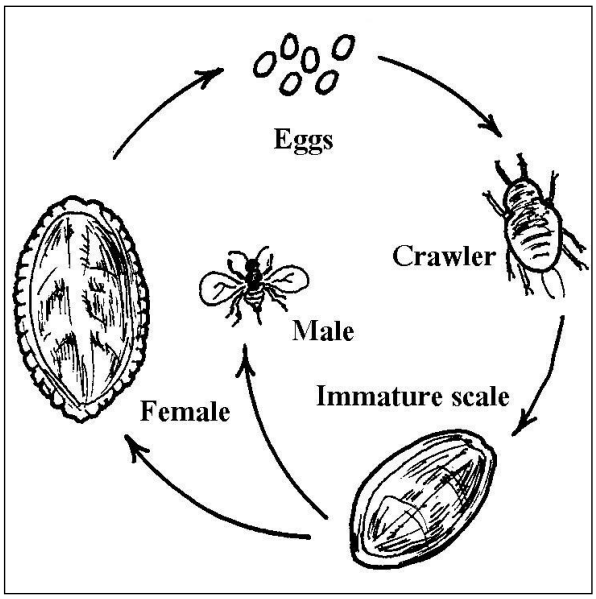


Figure 7.12. Soft scale life cycle.

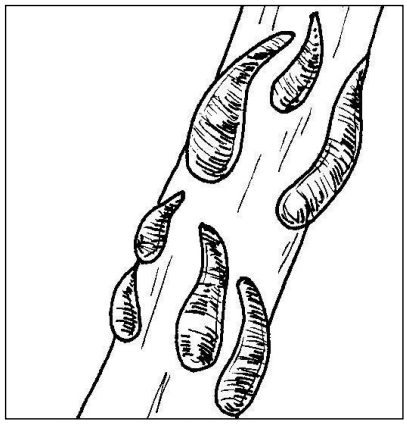


Figure 7.13. Oyster shell scales.

Young **San Jose scales** are black and overwinter. The female scale matures in May and early June, changing in colour to grey. Crawlers emerge from the females in June and move to feeding sites on branches and fruit. A second generation is produced during August to early October.

Management of scales: Timing of application of chemical controls is critical for success. During most of their life cycle, scales are protected from pesticides by their shell. The only time they are not protected is at the crawler stage, which is when the first instar nymphs emerge from eggs.

Monitor crawlers with double-sided sticky tape traps that are wrapped around branches near female scales. Record the number of orange-coloured crawlers caught and replace the traps weekly. Treat the plants when either a sharp increase in crawlers is observed or when the peak density of crawlers is caught. More than one application may be needed to cover the entire crawler emergence period. The timing of the crawler stage varies between different scale species and occurs either in early spring or in June/July.

Sowbugs

Sowbugs, also called woodlice or pillbugs, have dark, segmented, flattened, oval-shaped bodies with 7 pairs of legs. They feed mostly at night, hiding in dark, damp places during the day.

Sowbugs feed mostly on decaying plant material. They will, however, occasionally feed on roots and stems or eat holes in leaves. They may cause severe damage to seedlings.

Two methods of prevention are soil pasteurization, and the removal of old boards and other rotted organic material from the area. The application of pesticides is rarely necessary

Spittlebugs

There are several different species of spittlebugs. Most overwinter as eggs, which are laid on or in the bark of vegetation. When the eggs hatch in the spring, the nymphs insert their sucking mouthparts into their coniferous or broad-leaved host and immediately begin to produce a protective coating of froth or spittle.

Spittlebugs have 1 or 2 generations per year depending on the species. When there are two per year, nymphs can be seen into the fall. The adults are highly mobile, and can walk, hop or fly. Adults do not produce spittle, but they do produce honeydew that can promote the development of sooty mold. The adults are 6-12 mm long and are very similar to leafhoppers, to which they are closely related.

Feeding by spittlebugs can spread viruses, and can result in reduced stem elongation and leaf deformation. However, most spittlebugs cause no damage to their host. Since their spittle is unsightly on ornamental crops, control of spittlebugs may be necessary or desired.

Management of spittlebugs: Wash infested plants with a strong spray of water to remove the spittle and to expose the nymphs.

Thrips

Thrips are long (0.5-1.0 mm), slender insects that feed on tender growth of some shrubs and trees. Their damage can be distinguished from mite damage by using a magnifying lens. They are rasping rather than sap sucking insects and injure both leaf and flower buds, causing distorted growth when the buds expand and early flower senescence. Thrips also can transmit several plant viruses.

Thrips live for 30-45 days. Female thrips are self-fertile and lay between 150-300 eggs. The eggs are inserted into plant tissue, which can result in the formation of oedema-like swellings. The nymphs of Western flower thrips drop to the soil to pupate, whereas Greenhouse thrips pupate on the plant.

Thrips are weak flyers, but can be dispersed great distances by air currents. They have been trapped at 3,000-5,400 metres above the earth in the jet stream. Such air currents can draw thrips into the Pacific Northwest from California.

Management of thrips: Thrips are more easily controlled in the early stages of infestation. Yellow or blue sticky traps are effective for early detection of thrips. The cards should be placed in the crop when the temperature is <18°C. Additional cards should be placed above the crop when the temperature is >18°C, since the thrips are more active and will be flying above the crop.

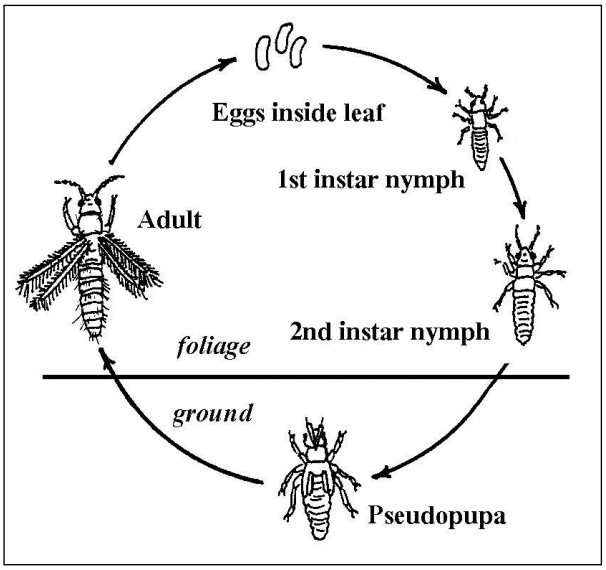


Figure 7.14. Thrips life cycle.

Use high pressure and high volume sprays when damage is noticed on young growth. Thrips hide deep in the crevices of expanding leaves and flowers. The frequency of pesticide treatments depends on temperature. During periods of high temperature, sprays will have to be applied 4-5 days apart to control newly emerged adults.

In the greenhouse, liming the soil below benches can control soil-borne pupae. Treat the soil with a solution of hydrated lime (180 g/L of water).

Talk to your suppliers for information on biological control agents available for thrips control.

Whiteflies

The two main whitefly species are the greenhouse whitefly (*Trialeurodes vaporariorum*) and the sweet potato whitefly (SPW) (*Bemesia tabaci*), which is also called Tobacco whitefly, or Silverleaf whitefly. Greenhouse whiteflies have wings that lay relatively flat across their backs, while the SPW's wings lie upraised at a tent-like angle. The SPW's body is smaller and is more yellow in colour.

Infested plants may lack vigour, wilt, and turn yellow. Whiteflies excrete large amounts of honeydew onto the leaves and flowers of infested plants. The honeydew may become colonized with a black sooty fungus giving the plant a dirty appearance and hindering photosynthesis.

The SPW will not overwinter outdoors in BC. Greenhouse whitefly will overwinter in protected areas under leaves outdoors in BC. Some hardy whiteflies such as the rhododendron whitefly are occasional problems on cut woody greens.

Adult whiteflies are about 1 mm long and resemble tiny white moths. Adults congregate on the undersides of leaves. Whiteflies are very prolific and have many overlapping life cycles. Females lay a number of small, whitish, oval eggs on the underside of leaves. Eggs are too small to see with the unaided eye. A female can lay up to 400 eggs.

After 5 to 10 days the eggs hatch into flat, scale-like nymphs or crawlers that move about the leaf before becoming immobile. After 3 nymphal stages and 1 pupal stage, the adults emerge. The pupae of whiteflies are scale-like and white in colour. They are often mistaken for the eggs. A complete life cycle requires about 3 - 4 weeks.

Management of whiteflies: Remove weeds from inside greenhouses and from a three metre wide band around the outside perimeter of greenhouses, as these can harbour whiteflies.

Carefully inspect all incoming plants for nymphs, scales, honeydew, sooty mould, or adults on leaves.

Monitor with yellow sticky traps dispersed evenly among plants, about 1 trap/100 m^2. Traps may be used to control very low adult populations. They can be used alone or in combination with parasites. Adults will be caught on sticky traps long before they are detected in the crop. This early detection is essential for early control. Thorough spray coverage of the undersides of leaves is essential for control.

Whiteflies can be managed effectively with biological controls. Biocontrol for the greenhouse whitefly includes the use of the parasitic wasps *Encarsia formosa* and *Eretmocerus eremicus*.

For SPW, the biocontrol program includes these wasps in addition to *Eretmocerus mundus*, particularly for early season introductions.

A predatory mite, *Amblyseius swirskii*, feeds on whitefly eggs and larvae. It also feeds on thrips and pollen so can be applied before whiteflies are seen as well as once whiteflies are present

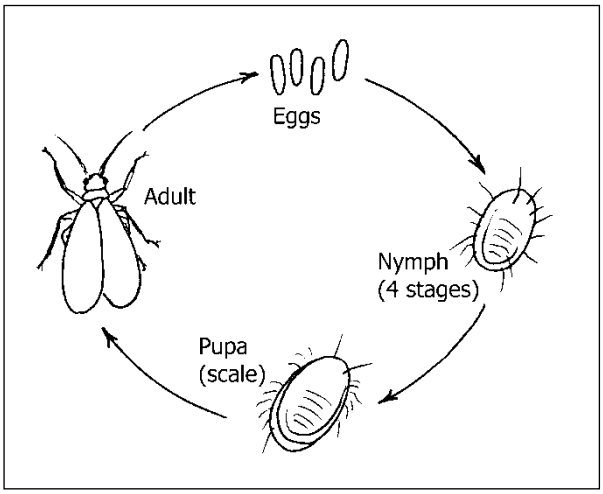


Figure 7.15. Greenhouse Whitefly Life Cycle (18 – 57 days).

White Grubs

White grubs are the larval stage of scarab beetles, such as European chafer, and June and Japanese beetles. The grubs are white and often have three pairs of legs near their heads, and will lie on their sides in a C-shaped position when exposed. White grubs feed on plant roots and can cause considerable damage to landscape and nursery plants.

The life cycle of most white grubs is completed in 12 months. The adult beetle will lay its eggs in the soil in the summer. As soon as the grubs hatch, they begin to feed on plant roots. The grubs move deep in the soil during winter to overwinter. When the soil warms in the spring, they move up to resume feeding. The grubs pupate in late spring and the adults emerge in early summer.

There is particular concern about the movement of **Japanese beetle** *(Popillia japonica*) in North America because it is known to feed on more than 300 plant species, causing significant plant and environmental damage. The white grub feeds on roots while the adult feeds on plant foliage.

Japanese beetle is native to Japan and was first detected in the US in 1916 and in Canada in 1939. It is present in New Brunswick, Nova Scotia, Ontario, Prince Edward Island, Quebec, and 36 US states.

There are phytosanitary requirements in Canada and the US to prevent the spread of Japanese beetle. The movement of rooted plants with soil or growing media is prohibited from infested to non-infested areas. For more information about movement requirements and the Japanese Beetle Nursery Management Program, contact the Canadian Food Inspection Agency.

Chapter 8 - Vertebrate and Mollusk Pest Management

Deer

Two species of deer are found in BC: the mule deer (including the black-tailed deer), found throughout most of the province, and the white-tailed deer, which is abundant in the Southern Interior valleys. Both kinds can cause serious damage to a variety of grasses, shrubs and trees (especially fruit trees), although some plant species are preferred over others. See Appendix Q for a listing of plant species that are not favoured for browse by deer. In spring and summer, most damage is done to new, leafy growth. In winter, buds and twigs may be eaten and bark stripped off trunks and branches of trees. Antler-rubbing may break branches and remove bark. Damaged plants are set back in growth and may never develop properly.

Management

Fencing is the best solution for chronic deer damage. Woven wire fences should be at least 2.4 m high and use a 15 cm wire mesh to keep deer out. The mesh should be secured as close to the ground as possible to prevent deer from crawling underneath. Solid board or panel fences need be only about 1.5 m high, because deer are much less likely to jump over them. Electric fences are also effective and are much less expensive. Electric fences should be 1.5-2.1 m high with 7-9 strands of smooth, high-tensile wire at 20-30 cm spacing. A high-voltage energizer must be used with this type of fence. For information on fencing design, consult the *Crop Protection and Wildlife Control Fences* factsheet, available from Regional Offices of the Ministry of Agriculture.

Chemical repellents, such as putrescent whole egg solids (e.g. Deer-Away Big Game Repellent), effectively repel deer. Dormant trees and shrubs should be dusted when moist, so that the repellent will adhere to the leaves and twigs. Thiram (e.g. Skoot) is a rabbit repellent, but is also effective against deer (see *Rabbits* below). Repellents may not work if deer are numerous or very hungry. Contact suppliers for additional information on the specific products available.

Field Mice (Voles)

Field mice, also called voles (not to be confused with moles), include the Townsend's vole on the South Coast and the meadow vole and mountain vole in the Southern Interior. Voles are 13-23 cm long, including the tail. Compared to house mice, they have shorter ears (barely projecting above the fur) and short, furry tails that are up to ½ the length of the body. House mice have longer, naked tails. Field mice are mainly pests of agricultural crops, but sometimes invade gardens next to farms or uncultivated fields. Their numbers fluctuate widely; in some years they can be abundant. They eat almost any kind of plant matter including grass, root vegetables, plant roots, and in winter, the bark of trees and shrubs. In the winter, they will frequently girdle the roots, crown and stems of field-grown trees, especially if there is grass or snow cover around the base of the plants. They build underground burrows, and the small burrow openings are a sure sign of field mouse activity.

Management

The best control, where possible, is frequent mowing or cultivation of vegetation within or next to crop areas. Field mice prefer the cover of tall grasses; they avoid areas that do not provide adequate cover. Trapping is not often practical in commercial crops. Ordinary mousetraps baited with peanut butter, apple slices or other fruit may help to reduce numbers. Cats can also be effective.

Poison baits. There are no "Domestic" labeled rodenticides registered for field mice, and rodenticides intended for house mice are ineffective for field mice. Rodent Bait (zinc phosphide) is registered for the control of meadow voles in orchards and nurseries. The bait must be placed in a covered bait station to protect it from the weather and to prevent accidental poisoning of other animals. Bait stations can be built from metal or plastic pipes, tin cans, and pieces of wood, or may be purchased commercially. They should be placed at 3-4 m intervals in areas where there are signs of mouse activity. The disappearance of the contents will indicate that mice are still present.

Mice, Rats (Coastal Area only), and Wood Rats

Two types of rats, the roof (black) rat and the Norway (brown) rat, infest buildings at the Coast. Both are long-tailed rodents about 40 cm long (including the tail). The roof rat is slender; it is usually black rather than brown, and has a tail longer than the body and big ears. The Norway rat has a tail shorter than the body and smaller ears.

The native bushy-tailed wood rat (also called pack rat) is found throughout the mainland. It is similar in size and shape to the Norway rat, but has larger eyes and ears, softer fur, and a hairy tail. It normally lives in rockslides and other broken terrain. The bushy-tailed wood rat often will invade cabins, storage sheds and other infrequently used buildings and carry off jewelry, kitchen utensils and other shiny objects, hence the name "pack rat." They can cause considerable damage by gnawing buildings or by eating stored food products.

The house mouse, which is found throughout almost all of the province, is about half the length of a full-grown rat, and is distinguished from a young rat by its smaller head and feet.

