BEST MANAGEMENT PRACTICES

Horticultural Crops

Agriculture Canada

Ontario Ministry of Agriculture and Food

Ministère de l'Agriculture et de l'Alimentation

What is a Best Management Practice or "BMP"?

- a proven, practical and affordable approach to conserving soil, water and other natural resources in rural areas

Who decides what qualifies as a BMP?

- a team that represents many facets of agriculture and rural land ownership in Ontario, including farmers, researchers, natural resource managers, regulatory agency staff, extension staff and agribusiness professionals

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Horticultural Crops
Integrated Pest Management
Irrigation Management
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Managing Crop Nutrients
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Pesticide Storage, Handling and Application
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Where to Find the Answers

Key

BOOKLET 2:
- ▶ Livestock and Poultry Waste Management

BOOKLET 3:
- ▶ Field Crop Production

BOOKLET 4:
- ▶ Horticultural Crops

BOOKLET 5:
- ▶ Farm Forestry and Habitat Management

Save Money

REDUCE FERTILIZER INPUTS:
- ▶▶ Nutrient Management
- ▶ Manure Handling and Storage
- ▶▶ Manure Application Systems
- ▶▶ Cover Crops and Rotation
- ▶▶▶▶ Soil Erosion Control (see Save the Soil)

REDUCE PESTICIDE INPUTS:
- ▶▶ Pest Management

ELIMINATE REPLANTING:
- ▶▶▶▶ Control Soil Erosion (see Save the Soil)

REDUCE ENERGY INPUT:
- ▶▶ Tillage Options
- ▶ Windbreaks and Shelterbelts
- ▶ Woodlot Management

REDUCE BUILDING MATERIAL COST:
- ▶ Woodlot and Plantation Management

BETTER TIME MANAGEMENT:
- ▶▶ Tillage Options
- ▶ Manure Handling and Storage
- ▶▶ Manure Application Systems
- ▶▶ Crop Rotation
- ▶ Woodlot Management

INCREASED YIELDS:
- ▶▶ Tillage Options
- ▶▶ Rotation
- ▶▶▶▶ Soil Erosion Control (see Save the Soil)
- ▶ Windbreaks and Shelterbelts
- ▶▶▶ Improve Soil Structure

Save the Soil

WATER EROSION CONTROL:
- ▶▶ Cover Crops and Crop Rotation
- ▶ Erosion Control Structures
- ▶▶ Tile Drainage
- ▶ Strip Cropping
- ▶▶ Buffer Strips
- ▶ Contouring
- ▶ Grass Headlands
- ▶▶ Tillage Options
- ▶ Intercropping
- ▶ Fragile Land Retirement

IMPROVE SOIL STRUCTURE AND REDUCE COMPACTION:
- ▶▶ Cover Crops and Crop Rotation
- ▶▶ Tile Drainage
- ▶ Grass Headlands
- ▶▶ Tillage Options
- ▶▶ Proper Application of Livestock Manures

WIND EROSION CONTROL:
- ▶ Tree Windbreaks and Natural Fencerows
- ▶ Vegetative Wind Barriers
- ▶▶ Cover Crops
- ▶▶ Tillage Options
- ▶▶ Strip Cropping

FRAGILE LAND RETIREMENT:
- ▶ Reforestation
- ▶▶ Buffer Strips
- ▶ Fencing to Prevent Livestock Access to Streams
- ▶ Wildlife Habitat Plantings

STREAMBANK PROTECTION:
- ▶▶ Buffer Strips
- ▶ Tile Outlet Protection
- ▶ Rock Protection on Banks
- ▶ Wildlife Habitat
- ▶ Low-flow Livestock and Machinery Stream Crossing

RELIEVING TILLAGE TRANSLOCATION:
- ▶ Reforestation and Intercropping
- ▶▶ Tillage Options
- ▶▶ Cover Crops and Crop Rotations
- ▶ Contouring
- ▶ Strip Cropping

Save the Water

CONTROLLING NITRATE LEVELS:
- ▶ Manure Handling and Storage
- ▶▶ Manure Application Systems
- ▶ Milkhouse Waste Storage and Treatment Systems
- ▶▶ Nutrient Management
- ▶▶ Cover Crops and Crop Rotations

CONTROLLING PHOSPHATE LEVELS:
- ▶ Manure Handling and Storage
- ▶▶ Manure Application Systems
- ▶ Milkhouse Waste Storage and Treatment Systems
- ▶▶ Nutrient Management
- ▶▶▶▶ Soil Erosion Control (see Save the Soil)

REDUCE SEDIMENT LOSS:
- ▶▶▶▶ Soil Erosion Control (see Save the Soil)

REDUCE BACTERIA LEVELS:
- ▶ Manure Handling and Storage
- ▶▶ Manure Application Systems
- ▶ Milkhouse Waste Storage and Treatment Systems
- ▶ Fencing to Prevent Livestock Access to Streams
- ▶ Low-flow Livestock Stream Crossing

PROPER PESTICIDE MANAGEMENT:
- ▶▶ Pest Management
- ▶▶▶▶ Soil Erosion Control (see Save the Soil) for Pesticides Attached to Soil

ADEQUATE WATER SUPPLY:
- ▶▶ Tile Drainage
- ▶ Irrigation and Water Table Management
- ▶▶ Water Conservation-Residue Management
- ▶ Water Conservation-Maintaining Trees

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HORTICULTURAL CROPS

INTRODUCTION

Unlike some of the other crops grown in Ontario, horticultural crops are usually grown on small acreages but are very valuable and require intensive, skilled management. Most are used or consumed directly by consumers. Today's consumers are very demanding. They want high quality and yet, are concerned about the environmental impact of agriculture.

Sustainability and competitiveness have become key words to horticultural crop producers. Growers need to be efficient in production to stay competitive and they need to conserve and protect soil and water to be sustainable. At times, these concepts appear to conflict but actually, they complement each other. Healthy soil and water will make horticultural crops more competitive.

To be considered a best management practice, an action must maintain or increase crop production while minimizing impact on the environment. In the case of many crops, this means using good management so that the crop is well-established and healthy. This allows growers to reduce treatments such as pesticides that may affect the environment. There is no one best management practice for all crops. The best ones for your farm will depend on your individual problems and opportunities.

This booklet does not cover every horticultural crop. Nor is it intended to give you exhaustive information on crop production. What this booklet will do is provide you with a place to start as you assess, develop and adapt your own system.

The booklet is divided into two major sections: Understanding the Basics covers problems and practices that are common to many crops; the other section looks at individual crops and outlines some best management practices.

You may wish to change your crop management system for many reasons: to save money, to increase yields, to save time and labour, to solve erosion problems or to reduce pesticide use. Whatever your reason, the first stage is to assess where you are now and what your goals are. Once that is done, this booklet will help you evaluate the options available.

UNDERSTANDING THE BASICS

Horticultural crop growers share many of the same management concerns of other producers. Although horticultural crops vary substantially, they all require skilled management to produce a high quality product. These crops rely on intensive management of soil, water, nutrient resources and pest populations.

Soil erosion can be particularly destructive to horticultural soils: removing crop inputs, soil and organic matter and damaging or stressing the crop.

SOIL MANAGEMENT

Soil is vital to all crop production, whether sod, vegetables or fruit. Healthy and productive soil helps crops develop good root systems and reduces crop stress caused by drought or excess rainfall. Intensive production of horticultural crops creates some unique challenges in soil management.

Soil erosion is a concern in many horticultural crops. Highly productive land is valuable and the supply is limited. Water and wind erosion can remove nutrients, other crop inputs, soil and organic matter. The crops, themselves, may also be damaged or stressed by erosion, increasing the possibility of disease. The following table shows a number of practices available to reduce or stop erosion.

Erosion control structures, such as berms and terraces, are covered in the Field Crop Production booklet.

EROSION TYPE	EROSION CONTROL STRUCTURES	COVER CROPS	TILLAGE & RESIDUE MANAGEMENT	WINDBREAKS & WIND BARRIERS	STRIP CROPPING
WATER	X	X	X	–	X
WIND	–	X	X	X	X

X = Effective Control Possible

The impact of wind erosion is often underestimated. If soil is visibly moving, more than 11 tonnes/hectare of soil is being moved.

Most horticultural crops leave soil exposed. Even relatively small amounts of residue can reduce wind and water erosion.

Tillage and residue management involves leaving some crop residues to protect the soil. Residue acts in two ways:

- ▸It protects the soil from the impact of raindrops and the resulting movement of soil particles and crusting.
- ▸It acts as small dams or windbreaks slowing the movement of wind and water across a field and reducing their ability to carry soil.

To protect soils, at least 20% residue cover should be left-but any amount will help. See the Field Crop Production booklet for a more detailed discussion of reduced tillage and equipment modifications.

Cover crops are planted to protect the soil surface and to maintain soil structure. They also help tie up excess nutrients, add organic matter to soil and control pests. There is a variety of cover crops available. Some are suited for specific uses. You must know what you want from a cover crop when making the selection. Ask yourself the following questions:

- ▸What kind of growth habit is needed? Do I need vigorous early fall growth as provided by oats, or vigorous spring growth as provided by rye? Is deep-rooting an important consideration? Or, am I looking for lots of top growth in mid-summer?
- ▸Should the cover crop survive the winter or die out?
- ▸Can it become a weed problem? What are the control measures?
- ▸What is the cost, availability of seeds, planting method?
- ▸Does it produce nitrogen (e.g. clover) or take up leftover nitrogen (e.g. rye)?
- ▸Are there benefits to soil structure?
- ▸Is the cover crop related to other crops in the rotation?
- ▸Will pest problems increase or decrease as a result of using the cover crop? For example, certain plant parasitic nematode populations often increase under red clover while they decrease with alfalfa.

A rye cover crop after processing tomatoes adds organic matter, holds some excess nutrients and protects the soil over winter.

COVER CROP SUGGESTIONS

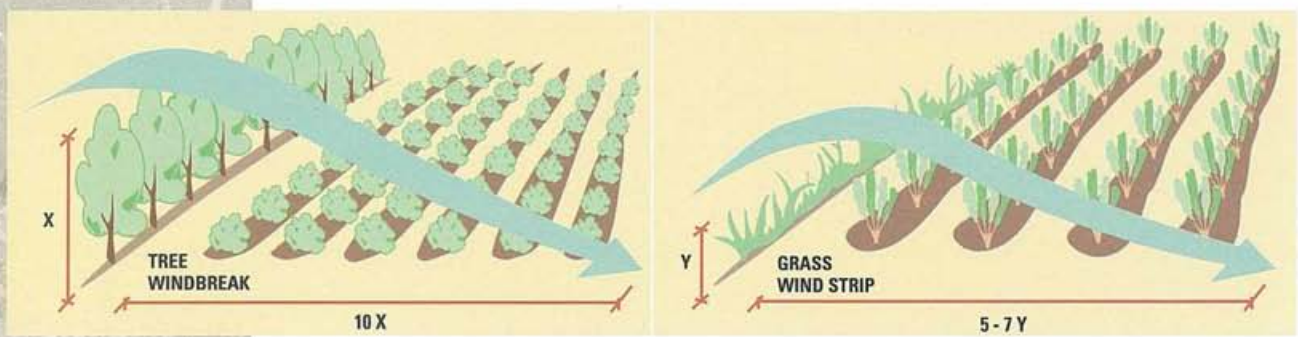
COVER CROP	SEEDING WINDOW	CROP CHARACTERISTICS							
		FAST GROWING	*DEEP TAP ROOT*	*FIXES NITROGEN*	*FROST TOLERANT*	*KILLED OVER WINTER*	*VOLUNTEER SEED POTENTIAL WEED PROBLEM*	*SUPPORTS NEMATODES**	
								Lesion	*Root-knot*
GRASSES									
Winter Rye	LS, EF, LF	X	–	–	X	–	–	+**	Δ
Winter Wheat	LS, EF	–	–	–	X	–	–	+	Δ
Barley	S, LS, EF	–	–	–	X	X	–	+	Δ
Oats	S, LS, EF	–	–	–	X	X	–	+	Δ
Ryegrass	LS, EF	–	–	–	X	–	–	Δ	Δ
Italian Ryegrass	ES, EF	X	–	–	–	X	–	Δ	Δ
Fescues	ES, EF	–	–	–	X	–	–	Δ	Δ
Corn	S, MS, LS	X	–	–	–	X	–	++	Δ
Sorghum-Sudan	ES, MS, LS	X	–	–	–	X	–	0	Δ
LEGUMES									
Red Clover	S	–	–	X	X	–	–	++	+++
Ladino Clover	S, EF	X	–	X	X	–	–	++	+++
Sweet Clover	S	–	X	X	X	–	–	Δ	Δ
Alfalfa	S, LS	–	X	X	X	–	–	Δ	+
Hairy Vetch	S, ES, MS, LS	–	–	X	X	–	–	++	+
Austrian Winter Peas	S, LS	–	–	X	X	?	–	+	+
Field Peas	S, ES, MS, LS	–	–	X	X	X	–	+	+
Soybeans	S, ES, MS, LS	X	–	X	–	X	–	+	+
BRASSICAS									
Spring Canola	S, LS	X	X	–	X	X	X	0	0
Winter Canola	LS	X	X	–	X	?	X	0	0
Tame Mustard	S, LS	X	X	–	X	X	X	0	0
Oil Radish	S, LS	X	X	–	X	X	X	0	0
OTHER									
Buckwheat	S, ES, MS	X	–	–	–	X	X	+++	0

NOTE: Seeding success dependent upon weather, particularly summer seedings.
*** Varietal difference in cover crop species may affect nematode reaction.**
**** Rye–whole season rating would be higher (+++).**

S = Spring **MS = Mid Summer** **EF = Early Fall** **X = Exhibits this characteristic usually**
ES = Early Summer **LS = Late Summer** **LF = Late Fall** **? = Inconsistent in some locations**
– = Not applicable

NEMATODE RATING CODES
Δ = Poor or non-host **+ = Ability to host** **0 = Some cultivars are non-hosts**

Windbreaks and wind barriers are covered in detail in the booklet on Farm Forestry and Wildlife Habitat Management. Wind barriers include a variety of possibilities, from short-term grain interseedings in muck crops to grass strips and fence-like materials to protect vegetables. Barriers reduce the speed of wind and lower its ability to carry soil. The area protected by a tree windbreak is about 10 times its height. The amount of protection provided by other types of barriers varies depending on height and the flexibility of the material.



Wind barriers reduce the speed and soil carrying ability of the wind. Tree windbreaks protect an area about ten times their height. Grass wind barriers are more flexible and can be pushed down by high winds, reducing the protected distance to five to seven times the barrier height.

Strip cropping involves planting strips or sections of a field with crops having different growth habits. For example, growers may alternate strips of early vegetables with later-seeded vegetables. Although management may increase, the soil surface is better protected.

SOIL STRUCTURE

Maintaining good **soil structure** is also a challenge for growers of intensively managed crops. Soil structure refers to how well soil particles are organized and held together as soil crumbs or clods. Structure influences the general health of the crop in the following ways:

- ►Water movement in and through the soil.
- ►The resistance of soil to erosion, crusting and compaction.
- ►A plant's ability to grow a good root system and take up nutrients.
- ►Aeration.

A good root system is essential to production, allowing the plant to exploit soil water and nutrients.

Soil Compaction

Tillage and cultivation tend to break down soil clods and organic matter. Organic matter is the glue that holds soil particles together. Production of high-quality horticultural crops requires timely operations. Sometimes, this means tilling, spraying or harvesting on soils

that are too wet. In addition, to be cost-effective, many of these operations have become highly mechanized. Running heavy equipment in wet conditions may cause soil compaction. Compaction means that the soil has become packed and pore spaces are reduced which decreases the soil's ability to hold both air and water.

Reducing Compaction

- ▸Avoid working on wet soils.
- ▸Reduce the number of trips over a field.
- ▸Keep the weight on an individual axle to below five tonnes. Use trailers with tandem axles.
- ▸Choose radial tires where extra traction is needed. They have up to 27% more surface contact than bias ply tires of similar size.
- ▸Four-wheel drive tractors have better weight distribution between axles.
- ▸Use good crop rotations that include deep-rooted crops or cover crops.
- ▸Limit traffic to certain areas or rows. If possible, use the same travel lanes each year.

Tillage and crop roots usually break up shallow or surface compaction. However, deep compaction or plow pans can be more difficult to deal with. Deep-rooted crops and frost action may help. Research shows that frost takes at least three winters to reduce compaction, assuming that no further compaction has taken place. Deep tillage or subsoiling is a prescription treatment for the worst areas.

It is important to subsoil properly or compaction is just moved deeper:

- ▸Know the depth of the problem.
- ▸Work on soils that are dry to the level of tillage.
- ▸Plant a deep-rooted cover crop to keep the soil open.
- ▸Make changes in your practices to avoid future problems.

Subsoiling is only a temporary solution and does not remove what caused compaction in the first place.

Scheduled harvest of perishable crops sometimes forces working on wet soils. Try to avoid compaction using other measures and plan to rotate away from the problem crops.

