BEST MANAGEMENT PRACTICES

Integrated Pest Management

Agriculture and Agri-Food Canada

Ontario

Ministry of Agriculture, Food and Rural Affairs

FOREWORD

In the pages of *Integrated Pest Management*, you'll find advertisements for a number of agricultural industry companies and programs, including: Zeneca, Ciba-Geigy, Cyanamid, Bayer, Agricultural Groups Concerned About Resources in the Environment (AgCare), Environmental Farm Plan and the Ontario Pesticide Education Program.

This book and *Irrigation Management* (released February 1996) are the first titles in the Best Management Practices Series to include advertisements.

The generous support of sponsors allows the Best Management Practices program to continue to produce high quality extension materials in the format and numbers that farmers demand.

As with all titles in the series, the content of *Integrated Pest Management* was developed by an independent team of researchers, growers, extension staff and agribusiness professionals. The integrity of the information remains the responsibility of Agriculture and Agri-Food Canada, the Ontario Ministry of Agriculture, Food and Rural Affairs, and the Ontario Federation of Agriculture.

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All those who contribute to the Best Management Practices program are dedicated to bringing you the latest information about environmentally sustainable agriculture. We thank our partners in industry for their help.

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

What is the BMP Series?

- innovative, award-winning books presenting many options that can be tailored to meet your particular environmental concern and circumstances

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INTRODUCTION

Whether or not we realize it, all of us rely on effective pest management to ensure adequate food supplies. We compete with insects, diseases and weeds for our share of food. It has been estimated that without pest management, pre-harvest crop losses would average 40 percent.

Since World War II and the discovery of DDT, society has increasingly looked to pesticides for pest control. However, reliance on this single pest management tool has brought with it a number of new challenges, which include:

- the development of resistant pest populations that are no longer controlled by specific pesticides, such as house flies, Colorado potato beetles, apple scab and triazine-resistant weeds such as lamb's quarters
- environmental health concerns, especially the contamination of water, by persistent pesticides such as aldicarb
- the negative effects of pesticides on non-target species and beneficial species, e.g., fish and wildlife habitat adjacent to and beyond the areas being treated
- changes in the pest complex following the use of broad-spectrum pesticides, and the emergence of new pest species due to the elimination of competitors or beneficials, e.g., mites, white apple leafhopper in apples, pear psylla, nightshade in tomatoes
- a lack of new pesticides to counteract resistant populations and control emerging pests.

These challenges have sparked a search for new approaches to managing pests. Integrated Pest Management, or IPM, is a system of managing pests that involves aspects of more than one control method – cultural, biological or chemical – in a program that is both economically and environmentally sound.

Honeybees act as pollinators and are an essential part of fruit production. They can be mistakenly poisoned by spray drift.

Over 700 species of pests worldwide have become resistant to specific pesticides. Here are three examples: herbicide-resistant lamb's quarters (left); fungicide-resistant apple scab (centre); and insecticide-resistant Colorado potato beetle.

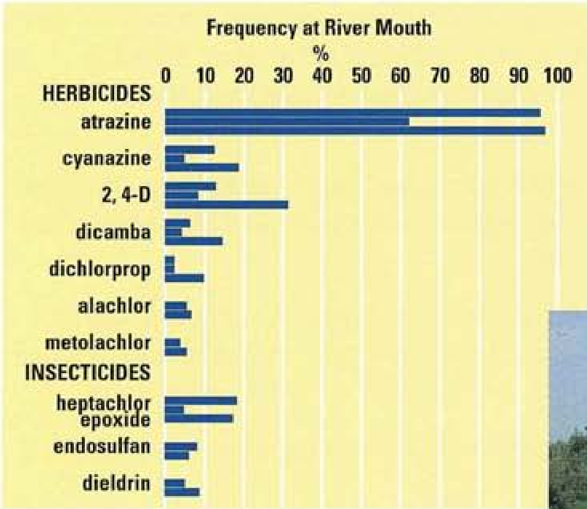
INTRODUCTION

Pesticides can be carried into streams and rivers via tile drains.

Pest monitoring means the grower or scout looks in the field to establish the presence of pests.

Pest identification involves finding out which pests are present in the field.

Pest thresholds are reached when the pest numbers reach a certain level, and it's time to take action to control them.