The deer mouse ranges in colour from grey to reddish-brown. It has larger ears than the house mouse, a white belly and white-sided tail. Although more common in woodlands, it can also occur in urban areas. **The deer mouse can transmit *Hantavirus* in BC (see below).**

Rats and mice are rarely seen unless numerous, but can be detected by the following signs:

- droppings (cylindrical and about 5 to 20 mm long with rounded ends in rats; about 3 mm long with pointed ends in mice),
- sounds (gnawing, squeaking, scampering),
- tracks on dusty surfaces or in snow,
- evidence of burrows or holes, or
- runways and greasy rub marks along walls.

Hantavirus gets into human lungs through exposure to infected feces (droppings), urine and saliva of the deer mouse. The deer mouse is the only known carrier in Canada, although the virus has been found in other rodents in the United States. *Hantavirus* can lead to severe respiratory infection or death.

Take safety precautions to avoid *Hantavirus*. When opening and cleaning buildings or storage facilities such as cabins, barns, garages or attics, open windows and let the room air out for a few hours, if possible. If you see any signs of rodent infestation or dead rodents, **do not sweep or vacuum,** since this will stir up infected dust. Instead, thoroughly wet the area with 10% household bleach (1 part bleach to 9 parts water) or a disinfectant such as Lysol, for at least 10 minutes. Clean up the material with a towel and mop or sponge with disinfectant again. Wear rubber gloves. Clean the whole floor, not just the spot where you see the droppings. Dispose of gloves and droppings in double plastic bags and bury. Wash hands thoroughly with soap and water.

Rodent-proofing buildings and eliminating sources of food, water and shelter for rodents are the best means of controlling rats and mice. Trapping and poisoning will provide only temporary relief. Eliminate water sources such as leaky taps or open pools. Get rid of piles of lumber or discarded material and clear vegetation and grass from around foundations so mice will not build nests there. Buildings can be made rodent-proof by installing tight-fitting doors and windows, and wire screen over basement windows and vents. Sheet metal kick-plates on wooden doors will stop rodents from gnawing through.

Management

Trapping is useful when only a few rodents are present. Traps should be baited with meat, bacon or fish for rats, and with cheese, cake or peanut butter for mice. Wood rats are considered wildlife under the Wildlife Act but property owners or occupants are allowed to trap and kill them to protect private property. Wood rats are fairly easy to trap. Either a standard rat-trap (snap trap) or a live trap can be effective. Appropriate baits include nut-meats, bacon rind, peanut butter and oatmeal, or dried fruit. There are no poisons registered for wood rat control.

Rodenticides are available for controlling house mice and Norway rats. Because of the wide variety of trade names for rodenticides, only the common names are given below. All of the poisons listed, except for red squill, are registered for both house mouse and Norway rat control.

Use one of the following according to label directions:

Anticoagulant rodenticides (multiple doses): may require several feedings to effect a lethal dose, but eventually cause death from internal or external bleeding. The most potent anticoagulants are brodifacoum☠, chlorophacinone☠, difethialone☠ and diphacinone☠; however, less toxic anticoagulants such as warfarin☠ (may also include ergocalciferol or sulfaquinoxaline) may also give adequate control, and are less hazardous to domestic animals. **Warning**: Diphacinone is highly toxic to dogs.

Acute rodenticides (single dose): are more toxic and can cause death after a single feeding. Covered bait stations, recommended for all rodenticides, are essential with single-dose rodenticides if there is a possibility of other animals being poisoned. Acute rodenticides include bromethalin☠ and zinc phosphide☠.

Rabbits (Cottontails) and Hares

Two kinds of rabbits, the eastern cottontail and the snowshoe hare, sometimes damage nursery crops. The eastern cottontail is found only on Vancouver Island and in the Lower Fraser Valley. It is about 40-45 cm long and weighs 1-2 kg. It is greyish-brown with a cinnamon patch on the back of the neck, and a white underside of the tail (hence "cottontail"). They eat many kinds of garden vegetables and flowers; few garden plants are immune to rabbit damage. Shrubs and trees may be damaged or even killed by rabbits chewing on bark during the winter. Twigs clipped off neatly indicate rabbit damage; twigs with a ragged edge are typical of deer damage.

The snowshoe hare, found most commonly east of the Coast Range, is a somewhat larger animal, with longer hind legs, and is usually white in winter. It sometimes damages young conifers in forest nurseries.

Management

Fencing or tree guards may be necessary for severe rabbit problems. A fence of 60 cm high chicken wire (2.5 cm mesh or smaller), fastened to the ground or slightly buried, will keep rabbits out. Valuable trees may be protected by cylinders of 6 mm mesh hardware cloth or hard plastic tree-guards, which will also prevent mouse damage.

Repellents that leave an unpleasant taste, such as Thiram-based repellents (e.g. Skoot), may be painted or sprayed on trunks and twigs of vulnerable plants. Thiram should not be used on edible plant parts within 14 days of harvest.

Trapping is permitted without a license or permit on rural, private land, since neither the eastern cottontail nor the snowshoe hare is protected by law. A permit to kill snowshoe hares is required on Crown Land. In winter, both are fairly easy to catch in live traps. In winter, cobs of corn or dried apples make good bait. Trapped rabbits may either be killed or released in a non-farming area.

Shooting rabbits may be effective if only a few are present. Consult local authorities regarding firearm bylaws and regulations.

Slugs and Snails (Mollusks)

Slugs and snails are soft-bodied mollusks. They are most prevalent in the spring, but can be active throughout the year if the temperature and humidity are suitable. Most will overwinter in the egg stage. The eggs are round, transparent or white, and are laid singly or in clutches of 3 to 50. Eggs hatch in the spring and the hatchlings mature during the summer before laying eggs in the fall. Because they require moisture for survival, slugs and snails are most active at night or during damp weather. Slugs often hide during the day in dark, damp, sheltered places such as under boards, pots, weeds and debris. In the summer, only a small percentage of slugs will remain above ground. Snails can remain on plants during the day but will withdraw into their shells on hot, dry days.

Slugs and snails have a diverse diet. Various species of slugs can eat algae, animal feces, centipedes, fungi, other slugs, insects, lichens, worms and plants. Slugs and snails damage many plant parts, including foliage, flowers, roots and tubers. They attack woody ornamentals, especially those with foliage on the ground and herbaceous perennials. Damage can be most severe in greenhouses and coldframes that are continually damp. They have rasping mouthparts that produce irregular holes in leaves. Silvery, slime trails on soil, grass and foliage is evidence that slugs and snails are present.

Figure 8.1. The slime trail on the daylily blooms is a sign of slugs and snails.

Management

Slugs prefer damp, shaded areas. Removing vegetative trash and other daytime hiding places helps to control them.

Trapping can provide effective control in small areas. Planks, grapefruit rinds or cabbage leaves can be placed on the ground overnight and the next day slugs sheltering underneath can be destroyed (cut in half). Unlike earthworms, slugs cannot recover from being cut in half. This method is not practical for very small slugs. Traps baited with fermented liquids are commercially available or they can be made from beer or fermented yeast.

Zinc or copper strips repel slugs and can be applied as a barrier around raised beds and greenhouses.

Baits can be used where slugs and snails are a serious problem. Baits containing iron phosphate can be used safely without the risk of poisoning pets and wildlife. Sprinkle the bait on the surface of the soil around plants. It must be ingested to be effective; it does not kill on contact. This product is as effective as products containing metaldehyde and much safer to use.

The molluscicidal effects of metaldehyde have been known since the 1930s. Metaldehyde disrupts the ability of slugs and snails to produce mucus, which reduces their mobility and ability to digest food.

Pets are attracted to metaldehyde; therefore it should only be used in a “bait protector”. Bait protectors can be made from a coffee can. Puncture the lower sides of the container with a can opener. Place the bait in the bottom of the can and replace the lid. This method will not protect dogs, since they can knock over the container or remove the cover to get at the bait. If there are dogs in the area and you wish to use metaldehyde, it is safer to use the RTU (ready-to-use) liquid formulation. Metaldehyde is not to be applied to plants after edible portions have formed.

Chapter 9 - Pesticides

This information on safe pesticide use is summarized from the BC Pesticide Applicator Course for agricultural producers. Study kits for the course are available from the Distribution Centre by phoning 1-800-282-7955.

Legislation

Laws protect applicators, bystanders, consumers and the environment. You can be fined for breaking the laws.

Canadian Laws

Pest Control Products Act & Regulations

Every pesticide used or sold in BC must be registered by Health Canada. Each label must have a PCP Act number on it. Using pesticides without a PCP Act # (from other countries) is against the law unless you have a Grower Requested Own Use (GROU) Import Certificate. The GROU program allows Canadian growers to import and use foreign versions of products registered in Canada. A list of the products approved under the GROU program is available on the PMRA website.

When a pesticide is applied to a crop, the crop and pest treated must be listed on the pesticide label. Using pesticides for uses not on the label is against the law. However, there are a few minor pesticide uses that may be registered but not on the label. This guide includes these minor uses. Information on minor use is available under "Pesticide Registration" on the Ministry's Pesticide Wise website.

Pesticides are labeled as Domestic, Commercial or Restricted. Restricted products are more hazardous and have special restrictions on the label.

The Food and Drugs Act

All foods must be free of harmful amounts of substances. Health Canada sets levels of allowable pesticide residues on crops at harvest. These levels are called maximum residue limits or MRLs.

The Canadian Food Inspection Agency takes random samples of crops to test for pesticide residues at the time of sale. If residues are more than the MRL the crop may be seized. If you follow the recommendations on the labels and wait the required days before harvest, residues should not be over the limit.

The Fisheries Act and Migratory Birds Regulations

You can be charged if you kill or harm fish or migratory birds with pesticides. This applies to creeks, rivers and lakes on your own property as well as on public land. It is illegal to introduce pesticides into waters either directly or indirectly through spray drift or run-off.

Transportation of Dangerous Goods Act

Certain dangerous goods cannot be transported unless you use shipping documents, special labels and vehicle signs. Ask your pesticide dealer if the product you have bought needs special transport procedures. Growers are usually exempt from this when they are transporting less than 500 kg of pesticide.

British Columbia Laws

Integrated Pest Management Act and Regulations

The BC Ministry of Environment also has rules about the sale and use of pesticides in BC. Rules that apply to farmers include:

1. Pesticides labeled Restricted or Commercial must be kept in vented and locked storage that has a warning sign on the door.

2. Anyone buying or using pesticides labeled Restricted must have an applicator certificate. Table 15.2 lists pesticides (referred to in this guide) that can be purchased and used only by certified applicators under the *Integrated Pest Management Act*.
3. An authorization such as a pesticide use licence, pest management plan or permit is required to apply pesticides to public land. Contact the regional Ministry of Environment office for details.
4. Businesses selling pesticides must be licensed and their sales people must be certified.
5. Anyone applying pesticides in exchange for a fee must have an applicator certificate and a Pesticide Use Licence. But, if you spray your neighbour's crops you do not need a license as long as the work is done as a favor and no money is exchanged.
6. Everyone must dispose of containers and leftover pesticides safely.

The Ministry of Environment was in the process of amending the Integrated Pest Management Regulation when this section was published. Proposed amendments to the regulation will require that pesticides used in landscaped areas are applied by trained people and, will change the way Domestic class pesticides are sold and update the schedule of excluded pesticides. Information on the changes can be found on the Ministry of Environment website.

WorkSafeBC

WorkSafeBC Regulations for Occupational Health and Safety apply to farmers who must be registered by WorkSafe BC. If you are unsure whether they apply to you, call WorkSafe BC at 1-888-621-7233. AgSafe (formerly FARSHA) (1-877-533-1789) can also provide information on WorkSafeBC regulations.

The WorkSafeBC regulations cover conditions of workplaces such as general safety procedures, hazardous substances, pesticides, confined spaces such as silos and storage bins, protective clothing and equipment, tools, machinery and equipment, and animal handling.

The regulations on pesticides outline requirements for pesticide applicator certification, emergency medical care, washing facilities, personal protective clothing and equipment, application equipment, pesticide application, posting warning signs, re-entry into treated areas, record keeping, drift prevention, and aerial application. Copies of the regulations are available from any WorkSafeBC office.

Their pesticide regulations state that workers must be over 16 years old and must have a valid pesticide applicator certificate from the Ministry of Environment if they mix, load or apply moderately or very toxic pesticides, or if they clean or maintain application equipment for these pesticides. Table 15.2 lists which pesticides are moderately or very toxic and, identifies which pesticides can only be used by certified applicators. Anyone under the age of 25 years is considered a young employee and must complete a "new or young employee" orientation. AgSafe can help develop or present a program for your farm.

The WorkSafeBC re-entry requirements are listed in this chapter in the Re-entry Restrictions Section. The record keeping requirements have been incorporated into the grower's spray record. Refer to the regulations for the rest of WorkSafe BC's requirements.

Toxicity

Some pesticides are more poisonous or toxic than others. The categories of pesticide toxicity used in this guide are listed in Table 9.1. The categories indicate short-term toxicity and are based on the LD_{50} of the active ingredient. The LD_{50} values are only a guide to the toxicity of a pesticide to humans.

Table 9.1. Oral and Dermal LD_{50} Values of the Short Term Toxicity Categories

Toxicity	**Oral LD_{50}** (mg/kg)	**Dermal LD_{50}** (mg/kg)
Very Toxic	0 to 50	0 to 200
Moderately Toxic	51 to 500	201 to 1,000
Slightly Toxic	over 500	over 1,000

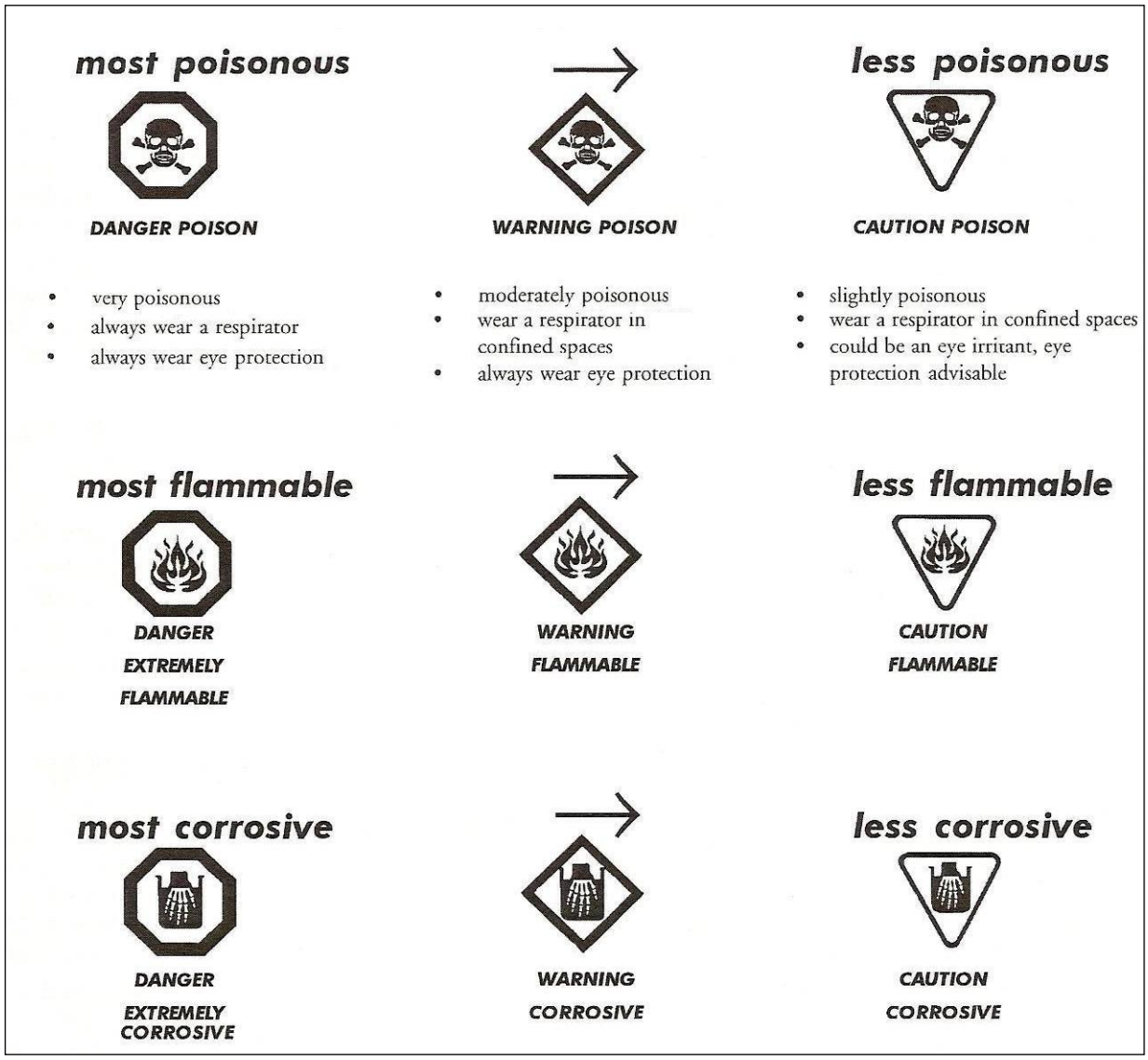


Figure 9.1. The pesticide warning symbols used to identify product hazards.