Given the soil conditions, this deep tillage implement is where it should be – parked. Subsoiling must be done properly, or problems can be made worse.

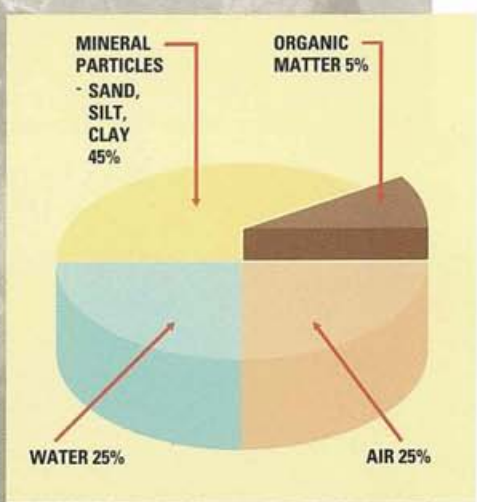
Reducing tillage where possible will help to retain soil productivity by reducing soil compaction and erosion losses of soil and organic matter.

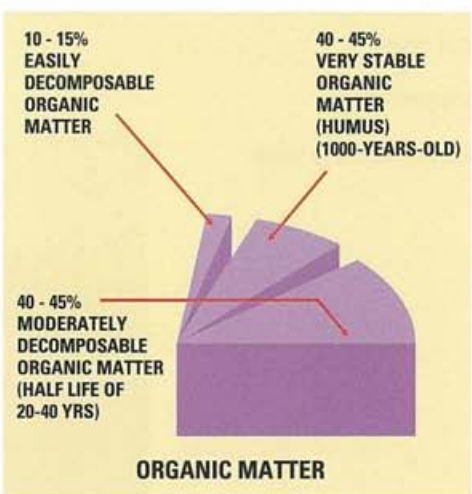
Soil Organic Matter

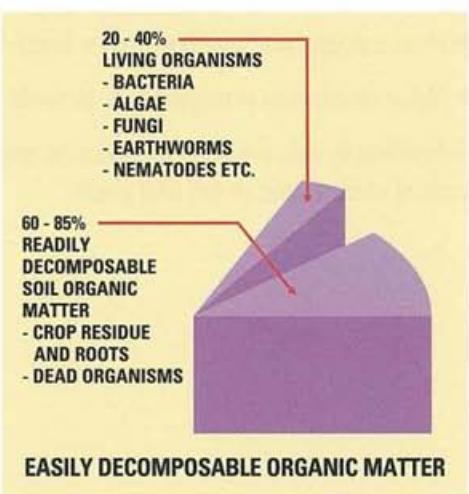
Soil organic matter is a very small part of the soil with a large role to play. Many soils used in horticultural production have soil organic matter levels between 2 and 4%. About 40 to 45% of the soil organic matter is very stable and resists decomposition. Another 40 to 45% is moderately stable. This portion is protected or held within soil clods and on clay particles and is very important to soil fertility, accounting for 40 to 50% of nutrients released each year. The remaining 10 to 15% is composed of living and dead organisms and decomposes easily.

Growers can directly affect the organic content of their soils. Excessive tillage, soil erosion and poor crop rotation will speed loss of organic matter. On the other hand, there are a number of practices that maintain and improve organic matter:

- ►Good crop rotations that return a variety of residues to the soil.
- ►Use of cover and green manure crops that add plant material to soil.
- ►Reducing tillage where possible.
- ►Adding organic matter such as manure, compost and other wastes. It is important to know what is in the material, though, first. (Any field application of organic off-farm waste, e.g. food processing waste, requires a permit from Ministry of the Environment.)
- ►Reducing erosion losses of soil and organic matter.
- ►Keeping tillage shallow to prevent dilution of organic matter.







Organic matter is only a small portion of the soil, but it is very important to soil fertility and good soil structure. Maintaining adequate soil organic matter levels is crucial to consistent production of horticultural crops.

WATER MANAGEMENT

Good quality water is needed for spraying, irrigation and household use. Horticultural crops tend to be very sensitive to moisture levels. Often, it seems there are only two levels — too much moisture and not enough. Irrigation and drainage are best management practices for many horticultural crops. Adequate moisture reduces plant stress and helps prevent disease.

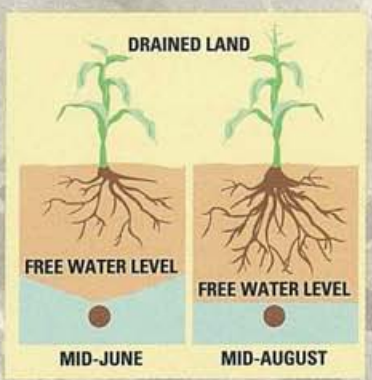
IRRIGATION

Irrigation must be applied properly to be cost-effective and to prevent harm to the environment. When irrigating:

- ►Know your soil type and its capacity to hold water.
- ►Know when moisture is critical to your crop.
- ►Use a scheduling method such as a tensiometer or the evapotranspiration model.
- ►Be aware of the weather forecast.
- ►Monitor the system when it is operating. Breakdowns cost money and waste crop inputs.
- ►Reduce losses from evaporation. When applying water, avoid the heat of the day. Apply on cloudy days and when wind speed is low.
- ►Keep good field records.
- ►Monitor for disease.
- ►If removing more than 50,000 litres (10,000 gallons) a day from a water source, get a permit from the Ministry of the Environment.

A rain gauge is an important tool in water management. Keeping accurate rainfall records will help in scheduling irrigation.

Reduce water loss when using overhead irrigation – avoid the heat of day, apply on cloudy days and when wind speed is low.



Good drainage is critical to the production of horticultural crops. Poor drainage does not encourage deep root growth, making the plants more prone to drought stress.

Soil testing is important. Make sure the sample represents the field.

When properly used, irrigation is an effective management tool. There are a number of publications available that can provide you with more detail on equipment and scheduling.

DRAINAGE

Drainage is critical to production of horticultural crops. Poor drainage adds stress to plants and makes them more prone to pests.

- ▸Ensure drainage is adequate. Repair or replace tiles that do not work.
- ▸Protect tile outlets to prevent damage to ditchbanks (see the booklet on Field Crop Production for details).
- ▸Use a header tile to reduce the number of outlets entering a ditch, where possible. This will help prevent ditch damage and reduce loss of field areas to slumping.

NUTRIENT MANAGEMENT

Good use of nutrient management will improve both your production and the environment. Cost-effective application will produce the best yield potential while minimizing costs. In turn, this helps reduce nutrients lost to the soil through leaching and water erosion.

Soil testing is an important first step. Soil test results will give you a base on which to analyze soil needs. Also do tissue tests, if available for your crop. This shows what plant nutrient levels are at that point in time, as opposed to what is available in the soil. This is particularly important for perennial crops.

Record keeping of soil and tissue tests will help track trends. Include observations on crop growth, yield, quality and weather conditions during the growing season.

Application of nutrients varies from crop to crop. For more details, check the sections on specific crops in the following section and the OMAF publications listed at the back. A few general best management practices include:

- ▸If possible, use split applications of nitrogen to reduce the possibility of loss by leaching. This will also increase management and application costs and may not be suited to all crops.
- ▸Keep soil healthy so that root systems will be most effective in using nutrients.
- ▸If nutrients are left after a crop harvest, use cover crops to hold them for the next crop.

To be competitive, horticultural crop growers have to produce high quality products efficiently. To be sustainable, soil and water resources must be protected and conserved. Best management practices need to be chosen and adapted to suit each farm operation.

PEST MANAGEMENT

Pesticides are often used to control pests in horticultural crops. However, they are often viewed as environmental hazards by the public. Integrated Pest Management (IPM) promotes the responsible and reasonable use of pesticides in combination with non-chemical controls. Relying only on pesticides for control has several disadvantages:

- ▸Insects, diseases and weeds can become resistant to pesticides.
- ▸Resurgence of the pest when the pesticide application kills a high proportion of its natural enemies. The pest population increases rapidly because natural enemies no longer provide control.
- ▸Secondary pests are created when pesticides kill the natural enemies of a non-target pest. Without natural enemies, the pest population increases to where it becomes a problem.
- ▸Possible environmental contamination (e.g. pesticides in well water).
- ▸Input costs for growers.
- ▸Potential health hazards.
- ▸Negative public attitude towards pesticides.

IPM SYSTEMS

There are four components to an IPM system:

- ▸Pest identification.
- ▸Monitoring.
- ▸Control guidelines.
- ▸Methods of prevention and control.

IPM can reduce pesticide use and yet, maintains quality standards by treating pests as part of the total management system. Components of the system include the physical and biological environment of the crop and pest. Pest management practices are combined with production practices to achieve economical, long-term solutions.

Development of a secondary pest.

Weather conditions can be monitored by systems such as this TOM-CAST station. The information can then be used to predict some diseases.

Pest Identification

Identifying the pest properly helps decide which method of control is best. Nutrient deficiencies or physical damage can cause symptoms similar to those caused by pests. Also, the presence of pests does not always cause economic damage. Factsheets on pests are available from the Ontario Ministry of Agriculture and Food to help in identification.

Monitoring

Monitoring allows you to forecast and evaluate potential pest problems. It identifies the pests present, estimates numbers and examines conditions favourable to pests. Monitoring allows accurate timing of pesticide applications which may reduce pesticide use. Each field should be watched separately because conditions vary. Monitor at least once per week and preferably twice per week when the pest is usually most active. Scouts may be hired to monitor the crop.

Good record keeping is essential. Complete written records help decision-making by supplying information on previous problems and applications. It is useful to record:

- ►Crop health.
- ►Pest species present.
- ►Weather and other environmental conditions.
- ►Population level of pests and beneficials.
- ►Sprays and other controls applied.

Methods of Monitoring

There are several ways to monitor pests.

Pheromone traps contain a chemical that attracts only the species of pest being monitored. This makes pest identification easier.

Physical traps are visually attractive to many types of insects. This can make pest identification time consuming.

Direct counts check the number of insects or the amount of disease on a set number of plants. Weed counts across the field will aid in herbicide selection.

Weather monitoring calculates when insects will first emerge in the spring or when a disease is most likely to occur (e.g. BOTCAST predicts when Botrytis leaf blight infection takes place in onions so fungicides can be applied at the best time).

Control Guidelines

Control guidelines, or thresholds, indicate when pesticides need to be applied to prevent economic losses. Timing of control measures is critical. Guidelines for insects are based on an economic threshold where the cost of not applying a control will be higher than applying a control. Guidelines for diseases, weeds, nematodes and vertebrates may be based on weather, history of the field or region, stage of the crop and other field observations.

Control Methods

There are three types of controls used in IPM systems: cultural, biological and chemical (pesticides). Cultural and biological controls are used wherever possible. When these are inadequate, pesticides are usually used. The most economical and reliable way to deal with pest problems is to avoid them when possible.

Cultural Control

Many cultural practices reduce pest damage. They prevent problems and are effective and economical. Examples are:

Site selection - choose sites that are less favourable to pests.

Cultivar selection - choose varieties that are resistant, when possible.

Crop rotation - rotate away from crops of the same family (e.g. turnip, cole crops and canola) to prevent some pests and help control weeds.

Inter cropping - planting a mixture of crops may reduce insect damage (e.g. underseeding brussels sprouts with clover). However, competition may reduce yields in some cases.

Cover crops - can provide shelter for beneficials.

Trap crops - plant crops to attract the pest away from the main crop. Pests can be killed with a localized spray. For example, in tomatoes, trap crops of potatoes and eggplant can be used for Colorado Potato Beetle (CPB).

Tillage - provides weed control and may kill some insects and pathogens.

Time and method of planting - may help to avoid a generation of the pest.

Sanitation - remove pest habitat such as cull piles, dropped fruit or other plants. For example, potato cull piles provide a place for potato blight to overwinter.

Pruning - removes a food source or a point for infection. For example, removal of pear suckers helps to keep psylla numbers down.

Clean seed and transplants - avoid introducing pests. Use seed that has been certified disease-free.

Eggplants are currently being used as a trap crop in tomatoes. Colorado Potato Beetles appear to prefer eggplant and potatoes over tomatoes.

Removing pear suckers will reduce psylla numbers.

Use of clean, disease-free plants such as these pepper transplants will help to prevent disease problems.

IPM systems take advantage of natural enemies such as this parasitic wasp which is emerging from an aphid exoskeleton.

Another example of a natural predator feeding on an aphid in a greenhouse operation.

Plant health - healthy plants are less prone to infection.

Irrigation - use good timing/scheduling to prevent disease.

Biological Control

Biological control uses a pest's natural enemies to control the population of the pest. Natural enemies include predators, parasites and diseases. The term, "beneficials", refers to predators and parasites of insect pests. IPM systems take maximum advantage of control by natural enemies.

There are two ways in which biological control is managed:

Encouraging natural enemies - provide shelters or food sources for natural enemies. For example, a sod or weedy cover in an apple orchard provides an overwintering site for predatory mites. These mites control European red mite and two-spotted spider mite.

- ►Select pesticides that have minimal effect on beneficials. For example, *Bacillus thuringiensis* (Bt) is specific to certain types of caterpillars.
- ►Time or schedule pesticide applications to have least effect on beneficials.
- ►Apply pesticides only when needed.

Adding natural enemies to provide control - adding natural enemies is not usually economical in the field. However, in greenhouse operations, it is often possible. For example, whitefly can be controlled with *Encarsia formosa* (a parasitic wasp). At present, work to develop pest diseases is continuing. In the future, more of these products may come on the market.

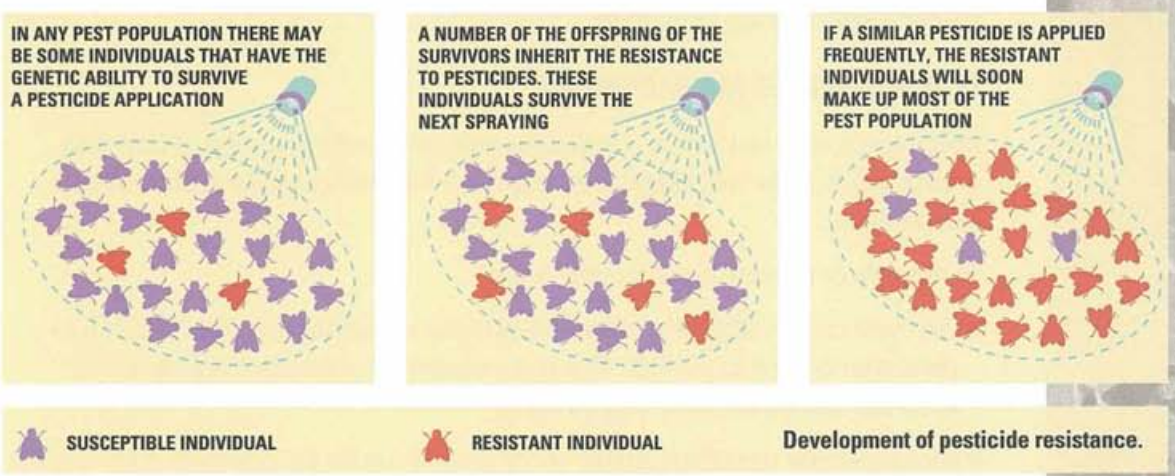
Resistance

Refers to the developed ability of a pest to survive applications of pesticides at rates that once killed most of that species. This ability is passed from generation to generation making the pesticide useless. Colorado Potato Beetle resistance, for example, is a major problem. With fewer new pesticides coming onto the market, resistance could become a more widespread problem. Resistance is most likely when pesticides are applied at lower-than-recommended rates and when either the same pesticide or pesticides with the same mode of action are repeatedly used.

Resistance Management

- ►*Use pesticides only when needed.*
- ►*Avoid pesticide residues.*
- ►*Alternate pesticides with different modes of action.*

- ▶ *Use recommended rates of pesticide.*
- ▶ *Use other controls where possible e.g. rotary hoe for weeds.*
- ▶ *Time pesticide sprays for the most vulnerable stage. For example, spray for the larvae of Colorado Potato Beetle rather than the adult.*



Development of pesticide resistance.

CHEMICAL FAMILIES AND THEIR COMMON NAMES

CHEMICAL FAMILY	COMMON NAMES
BIOLOGICAL CONTROL (BACILLUS THURINGIENSIS)	Dipel, Thuricide, Trident, M-One
SYNTHETIC PYRETHROIDS	Ambush, Cymbush, Ripcord, Pounce, Decis, Belmark
CARBAMATES	Pirimor, Lannate, Furadan, Sevin, Temik, Vydate
ORGANOPHOSPHATES	Guthion, Orthene, Metasystox, Parathion, Malathion, Cygon, Monitor, Lorsban, Diazinon
ORGANOCHLORINES	Thiodan, Methoxychlor

Summary

IPM systems can be effective and economical for horticultural crops. While the level of damage may be higher than when using chemical controls, long-term effectiveness is better. To be successful, IPM requires time and careful attention to pest identification and monitoring, control guidelines and methods of prevention and control.