This chart shows how frequently the main pesticides appeared at the mouths of the Grand, Saugeen and Thames rivers, from 1981 to 1984.

Pesticide contamination of soil and water can be prevented by having a proper mixing and loading area.

Based on observation and knowledge, not a predetermined calendar date, IPM has four main steps:

- ▸ identifying the pest(s)
- ▸ monitoring pest and beneficial species
- ▸ determining pest thresholds
- ▸ choosing control options and assessing their effectiveness.

IPM involves more than simply knowing that a pest is present and needs to be controlled. The objective is to keep the pest species below the population density that causes economic loss.

Field weather-station equipment monitors temperature and leaf wetness, and helps to forecast disease episodes on onions.

Corn is scouted for European corn borer egg masses by checking plants by hand.

INTRODUCTION

THE BENEFITS

- ▸ it's a systems approach, based on unbiased monitoring techniques, and backed by research or field experience
- ▸ more efficient use of inputs such as pesticides, fuel, water and time than with conventional pest control
- ▸ less reliance on a single management method and greater use of a variety of methods – pest resistance develops more slowly due to reduced selection pressure from chemicals
- ▸ chemicals are only used when necessary
  - ▹ fewer applications of pesticides due to better timing of sprays
  - ▹ less impact on soil and water, and non-target species of fish and wildlife
  - ▹ more stability in the pest complex with fewer emerging problems, because competitors and beneficials are not eliminated
  - ▹ longer availability of registered pesticides, because efficacy remains consistently high and improved spray coverage reduces use
- ▸ often an initial dramatic reduction in pesticide use and an immediate economic benefit to growers
- ▸ no loss of quality or yield

Canadian Seed Growers' Association

Pest control can take several approaches: mechanical control of weed seedlings (top); cultural control of seed-borne pests through use of certified seed (centre); and biological control – in this case, of flies with the help of Muscovy ducks.

INTRODUCTION

COST TO ONTARIO APPLE GROWERS USING DIFFERENT SPRAY OPTIONS

	CALENDAR SPRAYS	REGIONAL AGRI-PHONE	IPM SCOUT
# SPRAYS PER SEASON	26	18.75	11.50
COST PER HECTARE	$1451.00	$1052.00	$636.00

*cost of scout @ $30.00/ha. Source: B. Solymar, OMAFRA

Lacewings are important for biological control of aphids in many crops.

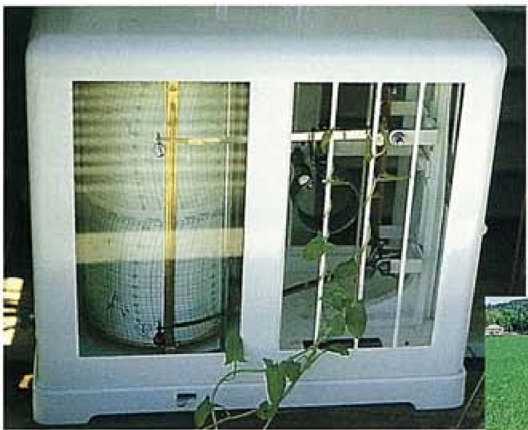
Calibrate your sprayer regularly: this will ensure that pesticides are applied at the correct rate with maximum spray coverage.

INTRODUCTION

THE CHALLENGES

- IPM is knowledge-driven, and requires a greater understanding and commitment on the part of growers than conventional pest control
  - pest management is complex and requires an understanding of the interactions among the species involved
  - effects of pest management on the environment, and wildlife and their habitat must be minimized
  - growers must be willing to keep up-to-date with research findings and monitoring techniques
  - IPM requires a long-term commitment
- IPM requires a sound research base, which is an expensive upfront investment for society
  - research component must be ongoing because living systems are dynamic
  - for some crops and pests, extensive research is needed to develop systems that are specific to each growing area
- on some crops, intensive IPM doesn't make economic sense, because the treatment costs and the amount of pesticide needed in conventional systems are low
- some expense is involved with monitoring equipment, weather-recording machines, scouts and consultants

A researcher studies insect pests.



This weather recorder continually tracks temperature in an orchard.

Small research plots are used to test new IPM techniques in onions.

You can learn the latest IPM techniques at twilight meetings like this one in the Alliston area.