Hazard Shapes and Symbols

Shapes and symbols on pesticide labels indicate how harmful a pesticide can be. The shapes indicate how hazardous the product is. The symbols inside the shapes tell you the type of hazard. If symbols are not on labels, the pesticide has very low hazard.

Exposure

Pesticides can enter your body through the skin (dermal), the mouth (oral), the lungs (inhalation) or the eyes. The skin is the most common route of poisoning for pesticide applicators. Skin contact may occur from a splash, spill or drift. Your skin is most likely to get contaminated when mixing and loading pesticides.

Hazard

The hazard of using a pesticide depends on both its toxicity and the amount of exposure. Reduce hazards by selecting pesticides with low toxicity and by reducing exposure. Wear protective gear and follow safety guidelines.

Poisoning and First Aid

Symptoms of Pesticide Poisoning

Know the poisoning symptoms of the pesticides you use. Read pesticide labels for symptoms. Effects from pesticide poisoning vary from person to person and are often hard to recognize. Some poisoning symptoms are headache, fatigue, nausea, dizziness, irritation of the skin or nose or throat, blurred vision, tiny pupils, trembling, perspiration, difficulty breathing, vomiting and unconsciousness. Call the Poison Control Centre or a doctor immediately if you suspect poisoning, and follow their instructions.

Poison Control Centres are open 24 hours a day. They give first aid information and treatments for poisoning. The phone number of the Poison Control Centre (1-800-567-8911) can be found in the front of the phone book under Emergency Numbers.

First Aid

Make sure you, and other people on the farm, know what to do in case of an emergency. Consider taking a first aid course and CPR course.

If someone has been poisoned:

1. Protect yourself.
2. Move the victim from the area of contamination.
3. Check if the victim is breathing. If breathing has stopped or is very weak, clear the airway and begin artificial respiration. Continue until the victim is breathing normally or until medical help arrives. When doing mouth-to-mouth resuscitation, use a plastic mask to protect yourself from poison.
4. Call the Poison Control Centre (1-800-567-8911) or ambulance. Be ready to tell them the pesticide name, active ingredient, and the PCP Act registration number.
5. Unless the Poison Control Centre or doctor tells you otherwise, follow the procedures listed below, then:
6. Transport the patient to the nearest hospital.

If a pesticide contacts the eyes, put on waterproof gloves and hold the eyelids open and rinse with clean water for 15 minutes or more. Do not use an eye cup. Do not use chemicals or drugs in the wash water.

If pesticide contacts the skin, put on waterproof gloves, remove the contaminated clothing and wash the affected area of the skin with lots of soap and water. Cover burned areas with a loosely applied, clean cloth. Do not apply any drugs or medications to the burned area. Do not use ointments, greases, creams, lotions or other drugs. If the victim is in shock, keep the person lying down and warm until medical help arrives.

If pesticide was breathed in, take the victim to fresh air as quickly as possible, loosen tight clothing and watch for signs of unconsciousness or convulsions. If breathing has stopped or is difficult, keep the airway open and begin resuscitation. Use a plastic facemask to protect yourself. To prevent chilling, wrap the patient in blankets but do not overheat. Keep patient as quite as possible.

If a pesticide is swallowed:

- If a person is conscious and able to swallow, give them ½ to 1 glass of milk or water. Larger quantities may cause vomiting.
- Do not induce vomiting.
- Call the Poison Control Centre at 1-800-567-8911 for further advice.
- If the patient is retching or vomiting, place the patient face down with their head lower than their body in the recovery position. This prevents vomit from entering the lungs and causing more damage. Do not let the patient lay on their back. Clean the vomit from the patient and collect some in case the doctor needs it for chemical tests.
- When medical advice cannot be obtained, check and follow the pesticide label for directions.
- The doctor may recommend administering activated charcoal to adsorb pesticide still in the stomach. Follow the doctor's instructions. Activated charcoal should be administered only with the advice of a medical attendant or doctor.

Protective Clothing and Equipment

Wear protective clothing and equipment to minimize exposure to pesticides. Remember to wear safety equipment during mixing and loading, application and clean-up. Always wear coveralls, waterproof boots, waterproof gloves and a proper hat. You may also need to wear eye or face protection, and a respirator, waterproof apron, waterproof pants and jacket. The equipment you wear depends on the pesticide and type of application. Therefore, follow the safety recommendations on the pesticide label.

Coveralls - Wear long-sleeved coveralls over full-length pants and long-sleeved shirts. Make sure the coveralls are closed at the neckline and wrists. Remove your coveralls as soon as you have finished your pesticide activities. Remove them immediately if they become wet through with pesticide. Wear waterproof clothing if you might get wet during pesticide application.

Some disposable coveralls are suitable for pesticide use. Check with your supplier to see which ones can be used for pesticide application. When removing disposable coveralls, do not contaminate inside the coveralls if you plan to use them again. Between wearing, hang them in a well-ventilated area away from other clothing. Do not launder disposable coveralls but do wash clothing worn under disposable coveralls as you would other clothing worn during pesticide use. Replace with a new coverall when severe pilling (balls on the surface), rips or holes appear. To discard, place in a plastic garbage bag and take to a landfill site. Do not dispose of used coveralls by burning.

Gloves - Always wear gloves when handling pesticides. Many glove materials are available. Use unlined, waterproof gloves unless the pesticide label recommends a specific material. Do not use gloves made of leather, cloth or natural rubber, or gloves with cloth linings. Make sure the gloves have no holes or leaks. Keep your coverall sleeves over the gloves and fold down the tops of the gloves to make cuffs. Wash your gloves before removing them and after each use.

Boots - Wear waterproof, unlined knee-high boots of rubber or neoprene when you load, mix or apply pesticides. Wear your pant legs outside of your boots. Do not wear boots made of leather or fabric. Wash the outside of your boots after each use.

Goggles and Face Shields - Wear goggles if there is a chance of getting pesticide spray or dust in your eyes. Do not use goggles with cloth or foam headbands. Do not wear contact lenses when handling pesticides. Face shields provide extra protection when mixing and loading toxic pesticides. Wash goggles and face shields after use.

Hats - Wear a waterproof hat when pesticides may be splashed or when you could be exposed to drift. Wear a wide-brimmed rubber rain hat when you will get wet with spray. Do not wear baseball caps, fabric hats, or hats with leather or cloth inner bands.

Aprons - Wear a waterproof apron when you pour and mix concentrated pesticides.

Respirators - Wear a respirator when the label says to wear one; or when the label says to avoid inhalation of dust, vapour, or spray mist; or if there is a danger poison symbol on the label; or if you are applying pesticides in an enclosed space. Make sure your respirator fits. Men should shave before using a respirator as facial hair prevents a proper fit.

Full-face respirators give more protection and may be more comfortable than a half-face mask and goggles.

Do not use dust masks when applying pesticides. They do not protect you from the fumes.

Specially designed, enclosed tractor cabs fitted with air-purifying devices can protect you from pesticide vapours. A regular enclosed cab is not adequate protection if a respirator is required.

Special respirators must be worn when using a highly toxic fumigant such as methyl bromide. Check the label for details.

Respirators must be approved by NIOSH or an agency sanctioned by WorkSafeBC. The cartridges remove toxic fumes from the air. Cartridges labeled for organic vapours or pesticides are needed for most pesticides. Filters remove dust and mist. Both filters and cartridges must be replaced regularly for the respirator to work.

When you use your respirator:

1. Check the intake and exhaust valves.
2. Make sure there are no air leaks around the face mask. Do an inhalation or exhalation test.
3. Change the dust filter after 4 hours of use or more often if breathing becomes difficult.
4. Change the cartridges after 8 hours of use or sooner if you can smell the pesticide. Replace cartridges at least once a year and more often if you use them frequently.

Protective Equipment for Fumigants, Smoke Bombs and Foggers

Use a full-face gas mask with correct canister when applying very toxic pesticides indoors. Keep a spare canister on hand as they can lose their effectiveness. A self-contained breathing apparatus that supplies clean air is recommended for indoor work with gases or extremely toxic compounds.

Wear a full-face mask when lighting smoke bombs and when airing the house. Light the bomb farthest from the door and work toward the door. If smoke bombs are placed in more than one path, they should be lit at the same time by a separate person in each path.

When using fogging machines, wear complete protective clothing, including hat, jacket, pants or coveralls, waterproof gloves and full-face mask.

Cleaning Protective Clothing and Equipment

After application, wash your gloves, boots, goggles, faceshield and apron. Wash your respirator face piece with soap and warm water. Then rinse it with clean water and dry it with a clean cloth. Keep the cleaned respirator in a plastic bag in a clean, dry place. Store the respirator and protective clothing away from pesticides and spray equipment.

Discard any clothing that has become soaked with a pesticide.

Launder all your clothing after each day of applying pesticides. Wash protective clothing separately from the rest of the laundry. Do not touch contaminated clothing with bare hands.

Use rubber gloves. Pre-rinse clothing using the presoak cycle. Use a high water level and the hottest water setting on your machine. Use a heavy-duty detergent.

If clothes are heavily contaminated, run through two complete cycles. Hang clothes outside to dry in the sunlight if possible. Clean the washing machine by running it through a full cycle with detergent and no clothes to remove any pesticide residue.

Personal and Environmental Safety Guidelines

Buying Pesticides

- Make sure the pesticide is registered for your specific use (crop and pest).
- Only buy an amount that you can use up in a year.

Transporting Pesticides

- Never transport pesticides with food, feed, fertilizer, clothing or household goods.
- Lock up the pesticides if you leave your vehicle.
- Never transport pesticides in the passenger section of any vehicle.
- Ask the supplier if you need shipping papers and vehicle warning signs.

Storing Pesticides & Shelf Life

Pesticides vary in their stability and response to storage conditions. Try to purchase a quantity of pesticide that can be used up in one growing season. However, under proper storage conditions most pesticides can be used after at least one year of storage. Follow these guidelines for storage:

- The law says Commercial and Restricted pesticides must be kept in locked and vented storage that has a warning sign on the door.
- Store pesticides in their original container with the original label. If a label is illegible or missing, label it with the trade name, active ingredient and PCP number. Then obtain a replacement label from your dealer or the PMRA website.
- Never keep pesticides near livestock, food, feed, fertilizer, seed, wells, water supplies or in your home.

- Pesticide storage should be 30.5 metres from any well.
- Keep herbicides separate from other pesticides.
- Return pesticides to storage when not in use.
- Keep a list of the pesticides in storage.
- Protect the pesticides from extreme temperatures. Freezing destroys some liquid pesticides.
- Close containers when not in use.
- Dispose of unwanted, unmarked and damaged containers.
- Keep containers above floor level to protect from dampness and flooding.
- Post emergency numbers nearby.
- Keep a fire extinguisher, broom and shovel, absorptive material and protective clothing nearby in case of emergencies.

Mixing and Loading Pesticides

- Wear protective clothing and equipment.
- Read and follow label directions.
- Choose a mixing and loading site away from people, livestock, pets, wells and water bodies.
- Measure accurately.
- Do not rip open paper pesticide bags. Slit them open with a sharp knife.
- Mix pesticides in still or low wind conditions. Stand upwind of the pesticide.
- Hold the container below eye level when measuring or adding pesticide into the spray equipment.
- Only use mixing equipment for pesticides and return it to locked storage when not in use.
- Triple rinse pesticide containers as soon as they are empty. Rinse measuring and mixing equipment. Put rinse water into the sprayer.
- Use clean water. The pH of the water should be from 5.0 to 7.0, and the alkalinity should be below 60 to 80 ppm.
- Prevent overflow. Do not leave the tank unattended.
- Prevent contaminating the water supply by leaving at least a 15 cm air gap between the end of the filler hose and the water in the spray tank. You can also use a backflow preventer valve.

Applying Pesticides

- Read and follow label directions.
- Use calibrated application equipment.
- Use the label rate.
- Wash before eating, drinking, smoking or using the toilet.
- Have fresh water and emergency supplies on hand.
- Make sure the area to be treated is clear of people and animals.
- Do not work alone when handling very toxic pesticides.
- Post warning signs if necessary to keep people out of treated areas.
- Use separate equipment for applying herbicides.
- Cover or remove animal food and water containers near the treatment area.
- Wear gloves to replace or clean plugged nozzles. Do not blow out a plugged nozzle or screen with your mouth. Use a soft brush or toothpick to fix plugged nozzles.
- Shut off the spray nozzles when you turn and stop the flow of granulars at the end of rows.
- Pesticides must be registered for chemigation before they can be applied through irrigation systems; the label will include instructions for chemigation. If chemigation is used, follow *Chemigation Guidelines for BC*. This publication is available from the Ministry of Agriculture.
- Use and maintain the tractor speed chosen during calibration.
- Prevent pesticides from contaminating non-target areas. Leave an untreated area around lakes, streams, ditches and wells. Spray downwind from sensitive areas.
- Minimize drift by:
  - Not spraying in strong winds or dead calm. There is usually less wind in the early morning and late evening.
  - Not spraying when temperatures are greater than 30°C.
  - Using a drift control agent.
  - Using drift guard or other specialty nozzles that reduce drift.

- Using boom sprayers with as low pressure as possible, the correct nozzles, large volumes of water and setting the boom as near to the ground as possible to still get uniform coverage.

After Applying Pesticides

- Clean equipment away from water supplies.
- Remove and clean protective clothing and equipment.
- Shower.
- Keep records of every application.

Disposal of Unwanted Pesticides

- Calculate the amount needed so none is left over.
- Do not re-spray an area to get rid of leftover spray.
- Apply left over material according to label directions on another site or crop listed on the label. Do not put unwanted pesticides into sewers, down drains or on the land.
- Contact the regional office of the BC Ministry of Environment or Ministry of Agriculture for information on the disposal of unwanted pesticides.

Disposal of Containers

- Drain the container into the spray tank for at least 30 seconds or shake out the bag.
- Triple or pressure rinse drums, glass bottles, plastic and metal containers. Single rinse plastic and paper bags.
- Put the rinse water into the spray tank.
- Crush, puncture or damage empty containers so they cannot be re-used.
- Return containers to the pesticide storage until they can be taken to a public dump, back to the supplier or to a collection site. Containers can be buried on your land 0.5 metres below the surface. The site must be flat, not a bog, gravel or sandy soil and at least 200 metres from wells, lakes, rivers, streams or ponds.
- Do not burn pesticide containers.

Re-entry Restrictions

People can be poisoned by working in pesticide-treated areas too soon after application. Poisoning may occur due to inhaling pesticide vapour or handling treated plants. Farmers are required to post a sign that informs workers when they can enter a field. The sign must state the application date and the re-entry time. Signs can be obtained from AgSafe.

Most pesticide labels state when a treated area can be re-entered. The restricted-entry interval (REI) is the period of time that agricultural workers, or anyone else, must not do hand labour in areas after a pesticide has been applied. The purpose of the REI is to allow time for pesticide residues and vapours to dissipate to safe levels before work can be resumed in the area.