VEGETABLES

Cereal crops like wheat make a good break in a crop rotation, helping to build and maintain soil organic matter and soil structure.

FIELD-SEEDED AND TRANSPLANTED VEGETABLES

Economic and environmental pressures are challenging Ontario vegetable producers. Growers need to produce a high-quality product efficiently to remain competitive, however, soil and water resources must also be preserved. Healthy, productive plants require healthy soil and clean water.

SOIL AND WATER MANAGEMENT

Intensive vegetable production, whether for processing or fresh market, returns little organic matter to the soil. Tillage used to prepare the seedbed increases the loss of organic matter.

To maintain or increase organic matter levels:

- Use cover crops within the rotation. Following short-season vegetables, establish a cover crop as soon as possible. This green manure crop increases organic matter levels and also breaks some pest life cycles.
- For long-season vegetables, annual or cereal rye is usually the best cover crop. It grows well in cooler weather such as late autumn and early spring. Rye's large, fibrous roots help hold the soil together, preventing erosion. Tillage or herbicides will kill the rye prior to spring planting.
- When a cereal crop precedes vegetables, underseed the cereal with either clover or alfalfa to improve soil structure and reduce compaction. Legumes produce nitrogen, so make allowances in your nutrient applications.
- Reduce tillage and add manure, mushroom compost (a permit is required by Ministry of the Environment for the application of organic off-farm waste) and other plant waste. Take care not to increase soil compaction. Adjust the following year's nutrient application depending on the content of these materials.

Soil Compaction

Soil compaction is a growing concern for vegetable producers. Increased mechanization has led to larger and heavier equipment to ensure planting and harvesting are handled on time.

Seedbed preparation and harvest operations under wet soil conditions are the major causes of soil compaction. Perishability and maturity of the vegetable crop are important to quality. Because staying out of wet fields is often not an option, research continues into solutions.

WEIGHTS OF SOME HARVEST EQUIPMENT

EQUIPMENT	WEIGHT (TONNES)
PEA COMBINE	≈ 17
TOMATO HARVESTER	11 - 14
TRANSPORT WAGONS	3 - 16
SWEET CORN HARVESTER	11
SELF-DUMPING CARTS	3 - 8

Crop Rotation

Crop rotation is a best management practice for vegetable growers. It will address loss of organic matter, disease, weed and insect pressures, soil nutrition, compaction and erosion. Two rules of thumb:

The longer the rotation, the better.

Rotate between different families of crops.

In designing a rotation, ask yourself the following questions:

- ▸Is the rotation profitable?
- ▸Are the yields sustainable?
- ▸Does the sequence allow the use of cover crops?
- ▸Does it make use of nitrogen produced by an earlier crop?
- ▸Does it allow for timely planting and harvest?
- ▸Are harmful herbicide residues left?

Recent tomato research shows that yields improve with good crop rotations. Building and maintaining soil resources should produce similar results for all vegetable crops.

Processing peas can be particularly hard on soil structure. Tightly scheduled planting and harvest seasons mean soil moisture levels may not be optimum when machinery, such as pea combines, are running over the soil.

Early or short season crops such as melons allow the use of cover crops and green manure crops to build and maintain soil organic matter.

FAMILIES OF CROPS

FAMILY (COMMON NAME)	EXAMPLES
CRUCIFERAE (MUSTARD)	Cabbage, Cauliflower, Broccoli, Rutabaga, Brussels Sprouts, Rapeseed, Canola, Oilseed Radish
GRAMINEAE (GRASS)	Wheat, Rye, Barley, Oats, Corn
LEGUMINOSAE (PEA)	Snap Bean, Pea, Alfalfa, Clover, Soybeans
SOLANACEAE (NIGHTSHADE)	Tomato, Potato, Eggplant, Pepper
CUCURBITACEAE (MELON)	Pumpkin, Squash, Cucumber, Melons
LILIACEAE (LILY)	Asparagus
UMBELLIFERAE (PARSLEY)	Carrot, Parsnip, Celery
CHENOPODIACEAE (GOOSEFOOT)	Beet, Spinach, Chard
AMARYLLIDACEAE (AMARYLLIS)	Leeks, Onion, Garlic, Chives, Shallots

"Fall broadcasting of rye followed by bedding for my tomato crop is my definition of 'lazy man's wind control'. It's easily accomplished and does the trick in preventing early season sandblasting."

P. Brunato, Tri-B Farms Ltd., Leamington, Ontario

Wind and Water Erosion

Level sandy soils are at the highest risk of wind erosion while hilly fields are also subject to water erosion. Windbreaks, grassed waterways and other structures address problems in the long-term. Increased residue on the soil surface and use of cover crops will help in the short-term.

For precision-seeded crops, choose a field sheltered by a windbreak, woodlot or other means. Strip cropping with another crop will also cut down wind. If a field is particularly prone to wind erosion, broadcast oats or barley prior to planting the vegetable. The cereal will shelter the seedlings. A timely application of contact grass herbicide will kill the cover crop before it competes with the vegetable.

In some transplanted vegetable production systems, ground beds roughen the soil surface which slows water, wind and soil movement. Some growers are also managing cover crops on ground beds to control wind. Another alternative is the use of narrow grass strips spaced across a field to reduce the speed and soil-carrying ability of wind.

A rye cover crop on beds can be managed with a timed application of herbicides to provide short-term wind protection in the spring. This system also minimizes the number of passes over the field in spring.

Irrigation

Average rainfall is irregular and sometimes is inadequate for vegetables. Irrigation can be profitable with high-value vegetable crops. Both overhead and sprinkler irrigation systems are being used in Ontario. Overall costs are comparable. Drip irrigation has two advantages: reduced water needs and uniform soil moisture; but, overhead irrigation is adaptable to any crop and can be used for frost protection.

Irrigation is important after planting until seedlings emerge and during fruit development. Most vegetables have periods where a lack of water can affect yield and quality. Use a scheduling method such as the tensiometer or the evapotranspiration model to assist in irrigation timing.

DRIP VS. OVERHEAD IRRIGATION

DRIP IRRIGATION	OVERHEAD IRRIGATION
Requires up to 50% less water than overhead irrigation.	Requires more water because of evaporation and run-off.
Provides a more uniform availability of water through season.	Larger fluctuations in soil moisture levels.
Higher fixed costs if irrigation not required because of adequate rainfall. Lower variable costs when irrigation is required.	Decision to irrigate not made until required; therefore, lower carrying costs on fixed portion. High variable costs when irrigating because larger water volumes pumped and more labour intensive.
Easier to irrigate through harvest since only growing area wet.	Must schedule irrigation around harvesting operations.
More efficient use of fertilizer.	Requires more fertilizer.
Certain crops are not adaptable to drip irrigation.	Any crop can be sprinkler irrigated.
Fixed location.	Mobile which facilitates land rental and crop rotation. Some frost control.
Relatively new technique, grower must develop skill.	Many growers already have sprinkler systems.

CRITICAL GROWTH STAGES FOR MOISTURE STRESS

CROP	CRITICAL GROWTH STAGE
SNAP BEAN	Flowering and pod setting
BROCCOLI	Head formation and enlargement
CABBAGE	Head formation and enlargement
CARROT	Root enlargement
CAULIFLOWER	Planting to harvesting
SWEET CORN	Tasselling, silking and ear filling
CUCUMBER	Flowering and fruit enlargement
MUSKMELON	Flowering and fruit enlargement
PEAS	Flowering and pod formation
PEPPER	Transplanting, fruit set and development
PUMPKIN, SQUASH	Flowering and fruit development
TOMATO	Flowering, fruit set and enlargement
WATERMELON	Blossom to harvesting

Pepper production on plastic with drip irrigation. The plastic has been cut away to show the irrigation line slightly buried and one of the emitters.

Plasticulture

This practice combines plastic mulches with row covers and drip irrigation. The practice is costly and is only practical with fresh market vegetables. Benefits include: early harvest, increased early season yield, improved quality and reduced soil movement due to erosion. Removing and disposing of plastic materials in land fills after harvest is a drawback.

NUTRIENT MANAGEMENT

The most important aspect of nutrient management is to soil test before applying anything. Applying too much fertilizer is expensive and also may affect surface and groundwater. Too little fertilizer may affect yields.

Each vegetable crop requires a different fertilizer program. Start by considering the base fertility of your soil. When taking soil samples, be sure to take samples that are representative of the whole field. Good record keeping can help you track a field's fertility over time and assist in making decisions.

"The money spent on soil tests is one of my best investments. Every tomato field gets soil-tested every year. By following fertilizer recommendations, I feel we have saved money and improved our yields."

P. Richards, Dresden, Ontario

PEST MANAGEMENT

Integrated Pest Management helps reduce pesticide use while maintaining yield and quality. See the section on Pest Management in Understanding the Basics for more information.

Cultural Control

- ▸Select the most resistant variety of your crop.
- ▸Select a site that reduces problems.
- ▸Reduce stress and injury to crops. These allow pests to get started.
- ▸Use good sanitation practices. Till under or bury culls.
- ▸Control weeds that may harbour pests.

Chemical Control

When choosing a pesticide, always refer to the pesticide label and consider:

- ▸The days to harvest interval.
- ▸The impact on beneficial insects. For example, consider when honey bees are most active. *Bacillus thuringiensis* (Bt) is least likely to harm beneficials because it is specific for each type of insect. Synthetic pyrethroids are not persistent but they do affect a broad spectrum of species.
- ▸Use strategies to reduce the chances of pests becoming resistant. Rotate chemical families.

Weather conditions - some pesticides work better under specific environmental conditions. For example, synthetic pyrethroids are most effective in cool temperatures while others such as carbamates and organophosphates work best in warm conditions.

The life cycle of the pest - adult insects are more difficult to control than immature forms. Larger, mature weeds are more difficult to kill.

Cole Crops

The development of an IPM program for cole crops is underway at the Simcoe Research Station. Special attention is being paid to the identification of insect tolerant cultivars. Cultural practices such as trap cropping are being evaluated.

MONITORING FOR INSECTS ON COLE CROPS

INSECT PEST	VISUALLY MONITOR BY	YELLOW PAN TRAPS	PHEROMONE TRAPS (INDICATES PRESENCE ONLY)
CABBAGE MAGGOT	Observe eggs in soil at plant base	Adults	–
FLEA BEETLE	Count on leaves and observe chewing damage	–	–
THRIPS	On or between leaves	–	–
CABBAGE LOOPER	Count larvae on leaves	–	X
APHIDS	On or between leaves Observe damage to leaves	–	–
DIAMONDBACK MOTH	Count larvae on leaves	–	X
IMPORTED CABBAGE WORM	Count larvae on leaves	–	–

X = Suitable **– = Not Applicable**

While very limited insect damage may be tolerated on cabbages, consumers will not tolerate any insects on broccoli, cauliflower or brussels sprouts. Particular care must be taken when monitoring these crops for insects.

Cabbage looper larvae.

CULTURAL PRACTICES TO CONTROL DISEASE IN COLE CROPS

CONTROL PRACTICE	ALTERNARIA DISEASES	BLACK ROT BLACK LEG	CLUB ROOT	DOWNY MILDEW	SCLEROTINIA	VIRAL DISEASES
Tolerant or resistant varieties	–	X	–	X	–	–
Disease-free seed and transplants	X	X	X	X	–	–
Clean seedbed	X	X	X	X	X	–
Good air circulation	X	X	–	X	X	–
Proper pH	–	–	X	–	–	–
Avoid overwatering	X	X	–	X	X	–
Eliminate weeds	X	–	X	–	X	X
Don't work when foliage is wet	–	X	–	–	–	–
Don't bruise head at harvest	X	–	–	–	X	–
Incorporate crop residues immediately	X	X	X	X	X	–
Clean all equipment	–	X	X	–	–	–
Rotate crops	X	X	X	X	X	X

X = Suitable Control Practice

Alternaria black spot on cauliflower head and leaves.

Tomatoes

Disease control - TOM-CAST is a weather-monitoring program used to time fungicide spray for field tomatoes. A daily disease severity value is determined by the average temperature during hours when foliage is wet. Once the value reaches a certain level, growers should apply fungicide. About 80% of processing tomato growers use TOM-CAST to time their first spray and 50% continue to use the system through the growing season. By following the system throughout the season, growers can usually save between one and three sprays. Further research is underway.

Insect control - the Colorado Potato Beetle can do great damage to tomatoes, particularly when emerging adult beetles attack young plug transplants. While a number of insecticides are available, the beetle is resistant to several of them. This is a particular problem in areas with large acreages of both tomatoes and potatoes. Field rotation can help to reduce CPB pressure.

Trap cropping can help to reduce pesticide use. Plant strips of potatoes or eggplant, which the insects prefer, at the edges of tomato fields to trap adult beetles. When the beetles are concentrated on the trap crops, apply insecticides to them. The results are fewer sprays on a more concentrated area.

"In 1991, I planted one row of potatoes at the edge of my tomato field and one row down the middle of the field. I had to spray the potatoes three times for Colorado Potato Beetle but I only sprayed the tomatoes once."

E. Gyori, Harrow, Ontario

A potato trap crop for Colorado Potato Beetle control in processing tomatoes allows growers to reduce the number of overall sprays.

Promising research continues into encouraging natural predators, mulching and barrier crops.

Other tomato pests include:

- ►Flea beetles.
- ►Tarnished plant bugs.
- ►Fruit flies.
- ►Grasshoppers.
- ►Cabbage loopers.
- ►Aphids.
- ►Hornworms.
- ►Crickets.
- ►Variegated cutworms (monitored regionally by OMAF and processors).

These pests rarely require treatment. Check OMAF Publication 363 for control measures.

Soil pathogens - high levels of plant parasitic nematodes and *Verticillium dahliae* cause stunted, wilted, low-yielding tomato plants, especially on sandy soils. To control the problem:

- ►Rotate crops to avoid pest build-up.
- ►Plant cover crops such as annual and perennial ryegrass, alfalfa, non-flowering marigolds or work in green material from oilseed radish or mustard to reduce populations. Oats and winter wheat have little effect on populations. Nematode populations increase under clover, corn and many vegetable crops.
- ►Improve organic matter, drainage and soil structure to promote good root growth.
- ►Test your fields. Ensure that the samples are representative.
- ►If threshold levels have been reached, fumigate. Then, concentrate on the other control measures to prevent repeated build-up.

High levels of plant parasitic nematodes, such as the root lesion nematode, combined with *Verticillium dahliae* can cause significant yield reductions in tomatoes.

Peppers

European Corn Borer is the major insect pest. Pheromone traps capture males. Traps are monitored regionally and adult flight patterns collected as part of the OMAF Pest Alert program. Check the Agriphone for details. Growers can also put out traps to monitor their own fields. Pests such as aphids and pepper maggots rarely require control, but tarnished plant bugs are becoming more of a problem.

Bacterial spot is the major disease threat. Fixed Copper may reduce the spread of this disease if weather conditions are not too favourable.

Field-Seeded Vegetables

Includes peas, sweet corn, snap beans, cucumbers, carrots, beets, pumpkins, squash, spinach, radish and rutabaga.

Primary pests attacking these vegetables are root-rot organisms and maggots. To reduce the problems:

►Maintain and increase soil organic matter levels.

►Use crop rotation.

►Make sure all seed is treated with fungicide.

►Ensure adequate fertility.

►Improve drainage.

►Ensure good soil structure. Reduce or avoid compaction.

Summary

There is a saying, "A chain is only as strong as its weakest link." Success in the management of vegetable production is like that chain. Each decision reflects two considerations: short-term viability and long-term sustainability.

With the trend towards growing supersweet sweet corn for freshmarket, creating good conditions for germination and early growth is critical.

POTATOES

Any practice considered for potato production must be cost-effective. But sustainability is more than just an economic issue, it also considers environmental factors. Best management practices bring together concerns for the environment and the need for efficient production of a high-quality product.

Potato harvest is highly mechanized, involving numerous trips over the field. Good soil management should be practiced to reduce the effects of soil compaction.

SOIL MANAGEMENT

Potato production is hard on soil structure. Crop rotations can help. Try to rotate out of potatoes for at least a year. Avoid continuous potatoes. Use cover crops.

Compaction and poor soil structure can cause several problems:

- ►Soil crusting and reduced plant emergence.
- ►Poor aeration reduces crop vigour and leads to inconsistent yields.
- ►More misshapen tubers.
- ►Increased soil erosion by water.