INTRODUCTION

- availability of IPM systems varies from place to place, and is often unavailable to growers in isolated areas
  - cost of delivering a knowledge-based system is prohibitive where only a small area is grown
- IPM programs aren't easily transferred from area to area
  - programs are unique to each crop production area because of variations in climates and pest complexes

The Hirst spore trap is used to trap spores that initiate plant diseases.

The temperature recorder is kept in a ventilated white box called a Stevenson screen. A second machine, the Dewitt leaf wetness recorder, collects data to predict apple scab infection periods.

Pheromone traps are used to track the flight of tentiform leaf miner adults in apple orchards.

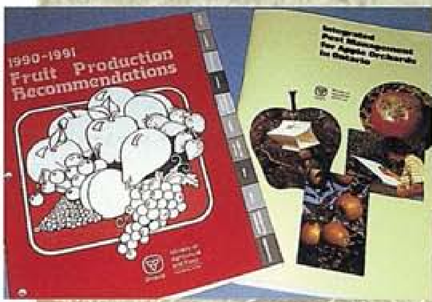
INTRODUCTION

INFORMATION SOURCES

How you obtain crop-specific pest management information will depend on the crop and the complexity of the problem. For relatively low-value crops such as hay or corn, with a per-hectare value of about $600, information is delivered on a regional basis through radio broadcasts, newspapers, government publications and winter meetings.

For high-value crops such as apples (per-hectare value of $7,500), or greenhouse flowers (per-hectare under-glass value of $300,000-$400,000), information is available through weekly on-farm scouting, daily recorded phone messages, as well as publications, newsletters and twilight meetings.

In some instances, growers may run their own IPM programs, generating their own information while using extension staff as a resource.



Government publications are a good source of pest management information. Some titles are listed on the back cover.

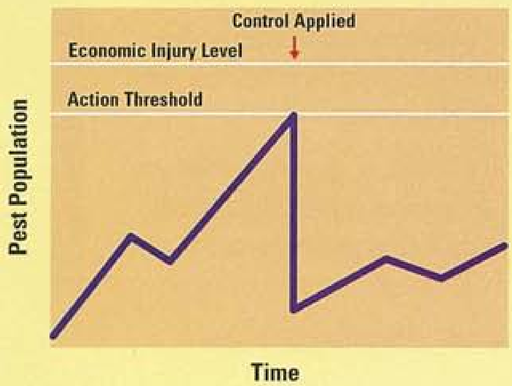
TERMINOLOGY

Throughout this booklet, we'll be using terms that are basic to IPM. Here are some definitions to see you through.

DIRECT PEST	• one that injures the portion of the crop that is sold, e.g., the codling moth, which attacks the fruit of apples
INDIRECT PEST	• one that injures part of the crop plant, but not the part that is sold or consumed • generally we tolerate higher levels of indirect pests than direct pests because they are less harmful economically
ECONOMIC INJURY LEVEL	• the pest density that causes damage equal in value to the cost of the treatment • researchers hope to have numerical values for all crops and pests, but in reality very few have been well-documented – in fact, the economic injury level for a given pest may vary, depending on the crop growth stage, crop stress and market demands
TREATMENT OR ACTION THRESHOLD	• the density of pests at which control measures should be applied • lower than the economic injury level, allowing time for control measures to take effect
BENEFICIALS	• natural enemies of crop pests that help control them and keep populations in balance • could be predators or parasites, insects or diseases

INTRODUCTION

TIMING OF PEST CONTROL



Controls are applied as soon as the pest levels reach the action threshold.

This indirect pest, the tentiform leaf miner, attacks apple foliage. A low level is tolerated in commercial orchards.

This direct pest, the codling moth, attacks the apple fruit. This means there is a very low tolerance level of them in commercial orchards.

A stink bug is considered a beneficial insect. It helps to reduce the Colorado potato beetle population by eating beetle eggs.

BEST MANAGEMENT PRACTICES FOR MONITORING

IPM is information-driven, and monitoring is the front-line for information-gathering. Careful monitoring tells you what pests and beneficials are in your crops, how many and when.