WorkSafeBC has also established REIs for pesticides. Their regulations require people to not enter a treated field until they have waited the following periods:

- 24 hours for a slightly toxic pesticide,
- 48 hours for a moderately or very toxic pesticide, and
- the total of the re-entry intervals for tank mixes of moderately and very toxic pesticides.

Growers should follow the REI stated on the pesticide label. If there is no REI on the label, then growers should apply the REI periods established by WorkSafeBC.

The Pest Management Regulatory Agency (PMRA) has prepared a guideline to follow if a farmer needs to enter a treated area before the end of the REI. The guideline states that a certified applicator may enter a treated area during the REI period to perform short-term tasks provided:

- No entry for 4 hours following the end of pesticide application.
- No hand labour activity is performed.
- The certified applicator wears the personal protective equipment that the label specifies for mixing/loading and wears a NIOSH-approved respirator if entering within 4-12 hours after application.
- The time in the treated area during the REI doesn't exceed one hour in any 24-hour period.

- Decontamination supplies are available for washing off pesticides and pesticide residues.

Information on the label REI and relative toxicity of each pesticide is provided in Table 15.2. Use the REI on the label if it is longer than the WorkSafeBC re-entry interval.

Grazing Restrictions

If animals are to graze a treated area, check the pesticide label for grazing restrictions. Wait the required time before grazing.

Environmental Precautions

Buffer Zones

Many pesticide labels now contain buffer zone information. Buffer zones are strips of land next to sensitive areas, in which pesticide application is not permitted (see Figure 9.2). The purpose of the buffer zone is to protect sensitive areas from pesticide drift. Applicators are required to leave a

buffer zone when the label says to. A buffer zone only needs to be left between the end of the spray boom and the downwind sensitive area. Labels will tell you what sensitive areas must be protected and the size of the buffer zone. Labels may require protection of water bodies (aquatic) or planted areas (terrestrial).

Protecting Fish and Other Wildlife

Some pesticides are toxic to fish, birds and wildlife. Exposure to trace amounts of these pesticides may be lethal. Destroying the vegetation along fish-bearing water harms fish by removing food and shelter, but also increases the risk of pesticide entry.

Protect fish and wildlife from pesticide poisoning by following label precautions, safety guidelines in the guide and the guidelines below:

- Use pesticides only when necessary.
- Select the least toxic and least persistent pesticide.
- Follow label directions regarding the size of buffer zones from downwind bodies of water to keep pesticides out of the water.
- Do not destroy vegetation along fish bearing waters and do not spray with pesticide.
- Incorporate granular insecticides.
- Use precautions to prevent drift, leaching and run-off to areas outside the treated area.
- Store treated seed where it cannot be eaten by animals.
- Place baits in covered bait stations.

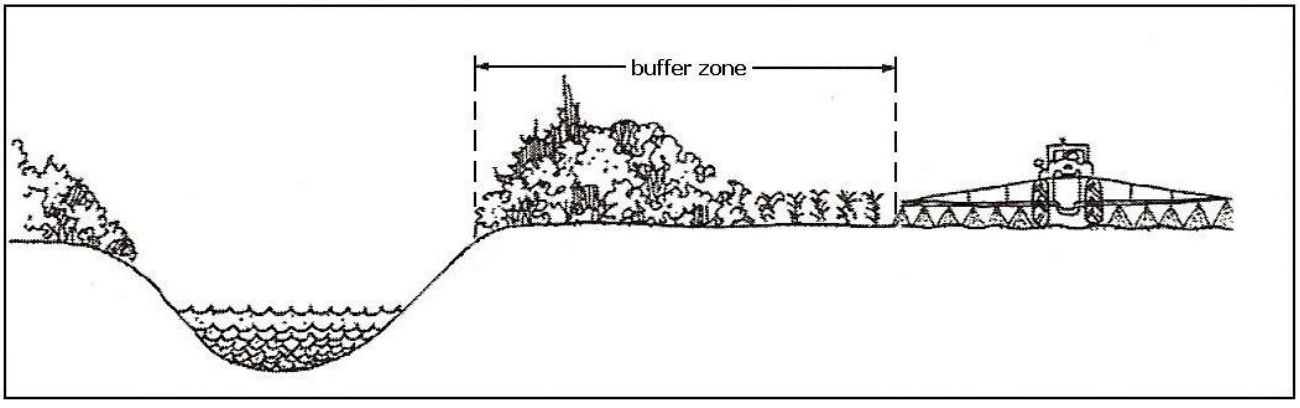


Figure 9.2. Schematic of a pesticide buffer zone.

Protecting Bees and Beneficial Insects

Bees and other pollinating insects are essential for the production of many crops, while other insects can control pests. Many pesticides, particularly insecticides, are very toxic to honeybees, wild bees and beneficial insects. Protect these insects from pesticide poisoning by:

- Telling nearby beekeepers about your spray program.
- Not applying pesticides near hives.
- Not applying pesticides toxic to bees when plants are in bloom.
- Selecting formulations least harmful to bees. Microencapsulated formulations are very hazardous; dusts are more hazardous than sprays; wettable powders are more hazardous than EC and liquid formulations; granulars are least hazardous to bees.
- Reducing drift.
- Timing applications carefully. Evening sprays are less hazardous than morning sprays. Both are safer than midday.

Protecting Groundwater

Groundwater is the source of water for wells and springs. It is very difficult to clean contaminated groundwater. The solution to groundwater contamination is prevention.

Groundwater contamination is most likely to occur where soils are gravelly or sandy, the water table is close to the soil surface, there is high rainfall or extensive irrigation, or the pesticide is injected or incorporated into the soil. Pesticides that are persistent in the soil, are weakly absorbed and leach quickly, or are highly soluble may contaminate groundwater.

Remember to avoid spills, drift and irrigation run off, and to properly dispose of unwanted pesticides and empty containers. Never store pesticides near wells or pumphouses and guard against leaking containers.

Well construction, maintenance and location can be factors in contamination. Maintain proper seals between pump and pump base, as well as seals between well casings.

Streamside Protection

Growers are encouraged to examine their farm activities and modify any practices that could put fish habitats at risk. Some areas where risk may occur include the use of pesticides, fertilizers, manure and woodwaste.

Emergency Response

- Keep the phone numbers for the Poison Control Centre, doctor, ambulance and Provincial Emergency number for dangerous goods spills nearby (1-800-663-3456). The Poison Control Centre phone number is in the front section of the telephone book.
- Have protective gear and equipment easily available.
- Keep absorptive material, a container for contaminated waste, tools to pick up contaminated material, bleach and hydrated lime available.

Spills

- Protect yourself.
- Keep bystanders away.
- Do not eat, smoke or drink during clean up.
- Work upwind of the spill.
- Contain the spill. Surround and cover it with absorbent material.
- Clean up the spill.
- Decontaminate the area using bleach or detergent. Absorb excess liquid with absorbent material.
- Put contaminated absorbent material in the special waste container and seal it.
- Remove and wash protective gear. Shower.
- If you need help, call the Provincial Emergency number (1-800-663-3456).

Fires

Fires involving pesticides can be very dangerous. Burning pesticides may release toxic fumes that are poisonous to firefighters, bystanders and animals, or that may contaminate the environment. Pressurized containers can explode. Pesticides can spill out of containers damaged by the fire. Run-off from fighting a fire can contaminate a larger area.

Ahead of time, give your fire department a list of all pesticides in storage (brand names, active ingredient, PCP #'s and quantity remaining). Update the list each year.

In case of a fire, call the fire department and tell them there is a fire involving pesticides. Keep people and animals away from the fire.

For more information on practices to reduce the risk of a fire and to deal with fires that involve pesticides, check out the Ministry's Pesticide Wise website.

Tank Mixing Pesticides

It is often economical and convenient to apply a mixture of two or more pesticides when more than one pest is to be controlled. However, proceed with caution because mixing non-compatible pesticides can result in damage to the application equipment or crop, or reduce pest control. The best source of information on tank mixing is the pesticide label; many labels do contain information on pesticides that can be used in a tank mix. Some labels even contain directions for mixing the product with other pesticides. Alternatively, information on pesticide compatibility can be obtained from the registrant and extension specialists.

If you are uncertain whether two pesticides are compatible, perform a compatibility test prior to applying the tank mix. Test the compatibility by mixing the pesticides in a small volume of water in the relative proportions that you plan to use them. The components should mix well when the mixture is stirred or shaken. The mixture should not separate nor should components settle out rapidly upon standing. When applying a new tank mixture, it is recommended to apply on a small scale.

In general, it is riskier to mix two different types of formulations, for example wettable powders with emulsifiable concentrates. When using emulsified concentrates, always read the warnings on the manufacturer's label. Tank mixes should be applied promptly to reduce the risk of crop injury or a decrease in effectiveness.

Spray injury can also arise from a variety of other causes. Improper operation of sprayers, excess dosage of chemicals, sudden weather change during or following spraying, sprays applied at low volume, or spraying during extremely hot periods (32°C or higher) may cause either fruit or foliage injury.

Growers are allowed to apply unlabelled tank mixes of registered pesticides as long as:

- The application timings of all products tank mixed are compatible with regards to crop and pest staging.
- Each product tank mixed is applied in accordance with its registered product label. In cases where use directions differ for the products to be tank mixed, the most restrictive directions must be followed.
- The tank mix is not specifically excluded or contradicted on either tank mix partner label.

Adjuvants

Adjuvants can be an important part of a pest control program because they help to overcome some of the variables that potentially reduce the effectiveness of a pesticide. Adjuvants are used as spray solution additives to prevent problems associated with spray application such as beading, incomplete coverage, run-off, adverse water quality or removal through rain and wind.

Adjuvant products include surfactants, wetting agents, crop oils, thickeners, drift control agents, penetrants, anti-foam agents, stickers and spreaders. When choosing an adjuvant, decide which aspects of the spray application need improvement. In addition, the environmental conditions before, during and after the application, as well as the characteristics of the plant surface should be taken into consideration.

Surfactants are perhaps the most frequently used class of adjuvant. Surfactants reduce the surface tension of a solution so that it can spread and cover a surface more efficiently. Surfactants are classified as non-ionic (uncharged), cationic (positively charged), and anionic (negatively charged). Spray coverage can also be improved by the type and set-up of the application equipment.

Not all pesticides are labeled to be used with an adjuvant. Always consult the product labels as some combinations can be hazardous for your health, damaging to crops or cause the product to be ineffective. For example, spray tank mixes of copper fungicides and organosilicone surfactants should be avoided because the surfactant can enhance foliar uptake of copper and lead to phytotoxicity.

Chapter 10 - Pesticide Application Equipment

Ground-based Application

Most farms use ground-based equipment to apply pesticides. Hand-operated or backpack sprayers are common on all farms for spot treatments and areas difficult to reach with tractors. Motorized sprayers are used on most farms. For more details on pesticide application equipment and calibration, see the *Pesticide Applicator Course for Agriculture Producers*. Information on how to purchase a study kit and write the certification exam is available on the Ministry of Environment website.

Boom Sprayers

The most common motorized sprayer is a boom sprayer with a pump that provides enough liquid pressure to spray the target from nozzles located on the boom. High pressure sprays (700-2,000 kPa or 100-300 psi) are typically required for insecticides and fungicides. The same sprayers can be used at lower pressures for herbicides.

Sprayers with Hand Guns

Tractor mounted sprayers with hand guns are often used to spray insecticides and fungicides in nurseries. Hand guns can be used with dilute sprays where the plants are sprayed for thorough coverage. The same procedure that is followed for backpack type sprayers should be followed to determine how much area can be sprayed with a tank of water before the pesticide is mixed (refer to *Calibrating Hand Operated Sprayers*). Herbicides can be more accurately sprayed by a tractor driven boom sprayer. Pesticide application also tends to be more uniform with backpack sprayers or granular applicators than with handguns.

Backpack Sprayers

The most common spraying equipment on small operations is the backpack sprayer. It is suitable for high-volume or dilute spraying both in field and greenhouse conditions. Basic, low cost backpack sprayers will generate only low pressures and lack features such as diaphragm pumps, agitators, pressure adjustment controls (regulator) and pressure gauges found on commercial grade units. These low-pressure sprayers without pressure regulators and gauges should not be used for applying insecticides and fungicides where uniform coverage is crucial. This is especially true with some of the new plant growth regulators where uniform coverage is a crucial part of their effectiveness. These sprayers with their limited control options are better suited for the home gardener situation.

Diaphragm pumps and agitators will allow the sprayer to be used with wettable powder sprays more effectively. Pressures should be above 80 psi to achieve the finer sprays suitable for applying insecticides and fungicides. Pressure gauges and pressure regulators enable the sprayer to operate at higher pressures (80-200 psi) and the operator to achieve a more uniform output from the sprayer. Note that a smooth uniform walking speed and spray wand motion is also required to achieve uniform coverage. Nozzles must be selected for the operating pressure of the sprayer and spraying conditions. Backpack sprayers should have a positive shut-off spray control valve to eliminate pesticide drips from the wand and nozzle. Drip-proof nozzle assemblies are also available as an alternative. Ball check valves in the nozzle body require 5 to 10 psi of liquid pressure to start spraying and close when the pressure drops below this level to prevent drips.

Chemigation

Chemigation, or the application of pesticides through an irrigation system, can be done only if directions for chemigation are on a pesticide label. An irrigation system used for chemigation must be specially designed for the application to be safe and effective. Information on chemigation is in *Chemigation Guidelines for British Columbia* by the Sustainable Agriculture Management Branch, BC Ministry of Agriculture.

Airblast Sprayers

Airblast sprayers for spraying insecticides and fungicides have become more common on larger farms. These use a combination of air and liquid to deliver the pesticide to the plant. The pesticide is pumped through nozzles into a blast of air from a high-speed fan. Airblast sprayers may use lower water volumes than boom sprayers. However, drift can be more of a problem due to the fine droplets required for thorough coverage when spraying at low volumes. The components of airblast and high pressure boom sprayers are very similar except for the added fan and air manifold on the air-blast sprayer. A separate boom on the airblast sprayer is required for spraying herbicides if a separate sprayer is not used. Airblast sprayers will not be discussed further in this guide.

Operation of Sprayers

Essential components of any chemical spraying equipment are the power source, pump, tank and nozzles. Others that must be considered are agitators, screens, filters, valves, pressure regulators, booms, hoses, gauges and hand-guns (see Figure 10.1).

Power Source

The power sprayer is normally driven by the PTO (power take-off) of the tractor or by an auxiliary engine. The power rating of these should be double the theoretical power required by the pump.

Pumps

A pump creates the pressure required for atomization and penetration of the spray on almost all types of sprayers. Choose a pump having the characteristics required for the job. Common pumps include:

- roller pump—excessive wear can occur with wettable powders,
- piston pump, and
- diaphragm pump.

For spraying insecticides or fungicides, sprayers require either diaphragm or piston pumps to develop the higher pressures needed (700 kPa or 100 psi) to get thorough plant coverage. Determine the capacity of the pump by the highest rate of application the sprayer is expected to deliver, an adequate volume for agitation and an additional 25% volume to account for the pump's wear. During operation there should always be flow in the bypass line indicating the pump has sufficient capacity to send some excess to the tank.