SAMPLE ROTATIONS FOR PRACTICAL SITUATIONS

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
Where cash cropping is the only option:	Potatoes Winter wheat –	Winter wheat Short fallow period Rye cover crop	Potatoes Winter wheat –	– – –	– – –
For short-term, leased land agreements:	Potatoes Cover crop	Potatoes Cover crop	– –	– –	– –
For long-term "soil investment":	Alfalfa – –	Alfalfa – –	Potatoes Winter wheat –	Winter wheat Short fallow Rye cover crop	Potatoes Rye –

Ask yourself the following questions about your water management practices:

- **Do you have a rain gauge in every field and keep records of rainfall?**
- **Do you know the pH level of your water for consideration in irrigation and spraying?**
- **Do you regularly test your well for chemicals, bacteria and nitrates?**

Hard pans can develop on sandy soils, particularly when there is heavy traffic on wet soil. Increasing potassium levels near the roots may help overcome some of the effect. Building organic matter levels will produce longer-term benefits. Use crop rotations, cover crops and manure. Good production depends on healthy, vigorous roots. Improving soil structure can improve yields.

A good practice is to plant a cereal crop in September or October and subsoil or chisel plow in late October or November when the ground is dry. This will break up hard layers but leave enough cover to prevent erosion.

WATER MANAGEMENT

Many of the decisions a farmer makes to improve soil will also improve water quality. Water quality is important for spraying, irrigation and personal use.

Irrigation

More and more farmers are turning to irrigation to provide relief from droughts. Properly used, irrigation can help plants stay healthy and vigorous; however, leaching of nutrients and increased disease may result from over-irrigation. Consider the following when managing irrigation:

- Know your soil type and its capacity to hold water.
- Know how your crops store water. Demands change as crops develop.
- Use an irrigation scheduling method such as a tensiometer or the evapotranspiration model.
- Know the weather forecast.

As long as the soil is dry, subsoiling or chisel plowing a cover crop in mid-fall can help to break up plow layers. Take care to leave enough cover to prevent erosion.

- Monitor irrigation and use a rain gauge to measure the quantity applied.
- Watch for blight.
- On level fields with small hollows, use a "dammer diker". This machine makes small holes between the rows that trap the water where it is applied — preventing water flow to low spots.

Irrigate when available moisture is below 50% of field capacity, wind speeds are less than 20 kilometres per hour, during evenings or calm, cloudy days. Irrigation can also be used to reduce soil blowing.

NUTRIENT MANAGEMENT

A healthy, well-nourished crop can withstand stress from drought, insects and weeds. Growers should supply the particular nutrients needed on a field by field basis. This prevents waste of fertilizer and lost yields.

Take soil tests - take samples carefully and map the field properly. Sample trouble areas separately.

- ▶ Establish yield goals based on your previous records; fertilize for a realistic yield goal and to improve your soil. Your own experience and the variety of potato will affect decisions.
- ▶ Leaf tissue test before bloom, particularly in poor areas.

Tuber test - take two weeks before harvest or at harvest to gauge storability of crop. Optimum levels of tuber calcium improve storability.

Keep good records - record all samples taken and make careful maps. Use records to correct problems and to refine programs.

R.J. Mackenzie, Alliston, finds, "Placement and timing of fertilizer applications are critical for the production of a quality crop." Providing the required nutrients at each stage of growth, in the most effective way, is a challenge for all growers.

SAMPLE FERTILITY PROGRAM*

FALL	Broadcast 50% of potassium requirement.
SPRING	Broadcast, or band in planter, the remaining potassium. Split nitrogen 25% ppi (urea), 50% in the planter mix (ammonium sulfate/ammonium nitrate), 25% at second hilling (urea, calcium nitrate).
PLANTER MIX	Band on either side of seed piece. Include phosphorus, magnesium, sulphur, zinc and calcium if needed.
FOLIAR APPLICATION	If boron or zinc levels are low, apply in irrigation or sprayer. Manganese is most effective if applied this way.
SOIL APPLIED	Boron can be applied in a sprayer with pre-emergent herbicides at levels not higher than 9 kilograms per hectare. Lime may be spread in the fall at a rate of 2.5 tonnes per hectare.

*** Example only.**

The importance of secondary nutrients and micronutrients is often overlooked. Calcium is essential for internal quality and storability. If calcium levels test low, add a gypsum source to the planter mix to ensure that levels are adequate in the immediate vicinity of the tuber. Application of excess nitrogen, phosphorous or potassium will not correct problems with micronutrients.

Newly hatched Colorado Potato Beetle larvae with eggs.

Defoliation by Colorado Potato Beetle.

PEST MANAGEMENT

Modern pest management uses both cultural and chemical controls to produce a quality product. A number of non-chemical controls are in use and others are being examined.

Cultural Control

Scout fields during the crop season, walk your whole field every two or three days. Keep records of weather, pests present, numbers and stage of development and crop condition. Use OMAF programs and information lines for pest updates.

Use a good crop rotation to break pest cycles.

Use a short fallow period to reduce weed pressure and reduce some soil-borne pests but beware of soil erosion.

Use good sanitation practices. Control weedy areas. Clean and disinfect storage and equipment. Bury or dispose of culls.

Chemical Control

Manage your sprayer - calibrate the sprayer regularly. Regularly clean nozzles and components of sprayer. Use recommended rates of pesticides when applying. Mix spray as required. Be careful when working with chemicals.

Monitor water quality - be aware of pH levels and test water regularly.

Colorado Potato Beetle

Colorado Potato Beetle is probably the most frequent and serious pest. Good management is essential because this pest quickly becomes resistant to chemicals. The beetle's life cycle is:

- ►Adults emerge and lay eggs, approximately 300 per female.
- ►Eggs hatch in 5 to 10 days.
- ►Larvae 4 instars in 13 to 15 days.
- ►Larvae - enter the soil for 8 to 10 days. Emerge as adults.

Colorado Potato Beetle adult.

Resistance Management

Time spray when larvae are small, (their most vulnerable stage.) For best control, apply spray to first generation before third to fourth instar.

Use dip tests before spraying. These tests help to avoid applying ineffective materials.

Rotate chemical families to vary the mode of action against the insect. Use each chemical only once or twice a season.

For more information, refer to the "Understanding the Basics" section of this booklet.

Alternative Tactics

Rotation and isolation - to reduce the movement of Colorado Potato Beetle, isolation by streams or bush is necessary.

Microbial - it is effective on small larvae only.

Mechanical treatments - suction, flamers, ditches and traps.

Botanicals - a natural insecticide (e.g. Rotenone).

Trap cropping - plant some of the rows in the field to a crop preferred by the beetles so that control efforts can be concentrated on smaller areas.

Summary

Field scouting and good record keeping are important. To responsibly manage your crop, you must know soil type, fertility levels, weed pressures, cropping history, insect pressures, drainage patterns, pH levels, etc. Take notes and get advice.

Effective managers question all aspects of production, seek information and try innovative practices. A good crop rotation is important. Keep up with practices and developments in other areas that may assist you. Remember that a change in one part of your management system will affect the other parts. Plan ahead.

Pesticide dip tests will help you to determine resistance and avoid applying ineffective materials.

Aphids

Aphids can reduce yields and transmit viruses. Scout fields and use aphicides responsibly. Resistance has already been recorded.

Subsidence or decreasing soil level is a problem with organic soil. The stake on the right with the cross pieces marking different levels, illustrates the rate of subsidence on the Bradford Marsh.

MUCK CROPS

Organic soil is a valuable resource but must be protected to maintain good yields of high-quality vegetables. These soils are very susceptible to wind erosion. As water is drained, organic matter is "eaten up" by microorganisms and soil gradually disappears in a process called subsidence.

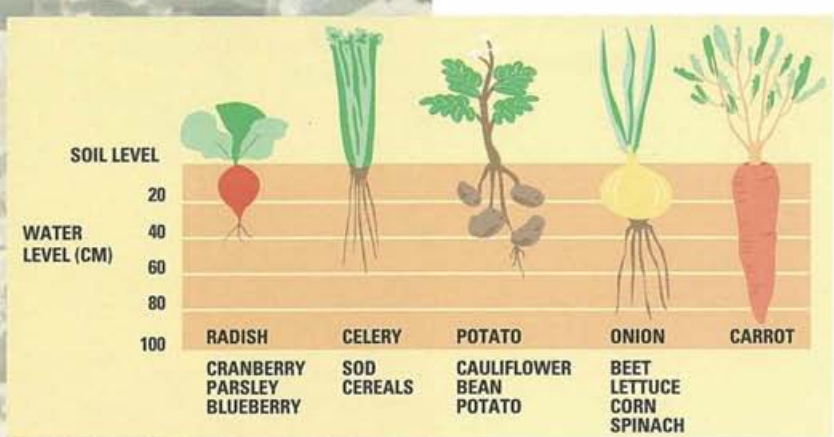
Pesticides are necessary to produce the vegetables that consumers demand. Yet, a number of steps will help reduce the use of chemical pesticides. These materials are expensive so reduced usage is also cost-effective. Best management practices must make economic sense, be practical and fit present farm operations.

SOIL MANAGEMENT

Subsidence - Organic soils such as muck or peat are very high in organic matter content — from 30 to 98%. The organic matter begins to disappear as soon as soils are exposed to air. When organic soil is drained and farmed, soil levels decrease. To slow the rate of loss, two possibilities are:

- **Copper application** - Copper is required by crops such as onions and lettuce and also helps reduce subsidence by slowing the growth of microorganisms. Apply copper to new muck at a rate of 14 kilograms per hectare (56 kilograms/hectare copper sulphate) each year for three years. Afterwards, apply five kilograms per hectare (20 kilograms of copper sulphate) to the soil with broadcast fertilizer every second or third year.

- **Water table control** - Draining organic soils exposes soil to the air and increases loss. By keeping as much of the soil profile as possible under water, subsidence decreases. Recommended water table levels are shown in the diagram/chart (below). The water table can be controlled by keeping water in drainage tiles or filling ditches and storage tanks and allowing water to flow back into tile drains as shown in the diagram. This also provides water to the roots of the crop which is cheaper than overhead irrigation and reduces the risk of spreading certain diseases (e.g. Septoria late blight of celery).



Control the water table at the right level for each crop.
(NOTE: Diagrams of vegetables are not to scale).

Wind Erosion

Erosion also increases soil loss. Blowing soil can bury seed too deeply, cut young seedlings and fill ditches. High winds may even blow away seed with the soil. To reduce erosion, seed barley, or another cereal crop, on the same day as the crop is planted.

A broadcast seeding of barley provides the best wind protection. Make sure to kill the barley before it competes with the crop. Row seeding works well if the wind usually blows in one direction. The rows should be at right angles to the prevailing winds. Plant one row of barley per four to eight rows of onions.

BARLEY INTERSEEDING TO REDUCE WIND DAMAGE

	BROADCAST	ROWS
Seeding rate*	50 - 75 kilograms/hectare (1 ½ bushels/acre)	60 seeds/metre row
Height to spray herbicide	10 centimetres	15 centimetres

*** Seeding rate will depend on seed quality. Lower rates may be used if germination rate is high.**

Seeding on ridges also reduces wind erosion. It works especially well for carrots but can work with lettuce and onions if the soil is not too dry. Growers use bed shapers to form the ridges. Ridges are 66 to 88 cm wide and 20 cm in height. Equipment is also available to form ridges when the crop is transplanted.

Winter cover crops reduce wind and water erosion as well. Ideal cover crop choices for muck soils die out completely over the winter and do not leave tough roots or leaves to get tangled in the seeder. Possibilities include oilseed radish, spring barley and annual ryegrass. Seed the cover crop between August 15 and September 15. Be prepared to mow or chop oilseed radish, if it starts to flower, to prevent seed set.

Row seeding of a cereal crop provides good protection if damaging winds usually come from one direction. Broadcast seeding provides better wind protection.

SOME SEEDING RATES FOR COVER CROPS

COVER CROP	RATE TO BROADCAST	RATE TO DRILL
OILSEED RADISH	20 kilograms/hectare	12 kilograms/hectare
BARLEY	65 kilograms/hectare	60 kilograms/hectare
ANNUAL RYEGRASS	12 kilograms/hectare	10 kilograms/hectare

Tillage

It is important not to over-cultivate muck soils.

- ►In the spring, disk the soil to mix in fertilizer then deep cultivate to a depth of 20 to 30 centimetres.
- ►Leave the land as rough as possible while making sure there are no clumps that will interfere with the seeder.
- ►Conserve as much moisture as possible.
- ►Try not to overdrain the land. However, it may be necessary to cultivate low spots or wet fields twice, to dry land enough for seeding.
- ►After seeding, do not disturb the soil until the crop is established. The thin crust formed will help to resist wind erosion.
- ►Only plow once every two or three years in the fall, particularly after growing carrots. This turns carrot tops under and exposes a small amount of peat soil.
- ►If there is a drainage problem, use a subsoiler in the fall every second year.

Seeding on ridges works especially well for carrots and does provide some wind protection.

WATER MANAGEMENT

As stated previously, water table control is particularly important. Subirrigation from below roots is good in most cases although it can increase the concentration of salts in the soil. Overhead irrigation increases the risk of some diseases and should be done at night if possible.

Avoid water erosion on flooded fields. In the spring, drain water through soil and into drainage tiles. Don't let water run off the surface. Replacing drainage ditches with header tiles also helps. Watch the natural flow of water before installing header tile.

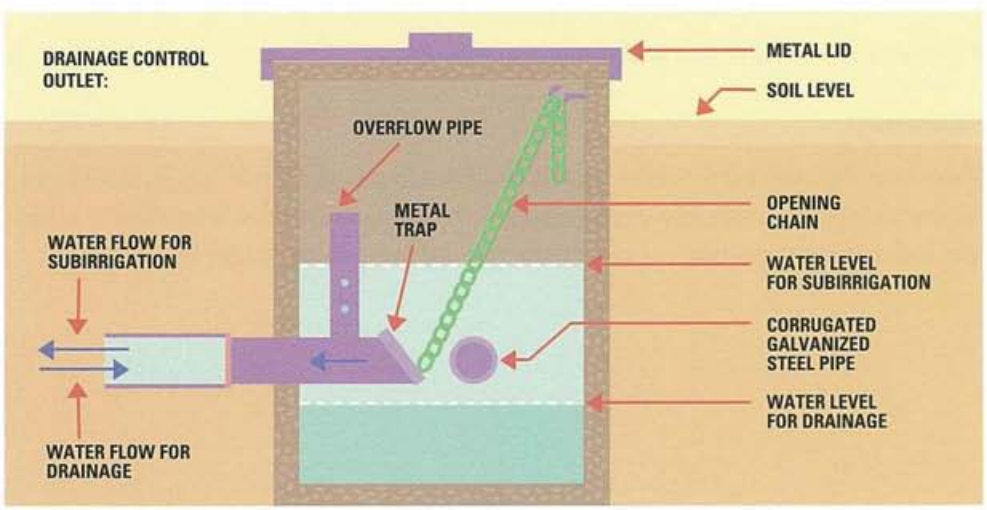
NUTRIENT MANAGEMENT

Annual soil tests are important. Newly-developed muck soils tend to be low in most plant nutrients except nitrogen. After muck soils have been farmed for many years, levels of potassium and phosphorus can increase and may become excessive.

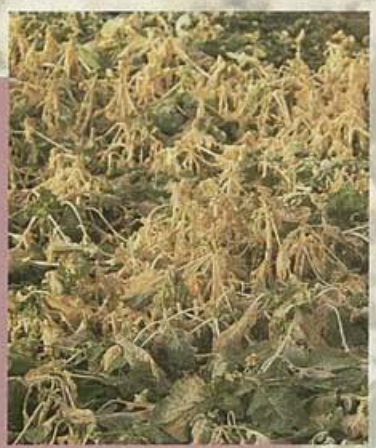
Muck soils usually lack micronutrients. A complete soil analysis is a good investment. Add any required micronutrients to spring fertilizer or as a foliar spray. Check the OMAF Vegetable Production Recommendations Publication 363 for the correct timing and application method for each micronutrient and crop.

Keep good records of soil tests each year to see if changes are occurring in either nutrient or pH levels. The best pH level for vegetables on organic soils is 5.5 to 6.5 but onions will produce well at a range of 5.1 to 7.0.

Applying the correct amount of fertilizer according to a soil test is the best approach. Too much fertilizer reduces yield and quality and costs money.



To drain land, the square metal trap is removed and water flows out drainage pipe. If necessary, excess water may be pumped out this way if water rises to the height of the tile. For subirrigation, metal cover is closed, causing cistern to be filled above the level of the tile. Excess subirrigation water flows into top pipe and into drainage tile.



Oilseed radish shows promise as a cover crop for muck soils; it does not overwinter, it is inexpensive and it may help to suppress nematodes.

PEST MANAGEMENT

Growers can reduce the use of pesticides by taking the following steps:

- ►Use varieties of vegetables that resist pests. This is the only possibility for diseases such as Fusarium yellows in celery or pink root in onions.
- ►Rotate crops. Onions and carrots are a good combination. Avoid growing carrots after lettuce or potatoes because soil-borne diseases such as Sclerotinia and Rhizoctonia will be worse.

Make full use of alternative control methods such as:

- ►Root-knot nematode is the most significant problem nematode on muck crops. Grains and grasses are not hosts of this nematode. Cover cropping with grasses can help to control the population.
- ►Oilseed radish may suppress nematodes. (Till under at green pod stage.)
- ►Late plowing when there's a crust of frost to reduce nematode populations.
- ►Winter flooding with a thin layer of water to reduce Onion white rot, Sclerotinia white mold on carrots, possibly even carrot weevil and nematodes.
- ►Removing cull piles off the field.