HOW TO MONITOR

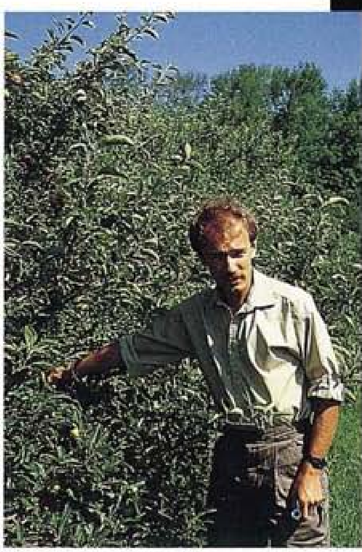
Monitoring begins by taking representative samples of plants, insects and weeds. The size, type and number of samples necessary for each pest and crop combination are determined by research. It's important to sample correctly in order to get an accurate picture of the problem.

Sampling can tell you whether:

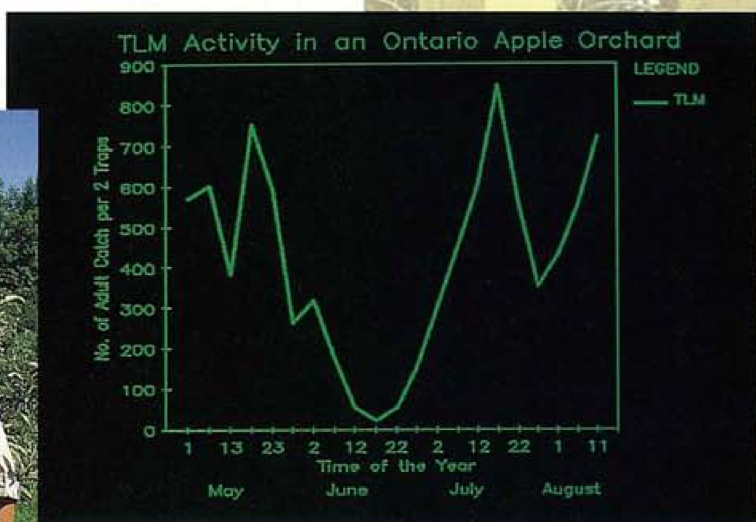
- ▸ the pest is indirect
  - ▹ a certain low level is usually tolerable
- ▸ the pest is direct
  - ▹ its presence should be detected as soon as possible and action taken if thresholds are reached
- ▸ the pest has the potential to increase very rapidly
  - ▹ if so, it will need constant monitoring
- ▸ natural enemies are present
  - ▹ if so, at what level and their contribution to pest control
- ▸ any pest control actions have been successful
- ▸ the pest complex has changed.

Sampling methods vary according to the pest and its stage of development. In the case of leafrollers on fruit, pheromone traps are used to sample for adults, and terminal growth on the trees is checked for larvae.

For weed sampling in field crops like soybeans and corn, sometimes the field is scouted in a W-pattern and 20 quadrants are sampled along the W. Other times, a certain row-length is sampled 10 times in the field and the weeds are counted along these rows.