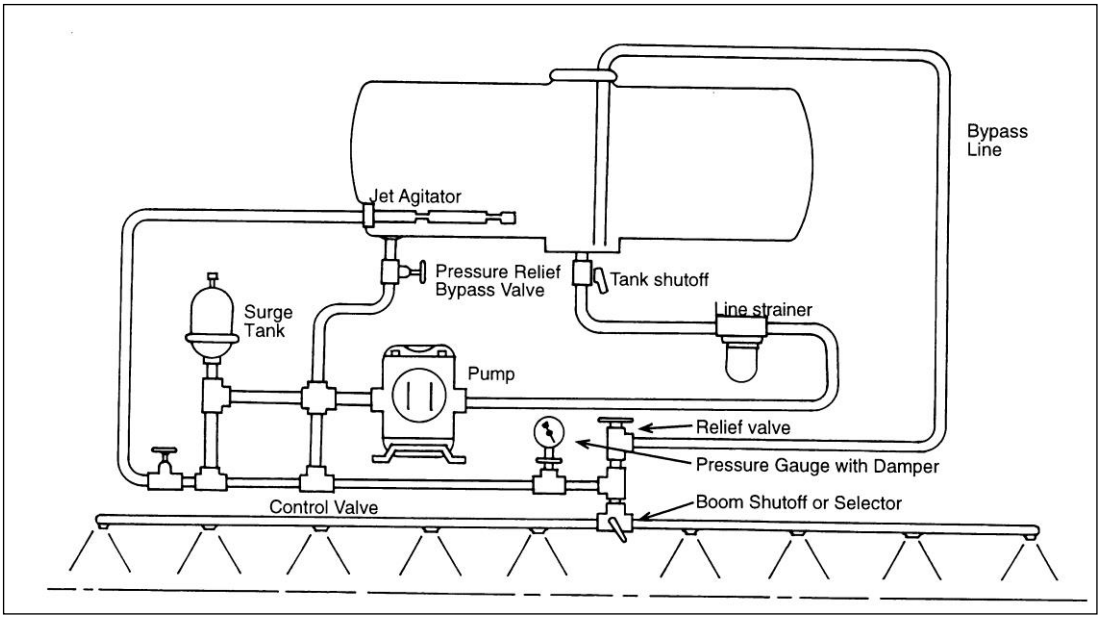


Figure 10.1. Components of chemical spraying equipment.

Note the maximum rpm allowed for the pump and always operate the tractor throttle so that the maximum is not exceeded. Be aware that increasing the pump's rpm will also increase its output, therefore, the tractor's throttle setting must be fixed during calibration and sprayer operation. Operating at too low an rpm may decrease the pump's output below that required for the sprayer.

Tanks

The size of the spray tank depends on the intended application rate and the mounting space available. The tank should be equipped with a large, screened opening for easy filling and cleaning. Tanks may be constructed of steel, stainless steel, epoxy-coated steel, fiberglass, polyethylene or aluminum. Fibreglass, stainless steel and polyethylene tanks are preferred because of their rust and corrosion resistance.

The herbicide Roundup and liquid nitrogen fertilizers must not be put in galvanized steel tanks, as a hazardous chemical reaction can result.

The rusting of steel tanks can be reduced by proper draining, cleaning and airing of the tank after use and by the use of rustproofing compounds. Either hydraulic bypass or mechanical agitation must be provided. If hydraulic agitation is used in the spray tank, additional pump capacity is required. Mechanical agitation is preferred if wettable powders are to be used.

Mechanical agitation with paddles gives the best mixing for wettable powder formulations. If hydraulic agitation is used, 1/10 to 1/20 of the tank capacity should be recirculated per minute. This flow should be supplied from a separate pressure line, not from the relief valve bypass.

Tanks should be equipped with drains in the lowest part of the tank to allow complete emptying of the tank. Drains should be easy to operate to encourage operators to drain the tank at the end of each day.

For proper mixing of pesticide dilutions, it is important to know the volume capacity of the spray tank. When partial tanks of spray mix are needed an accurate dipstick or gauge will enable the operator to mix the correct amount.

Hoses

Suction hoses (from the tank) should be reinforced so they will not collapse, be resistant to chemicals and oils, and be of the same diameter as the pump

inlet hole. The same type of hose can be used for the bypass line.

Hoses on the pressure side of the pump must be able to handle pressures higher than the intended use and preferably as high as the maximum pressure the pump can develop. To avoid excessive pressures on the hose, the relief or unloading valve should be released before flow to the boom is shut off.

Nozzles

The size of droplet produced by various nozzles depends upon operating pressures and nozzle design. The droplet size decreases with a higher pressure and with a smaller nozzle tip opening. Droplets that are too big give poor coverage and droplets that are too small drift easily.

Types of Nozzles

The main nozzle types used for chemical application are:

- **Flat spray nozzles** (also called fan type or TeeJets). These are used for low-pressure spraying such as the application of herbicides and insecticide drenches. They produce a fan-type pattern with less material applied along the edges of the spray pattern (see Figure 10.2). By properly overlapping the spray, a uniform application is produced across the spray boom. Offset flat spray nozzles at an angle of 10 degrees to the boom to prevent interference of the overlapping spray patterns. Nozzle spacing on the boom and the height of the boom above the target are critical to obtain a uniform application. Sprayer equipment suppliers and nozzle manufacturers' catalogues can advise growers as to the correct height of the boom at different nozzle spacings and for different nozzle spray angles. Do not operate these nozzles above 400 kPa (60 psi) to prevent excessive wear and fine spray droplets. Refer to manufacturers specifications for recommended nozzle pressures.

- **Even spray nozzle tips**. These produce an even spray pattern across the entire fan width (see Figure 10.2). These nozzles are used in band spraying of herbicides where there is no overlap from other nozzles. Align even spray nozzles with the spray boom. These nozzles are designed to operate at low pressures (less than 400 kPa or 60 psi). Refer to manufacturers specifications for recommended nozzle pressures.

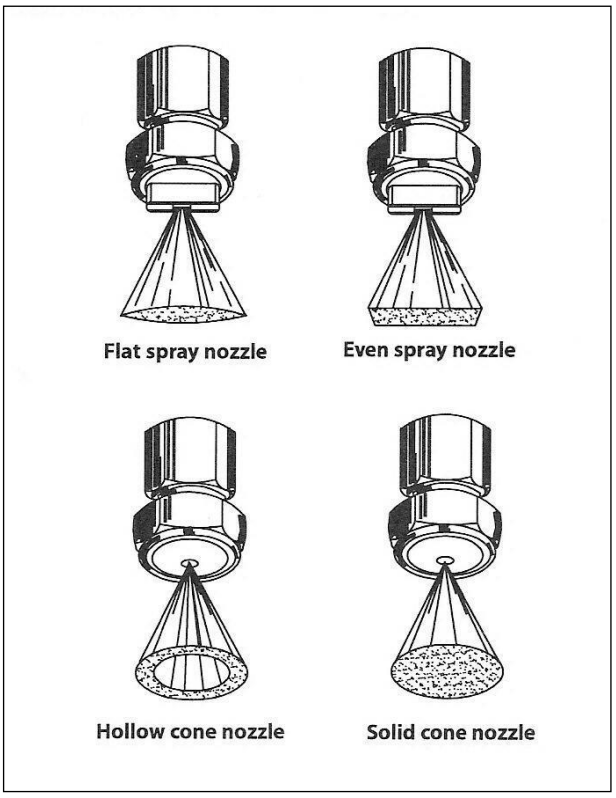


Figure 10.2. The main nozzle types use for chemical application.

Cone nozzle tips. These are used for medium to high-pressure spraying (700-2,000 kPa or 100-300 psi) and are mostly used for fungicides and insecticides. These nozzles produce a good swirling mist so the spray material can reach the undersides of leaves. Nozzle spacing should allow the adjacent spray patterns to cover the entire target otherwise skips may occur. An example of skips would be when the nozzles (and boom) are too close to the plants, the plants close to the boom and between the nozzles will be missed.

Cone nozzles are available as either hollow cone or solid cone types – both produce the same swirling mist but the solid cone nozzles are used when larger volumes are required (see Figure 10.2). The cone nozzles most commonly used in the industry are two-piece disc-core nozzles, which must be installed correctly with the rear nibs facing the nozzle body (see Figure 10.3). Cone nozzles are used in both boom and most air-blast sprayers.

Nozzle Sizes

Various sizes of flat, even and cone nozzle tips may be used to obtain the volume of water desired. Consult with your sprayer equipment supplier as he has information on nozzle outputs for the various nozzle sizes.

Ask for a catalogue with nozzle outputs in litres per minute. For your convenience, nozzle outputs for Spraying Systems Co. flat spray tips and disc-core type hollow cone spray tips are in Tables 10.1 and 10.2, respectively.

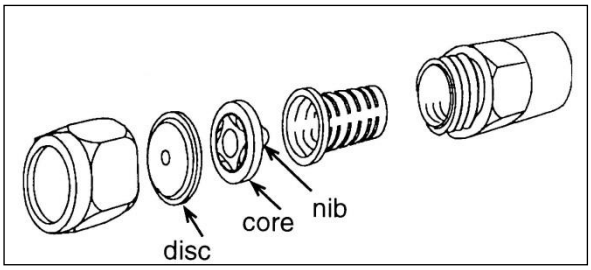


Figure 10.3. Assembly of disc-core nozzles.

Nozzle Tip Materials

Nozzle tips are made from a variety of materials. Choice of material depends upon the abrasiveness of the spray mixture. Wettable powders are more abrasive than emulsions. Brass tips are cheap but the metal is softer and the tips wear faster. In increasing order of durability, the following materials are used: plastic, brass, stainless steel, hardened stainless steel, ceramic, and tungsten carbide. By making flat and even spray tips out of colored plastic with a small amount of stainless steel or ceramic in the center with the spray orifice, the more durable tips can be made at a very reasonable cost. These nozzles are more cost-effective than nozzles made entirely of brass.

As nozzle tips wear out, the rate of application increases. Tests have shown that some wettable powders wear nozzle tips sufficiently to increase the rate as much as 12% after spraying only 20 ha. For this reason, frequent calibration of equipment is necessary. Also, very worn nozzles should be replaced because their spray pattern is distorted, which will result uneven application.

Hardened stainless steel discs and brass cores have been the materials chosen by many growers using hollow cone disc-core nozzles. The hardened stainless steel discs have corroded relatively easily affecting the nozzle outputs and distorting the spray patterns. A much more durable choice is the ceramic disc and cores, and they do not rust.

The ceramics require an extended nozzle cap and a plastic nozzle strainer to protect the ceramic from pinching and cracking between the brass nozzle cap and body. The added expense is quickly paid for in the increased durability from both wear andcorrosion. Keep pairs of discs and cores together and do not mix them up during nozzle cleaning.

Both the disc and cores wear and they should be kept together to determine the wear rate of the nozzles.

Table 10.1. Spraying Systems Co. flat spray nozzle outputs (litres per minute).

	Pressure (psi)									
Nozzle*	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**
8001	0.23	0.27	0.30	0.33	0.35	0.38	0.40	0.42	0.44	0.45
80015	0.35	0.42	0.45	0.49	0.53	0.57	0.61	0.64	0.66	0.68
8002	0.45	0.53	0.59	0.64	0.70	0.76	0.79	0.83	0.87	0.91
8003	0.68	0.79	0.89	0.98	1.06	1.14	1.21	1.29	1.34	1.40
8004	0.91	1.06	1.19	1.32	1.42	1.51	1.61	1.70	1.78	1.85
8005	1.17	1.32	1.48	1.63	1.76	1.89	2.01	2.12	2.21	2.31
8006	1.40	1.59	1.78	1.97	2.12	2.27	2.40	2.54	2.65	2.76
8008	1.85	2.16	2.38	2.61	2.82	3.03	3.20	3.37	3.54	3.71
8010	2.31	2.69	2.99	3.29	3.54	3.79	4.01	4.24	4.43	4.62
8015	3.48	4.01	4.47	4.92	5.30	5.68	6.02	6.36	6.66	6.96
8020				6.55	7.06	7.57	8.02	8.48	8.88	9.27

* Nozzle output for the 65 and 110 degree spray angles is the same as 80 degree (i.e. 6501, 8001, & 11001 are equal); only extended range (XR) nozzles should be operated below 30 psi.

Table 10.2. Spraying Systems Co. hollow cone (disc-core) nozzle outputs (litres per minute).

		Pressure (psi)							
Disc	**Core**	**80**	**100**	**125**	**150**	**175**	**200**	**250**	**300**
2	25	0.83	0.95	1.02	1.10	1.19	1.29	1.42	1.55
3	25	0.98	1.10	1.21	1.32	1.42	1.51	1.67	1.82
2	45	1.06	1.21	1.32	1.44	1.55	1.67	1.84	2.01
3	45	1.25	1.36	1.51	1.67	1.80	1.93	2.14	2.35
4	25	1.51	1.70	1.87	2.04	2.20	2.35	2.59	2.84
5	25	1.82	2.04	2.25	2.46	2.65	2.84	3.12	3.41
4	45	1.89	2.12	2.35	2.57	2.76	2.95	3.27	3.60
6	25	2.35	2.65	2.93	3.22	3.44	3.67	4.09	4.50
5	45	2.42	2.69	2.97	3.26	3.50	3.75	4.18	4.62
7	25	2.76	3.07	3.39	3.71	4.09	4.47	4.83	5.19
6	45	3.14	3.52	3.94	4.35	4.69	5.03	5.62	6.21
8	25	3.37	3.67	4.09	4.50	4.83	5.15	5.75	6.36
7	45	3.67	4.20	4.66	5.11	5.53	5.94	6.64	7.34
8	45	4.58	5.11	5.73	6.36	6.85	7.34	8.21	9.08
10	45	5.94	6.70	7.48	8.25	8.86	9.46	10.60	11.73

Screens

Screens prevent foreign material from entering the system, clogging the nozzles and wearing out the sprayer.

Suction strainers, line strainers and nozzles should all be equipped with 50 mesh or coarser screens when wettable powders are to be used. Some pesticides may require coarser suction strainers. It may be necessary to have more than one suction strainer cartridge for the sprayer.

Screens finer than 50 mesh (100 mesh, for example) may plug with some wettable powders.

Screens are generally used in fine nozzles, but slotted strainers can be used in those that have a larger opening. Consult the nozzle manufacturer's catalogue for recommendations on specific screen mesh sizes for specific nozzles. Generally for flat spray nozzles with small holes (TeeJet 80015 or smaller) a 100 mesh nozzle is recommended.

Generally larger nozzles (TeeJet 8002 to 8008) should use a 50 mesh screen. Disc-core cone nozzles should normally be used with a slotted strainer equivalent to a 16 mesh screen (any Spraying Systems Co. D3 or larger disc and No. 25 and larger core). A slotted strainer equivalent to a 25 mesh screen should be used with D2 discs.

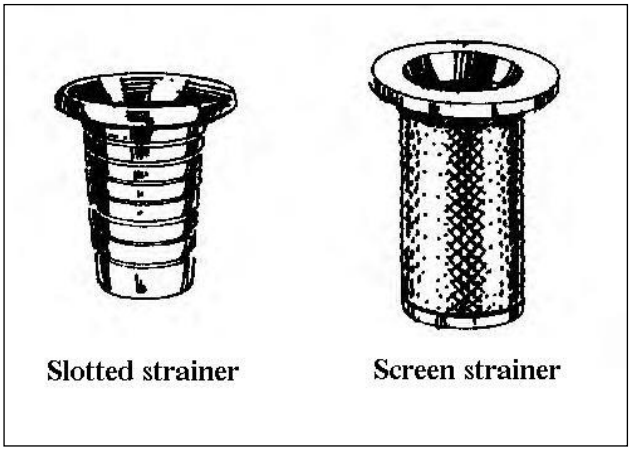


Figure 10.4. Slotted and screen strainers.

Clean screens and strainers are essential to the efficient operation of the spray system. They should be cleaned often and checked for breaks in the screen. If the nozzle screens are plugging too often, check to make certain the chemicals are properly mixed, the spray tank and plumbing system are properly rinsed and cleaned between sprays, and that the suction and tank screens are in place when filling and using the sprayer. If the plugging problem persists, consider changing to an alternative pesticide formulation. Also check to see if a larger nozzle that has a larger recommended screen size can be used. Do not operate the sprayer without the recommended nozzle screens.

Mixing Chemicals

When mixing the chemical in the sprayer tank, NEVER put the chemical in first and then top with water. Always fill the tank 1/3 to 1/2 with clean water, start the agitator and then add the required quantity of chemical. Continue agitating while filling the tank.