Schedule sprays to be most effective by:

- ►Walking your fields regularly or hiring a pest management scout.
- ►Ensuring your sprayer is calibrated to operate efficiently.
- ►Listening to the local Agriphone for recommendations.
- ►Spraying according to pest management thresholds.

Summary

These best management practices provide solutions to everyday problems. In most cases, the cost is minimal, especially when compared to long-term benefits. When BMP's are in use, soil and water essential to crop production are being protected for the future.

FRUITS

TREE FRUIT

There is a need to develop fully-integrated orchard management systems that will promote production and be environmentally sound. Healthy and vigorous orchards produce high-quality fruit at the best possible cost and also, reduce the need for chemical treatments.

Best management practices for orchards include attention to: site preparation, soil management, water management including irrigation and drainage, nutrient management and pest management. Growers can adjust each component to maximize profits while protecting the environment.

ORCHARD SITE PREPARATION

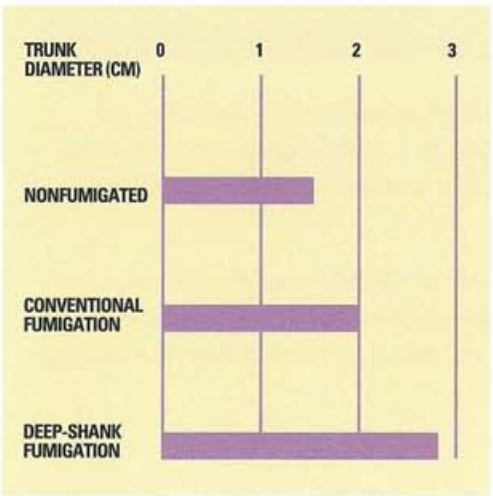
When planning a new orchard, select and prepare an appropriate site at least one to three years in advance. Consider soil testing, past levels of nematodes, organic matter levels, perennial weed control, drainage, soil depth, slope, stoniness and frost pockets.

Soil testing is a must prior to planting. Determine nutrient and pH levels and correct any problems.

Control nematodes, especially Root Lesion nematode. This is crucial to proper establishment of young fruit trees. Nematodes can damage roots and allow fungi to enter roots, disrupting water and nutrient absorption. To determine whether fumigation is necessary, look at the previous crop (corn, for example, increases nematodes), soil type (sandy soils tend to have higher populations than clays), rootstock's tolerance to nematodes and the results of soil samples. If counts are higher than 1,000 nematodes per kilogram of soil, treatment is recommended.

Plan ahead – consider soil test results, past levels of nematodes, weed control, drainage, soil depth, slope, stoniness and frost pockets.

A new fumigation method uses a twin-shank subsoiler to deliver the chemical in a narrow band at three depths.



Comparison of fumigation methods on one-year-old McIntosh apple seedlings (M26 Rootstock). ***(Dr. J.W. Potter, Ag. Canada Vineland)***

Fumigation

Applying fumigants is usually done with a three-point hitch cultivator which places fumigants in a shallow band 1.75 metres wide and 15 centimetres deep. The entire field can be fumigated or just the strips where trees will be planted. Before applying fumigants, prepare a good seedbed. A new method uses a twin-shank subsoiler to deliver fumigant in a narrow band at 15, 30 and 45-centimetre depths. Establishing the sod cover in the summer before fumigation is recommended. Fumigating row strips through the sod allows better weed and erosion control. This may give better nematode control and also subsoils the planting area. The reduced tillage also preserves organic matter and reduces erosion.

Tree Density

Deciding how wide the tree rows should be and how far apart trees should be planted will affect productivity, nutrient management, pest management and water requirements. Before making a decision, consider equipment requirements, availability of skilled labour and availability of irrigation water.

Apples

Tree density has steadily increased over the years as dwarfing rootstocks replace standard rootstocks. The most cost-efficient systems in use are high-density training systems, such as slender spindle (1,750 trees per hectare). The advantages are:

- ►Earlier production with higher yields.
- ►Orchard efficiency is higher (more fruiting wood is produced per hectare).
- ►Production costs per bin decrease.
- ►Potentially higher-quality fruit.
- ►Pesticide use may decline (tree row volume techniques).
- ►Cost recovery time is shorter.

This system requires:

- ►High initial investment.
- ►More professional skills and management are needed.

An example of a highly coloured Empire crop resulting from good sunlight penetration into canopy.

Peaches

The standard for Ontario is 417 trees per hectare. This allows easy movement of standard equipment. The slender spindle system allows densities of 834 trees per hectare. Research completed in 1991 shows yields up by 17% compared to the standard system. Consider the following when making a decision:

- ▸Higher costs to establish orchard.
- ▸Pruning methods will be different.
- ▸Training of trees is critical in the first and second years.
- ▸75% of all work can be done from the ground.

Peach training systems.

SOIL MANAGEMENT

Good soil management in orchards should promote tree growth and good health, productivity and overall fruit quality while preserving soil structure. Issues include ground covers, organic matter and erosion.

Soil management systems include clean cultivation, cultivation plus cover crop, sod plus herbicide strip, sod plus mulch and intercropping between tree rows. In Ontario, growers usually use sod or cultivation plus cover crop. Clean cultivation decreases organic matter, degrades soil structure, increases erosion and increases the potential for winter injury.

Sod with a herbicide strip in these Spartan apples helps to maintain soil structure and prevent soil erosion.

Cultivation/Cover Crops (Peaches)

Soil is worked in April and cultivated regularly until early June. Cultivation reduces competition for moisture between trees, grasses and weeds and increases the air in the soil and soil temperatures (which may help reduce risk of spring frost). In mid June, a cover crop is planted.

When cultivating an orchard, leave some plant material on the soil. The purpose of cultivation is to suppress annual weed growth, not to overwork the soil.

Factors to consider when deciding on the cover crop include:

- Ease of establishment.
- Dry matter produced.
- Effect on nematodes and pests.
- Nutrient interactions.

The cover crop most widely used is annual ryegrass. It establishes quickly and will survive droughts by delaying establishment until conditions improve.

Sod Systems

Producers grow permanent sod between tree rows and mow sod for the life of the orchard. Advantages are:

- Decreased erosion.
- Increased organic matter.
- Water penetrates soil more easily.
- Decreased soil compaction.
- Moderate soil temperatures.
- Decreased mechanical injury of roots.
- Easier orchard operations.

A permanent sod system in peaches.

GRASS VARIETIES FOR ORCHARDS

TYPE	CHARACTERISTICS
CREEPING RED FESCUE	Harder to establish Drought tolerant Fine grass which requires less mowing Persistent Decreases nematode population
PERENNIAL RYEGRASS	Provides good cover, less weed growth Vigorous, fast establishment Suppresses nematode population Dwarfing varieties available
TALL FESCUE	Very vigorous, giving good cover Requires more mowing Shorter types available
ITALIAN (ANNUAL) RYEGRASS	Similar to perennial ryegrass Winterkills Decreases nematode populations Main use in vineyards and peach orchards (non-permanent cover)
MIXES	Includes all the above Preferred practice

Some growers are trying to establish sod the year before planting. In the fall, sod in the tree row is killed with a herbicide. The following spring, trees are planted into the dead grass without cultivation.

A strip of bare ground at the base of the tree helps to reduce competition for moisture from the sod and aids in vole and mice control.

Herbicide Strips

The objective of a herbicide strip is weed suppression during the critical growth stage from early spring to mid summer. A strip of bare ground is left at the base of the trees to reduce competition for moisture between trees and grasses and to aid in the control of voles and mice. The wider the strip, the better tree growth will be. However, a permanently bare strip creates soil problems, increases the possibility of roots being injured over the winter and encourages perennial weeds.

The best solution is to use mulches. Mulches are organic material that are placed within the tree row. Mulches should be applied early to allow decomposition before fall months.

ADVANTAGES ARE	DISADVANTAGES ARE
Moisture is retained/conserved	Mulches may encourage rodents
Soil temperatures are moderated	Material and labour increases costs
Microbial activity is higher	Potential for excessive nitrogen
More extensive rooting is encouraged	Introduction of weed seeds
Soil structure improves	Mechanical harvest of fall apples more difficult
Enhanced nutrient availability	

Possibilities for mulch include: straw, hay (legume hay may contain high levels of nitrogen which may increase late tree growth causing winter damage), wood chips and related products, decomposed organic wastes (e.g. grape pomace — Ministry of Environment permit required) and grass clippings. Apply mulches when soil moisture is high, usually in the spring.

Some growers are modifying their mowers to throw sod clippings into the row area as a mulch.

Compaction

The constant movement of equipment between tree rows may compact soil and result in poor drainage. Subsoiling or mechanical aerators open up soil. However, care must be taken to prevent unwanted root pruning. Techniques should be used when soils are dry as working on wet soil will make problems worse.

WATER MANAGEMENT

Drainage

Surface and soil drainage improve tree growth. If tree roots are in waterlogged soils for extended times, trees become stunted and may die. If drainage does not move water away fast enough, consider:

- ▸French drains, crushed stone over tile drains to the soil surface.
- ▸Planting trees directly over drains (provided that roots won't enter tile lines).
- ▸Building catch basins in the orchard.
- ▸Not planting in that area.

Irrigation

Improves tree growth and health, fruit development and size, and fruit bud initiation. Overhead or trickle irrigation systems are most common. When deciding on a system, consider the following factors:

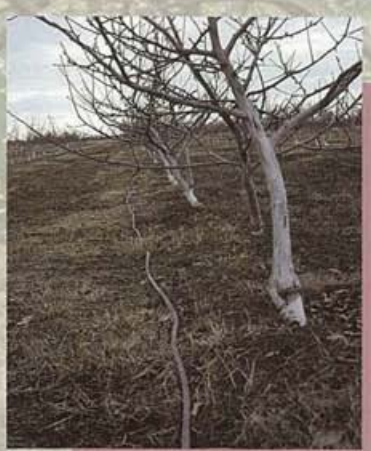
- ▸Water source, quality and supply.
- ▸Water requirements.
- ▸Equipment available.
- ▸Set-up costs.
- ▸Yearly maintenance and operational costs.

Irrigation should begin when 50% of available soil moisture is used and continued until fruit bud initiation is complete. Use a climatic scheduling program or a tensiometer to help in scheduling.

Overhead irrigation may wash pesticides off leaves and fruit. Time applications prior to pesticide use. With trickle irrigation, you may apply fertilizers through the system. Take care that fertilizer does not flow into the water source.

Harrow Research Station Irrigation Study. Peach trees (11-years-old), irrigated when available soil moisture was down to 25%. Cross section in soil at drip line. Note root avoidance of grey sand; this also shows the importance of site and soil selection. *(R. Layne, Ag. Canada, Harrow)*

A tensiometer is a valuable tool for scheduling irrigation. An alternative is to use the climate scheduling program which takes into account the moisture holding capacity of the soil and the evapotranspiration losses of the crop.



Trickle irrigation maximizes effective use of water.

Monitor nutrient uptake with yearly leaf analysis.

NUTRIENT MANAGEMENT

For all tree fruits, nutrients are important. Start by testing soil to determine what nutrients are already available. Do leaf analysis yearly to monitor nutrient uptake. Foliar micronutrients may be used when deficiencies appear. The acceptable range is narrow and over-application may cause damage.

Apply fertilizer when crops need it for growth, depending on the soil management practice used (sod vs. cultivation) and soil type. A healthy sod is one of the best indications of good fertility in the orchard.

PEST MANAGEMENT

Integrated Pest Management (IPM) has been used on tree fruits for more than 20 years. IPM involves monitoring orchards for disease and insects and spraying according to actual findings. Spraying takes place when a pest reaches a determined threshold.

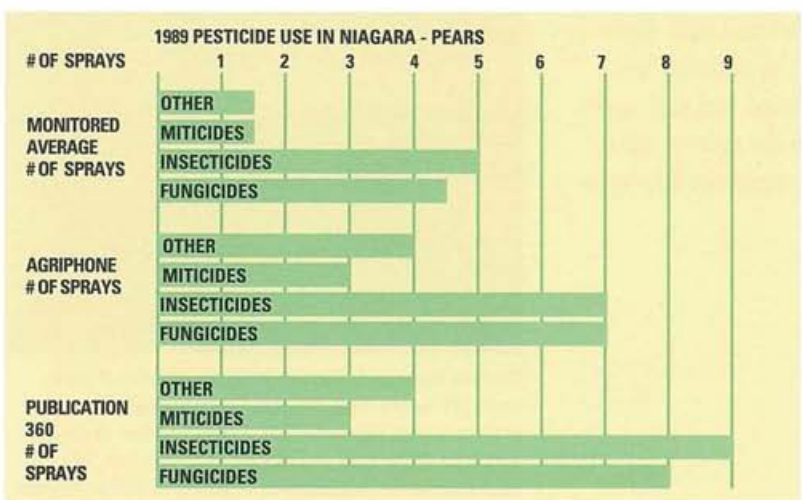
Monitoring

Monitoring equipment includes pheromone traps, physical traps, visually-attractive traps, tapping trays for direct counts and hand lenses. Understand the life cycle of the pest to know the best time and method of controlling the pest. For example, apple scab spores will only grow in specific temperature and moisture conditions. If there is no rain, there is no need to spray.

Monitoring must be done regularly and properly. Orchards should be scouted each week. Some growers hire scouts to handle the responsibility for them. The local OMAF Pest Management Advisor will help interpret monitoring results and make recommendations on applications.

Nitrogen Application

Apply nitrogen in early spring before sod growth. Band nitrogen at the drip line of the tree. If cultivation is used, apply nitrogen after the grass has been worked in. Otherwise, grass will take in nitrogen and trap it for several weeks. Late or excessive applications will stimulate late growth, affect fruit quality and affect winter hardiness.



1989 Pesticide Use in Niagara – Pears.
(G. Walker, OMAF Vineland)

Applications

When using pesticides, growers should be concerned about:

- ▸Safety of the operator and other employees.
- ▸Pesticide costs.
- ▸Application costs.
- ▸Timing of application.
- ▸Biology of the pest.
- ▸Maintenance and calibration of sprayer.
- ▸Impact of spray drift and leaching into groundwater.
- ▸Damage to surrounding crops.
- ▸Weather conditions.
- ▸Coverage and spray penetration.
- ▸Water quality.
- ▸Rate of water used.

To tell if your pest management practices are working, check your crop at harvest. Insect and disease-damaged fruit will be easy to see. If the percentage of culls is too high for your goals, assess practices and adjust. Be sure to set an economic threshold for damaged fruit. After all, input costs will increase, so be sure the investment is worthwhile. Keep good records on applications so that information can be used to spot any trends.

Alternatives to Chemicals

A number of options are being researched and developed including:

Predators/parasites - feed on insects in an orchard. Consider introducing these or selective use of pesticides to encourage natural development.

Pheromones - disrupt mating for Lesser Peach Tree Borer, Codling Moth and Oriental Fruit Moth. (Not currently registered in Ontario.)

Viruses (Granulosis)- are sprayed onto an orchard to attack a certain pest such as the Codling Moth in apples and pears. Work is in preliminary stages.

Ground covers - are adjusted to attract parasites and predators or to lure insects away from trees.

Using resistant varieties - apple cultivars resistant to scab and mildew and Fire blight resistant pears are now available.

Summary

When considering best management practices for tree fruit production, growers must understand the interactions among all components of the management system. When making adjustments or changes to one component, other aspects may be affected.

Seeding a ground cover. Ground covers can be managed to attract parasites and predators or to lure insects away from trees.

The goal in small fruit production is high yield of quality fruit while preserving the environment for future production.

SMALL FRUIT

When growing small fruits, growers must provide an environment that reduces the risk of pests and disease while keeping plants healthy. The result will be a good yield of high-quality fruit. Consumers are increasingly concerned about environmental issues such as pesticide use. Fortunately, by using best management practices, the need for pesticides may be reduced.

SOIL MANAGEMENT

When planting small fruits such as strawberries, raspberries and blueberries, it is important to start planning and making changes at least a year before establishment takes place. Follow these steps:

Soil test - this will provide a reading of soil nutrients, organic levels and pH. Interpret results carefully. Even minor imbalances may cause problems to crops. Adjust soil pH to the following levels: 6.5 for strawberries and raspberries and 4.5 to 5.2 for blueberries.

Prepare site - the year before planting, consider soil fertility, organic matter levels, perennial weeds, drainage, pest levels and soil pH and improve where possible. Examine previous soil test results, earlier crop histories and drainage.

Determine nematode populations - if the site was planted in other small fruits or in orchards, take a soil sample to determine nematode populations. Nematodes damage roots and allow diseases to attack. If counts of root lesion nematodes exceed 500 per kilogram of soil, plants may be stunted and unhealthy. For raspberries, counts of 100 dagger nematodes per kilogram heighten risk of Tomato Mosaic Virus (Crumbly Berry Disease).