For tank-mixes of two or more chemicals, first check the product label for compatibility information. Add the first chemical at the 1/3 to 1/2 full stage and the second chemical at the 2/3 to 3/4 full stage. Mixing by this method will ensure that the chemical is completely mixed in the water. To keep the chemical completely mixed keep the agitator on until you are finished spraying. Never turn off the hydraulic agitation to get enough pump pressure to spray–the chemical will not stay mixed in the water.

For best results, wettable powders should be premixed before being added to the spray tank. Make a slurry of wettable powder and water and then pour it into the spray tank.

Always follow manufacturers' directions when mixing. Always keep the agitator running once the spray materials have been added to the tank.

Excess Pesticide Spray Tank Mixtures

Avoid mixing surplus spray by carefully calculating rates, calibrating the sprayer and carefully measuring the area of the fields. If too much is mixed, use that material according to label directions on another crop or site listed on the label. If no such area can be found, spray the mixture over an area on the property where it will cause no damage.

Never re-spray the treated field with extra tank mix. Spraying an area twice will double the rate and may cause high residues in the crop or soil.

Sprayer Cleaning

Immediately after use, drain and collect any excess spray mixture. This excess material can be very difficult to dispose of properly, therefore sprayers should be properly calibrated to avoid any excess.

Then flush the sprayer with soapy water and rinse with clean water. Talk to the equipment dealer to have a new drain installed if the current drain is hard to use. Select a cleaning area where water will not contaminate wells, streams or crops.

Separate equipment is recommended for applying 2,4-D, MCPA or similar hormone-type herbicides. If this is not possible, use separate sprayer hoses when using these chemicals as they cannot be properly washed out of the hose lines. To thoroughly clean equipment after applying 2,4-D, MCPA, etc., follow these steps:

1. Drain and collect any excess spray mixture from the tank.
2. Rinse tank, lines, screens, pumps and nozzles thoroughly with warm water.
3. Remove pressure chamber and line strainer and drain.
4. Fill tank with 100 L of warm water and then add one of the following:
    - 1 L household ammonia or Agri-Kleen; or
    - 500 g washing soda, lye or Nutrasol.
5. Spray out a small amount of solution and leave remainder in tank overnight.
6. Drain and rinse the equipment several times with warm soapy water. Rinse out the soapy water with clean water.

Even stainless steel nozzles will rust if left in the sprayer. Nozzles and nozzle screens should be removed and cleaned each fall and stored in a can of light oil or diesel fuel for the winter. After a spray application the nozzles should be cleaned and coated with a light coat of oil to prevent corrosion. Ceramic nozzles are not subject to corrosion.

Before winter storage, remember to drain the pump, boom and all lines to prevent frost damage. Add light oil or antifreeze during the last rinsing to leave a protective coating on all parts.

Sprayer Calibration

Calibration helps ensure good pest control. It also helps prevent crop damage from pesticides, high pesticide residues, and environmental contamination. Calibrate all application equipment to ensure a pesticide will be applied accurately and uniformly at the recommended rate.

Calibration involves preparing the equipment so it is working properly, measuring the delivery rate, adjusting the equipment to change the delivery rate, and calculating how much pesticide to add to the sprayer tank. Calibrate equipment regularly (at least once per year) to make sure the output is not changing. Also calibrate equipment when it is new and when making changes that affect the delivery rate. Proper calibration will minimize, if not eliminate, left over mixed pesticides in the sprayer tank that can be very difficult to properly dispose.

Calibrating Boom and Airblast Sprayers

There are four basic procedures to be carried out when calibrating boom and airblast sprayers. Details on these procedures are given below. (Also refer to the *Pesticide Applicator Course for Agricultural Producers*.)

Use the *Calibration Worksheet – Boom Sprayer* in this section to follow these four procedures when applying pesticides to your crop.

1. set-up
2. measuring delivery rate
3. adjusting delivery rate (if different from recommended rate)
4. calculating how much pesticide to add to the spray tank

Set-Up

During set-up check that the sprayer nozzles, forward speed and spray pressure are correct for the applied pesticide, the weather and the crop conditions. Check the equipment to ensure all parts are in good condition and working properly (see the sprayer's operating manual).

The sprayer must apply the pesticide uniformly across the width of the boom and over the whole field.

The proper set-up of a sprayer will take more time than all the other steps involved in calibration. The *Calibration Worksheets – Boom Sprayers* at the end of this section give a thorough checklist to use for your sprayer set-up.

You must choose which nozzles to use, nozzle pressure, tractor throttle setting and gear (forward speed) before you can move on to the second step in calibration, "Measuring Delivery Rate".

The last page of the *Calibration Worksheet – Boom Sprayer* gives formulas for checking the speed of your tractor gears. Having the speed of each gear used for spraying will help to make adjustments in the sprayer's delivery rate. To use the calibration formulas you must also determine your sprayer's swath width.

Selecting Spray Volume

Before calibrating your sprayer, you should know how much spray mixture should be sprayed in your field. The recommended amount of spray mixture (spray volume) can usually be found on the pesticide label or in this guide. The spray volume will depend on crop, stage of growth, the pest, the pesticide, weather, soil conditions and the method of application.

For herbicides, spray volumes range from 50 to 1,000 L/ha (20 to 400 L/acre). Refer to the product label for specific recommendations. Pesticide application rates and spray volumes for herbicides are normally given as a broadcast treatment as if the entire field is sprayed. However, in many crops, most herbicides are applied in bands along the rows spraying only a part of the field. Therefore, to spray only bands and not the entire field, the amount of area actually treated must be calculated to determine how much herbicide to add to the sprayer.

Most fungicide and insecticide labels for ornamental crops suggest applying a dilute spray mixture for thorough coverage of the plant. The pesticide application rate is usually a dilution rate of pesticide per volume of water. The size and density of the plants to be sprayed will determine the volume of spray mixture required per acre. Some labels will also include a spray volume on the label usually around 1,000 L/ha for ornamental crops.

Sprayer operators should carefully monitor the foliage including the lower stems and undersides of lower leaves to ensure thorough coverage. Water sensitive spray cards are available to assist in carrying out this task. Also monitor spray drift.

Selecting Nozzle Pressure

Herbicides are generally applied with flat spray nozzles at low pressures (200 to 275 kPa or 30 to 40 psi) to keep drift to a minimum. Do not use higher pressures unless they are specifically recommended.

Some new nozzles are available that work over extended pressure ranges including pressures as low as 100 kPa or 15 psi.

Insecticides and fungicides are applied with disc-core nozzles at pressures up to 2,000 kPa (300 psi) depending upon the pest to be controlled and the density of the foliage.

Many nozzle manufacturers have chosen to report nozzle outputs with pressures in "bar" not kilopascals (kPa). The bar unit is equal to 100 kPa. Pesticide labels report pressures in kPa.

Use a pressure gauge on the sprayer marked in both psi and kPa (or bar) so both units can be read directly from the gauge. The maximum pressure on the pressure gauge should be twice the maximum spray pressure used to protect the gauge from damage and allow it to be read accurately.

Determine Sprayer Swath Width

Swath width is the width of treated area over which spray droplets or granules are distributed in one pass of the applicator. In a broadcast spray, it is the nozzle spacing multiplied by the number of nozzles and for band treatments it is the sum of the treated band widths (see Figures 10.5 and 10.6). For row crops it is the row spacing (from center-to-center) multiplied by the number of rows (see Figure 10.7). Swath width is usually measured in meters or feet. The swath width is used in sprayer calibration to calculate the sprayer's delivery rate. As the sprayer swath width is based on the treated area, the delivery rate will also be based on the treated area when band spraying herbicides.

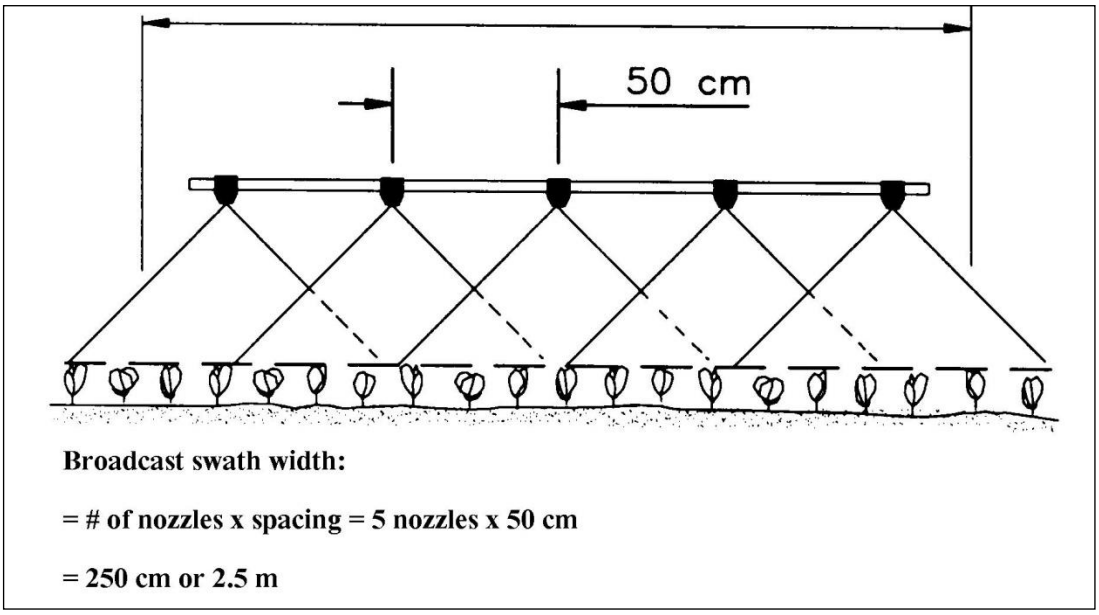


Figure 10.5. Determining broadcast swath width.

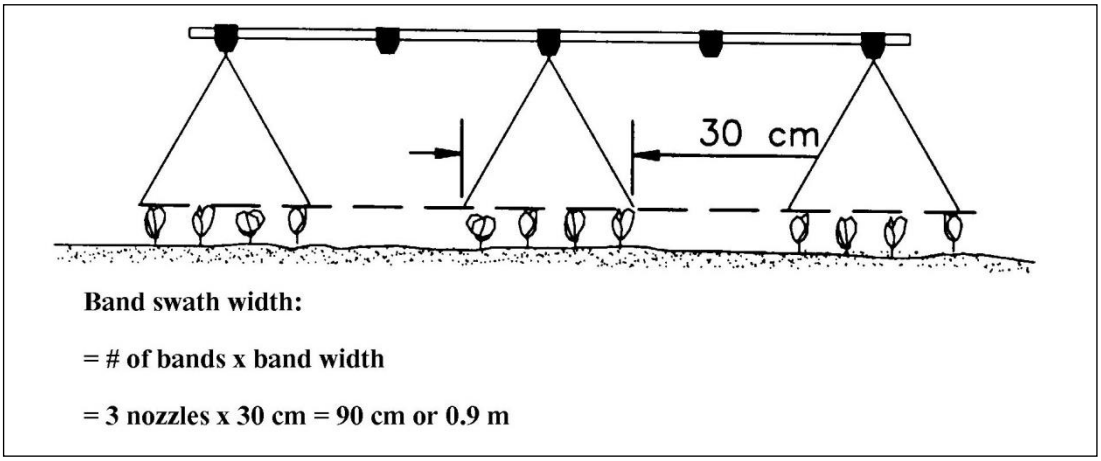


Figure 10.6. Determining band swath width.

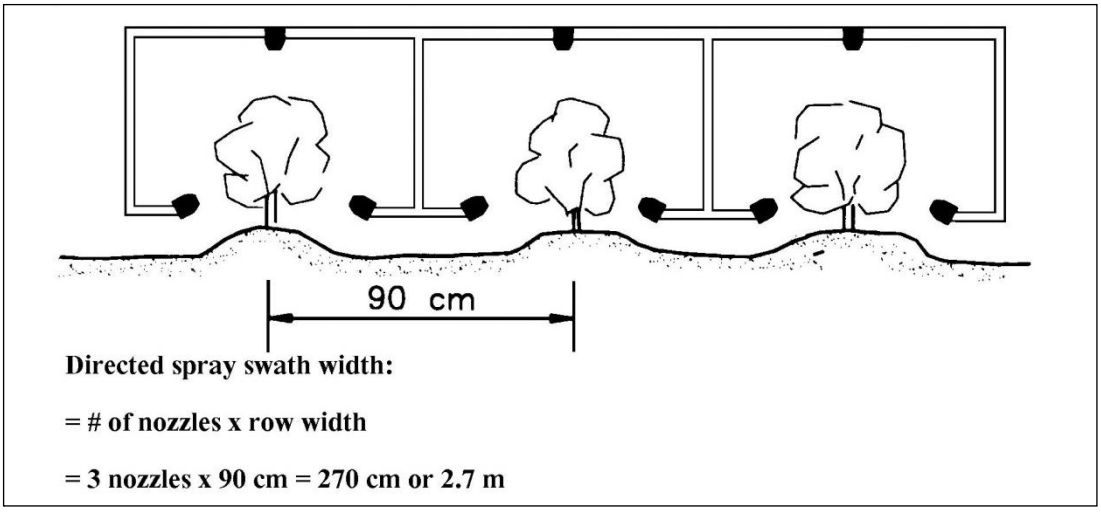


Figure 10.7. Determining directed spray swath width.

When sprayers are set-up during calibration, check to make sure that the driving pattern used in spraying does not cause skips—areas of the field not sprayed between successive passes of the sprayer. The sprayer boom may also overlap the first pass when spraying the next strip or swath. Both skips and overlaps can be caused by not matching the nozzles on the boom to the driving pattern of the sprayer. With skips and overlaps, either pests will go uncontrolled or high spray residues can occur that may be dangerous to humans, plants and the environment. While spraying, the true swath width of the sprayer is determined by the driving pattern of the sprayer through the field.

Measuring Delivery Rate

There are two basic methods used to measure sprayer delivery rates—the test area method and the timed output method. The test area method uses fewer calculations, however, it can take longer to carry out. If an entire acre or hectare is used as the test area, the measured discharge of water is the delivery rate per acre or hectare and no calculations are required. The most common problem with the test area method is measuring the amount of spray water discharged. If too small a test area is used or it is not covered with enough passes the actual amount of water discharged is too small to accurately measure in the tank. The amount of spray discharged in the test should be at least 10% of the tank's volume. The tractor and sprayer tank should be parked in the exact same location and the water must settle in the tank after stopping, before measuring the tank level again.

The timed output method can avoid these problems, however it will require more calculations. Follow the procedures given in the *Calibration Worksheet–Boom Sprayer* at the end of this section.

Adjusting Delivery Rate

If the measured delivery rate of the sprayer is different than the spray volume listed on the pesticide label or recommended in the production guide, it can be adjusted in three ways:

1. Nozzle size should be changed before making large changes in delivery rate. Check with the nozzle supplier or an agricultural advisor. Obtain a catalogue listing nozzles and nozzle outputs in litres per minute (L/min).
2. Forward speed changes will adjust the delivery rate. Slower speeds increase the amount sprayed in a field, and faster speeds reduce the amount. If the delivery rate is 112 L/acre at 6 mph, then by halving the speed to 3 mph the delivery rate is doubled to 224 L/acre.

   Speed changes are usually made by using a different gear in order to keep tractor rpm's and spray pressure constant and within the range recommended for the sprayer pump.
3. Spray pressure should be set for the correct droplet size. Changing pressure is recommended only for very small changes in delivery rates. Otherwise the droplet size will change and cause drift or runoff problems. Since pressure must be increased four times to double the delivery rate, this is not a good way to adjust delivery rate.

After making the adjustments, measure the delivery rate again.

Calculating How Much Pesticide to Add to the Spray Tank

When the sprayer delivery rate is known, then calculate how many acres can be sprayed by a full tank and how much pesticide to add to the spray tank. Formulas to use when spraying only a partial spray tank are also given in the *Calibration Worksheet-Boom Sprayer* at the end of this section. Be very careful to accurately measure the area to be covered by the last tank to minimize left over spray mixture in the tank when you are finished spraying.

Boom Sprayer – Calibration Worksheet Examples

Refer to the *Calibration Worksheet-Boom Sprayers* in this section when working through the following examples.

Example 1: Sprayer Calibration (per area rate)

The pesticide label reads "apply 4.75 kg/ha in 1,000 L/ha". The pesticide is to be applied to the foliage with the plants grown in rows spaced 1.2 m apart. The sprayer boom covers 4 rows and sprayed 105 L of water when making two runs (passes) over a 100 m long test strip. The sprayer's tank holds 1,000 L.

(a) What is the sprayer swath width?

From Calibration Worksheet under Set-up ❶ – Swath Width,

Row crop swath width = 4 rows x 1.2 m = 4.8 m

(b) What is the delivery rate (litres per hectare) of the sprayer ?

Follow Steps 1 – 8, Measuring Delivery Rate ❷ –Test Area Method, from the Calibration Worksheet

Test area = 100 m x 4.8 m x 2 runs
= 960 m^2

Follow Step 9 , Measuring Delivery Rate ❷ – Test Area Method, from the Calibration Worksheet

Delivery rate = 105 L ÷ 960 m^2 x 10,000 m^2/ha
= 1,090 L/ha

The sprayer is operating at a delivery rate of 1,090 L/ha. The delivery rate is close enough to the desired spray volume of 1,000 L/ha. Use the delivery rate of 1,090 L/ha when calculating how much pesticide to add to the tank.

(c) How many hectares will be covered with one full tank of spray?

Follow Calculating How Much Pesticide to Add to the Tank ❹a – Full Tank, from the Calibration Worksheet

Area covered by a full tank = 1,000 L ÷ 1090 L/ha = 0.92 ha

One full tank of spray will cover 0.92 ha.

(d) How much pesticide must be added to a full tank of water?

Follow Calculating How Much Pesticide to Add to the Tank ❹a – Full Tank, from the Calibration Worksheet

How much pesticide to add to a full tank = 4.75 kg/ha x 0.92 ha = 4.37 L

Add 4.37 L of pesticide to make one full sprayer tank of spray mixture.

Example 2: Sprayer Calibration (per dilution rate)

The pesticide label instructions are to "apply 2 kg of pesticide in 1,000 L of water and to spray the foliage thoroughly". The grower has a 450 L sprayer tank and plans to spray pesticide on plants that are grown on beds 5 ft wide and the sprayer covers one bed at a time.

Before starting the grower should determine how much area a full tank will spray. This will allow the right amount of pesticide to be mixed. This can be done by following the Calibration Worksheet at the back of the guide. The grower sprays a 330 ft long test strip with two passes (runs) to measure the sprayer's delivery rate. The sprayer discharges 75 L over this area.

(a) What is the sprayer swath width?

From Calibration Worksheet under Set-up ❶ – Swath Width,

Row crop swath width = 1 rows x 5 ft
= 5 ft

Note: the entire bed is treated as one "row"

(b) What is the delivery rate (litres per acre) of spray applied?

Follow Steps 1 – 8, Measuring Delivery Rate ❷ – Test Area Method, from the Calibration Worksheet

Test area = 330 ft x 5 ft x 2 runs
= 3,300 ft^2

Follow Step 9, Measuring Delivery Rate ❷ – Test Area Method, from the Calibration Worksheet – 75 Litres are sprayed on the test strip:

Delivery Rate = 75 L ÷ 3,300 ft^2 x 43,560 ft^2 /acre
= 990 L/acre

The grower checks the foliage and determines that the coverage is thorough and does not run off the leaves.

(c) How many acres will be covered with one full tank of spray?

Follow Calculating How Much Pesticide to Add to the Tank ❹a – Full Tank, from the Calibration Worksheet

Area covered by a full tank = 450 L ÷ 990 L/acre
= 0.45 acres

One full tank of spray will cover 0.45 acres.

(d) How much pesticide must be added to a full tank of water?

Follow Calculating How Much Pesticide to Add to the Tank ❹a – Full Tank, from the Calibration Worksheet

How much pesticide to add to a full tank = 2 kg/1,000 L x 450 L tank
= 0.90 kg

Add 0.90 kg of pesticide to make one full sprayer tank of spray mixture.

Example 3: Sprayer Calibration for Applying Herbicides in Bands (Hectares)

A grower has set-up a 900 L sprayer to spray plants with row spacings of 120 cm. The grower wants to spray the herbicide in bands that are 60 cm wide centred over each row. The label says to spray 2 kg/ha in a minimum of 300 L/ha of water (broadcast). The sprayer boom sprays 4 rows in one pass. After spraying a 226 m long strip four times, the discharge was measured to be 95 L. The field is 7.6 ha.

(a) What is the sprayer swath width?

From Calibration Worksheet under Set-up ❶ – Swath Width,

Band swath width = 4 bands x 60 cm
= 240 cm
= 2.4 m

(b) What is the delivery rate (litres per hectare) of the sprayer ?

Follow Steps 1 – 8, Measuring Delivery Rate ❷ – Test Area Method, from the Calibration Worksheet

Test area = 226 m x 2.4 m x 4 runs
= 2,170 m^2 (treated area)

Follow Step 9, Measuring Delivery Rate ❷ – Test Area Method, from the Calibration Worksheet

Delivery rate = 95 L ÷ 2,170 m^2 x 10,000 m^2/ha
= 438 L/ha (of treated area)

The sprayer is operating at a delivery rate of 438 L/ha. The delivery rate is above the 300 L minimum and is okay.

(c) How many hectares (of treated area) will be covered with one full tank of spray?

Follow Calculating How Much Pesticide to Add to the Tank ❹a – Full Tank, from the Calibration Worksheet

Area = 900 L ÷ 438 L/ha
= 2.05 ha (treated area)

One full tank of spray will cover 2.05 ha of treated area.

(d) How much herbicide must be added to a full tank of water?

Follow Calculating How Much Pesticide to Add to the Tank ❹a – Full Tank, from the Calibration Worksheet

Pesticide = 2 kg/ha x 2.05 ha
= 4.10 L

Add 4.10 L of **herbicide** to make one full sprayer tank of spray mixture.

Calibrating Granular Applicators

Calibration of granular applicators involves the same first three steps as a boom sprayer:

1. set-up
2. measuring delivery rate
3. adjusting delivery rate

Granular pesticide applications are often broadcast. See the *Pesticide Applicator Course for Agricultural Producers* for more complete information and information on other types of equipment. There are several factors that can cause variation in output including, size of meter openings, roughness and slope of the field, forward speed, and granule flowability.

Set-up

Set-up includes inspecting the equipment to make sure it is cleaned, lubricated and operating according to the operator's manual. Set the equipment to the approximate settings to deliver the recommended application rate.

Swath width on tractor mounted spinning disc and oscillating spout spreaders is going to depend on the PTO (and engine) rpm. Proper spreading width, overlap of tapered patterns and swath width will require several test runs to determine settings that will work in your crop. The settings will be dependent of crop canopy height as well and uniformity of the spreading pattern will be difficult to ascertain. The applicator swath width is based on the driving pattern, which is dependent on the driving lanes in the nursery.

Pneumatic spreaders that use air to carry the granules through hoses to individual distributing nozzles will drop the granules directly over the crop. On a smaller scale, gravity drop granular pesticide applicators with distributing nozzles could be used as well.

Measuring Delivery Rate

Delivery rate is generally determined by measuring the amount of granules discharged while the applicator is run over a test area. It is usually necessary to capture the output and weigh it.

- Mark out a measured test strip at least 60 m or 200 ft long.
- Fill the applicator hopper(s) about half full of granules.
- Choose a tractor gear and throttle setting.
- Attach bags or other containers under each downspout to catch the granules during calibration. For granular equipment that uses air flow for distribution, either use porous mesh bags (e.g. nylons) or shut off the air flow and catch the granules from directly under the metering device.
- Drive towards the first stake at the correct speed and discharge granules over the test strip only.
- Repeat until enough granules are discharges to allow for accurate weights to be measured. Record the number of runs.
- Weigh the granules from each bag or container and record the amounts. Compare the individual weights and then add them together. Check for uniform distribution across the swath. Make adjustments and retest.

Determine the delivery rate using the following formula:

Delivery rate (kg/acre) = amount collected in test (kg) x 43,560 (ft^2) ÷ test area (ft^2)

Example:

You want to apply 55 kg/acre of granular pesticide. After driving over a 330 ft test strip once using a 30 ft swath width, 10.5 kg of granules were collected. What is the delivery rate?

Answer:

Test area = 330 ft x 30 ft x 1 run = 9,900 ft^2

Delivery rate = 10.5 kg x 43,560 ft^2/acre ÷ 9,900 ft^2

= 46.2 kg/acre

Adjusting Delivery Rate

Increase the meter opening to discharge more granules and retest.

Calibrating Hand-Operated Sprayers

Sprayer Set-up

Hand-operated sprayers should be checked to make sure there are no leaks, especially where the hose enters the tank and around the trigger valve. The nozzle should deliver a uniform spray pattern. Many nozzles can be adjusted to produce the desired droplet size. Adjust the nozzle to produce a coarse spray (larger droplets) for herbicide and medium to fine spray (smaller droplets) for insecticide and fungicide applications.

For uniform spray application it is important to maintain constant spray pressure and coordinate the walking speed with uniform back and forth movements of the nozzle. The back and forth movements determine the swath width.

Most pesticide labels specify an amount of pesticide per unit area (e.g. apply 2.4 L/ha). Some pesticides like Roundup give directions to dilute an amount of pesticide in water and apply with thorough and complete coverage (e.g. Roundup—1 L of product in 100 L of water). See *Application Rate Given as a Dilution with Water*, below.

Application Rate Given as a Dilution with Water

When the application rate is given as a dilution rate, then the amount of pesticide to mix in a full tank can be calculated directly.

Example:

A label recommends mixing 1 L of pesticide in 100 L of water and applying to foliage with thorough coverage. A 12-litre backpack will be used.

Answer:

The amount of pesticide to add to the tank can be calculated with the following formula:

Amount of pesticide = label rate (product amount ÷ water volume) x sprayer volume

Amount of pesticide = 1 L product ÷ 100 L water x 12 L tank

= 0.12 L product/tank

If only a partial tank full (e.g. 8 L) of pesticide mix is required, use that figure as the "sprayer volume" input in the formula.

Also estimate how much spray mixture is needed for the job so tank mix is not left over. Do this by applying water to a measured test area and determine the total amount of mix needed. Use the same procedures that follow for pesticide application rates given as an amount of pesticide per unit area.

Application Rate Given as Amount of Pesticide per Acre

Measuring delivery rate of the hand-operated sprayer follows the same basic steps as with the tractor mounted boom sprayer but on a smaller scale. Remember during set-up of the sprayer that a steady walking speed and swath width must be used.

1. Mark out a measured length of test strip at least 60 feet long.
2. Fill the tank about half-full with water and record the volume or level of water. Pump the tank to the pressure level that will be used.
3. Carefully spray the measured test strip while maintaining a steady forward speed and pumping action. Repeat enough runs over the test area until at least 10% of a full tank has been sprayed.
4. Measure the volume of water sprayed in the test strip by refilling the tank to the starting level.

Follow these steps to determine the application rate:

(a) Calculate the test area:

Test area (ft^2) = strip length (ft) x swath width (ft) x # runs

(b) Calculate the delivery rate:

Delivery rate (L/acre) = water sprayed (L) ÷ test area (ft^2) x 43,560 ft^2/acre

Adjust the delivery rate as necessary by changing the walking speed.

(c) Calculate the amount of area sprayed by a full tank:

Area sprayed (by full tank) = tank volume (L) ÷ delivery rate (L/acre)

(d) Calculate how much pesticide to add to the spray tank:

Amount of pesticide to add to tank = application rate x area sprayed by one tank

Example:

A grower wants to spray bushes with a pesticide at a rate of 0.5 kg/400 L of water per acre. A test strip of 60 ft long covering one side (one half) of the bushes is sprayed with one pass of water to measure delivery rate. The bushes are in rows 10 ft apart. To refill the spray tank 2.9 L of water is required. Determine the delivery rate, area sprayed by a full tank and the amount of pesticide to add to a 12 L tank.

Answer:

(a) Test area = 60 ft x 5 ft (one side only) x 1 run
= 300 ft^2

(b) Delivery rate = 2.9 L ÷ 300 ft^2 x 43,560 ft^2/acre
= 421 L/acre

(c) Area sprayed (by full tank)
= 12 L ÷ 421 L/acre
= 0.0285 acre

(d) How much pesticide to add to one tank
= 0.5 kg/acre x 0.0285 acres
= 0.0143 kg
= 14.3 g

Measured delivery rate	L/ha *L/acre*
Area sprayed by a full tank	ha *acre*
Tractor gear	
Throttle	rpm
Forward speed (if Timed Output)	km/h *mph*
Nozzles	
Pressure	kPa(psi)
Date	

Calibration Worksheet – Boom Sprayer

Follow this step-by-step procedure to calibrate a sprayer. All liquid volumes are in litres (L), but you can use either metric or imperial units for distance and area (don't mix them). Circle the units used such as 500 (L/ha) L/acre.

After you've finished calibrating your equipment, **write key data in the box at left for future reference.**

Use the Pesticide Use Calculation worksheet to find the area sprayed by a full tank, and to calculate how much of each pesticide you'll need to buy and add to each tank.

❶ Set-up

Inspection Before Sprayer Start-up ☑

- ❑ Tank size is _____ L
- ❑ Calibration strip or dipstick for tank?
- ❑ Tire pressures okay?
- ❑ Hoses in good condition?

Filler opening screen
- ❑ in place? clean? good repair?
- ❑ mesh size correct?_____

Suction screen
- ❑ in place? clean? good repair?
- ❑ mesh size correct _____

Nozzle screens (check each one)
- ❑ in place? clean? good repair?
- ❑ mesh size correct?_____

Nozzles
- ❑ nozzle type okay
- ❑ all same size/ID#? (record in box above)
- ❑ correct nozzle spacing of_____cm *(in)*
- ❑ nozzles spaced evenly?
- ❑ aligned for crop?
- ❑ are there nozzle check valves?

Boom height
- ❑ above target?_____cm *(in)*
- ❑ is boom level?

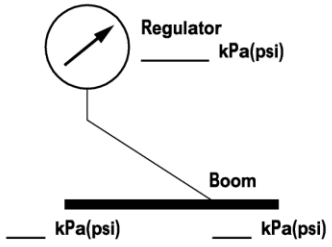
Surge tank (piston & diaphram pumps only)
- ❑ working properly?
- ❑ air pressure correct at_____kPa(psi)

Inspection with Sprayer Running ☑

Fill the tank more than half full with clean water.
- ❑ start sprayer pump & run tractor throttle at _____ rpm. Note pump's maximum rpm is_____.
- ❑ open boom valve to fill lines and begin spraying
- ❑ clean nozzles producing distorted patterns and retest
- ❑ throw out damaged nozzles and replace them

Check and fix any problems
- ❑ leaks?
- ❑ valves working?
- ❑ agitation okay?
- ❑ bypass flow okay?
- ❑ adjust pressure regulator to get right spray pressure at the nozzles

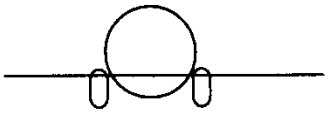
Check sprayer pressures
- ❑ measure pressure at regulator and on booms
- ❑ pressure drop less than 10%?
- ❑ pressure gauge working?



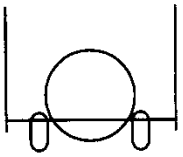
Measuring Nozzle Output

Draw nozzle locations on the diagram below and number them to identify which ones may need to be cleaned or replaced after testing. As the sprayer runs, collect and record the output for a set time eg. 1 minute, 30 sec or 15 sec. Measure in litres.

Horizontal boom (include drop pendents)



Vertical boom (include over-the-row booms



Nozzle Output
Litres per _____ sec

1. _____ Litres
2. _____ Litres
3. _____ Litres
4. _____ Litres
5. _____ Litres
6. _____ Litres
7. _____ Litres
8. _____ Litres
9. _____ Litres
10. _____ Litres
11. _____ Litres
12. _____ Litres
13. _____ Litres
14. _____ Litres
15. _____ Litres
16. _____ Litres
17. _____ Litres
18. _____ Litres
19. _____ Litres
20. _____ Litres

Total _____ Litres

1. In the box below, divide total output in L by the number of nozzles to find the average output per nozzle for collection time.