Alternatives to chemical fumigation include:

- ▸ Allowing soil to lay fallow for at least one full growing season in a weed-free condition. While this reduces pest risk, it may cause erosion and breakdown of soil structure.
- ▸ Planting cover crops for one year prior to the fruit crop. Use alfalfa, brome hay or another crop that suppresses nematodes.

Organic Matter

Increasing organic matter levels in the soil will improve its ability to hold water and nutrients. If a soil test shows organic matter levels are low, consider using cover crops, or adding manure, straw or hay.

Tillage, including cultivation between rows, breaks down organic matter. To reduce loss, reduce the depth and amount of tillage.

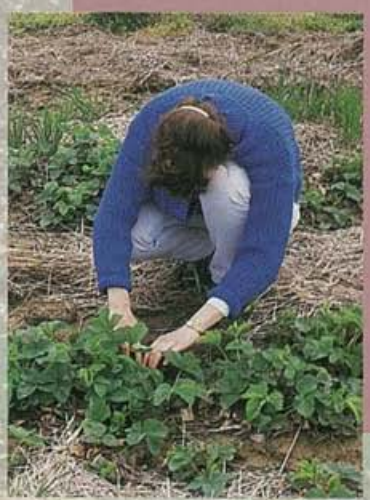
In established raspberry and blueberry fields, permanent sod between rows will reduce soil compaction and erosion, improve soil organic matter levels, make harvesting easier and moderate soil temperatures. The recommended grass for sod cover is Creeping Red Fescue and mixes containing it. This species is relatively resistant to equipment traffic, moderately vigorous and becomes dormant in hot summer months when the crop needs available moisture.

Mulches

The use of wheat straw mulches controls winter injury to **strawberries**. Mulches are also useful during the growing season to control fruit rots, especially Leather Rot. Mulch keeps berries off soil which reduces the spread of fungi to fruit. When the mulch is worked into soil, it adds to the organic matter levels. Timing of mulch application is important. If it is applied too early, plants don't harden; if applied too late, winter injury is possible.

With **blueberries**, a layer of permanent mulch at the base of bushes is essential. Since blueberry roots are shallow, the mulch will preserve soil moisture, decrease soil temperature during the summer, protect roots from winter injury, increase organic matter and provide weed control. Mulches may be sawdust, wood chips, chipped brush or acidic peat moss. If finding mulch is difficult, produce your own by chipping brush and composting it for a year. Some hardwoods, such as walnut, and softwoods, such as cedar, may cause crop growth problems.

Mulching can be used in **raspberry production** to control soil temperature and to conserve moisture.



Straw mulches in strawberries control winter injury, but also keep berries off the soil reducing the spread of fruit rots.

Soil Compaction

Soil compaction is evident in areas that are highly-travelled such as alley ways between strawberry rows and grass strips between raspberries and blueberries. In strawberries, subsoil the alley way when necessary depending on soil type and the amount of traffic. In sod fields, the use of mechanical aerators will have the same effect. Dry soil conditions are necessary for the most effective use of these techniques.

Two Best Management Practices for blueberries include using a combination of a sod ground cover and trickle irrigation.

WATER MANAGEMENT

Drainage is important for productive small fruit crops. Standing water and water-saturated soils increase the development and spread of disease and increases the chance of winter injury damage. Prior to planting, establish tile drainage and good surface drainage.

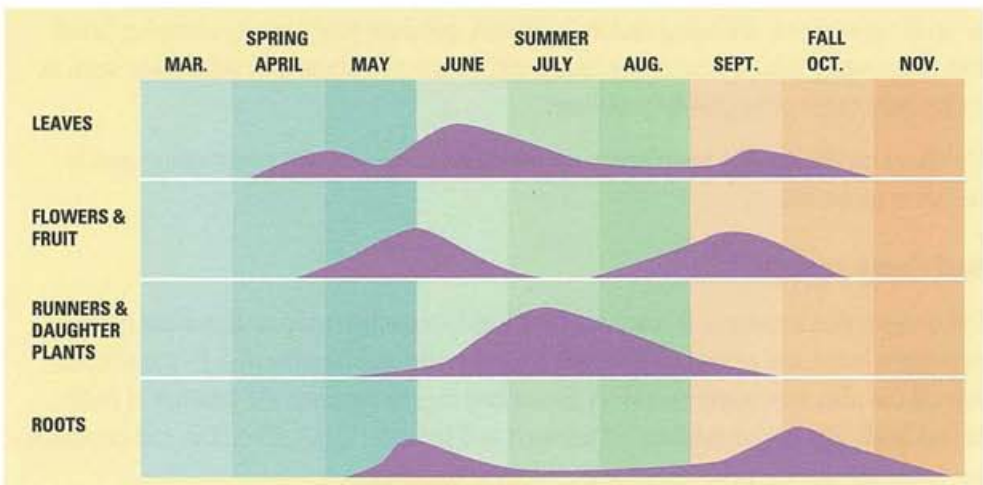
Irrigation of small fruits is important. Small fruits have shallow roots; proper moisture levels must be maintained. Irrigation cools the soil around the roots which encourages root growth. Water is also important when fruit is growing and in the late summer during bud initiation. Trickle irrigation is best suited for raspberries and blueberries. Overhead irrigation does require large volumes of water. However, it can also be used for frost protection in strawberries and low bush blueberries.

Begin irrigation when at least 50% of the moisture in the soil has been used. Trickle irrigation should begin early in the season since small amounts of water are applied at a time. Continue irrigation until after harvest to ensure proper plant growth and bud initiation for the next season.

NUTRIENT MANAGEMENT

Test soils annually to see what nutrients are needed. Also, test leaves to determine nutrient levels. Your fertilizer program can then be fine-tuned for each field. The amount of fertilizer will depend on yield goals, planting density, soil type and the crop. For example, blueberries may need sulphur-based fertilizers to keep soil pH levels low.

Foliar micronutrients are helpful in adjusting nutrient deficiencies. They allow rapid responses. Visual inspection and leaf analysis will indicate need.



A strawberry plant's water requirement through a typical growing season. Peaks on the graph indicate periods when water is particularly important for the plant part listed on the left.

PEST MANAGEMENT

The use of pesticides in small fruit production controls weeds, insects and diseases. Before deciding on control, monitor fields closely to understand pest problems. Keep a record of each field's crop history and previous problems. Any field with a history of Verticillium wilt, Red steele and Black root rot should be avoided. Don't plant into a field that has recently grown tomatoes, peppers, eggplant, melons, raspberries or strawberries. Allow at least two years between small fruit crops. Also, consider herbicide residues or carryover.

An Integrated Pest Management system, including monitoring, timing of sprays and cultural practices, will help to reduce the amount of pesticide used on a crop.

Cultural Control

Crop rotation reduces weed problems and may reduce disease and nematodes.

Select varieties to minimize disease.

Pruning and trellising decreases insect and disease pressure by allowing better movement of air and better penetration of pesticides.

Weed control along the perimeters of the field will eliminate hosts for insects.

Cane density pruning to 10 to 15 canes per metre and maintaining narrow raspberry row width (30 cm) increases light penetration and improves yields.

Monitor small fruits and keep good records to better time sprays and cultural practices.

Pruning and trellising decreases insects and disease pressure by allowing better movement of air and better penetration of pesticides.

Biological Control

►Parasites and predators occur naturally in the environment and feed on insect pests. Avoid pesticides that will harm these.

Chemical Control

►Understand the **pest's life cycle** and apply chemicals at the stage when the pest is most vulnerable. Rainfall and temperature play an important part in pest development. Monitor your fields regularly and carefully. Some growers hire a scout for weekly or bi-weekly monitoring.

►To **control disease,** apply fungicides before damage occurs. In strawberries, for example, apply fungicide during the bloom period to avoid Botrytis grey mold. One or two well-timed sprays are more effective than five sprays between bloom and harvest.

►To **control insects,** monitor fields closely and spray according to action thresholds established for each insect. In strawberries, for example, 2.25 Tarnished Plant Bug nymphs per 15 flowers is an action threshold indicating that it is time to spray.

Alternative Pest Control

Insecticidal soaps - a two per cent solution, that will control 45% of some insects.

Bug vacs - to suck up insects.

Summary

The production of small fruits is intensive and costly. Good management must be practised to ensure profitability. By looking at all growing inputs and realizing how they interact, growers can make best management decisions. The goal is to keep yields high but preserve the environment for future production.

GRAPES

Grape growers need to use integrated vineyard management systems to promote production that is both economically viable and sustainable. It is important to establish and maintain healthy and productive vines through good management practices. This can help reduce the need for treatments that may adversely affect the environment.

To accomplish this, growers should consider:

- ►Site selection and preparation.
- ►Soil and water management.
- ►Pest management.

Integrated vineyard management is needed for economic and sustainable production. Use a combination of cultural management techniques such as hilling in row and alternate alley way cover.

Site Selection

Choose the site for planting vines with attention to:

- ►Air drainage. Good circulation will reduce the potential for disease and lower the risk of frost.
- ►Water drainage.
- ►Wind conditions and climate.

Site Preparation

Thorough land preparation is essential before planting.

- ►Improve the level of organic matter and soil structure. Consider using green manure or cover crops. Install tile and surface drainage as required.
- ►Build the fertility of your soil. Grape vines live and should be reproductive for a long time so make improvements before planting. Also adjust your soil pH to the range of 6.0 to 7.0 before planting.
- ►Control weeds, particularly perennial ones.
- ►Map and mark your fields. Lay out planting to allow air to circulate and to make spraying and harvest easy. Usually, vines are planted north and south to allow the most sun onto vines. If there is a slope, set the rows across the slope to reduce soil erosion, if possible.

A number of soil problems can be present when growing grapes; soil erosion is only one.

SOIL MANAGEMENT

Good soil management will sustain productive grape growing. When growing grapes, a number of soil problems are possible: compaction, erosion, loss of organic matter and poor soil structure.

Management Choices

Many grape growers practice clean cultivation. This may lead to soil erosion and poor soil structure. There are several ways to avoid these problems:

Annual cover crops - seed a cover crop such as Italian ryegrass in August and till it under the following May. Soil is protected during the winter months which reduces erosion.

Semi-permanent cover crops - seed perennial grasses and leave them for two or three seasons before tilling under. Some growers till alternate rows of cover crops each year. This method keeps soil covered for longer periods of time which reduces erosion still further.

Permanent cover crops - seed perennial grasses. This effectively reduces soil erosion but will compete with the grapes. Pay particular attention to nutrients and weed control when using this alternative.

Benefits of soil cover crops in vineyards:

- ►Reduces erosion.
- ►Holds snow to prevent deep freezing.
- ►Maintains soil organic matter.
- ►Can take up extra soil nitrogen in the fall to allow vines to harden off.
- ►Allows cleaner harvesting and other operations in the vineyard.

Some growers compromise, using a sod cover in alternate alley ways and an annual cover crop like oilseed radish in the others.

Soil Structure and Compaction

Grapes, like all crops, need a good root system to be productive. Soil with good structure provides a suitable area for growing roots. Grape roots can penetrate for three to four metres (10 to 12 feet) if soil is in good condition. Soil structure and compaction can be improved by attention to the following practices.

- ►Replace or build the level of organic matter in soil by using cover crops, manure or organic mulches. (Any organic, off-farm waste requires a permit from Ministry of the Environment.)
- ►Reduce the amount of cultivation or use permanent grass cover crops.
- ►Reduce the number of trips over a field. Combine jobs where possible.
- ►Stay off wet soils as much as possible.
- ►Reduce the weight of equipment.
- ►Use deep-rooted cover crops.
- ►Subsoil where necessary at the depth of a compacted layer. Subsoil every two or three years only on dry soils and alternate row middles if possible.

WATER MANAGEMENT

Good water drainage is important for a healthy root system. Poor drainage which allows water to stand on or saturate soil increases frost-heaving damage to grape roots and trellises.

Use irrigation with care, particularly when growing wine grapes, as it will affect the quality of the fruit and delay wood maturity.

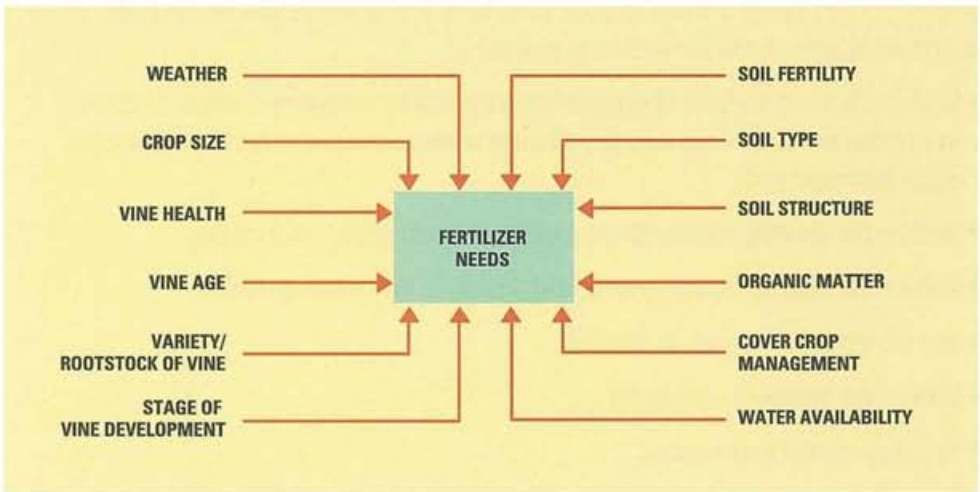
NUTRIENT MANAGEMENT

To manage nutrients effectively, test petiole and soil samples in combination with visual assessment and common sense. Petiole analysis is the most effective practice. Sampling is done in the first two weeks of September.

In established vineyards, usually only nitrogen and potassium additions are needed. Nitrogen can be applied in the form of manure or as inorganic nitrogen. Potassium comes from applications of muriate of potash. For the best results, band fertilizer on grape rows. Do not automatically apply fertilizer every year; petiole analysis will show needs. To prevent leaching and run-off, apply fertilizer in the late spring.

Use petiole analysis to assess nutrient needs.

Keep records of soil and petiole analysis, visual assessment of vine health, yields and weather conditions. These records and your own experience will help interpret problems and results from year to year.



Factors influencing the fertilizer needs of the crop.

PEST MANAGEMENT

Many of the points outlined in this section are preventive. Monitoring pests, using equipment in good repair on healthy vines, on well-maintained trellises and careful spraying will reduce problems.

Chemical pest control may be complemented by appropriate practices and cultural methods.

Cultural Practices

- ▸Select varieties that resist disease where possible.
- ▸Choose a system of training that allows light, air and sprays to penetrate.
- ▸Use good sanitation practices such as: tagging and removing vines with Crown-Gall, Eutypa dieback, or infections; removing **diseased** wood from the vineyard; chopping pruned wood finely and working into soil when vines are healthy; keeping row areas weed-free; and clearing wild grapes from fence rows and surrounding fields.
- ▸Use canopy management, to improve air movement, water evaporation and the penetration of light onto vines.
- ▸Keep trellises in good repair.
- ▸Monitor pest populations in each section of the vineyard. Refer to OMAF Factsheets and code-a-phone information for assistance.

Chemical Control

►Read and follow the label carefully.

►Use sprayers equipped with curtains to reduce drift.

►Calibrate equipment regularly.

►When possible, use directed sprays. For example, while the whole vine must be sprayed for black rot, only fruit needs spray for Botrytis.

►If sampling shows that only outer vines have insects, use a perimeter spray. Pay particular attention to the edges of wooded areas.

►Follow the strategies recommended for each pest. Alternate spray materials to reduce the chance a pest will become resistant.

To control weeds under grapevines, consider:

►A herbicide strip.

►Mulches.

Grape hoe - use the hoe during the early spring to reduce rates of herbicides. Herbicides should be applied after the final hill is in place.

Summary

When growing grapes, it is important to look at the future while working with the "here and now." It is in your best interest to use resources well to ensure both economic and environmental sustainability.

GREENHOUSE PRODUCTION

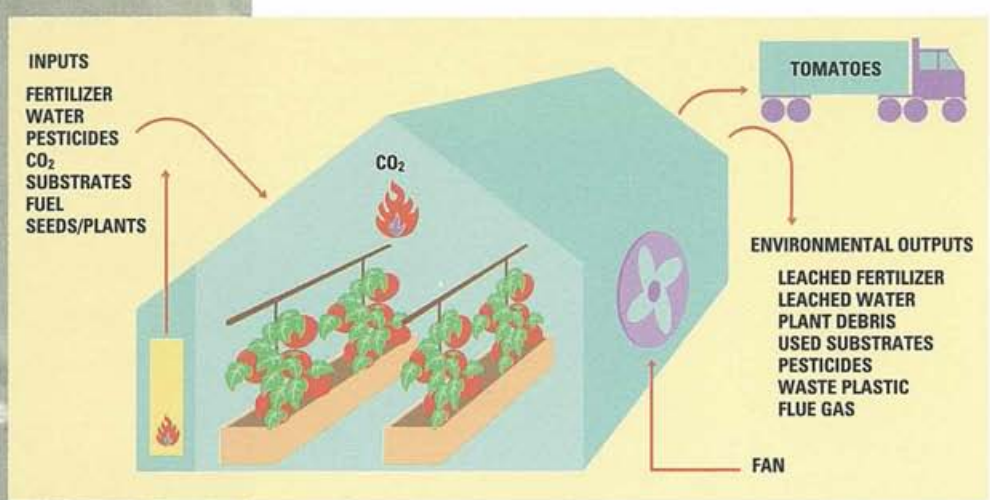
Greenhouses provide an enclosed growing environment that can be controlled, year round. This allows intensive culture with annual yields many times higher than field production. However, greenhouses also create a large amount of waste products that may have an environmental impact.

The Greenhouse Environmental Audit

Wastes from a greenhouse will vary with different crops, growing technologies and greenhouse structures. Using tomatoes grown in non-recirculating rockwool as an example, the table (below) shows the estimated output from a one-hectare, plastic greenhouse.

ESTIMATED OUTPUT PER HECTARE – TOMATOES IN ROCKWOOL

Tomatoes (40 kg/m²/yr)	400 tonnes/yr
Leached fertilizer salts	7.5 tonnes/yr
Leached irrigation water	4,000 m³/yr
Used rockwool (every 1.5 yrs)	114 m³/ha
Plant debris	40-60 tonnes/yr
Plastic greenhouse covering (every 3 yrs)	4 tonnes/ha



Sample greenhouse environmental audit-tomatoes in rockwool.

Major Environmental Concerns

- ▸Management of water and fertilizer run-off.
- ▸Waste management.
- ▸Reduction of pesticide use.

WATER AND FERTILIZER MANAGEMENT

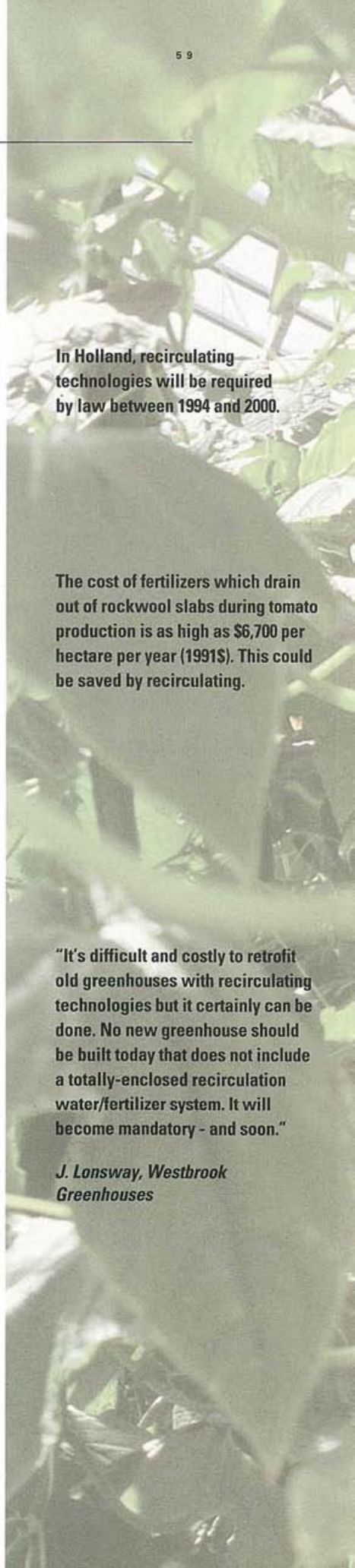
There is potential for groundwater contamination from greenhouse fertilizers, pesticides, wash-down waters, and roof shading/cleaning. We are not certain of the environmental impact of these discharges but we can reduce the amount of water and fertilizer lost to the subsoil. This involves technology to collect, adjust, and re-use fertilized irrigation waters.

Minimize leaching - water and fertilizer applied in excess of plant needs can be collected and held by:

- ▸Concrete floor "catch basin".
- ▸Sub-irrigation systems - e.g. flooded floors, ebb and flow benches, trough benches.
- ▸Drainage collection - e.g. plastic sheet or troughs for rockwool slabs, Lecadan® pots, bagged substrates.
- ▸Growing system containment - e.g. nutrient film technique (NFT) plastic troughs, deep flow systems, floating raft systems.

Adjustment and recirculation - once collected, the solution is recirculated immediately or held for later recirculation. In both cases, the solution may have to be re-conditioned in various ways for re-use. Recirculation is resource efficient, reduces water and fertilizer costs, and is more environmentally friendly.

Solution disposal - sometimes, some or all of the nutrient solution must be disposed of. This may be due to salt imbalances, end of a crop cycle, disease infection, or contamination. As this is a nutrient-enriched solution, there is the potential for pollution if released. Preferred disposal is to sewage systems, holding/settling ponds or as irrigation water to adjacent field crops. Least preferred is discharge into tile drains or surface water.



In Holland, recirculating technologies will be required by law between 1994 and 2000.

The cost of fertilizers which drain out of rockwool slabs during tomato production is as high as $6,700 per hectare per year (1991$). This could be saved by recirculating.

"It's difficult and costly to retrofit old greenhouses with recirculating technologies but it certainly can be done. No new greenhouse should be built today that does not include a totally-enclosed recirculation water/fertilizer system. It will become mandatory - and soon."

J. Lonsway, Westbrook Greenhouses

Plant debris is a large part of the waste produced by greenhouses. Composting or spreading the crop material on adjacent crop land are two good options for disposal.

Almost half of Ontario's greenhouse area is plastic. When these greenhouses are re-covered, 620 tonnes of plastic results as waste.

Half of Ontario's greenhouse vegetable production uses rockwool. Every time rockwool slabs are replaced, 83 transport truckloads of used rockwool must be disposed of.

WASTE DISPOSAL

Greenhouses produce large amounts of waste. Wherever possible, reduce, reuse and recycle. Three items that produce a lot of waste are: plant debris, soilless growing substrates and plastics.

Plant debris - to prevent diseases, all plant debris should be removed from greenhouses as soon as possible. The best management practice is to compost the material, although certain items, such as crop support strings or plant tags, will need to be managed separately. In certain cases, debris can be fed to livestock or applied to adjacent crop land as green manure.

Soilless growing substrates - substrates are either organic or inorganic. In vegetable production, they are typically thrown out after one to three years. In flower crops, the stock plants are replaced after 3-6 months because of disease concerns or because they are breaking down.

- ►Peat from peat bag culture (tomatoes, cucumbers) can be amended and composted and used by landscape firms. Peat is organic, environmentally friendly and eagerly taken by people for landscaping/gardening purposes.
- ►Inorganic substrates (e.g. rockwool) do not decompose and must be dumped in landfill sites. Recycling of rockwool is not yet available in North America. Some growers are shredding rockwool and spreading it on agricultural land.
- ►Inorganic expanded clay such as Lecadan® does not break down and, with sterilization, can be re-used. Use is still developmental.
- ►Commercial technologies that do not use growing substrates are available (NFT, Deep Flow Systems). These technologies may become important in the future.

Plastics - plastic film from poly greenhouses, plastic ground covers and substrate bags are major sources of waste. The technology exists to recycle plastic film but is not available in Canada. Options are landfill sites or stock piling for future recycling. Where possible, use glass instead of plastic when building new greenhouses. Other plastics, such as pots and trays, are generally made from re-ground materials and can be recycled. However, plastic recycling companies want the plastic to be dry and clean. This can be difficult to achieve.

PESTICIDE REDUCTION

►Know what pests you have in the greenhouse. Monitor them with careful crop inspection and by using aids such as yellow sticky traps for flying insects.

Physical Controls

►Screen over vent openings (be aware of reduced ventilation).

►Place large quantities of yellow or blue sticky tape or cards, depending on the insect, above the crop.

►Control pest-carrying weeds next to the greenhouse.

►Prevent infested plants from coming into the greenhouse.

►Attract insects to ultraviolet light traps.

►Consider new technologies, such as a "bug vacuum".

Sanitation is an important part of pest management. Take advantage of breaks in cropping to thoroughly clean the greenhouse.

Cultural Controls

Sanitation - remove plant debris. Sanitize people, tools and machines. Clean walks and surfaces. If you have had major disease problems and have a break between crops, consider complete sterilization of the greenhouse at that time. Soil or re-used substrates should be steam-pasteurized or fumigated.

Prevention - avoid introducing infested plants.

Environmental Manipulation - manage temperature and ventilation to prevent condensation on plant surfaces. Control nutrient solution temperatures and root zone aeration to prevent certain root-borne diseases.

Timing of Planting - if your cropping schedule permits, allow sufficient time between crop removal and replanting to reduce chances of pest carryover. This is usually a minimum of one week; the longer, the better.

Plant Health and Vigour - minimize plant stress (through adequate spacing, good nutrition, etc). A fast growing healthy plant is less susceptible to pests.

Seed Treatments - hot water, chemical and fungicide seed treatments can prevent a number of diseases. Treatments can be done by either the seed supplier or the grower.

Cross Contamination - minimize or eliminate other plants, including weeds, from the growing area. They can be a serious source of pests and diseases that otherwise would not be present.

- ►Use resistant varieties where possible to avoid diseases.
- ►All major greenhouse insect pests have biological control agents commercially available. In vegetable crops, biological control is a viable option. In ornamentals, biological control will become increasingly important as experience is gained. At this time, however, it is generally not appropriate on a large scale.
- ►When chemical control is required, use chemicals that will control the pest without affecting its natural enemies. Consult your Pest Management Advisor for chemicals compatible with biological control agents. Spot spraying might be useful. Certain pesticides are less toxic and more environmentally-friendly than others (for example, insecticidal soaps and microbial agents). Certain application equipment may be more efficient, resulting in less run-off and pesticide use. Foggers and ultra-low volume (ULV) applicators, for example, use less than traditional high-volume sprayers. There are concerns, however, that ULV applicators deposit pesticides on surfaces other than just the plants such as greenhouse walls. This may result in contaminated run-off when water condenses on the surfaces.

Whitefly is a major greenhouse pest. Fortunately an effective biological control agent is available.

BIOLOGICAL CONTROL AGENTS FOR GREENHOUSE INSECTS

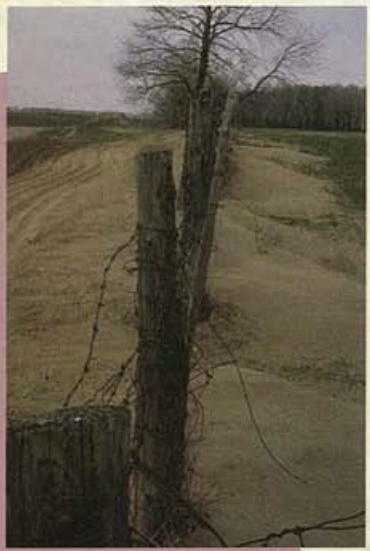
PEST	BIOLOGICAL CONTROL AGENT
WHITEFLY	Encarsia formosa
SPIDER MITE	Phytoseiulus persimilis
WESTERN FLOWER THRIPS	Amblyseius cucumeris Orius insidiosus
APHIDS	Aphidius matricariae Aphidoletes aphidimyza
FUNGUS GNAT	Hypoaspis miles Steinernema carpocapse
LEAFMINER	Dacnusa sibirica Diglyphus isaea

Growth Regulators

Growth regulators are used for height control of several greenhouse floral species. Pesticide concerns also apply to growth regulators. A new method of height control called "DIF" manages plant height by controlling the difference between day and night temperatures (i.e. cooler day temperatures). Most floral species respond to DIF. The number and rates of growth regulator application can be reduced when DIF is used. However, DIF will only work during the cold months of the year. Plant quality is superior when a combination of growth retardants and DIF is used.

Most floral species such as these lilies respond to the use of DIF.

TOBACCO



Tobacco soils are prone to wind and water erosion requiring good management to be productive.

Tobacco farmers have been concerned about soil and water quality since the 1930's. In fact, developing farming practices that take environmental issues into account is vital when farming on the sandy soils used by tobacco farmers. As new technology and scientific research become available, farmers must continue to re-examine and evaluate their cropping practices.

SOIL MANAGEMENT

Organic matter is vital when growing tobacco in sandy soils, particularly for nutrient storage capacity. It improves the soil's ability to hold moisture and helps to develop soil structure. The level in tobacco soils varies from less than one to about three per cent with most soils falling within the range of one to two per cent.

Rotation with rye is the traditional way of maintaining and increasing soil organic matter levels in the soil. Research shows that a rye-tobacco rotation is an effective way to maintain and increase soil humus. As markets change and new varieties are introduced, further research will be needed to understand nutrient uptake in tobacco plants and the interaction with cover and rotation crops. In particular, studies of the following areas are needed:

- ►Spring application of nitrogen to a rye crop including use of various forms of ammonium-based fertilizers.
- ►The timing and method of working straw into soils and the effectiveness of cover crops that were harvested vs. not harvested.
- ►The changes in organic matter as a result of late-summer application of nitrogen.
- ►The best time to work green manure into soil.

Along with using rye in rotation with tobacco, farmers may consider applying manure to sandy soils and knolls. Manure should be worked into soil as soon as possible to avoid loss through evaporation and surface run-off.

Soil texture also affects fertilization. Sandy soils do not store as much water and nutrients as do loam soils so good management is crucial. Soil structure must be carefully protected by:

- ►Working soil that is dry.
- ►Avoiding excessive tillage.
- ►Reducing traffic from heavy equipment.
- ►Where possible, minimize axle weight to no more than five tons per axle.
- ►Applying lime in the fall when soils are dry.

If these practices are not used, soil may become compacted. This destroys the large pores containing air in the soil. When there is not enough air, specifically oxygen, in the soil, plants cannot use nutrients as effectively. If your soil has a compacted layer, consider subsoiling at that level. See the section on Understanding the Basics for more information.

Farming systems that reduce the amount of tillage should improve and protect exposed soils. Some growers, as a result of reducing primary tillage, use excessive cultivation to create a good seedbed. More evaluation of the technique is required. To date, research into no-till systems shows reduced yields. At this time, no-till is not recommended for tobacco.

Row crop cultivation performed on a timely basis avoids crusting and increases soil roughness. Production is enhanced through:

- More water soaking into soil.
- Erosion by water is reduced.
- Wind erosion to early transplants is reduced.
- Soil temperatures are higher.
- Soils contain more air.
- Weed control is cost-effective.

Continued planting of windbreaks, use of strip cropping, rotation with rye and ridge tilling reduce wind and water erosion. These practices also increase the level of organic matter in soils and improve soil structure. At this time, moldboard plowing remains the best way to improve topsoil when combined with these methods. Any change will require further research.

Continued planting of windbreaks, use of strip cropping, rotation with rye and ridge tilling reduce wind and water erosion.

NUTRIENT MANAGEMENT

Before applying nutrients, it is important to determine the levels already in soils. Therefore, the following steps should be completed:

Test soil for nutrients and pH levels. Highly acidic soils, for example, do not make nutrients as available to plants and so fertilizer applications will be inefficient.

Test plant tissue to understand how plants are using nutrients. Although misleading at times, tests can show needs for micronutrients. OMAF Publication 298 says, "Very high levels of iron, manganese and zinc are occasionally found in the cured leaf and these are associated with a certain type of 'grey' tobacco."

Examine plants for nutrient stress by walking your fields.

Rates of nitrogen application vary with soil type and cropping practices. Follow the recommendations in OMAF Publication 298. Split applications of nitrogen address plant needs throughout the growing season. This will also reduce leaching and inefficiency in fertilizer use. Slow release forms of nitrogen may help but more research is needed. Banding fertilizer is both cost-effective and environmentally-friendly.

WATER MANAGEMENT

Factors such as tillage that affect organic matter and soil structure also affect water quality. Surface run-off and leaching are concerns. Any practice that keeps topsoil in place and increases the rate at which water soaks into soils will improve the soil's ability to hold water. This, in turn, controls the movement of water through soil. Many of the practices already discussed such as rye-tobacco rotation and the management of nutrients and pesticides help maintain water quality.

When rainfall is not adequate, irrigation may be needed. The rate that water is applied, the frequency of watering and knowledge of approaching rainfall will control movement of water in soils.

Good nutrient management techniques such as soil and plant tissue testing and field observation will pay off at harvest.

PEST MANAGEMENT

Present day pesticides have several advantages:

►They are less persistent in the soil.

►Lower toxicity.

►Employee safety is increased.

►They are not applied as frequently.

Research has shown that low rates of pesticides can be effective. For example, there are several alternatives for cutworm control that permit lower rates as compared to the soil treatment.

►Apply to the cover crop.

►Band the pesticide at planting.

►Apply a systemic pesticide in the planting water.

When crops are heavily infested with black root rot, a multi-purpose fumigation treatment is normally used. Other possibilities to reduce the problem include:

►Rotating the crop with corn.