Total Output Collected	÷	# nozzles	=	Average Output Collected
L	÷	noz.	=	L

2. For uniformity, find the maximum and minimum acceptable output (5% more or less than average). Replace if above maximum output.

Minimum Output	= 0.95 x	_____	**Average Output**	=	_____	L
Maximum Output	= 1.05 x	_____	**Average Output**	=	_____	L

3. Replace all nozzles if average output is 15% more than a new nozzle's output (from manufacturer's chart or discharge test).

Average Output per Collection	÷	Collection Time	x	Conversion	=	Average Output
L	÷	sec	x	60 sec/min	=	L/min

New Nozzle Output	x	Constant	=	Maximum AverageOutput
L/min	x	1.15	=	L/min

4. Clean and retest all nozzles below the minimum output. Replace those still below minimum output after cleaning. If more than 20% of the nozzles need to be replaced, change all of them.

Swath Width Do only ONE of these. You'll use the swath width for the calculation on the next page.

Broadcast swath: multiply number of nozzles by nozzle spacing; convert to metres or feet.

# nozzles	×	spacing	÷	conversion	=	**swath width**
noz	×	cm	÷	100 cm/m	=	m
noz.	×	*in*	÷	*12 in/ft*	=	*ft*

Band swath: multiply number of bands by width of each band; convert to metres or feet.

# bands		× band width	÷	conversion	=	**swath width**
	bands ×	cm	÷	100 cm/m	=	m
	bands ×	*in*	÷	*12 in/ft*	=	*ft*

Row crop swath: multiply number of rows by width of each row. (Note: rows are stated in metres or feet, so no conversion is needed.)

# rows		x row width	=	**swath width**
	rows x	m	=	m
	rows x	*ft*	=	*ft*

❷ Measuring Delivery Rate

You can use either of these methods to determine the actual delivery rate of the sprayer.

Test Area Method

1. Mark out a test strip at least 60 m or 200 *ft* long. Your strip was _____ m (*ft*) long.
2. Fill the tank about half full with water and start sprayer nozzles and agitation. Then set the pressure to what you want. Use the same throttle RPM you'll use in the field. Pressure _____ kPa(psi)
3. Choose a tractor gear to get desired forward speed. Gear_____Throttle_____rpm (as in step 2)
4. Record the volume of water in the tank before the test: _____L. Mark where the sprayer is parked so you can return it to the same position to measure water sprayed (level ground is best).
5. Drive towards the first stake at the correct speed, and open the boom valve as you pass it. Check the sprayer pressure. Close the boom valve as you pass the second stake.
6. Repeat until at least 10% of a full tank is sprayed. Record the number of runs (_____runs).
7. Return to the water filling site and park in the same location as in Step 4. Measure the amount of water remaining:_____L. Number of litres discharged during the test was_____L.
8. Calculate the test area. Multiply the strip length by your swath width by the number of runs.

strip length	×	swath width	×	#runs	=	**test area**
m	×	m	×	runs	=	m^2
ft	×	*ft*	×	*runs*	=	ft^2

9. Calculate the delivery rate. Divide water sprayed (L) by test area (m^2 or ft^2).

water sprayed	÷	test area	×	conversion	=	**delivery rate**
L	÷	m^2	×	10,000 m^2/ha	=	L/ha
L	÷	ft^2	×	*43,560 ft^2/acre*	=	*L/acre*

(L/ha = 2.5 times *L/acre* *L/acre* = 0.4 times L/ha)

Timed Output Method

1. Mark out a test strip at least 60 m or 200 *ft* long.
2. Fill the tank about half full with water and move to the test strip.
3. Choose a tractor gear and throttle for the forward speed you want. Gear_____ Throttle_____rpm. Use the same throttle RPM when measuring nozzle output (Step 7).
4. Measure the time in seconds required to pass through the test strip on four runs. Reach the desired speed *before* entering the test strip, and hold that speed constant throughout the test run.

   1st run_____ + 2nd run _____ + 3rd run _____ + 4th run _____ = _____seconds total time.
5. Calculate total distance travelled. Multiply test strip length (Step 1) by the number of runs. Your strip was _____ m*(ft)* long x _____ runs = _____ m*(ft)* total distance.
6. Calculate forward speed using the formula in the box at right.

total distance	÷	total time	×	constant	=	**forward speed**
m	÷	sec	×	3.6	=	km/h
ft	÷	*sec*	×	0.68	=	*mph*

7. Measure total nozzle output by spraying for a set time (such as 10 min) and divide volume (L) by time to find total output (L/min) OR use total nozzle output (L/min) from page 189.
8. Divide total output by forward speed and swath width and multiply by a constant to get the delivery rate.

total nozzle output	÷	forward speed	÷	swath width	×	constant	=	**delivery rate**
L/min	÷	km/h	÷	m	×	600	=	L/ha
L/min	÷	*mph*	÷	*ft*	×	*495*	=	*L/ac*

(L/ha = 2.5 times *L/acre* *L/acre* = 0.4 times L/ha)

❸ Adjusting Delivery Rate

If the delivery rate of your sprayer is different than the rate listed on the pesticide label or recommended in the production guide, it can be adjusted in three ways:

1. **Nozzle size** should be changed if you wish to make large changes in delivery rate. Check with your nozzle supplier or agricultural advisor. Obtain a catalogue listing nozzles and nozzle outputs.

The folowing formula can also be used to find nozzle size.

delivery rate		forward speed		nozzle spacing		constant		**nozzle output**
L/ha	×	km/h	×	cm	÷	60,000	=	L/min
L/acre	×	*mph*	×	*in*	÷	5,940	=	*L/min*

2. **Forward speed** changes will adjust the delivery rate. Slower speeds increase the amount sprayed in a field, and faster speeds reduce it. If your delivery rate is 112 L/acre at 6 mph, then by halving your speed to 3 mph you'll double the delivery rate to 224 L/acre.

Use these formulas to calculate alternative combinations of deliver rates and speeds.

present forward speed		present delivery rate		new forward speed		**new delivery rate**
km/h	×	L/min	÷	km/h	=	L/min
mph	×	*L/min*	÷	*mph*	=	L/min

Speed changes are usually made by using a different gear in order to keep tractor RPMs within the range recommended for the sprayer pump.

present forward speed		present delivery rate		new delivery rate		**new forward speed**
km/h	×	L/min	÷	L/min	=	km/h
mph	×	*L/min*	÷	*L/min*	=	*mph*

3. **Spray pressure should be set for the correct droplet size.** Changing pressure is recommended only for very small changes in delivery rates. Otherwise your droplet size will change and cause drift or runoff problems. Since pressure must be increased four times to double the delivery rate, this is not a good way to adjust delivery rate.

After making the adjustments, measure the delivery rate again and fill in a new Calibration Worksheet.

When your equipment is accurately calibrated and applying the desired delivery rate, you are then ready to spray. Use the Pesticide Use Calculations ❶ to determine how much pesticide to buy and how much pesticide to add to a full or partial tank.

WHEN should I calibrate my equipment?

1. Before using new or altered equipment.
2. When making any changes that affect the delivery rate.
3. At regular intervals to see if wear is affecting output.

Why should I calibrate my equipment?

1. So the pesticide is applied accurately and uniformly at the recommended rate.
2. To prevent harm to the crop from too much, too little or uneven coverage
3. To prevent wasting money spent on pesticides.

❹a Calculating How Much Pesticide to Add to a Spray Tank – Per Area Rate

Example: pesticide label reads: "use 3 L/ha in 1000 L of water" or "use 3 L/1000 L of water/ha".

Pesticide _____ Pest _____ Crop _____ Date _____

Fill in values for only one column – hectares or acres. Use only hectares or only acres; don't mix them. Use litres (L) for all liquid volumes. Use the italicized line if you are using acres.

	Hectares	Acres
Field area	_____ ha	_____ *acres* (*hectares* = 0.4 x *acres*)
Spray tank capacity	_____ L	_____ *L* (*L* = 3.79 × US gal. L = 4.55 × Imperial gal.)
Pesticide label application rate	_____ kg or L/ha	_____ *kg or L/acres* (*L/acres* = 0.4 × L/ha)
Spray volume	_____ L/ha	_____ *L/acres* (from label or production guide)

Check your Calibration Worksheets and choose a suitable sprayer setup and Sprayer Delivery Rate

Sprayer Delivery Rate	_____ L/ha	_____ *L/acres*

Copy values into the formulas below where needed.

How much pesticide to buy?

field area	×	pesticide label application rate	×	# applications per year	=	**pesticide to buy**
ha	×	kg or L/ha	×		=	kg or L
acres	×	*kg or L/acres*	×		=	*kg or L*

Full tank

Area covered by a full tank?

tank capacity	÷	sprayer delivery rate	=	**area covered**
L	÷	L/ha	=	ha/tank
L	÷	*L/acre*	=	*acres/tank*

How much pesticide to add to a full tank?

pesticide label application rate	×	area covered by a full tank	=	**pesticide to add**
kg or L/ha	×	ha/tank	=	kg or L
kg or L/acre	×	*acres/tank*	=	*kg or L*

Number of tankfuls required for area?

field area	÷	area covered by a full tank	=	**tankfuls required**
ha	÷	ha/tank	=	tanks
acre	÷	*acres/tank*	=	*tanks*

Partial tank

How much spray mix to make for a partial tank?

sprayer delivery rate	×	area remaining	=	**spray mix to make in partial tank**
L/ha	×	ha	=	L
L/acre	×	*acres*	=	*L*

How much pesticide to add to a partial tank?

pesticide label application rate	×	area remaining	=	**pesticide to add in partial tank**
kg or L/ha	×	ha	=	kg or L
kg or L/acre	×	*acres*	=	*kg or L*

❹b Calculating How Much Pesticide to Add to a Spray Tank – Per Dilution Rate

Example: pesticide label reads: "use 1 L/1000 L of water and spray foliage thoroughly".

Pesticide _____ Pest _____ Crop _____ Date _____

Fill in values for only one column – hectares or acres. Use only hectares or only acres; don't mix them. Use litres (L) for all liquid volumes. Use the italicized line if you are using acres.

	Hectares	**Acres**
Field area	_____ ha	_____ *acres* (*hectares* = 0.4 x *acres*)
Spray tank capacity	_____ L	_____ *L* (*L* = 3.79 × US gal. L = 4.55 × Imperial gal.)
Pesticide label dilution rate	_____ *kg* or L/1000 L of water (may be another amount of water)	
Spray volume	_____ L/ha	_____ *L/acres* (from label or production guide)

Check your Calibration Worksheets and choose a suitable sprayer setup and Sprayer Delivery Rate

Sprayer Delivery Rate _____ L/ha _____ *L/acres*

Copy values into the formulas below where needed.

How much pesticide to buy?

field area	×	pesticide label dilution rate	×	sprayer delivery rate	×	# applications per year	=	**pesticide to buy**
ha	×	kg or L/1000 L	×	L/ha	×		=	kg or L
acres	×	*kg or L/1000 L*	×	*L/acre*	×		=	*kg or L*

Full tank

Area covered by a full tank?

tank capacity	÷	sprayer delivery rate	=	**area covered**
L	÷	L/ha	=	ha/tank
L	÷	*L/acre*	=	*acres/tank*

How much pesticide to add to a full tank?

pesticide label dilution rate	×	tank capacity	=	**pesticide to add**
kg or L/1000 L	×	L	=	kg or L
kg or L/1000 L	×	*L*	=	*kg or L*

Number of tankfuls required for area?

field area	÷	area covered by a full tank	=	**tankfuls required**
ha	÷	ha/tank	=	tanks
acre	÷	*acres/tank*	=	*tanks*

Partial tank

How much spray mix to make for a partial tank?

sprayer delivery rate	×	area remaining	=	**spray mix to make in partial tank**
L/ha	×	ha	=	L
L/acre	×	*acres*	=	*L*

How much pesticide to add to a partial tank?

pesticide label dilution rate	×	spray mix in partial tank	=	**pesticide to add in partial tank**
kg or L/1000 L	×	L	=	kg or L
kg or L/1000 L	×	*L*	=	*kg or L*

Forward Speed Calculations

Date:_____

Calculate the forward speed of your tractor and sprayer in field conditions encountered during spraying. If you change tires, tire pressures, or tire lugs wear significantly, speeds will change. Also speeds will change between dry and very wet field conditions.

1. Mark out a test strip at least 60 m or 200 *ft* long.
2. Fill the tank about half full with water and move to the test strip.
3. Choose the tractor gear and throttle for the forward speed you want. Gear _____ Throttle _____ rpm. Use the same throttle RPM when measuring nozzle output (Step 7).
4. Measure the time in seconds required to pass through the test strip on four runs. Reach the desired speed *before* entering the test strip, and hold that speed constant throughout the test run.

   1st run _____ + 2nd run ____ + 3rd run ____ + 4th run ____ = _____ seconds total time.
5. Calculate total distance travelled. Multiply test strip length (Step 1) by the number of runs. Your strip was _____ m(*ft*) long x _____ runs = _____ m(*ft*) total distance.
6. Calculate forward speed using the formula in the box at right.

total distance	+	total time	x	constant	=	**forward speed**
m	+	sec	x	3.6	=	km/h
ft	+	sec	x	0.68	=	*mph*

Tractor #1 _____ Tire Size _____ Tire Pressure _____

Gear						
Throttle	rpm					
Time	sec					
Total distance	in *(ft)*					
Forward speed	km/h *(mph)*					

Tractor #2 _____ Tire Size _____ Tire Pressure _____

Gear						
Throttle	rpm					
Time	sec					
Total distance	in *(ft)*					
Forward speed	km/h *(mph)*					

Liquid Fertilizer Calculations

To calculate the amount of fertilizer needed for any given quantity of solution:

- **$\frac{\text{ppm required / elemental content (fraction) x litres required}}{1{,}000}$ = grams/litres required**
- **ppm (parts per million required) -** this is the feed concentration (when using blended or 'complete' fertilizers, you normally calculate the amount to dissolve based on the ppm nitrogen required).
- **elemental content of the fertilizer -** the fertilizer label lists the elemental content of each fertilizer constituent as a percentage. For "elemental content" in the calculation, put this percent in the form of a fraction, for example, 20% nitrogen = 20/100 = **0.20**. The only exceptions are for P and K. Since they are always expressed as **$P_2 0_5$** (phosphoric pentoxide) and **$K_2 0$** (potash), they must first be converted to their true elemental content:

  $P_2 0_5$ divided by 2.291 = P (elemental phosphorus content)

  $K_2 0$ divided by 1.205 = K (elemental potassium content)

- **litres required –** the amount of finished (dilute) fertilizer solution you plan to make up. If you plan to use a fertilizer concentrate injector you can calculate the injection ratio after you find the dilute rate (this causes the least confusion).

Examples:

- To prepare 500 litres of a 20-20-20 fertilizer at 200 ppm nitrogen concentration:

  $\frac{(200 \text{ ppm} / 0.20) \times 500}{1{,}000}$ = 500 grams per 500 litres

- To prepare 400 litres (final solution) of calcium nitrate (15.5-0-0-19) at 140 ppm Ca concentration for injection at 200:1:

  $\frac{(140 \text{ ppm} / 0.19) \times 400)}{1{,}000}$ = 295 grams per 400 litres (final solution)

Since you are going to inject this at 200:1, you will dissolve your 295 grams into 2 litres of water (400 litres finished solution/200):

400 litres/ 200 = 2 litres

- You plan to use diammonium phosphate (21-53-0) to supply 30 ppm of phosphorus to a bedding plant feed. Your tank holds 1,000 litres.

  First convert **$P_2 0_5$** to **P (53% / 2.291) = 23.1% P**

  $\frac{(30 \text{ ppm} / 0.231) \times 1{,}000 \text{ litres}}{1{,}000}$ = 130 grams per 1,000 litres