►Using crop varieties that are more tolerant to Black root rot.

Disposal of pesticide containers is a concern. The best answer to date is to increase use of refillable containers so that disposal is not necessary. This also is more economical.

Summary

The nature of tobacco soils forces use of best management practices. Many of these practices are long-standing traditions. However, new problems and challenges are continually being resolved. The benefits of research have helped farmers over the past 60 years and will continue to help into the future.

NURSERY CROPS

Some Green Manure Crops for Increasing Soil Organic Matter

Annual Ryegrass
Alfalfa
Field Corn
Sorghum-Sudan Grass

Some Cover Crops for Erosion Protection

Winter Rye
Winter Wheat
Spring Barley
Spring Oats
***Buckwheat**
Corn
Red Clover
Alfalfa
Hairy Vetch
Austrian Winter Peas
***Winter Canola**
***Tame Mustard**
***Oil Seed Radish**

*** Species may become a weed problem if allowed to go to seed.**

The nursery industry is facing a number of challenges in an effort to produce high-quality nursery stock while using economical and environmentally-sound systems. Best management practices for nursery production address concerns about soil conservation, pesticide use and water conservation and protection.

SOIL MANAGEMENT

Soil and soil quality, the basic ingredients of traditional field nursery stock production, can be removed and damaged by water and wind erosion. The following cultural practices improve soil structure:

- Crop rotation with sod crops or green manure crops improves soil structure, adds organic matter and can reduce soil erosion by 90%.

  Grasses combined with legumes grown for two years for maximum benefit. The dense root system produces a large amount of organic matter. Tap-rooted legumes (e.g. alfalfa) improve soil drainage by loosening soil.

- Green manure crops grown for less than one season then plowed down, in late summer or fall, before setting seed. These crops are useful when a more effective two year crop rotation is not feasible.

Cover crops are planted in August or early September between nursery rows or on fallow fields to protect soil for the winter. Know the crop cycle of cover, green manure and rotation crops to avoid future weed problems.

Excessive tillage reduces the size of soil clods. This can contribute to compaction, crusting and increased erosion. Soil structure can be heavily damaged by the use of machinery on wet soils. To minimize this damage:

- Tile drain wet fields.
- Delay working on these fields until dry.
- Reduce the number of trips over the field when tilling.

Such practices as contour planting nursery rows on sloping land, strip cropping and planting a cover between rows of trees have many benefits:

- Reduced wind erosion and soil movement (avoids sandblasting crops).
- Reduced soil loss from water erosion.
- Reduced soil structure damage as traffic and cultivation decrease.
- Reduced compaction from heavy machinery loads.

A sod crop growing between nursery rows with a narrow band of clean cultivation directly underneath trees.

A nursery pest, Japanese beetle, prefers sod or weedy areas for egg-laying using white, red, or alsike clover, buckwheat or alfalfa as alternate strip crops may discourage larval populations.

Wind erosion can be controlled with the maintenance of good soil structure and cover crops. Orienting the planting rows at right angles to the prevailing winds provides some protection. Windbreaks planted along the north and west boundaries or all around fields reduce wind erosion and protect sensitive nursery stock from wind burning and sand blasting. They also help to reduce crooked growth. See the booklet on Farm Forestry and Habitat Management for further information.

Surface run-off from nursery fields must be controlled to reduce pollution of watercourses and collection ponds. A grassed waterway can direct water movement through the field; it must be smoothly contoured with a constant grade and an easily-maintained, hard-wearing sod cover.

Buffer strips around irrigation ponds should be at least five metres wide, measured from the top of the bank back to the field. This allows for adequate maintenance and access. A wider buffer strip may be necessary depending on soil erodiblity, average slope and current vegetation. See section on Non-Tillage Options in the booklet on Field Crop Production for more information.

Drip irrigation of shade trees in the nursery.

WATER MANAGEMENT

Water is an important resource not only to growers but to off-farm neighbours. By reducing water use, the possibility of leaching and loss of nutrients through surface run-off decreases.

Drip irrigation is a very efficient system of watering larger field stock. It applies small amounts of water to the root zone area only. It also promotes compact root development which is important for subsequent tree survival in the landscape. In container production, drip irrigation is often not used because of difficulties of working around and moving containers when drip lines are present.

Pulse irrigation saves water in container production. Traditional irrigation comes from a long, single application of water from an overhead sprinkler. In pulse irrigation:

- ►Water is applied for about 15 minutes, four or more times.
- ►A pause of 30-60 minutes occurs between applications.
- ►During the pause, water fills the pores and wets hard-to-wet components of the medium.
- ►The medium is saturated before excess water drains from the pot. Water use is reduced by about 30%.
- ►Run-off from the container is minimized.

The nursery industry in Ontario is valued at $150 million per year according to a Stats Canada survey completed in 1990.

NUTRIENT MANAGEMENT

Nursery growers should test soils each year (midsummer to fall) to determine fertilizer needs for fields the following year (refer to OMAF Publication 383). Using slow release fertilizers on container stock is efficient and reduces nutrient run-off. Various periods of release are available, from several months to two growing seasons.

Timing of fertilization should be based on growth habit. Plants that have a single flush of growth should be fertilized in the fall and early spring before growth begins. For plants that have multiple flushes, split recommended applications among fall, spring and a third application as the first flush begins to slow down. Fall fertilization is effective because roots continue to absorb nutrients until soil temperatures reach 5°C. Do not fertilize field stock in late fall or early winter; fertilizer is not absorbed by roots and can easily run off frozen ground.

PEST MANAGEMENT

Weed Control

Weed control should be integrated, combining the use of mechanical, cultural and as necessary, chemical controls. The following methods control weeds in either a nursery field or container crop:

►Plant new crops in a weed-free field or media.

►Control weeds in perimeter areas (i.e. fence rows and windbreaks).

►To reduce weed seeds, properly store and compost manure before applying to the soil.

►Mow buffer strips to reduce seeds blown into irrigation ponds.

►Minimize run-off from weedy fields to ponds.

►Pump irrigation water from deep in the pond to avoid seeds on the water surface.

►Ensure weed-free material is planted.

►Do not move weeds between fields on equipment.

►Cultivate fields when seedlings are small.

►Use shallow tillage (2.5-5.0 cm) if herbicide has been applied.

A mowed grass strip between nursery rows with a weed-free strip at the base of the plants 0.5 to 1.0 metre wide can be maintained by: hand hoeing, mechanical cultivation, mulching with various organic materials, or herbicide application. For more information, refer to OMAF Publication No.75. Rodents often overwinter in mulch so, remove it from the base of plants in the fall and consider appropriate traps.

Weed control with container stock is more difficult than in the field because there are few effective registered herbicides. In container stock, the following measures will help:

- ▸Weed by hand.
- ▸Install a weed barrier of old polyethelene or geotextile fabric under pots. This prevents weed germination under the pots. Water ponding may occur if polyethelene is used.
- ▸Keep media components weed-free. Components stored outdoors should be covered.
- ▸If planning to use field soil, ensure that it comes from a source known to have few weeds and no herbicide residues.
- ▸Use weed discs in pots; these reusable barriers are made of materials that allow water and air movement while reducing seed germination.

Geotextile weed disc in container stock.

Insect and Disease Management

Because of the variety of plants in the nursery, insect and disease control poses many challenges. Integrated pest management (IPM) combines chemical, cultural and biological control techniques to address pest problems. Good sanitation and plant health reduce pest and disease problems.

The following procedures make up an effective IPM program:

- ▸Mapping the nursery. Identify plants which are most susceptible to insects and disease problems. Note which species and cultivars are affected first.
- ▸Monitoring the nursery at least once a week. Pay particular attention to sensitive species.
- ▸Identifying pests and beneficial insects, noting life cycle stages and population levels.
- ▸Making a decision on appropriate control from collected information.

Some selective insect traps are available but yellow sticky traps can be used to identify pests. Control insects at vulnerable stages of their life cycle. When a control is necessary, refer to OMAF Publication 383 and spray only those plants or species infested.

Few biological controls are available for use in the nursery but *Bacillus thuringiensis* var. *kurstaki* has been effective against gypsy moth.

Summary

Best management practices such as soil conservation, efficient water use, water source protection, and reduced chemical use through cultural and biological pest management methods benefit both the grower and the environment.

SOD PRODUCTION

According to Statistics Canada, 1990 sod sales in Ontario totalled $49 million, more than half of Canada's total sod sales.

Sod farming has a relatively low environmental impact. Pesticide use is minimal and nutrients are carefully managed. The amount of soil removed during harvest operations is the issue most often raised. This is offset by the environmental benefits of sod use. Construction sites are highly prone to wind and water erosion. The eroded soil goes directly into lakes and streams through storm sewers and waterways. However, sod can stabilize these fragile areas quickly which reduces soil loss and leaching and filters storm water. The use of best management practices during sod production can help to ensure efficient production of nursery sod.

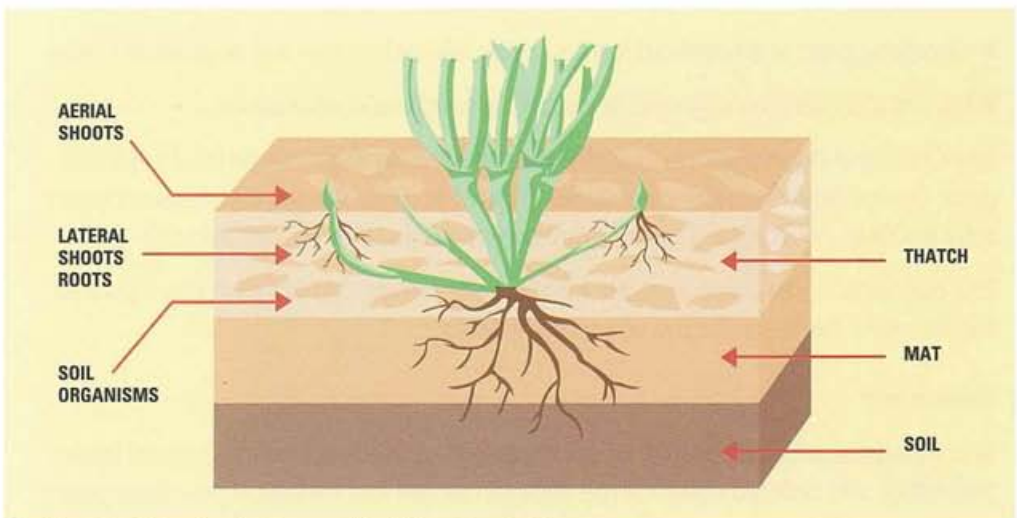
SOIL MANAGEMENT

During harvest of nursery sod, careful measures have shown that an average sod layer contains 9.4 millimetres of mineral soil and 8.5 millimetres of organic material. Nevertheless, many people confuse the two layers and believe two centimetres of soil are removed. Minimizing the removal of mineral soil has several advantages:

- ▸A reduction in soil loss from the production site.
- ▸More rapid rooting when laid on a properly-prepared site.
- ▸Lower roll weight which reduces transportation costs.

There are a number of ways to **reduce the loss of mineral soil:**

- ▸Properly preparing the soil prior to seeding.



Profile of turf showing the layers of thatch, mat and soil.

- ▶Encouraging rapid, vigorous root development through the use of phosphate and mowing practices.
- ▶Rolling the turf prior to cutting.

Before seeding, prepare a level surface with tillage and land levelling. If the soil is moist, roll immediately before harvesting sod to flatten irregularities. In combination, these two practices permit the cutter bar to operate at a uniform depth without skips or holes. Both avoid wasting sod and removing excess soil.

Tillers and rhizomes may develop to form in the organic or thatch layer. To encourage this, use irrigation, light frequent applications of nitrogen and frequent mowing.

Soil losses by water and wind erosion after harvest and before the next crop may be minimized by:

- ▶Light surface cultivation followed by seeding a winter cereal crop such as rye immediately after harvest.
- ▶Cutting the cover crop before it heads to avoid volunteer grain in newly-seeded grass.
- ▶Seeding recommended cultivars from mid-August to early September when the chance of heavy rains is lower. This will establish sod faster.

Keep the soil surface covered to avoid erosion. Over 90% of the grass roots are in the top five centimetres of the soil. This will help to enrich the soil after harvest. Deeper tillage before the seedbed is prepared may help reduce compaction problems.

Broadcasting fertilizer in preparation for sod establishment.

NUTRIENT MANAGEMENT

Another concern is the potential for surface and groundwater contamination with fertilizer. However, soil and water losses from run-off are lower than from any other agricultural crop. Therefore, loss of phosphorus will be minimal (it does not move downward in soil so can only be lost on soil particles carried in run-off). Sod is a heavy feeder on nitrogen and will absorb much of the soluble nitrogen before leaching can occur, if the applications are light and frequent.

Best management practices for fertilizer use are:

- ►Apply phosphorus and potassium based on soil tests.
- ►Apply phosphorus only once, immediately before seeding, when it can be incorporated and will increase seedling vigour.
- ►Apply nitrogen as needed based on the colour, density and vigour of the turf. The amount should be adjusted depending on desired growth.

Experience will help you judge how much nitrogen to apply. Light applications of not more than 50 kilograms per hectare of actual nitrogen should not produce soluble nitrogen for leaching. The frequency of applications should promote rapid, but not luxuriant growth. Excessive nitrogen may reduce root development and the strength of harvested sod. See OMAF Publication # 384.

PEST MANAGEMENT

Sod production uses both cultural and chemical measures for pest management. The goal is a break-free, harvestable roll with a dense root system that meets the specifications of the Nursery Sod Growers Association.

Use of good cultural management practices at seeding will encourage fast establishment of dense, vigorous turf.

Cultural Control

When establishing sod:

- ►Buy certified seed.
- ►Use disease-resistant varieties.
- ►Use different turf species in a mixture such as fine fescues and turf-type perennials.
- ►Irrigation and soil management practices to encourage rapid establishment of dense, vigorous turf.

During sod production:

- ▶Avoid excess irrigation.
- ▶Avoid long periods of leaf wetness.
- ▶Avoid excess thatch.
- ▶Avoid high nitrogen applications which make turf more prone to leafspot.
- ▶Use good mowing techniques, watching both timing and height. Mowing sod too close weakens the root system.

Chemical Control

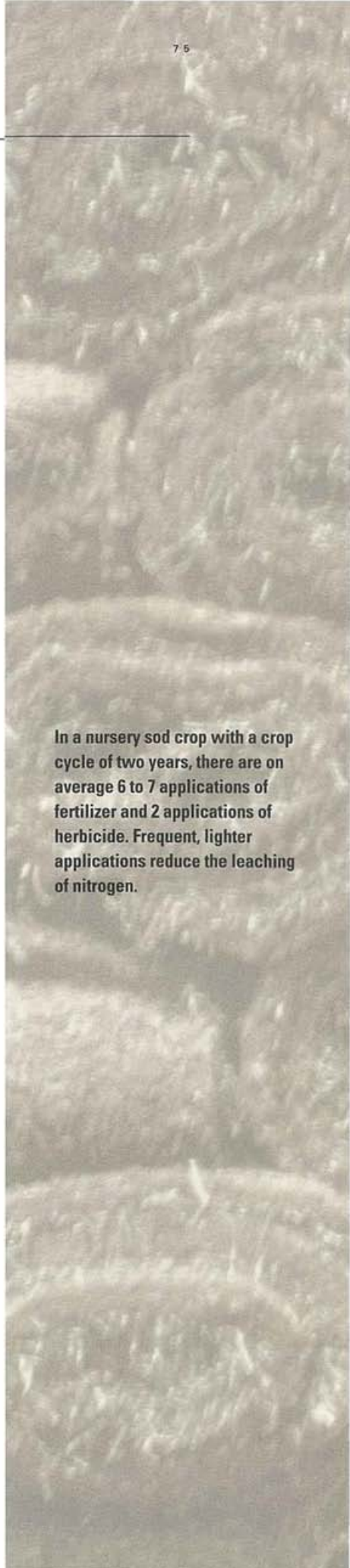
Sod production does not require large amounts of pesticides. The pesticides used most commonly are herbicides for broadleaf and grassy weed control. Fungicides are seldom needed in nursery production. On occasion, growers may need to use insecticides for localized control of chinch bugs, white grubs, cutworms and European chafer. When chemical control is needed:

- ▶Positively identify the problem and its extent before spraying.
- ▶Spray only those areas with the problem.
- ▶Use a properly-calibrated sprayer.
- ▶Be aware of all federal and provincial regulations regarding the use, storage and disposal of pesticides.

Summary

By using best management practices, healthy, competitive sod is produced. Use pesticides sparingly, plant cover crops between harvest and the next seeding, prepare a firm and level seed bed and encourage rapid development of roots.

These practices also ensure the future of the nursery industry at a time of increased public concern about agricultural practices.



In a nursery sod crop with a crop cycle of two years, there are on average 6 to 7 applications of fertilizer and 2 applications of herbicide. Frequent, lighter applications reduce the leaching of nitrogen.

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