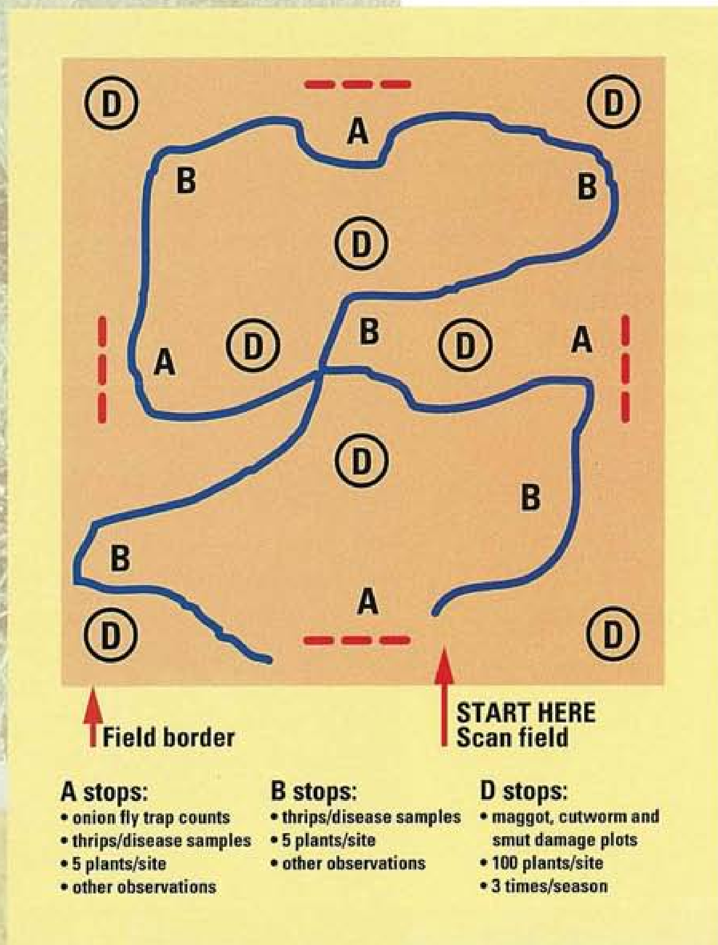


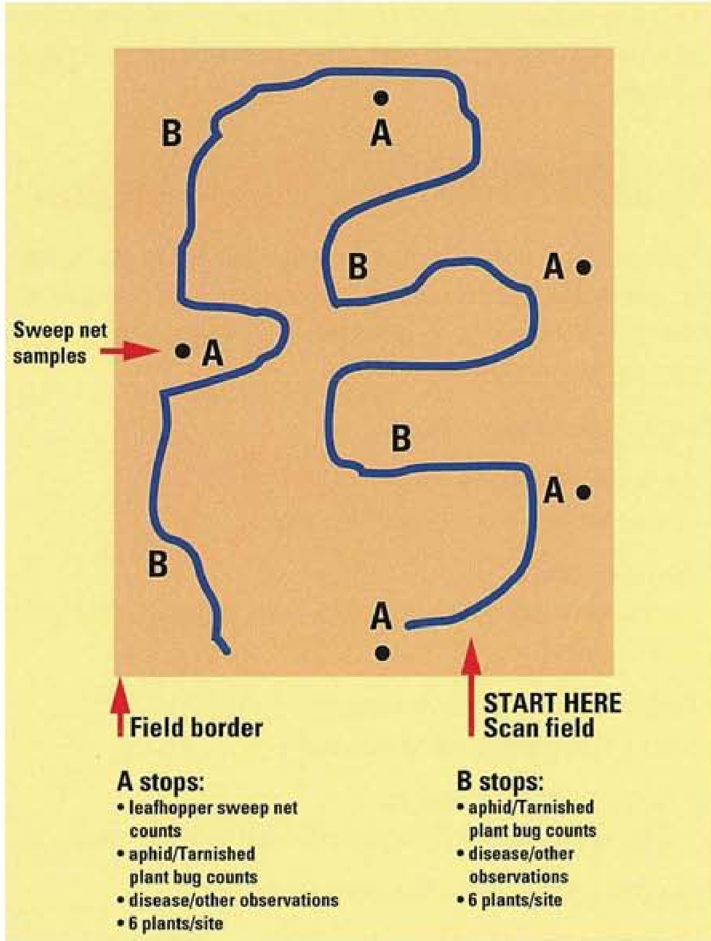
When monitoring in an orchard, leaves must be chosen correctly in order to get a representative sample.



Monitoring the tentiform leaf miner flight using pheromone traps gives us information that can be plotted on a graph each week. This provides a seasonal picture of the population.

BEST MANAGEMENT PRACTICES FOR MONITORING





Each field is mapped and sampled by the scout in a prescribed way, depending on the crop and the pests. On the left is a field scouting pattern for onions; a pattern for lettuce is shown on the right.

BEST MANAGEMENT PRACTICES FOR MONITORING

The following techniques are used to sample for pest and beneficial species. The method you choose will depend on the biology and stage of the pest. To find out more about pest biology, see page 17.

VISUAL COUNTS

The visual count technique lets you estimate numbers of pests and beneficial species per plant or unit area. It's used for weeds, diseases and insects. Leafhoppers, mites and potato beetles are commonly monitored this way.

A 10x-16x hand lens is often used, and a microscope may be necessary for small insects and diseases. Sampling protocol often prescribes a designated number of leaves when sampling for disease lesions per leaf or mites per leaf.

Apple scab lesions are also visible by the naked eye.

Aphids on the back of a rutabaga leaf can be seen without a hand lens or microscope.

European red mite eggs require magnification to be counted.

In the field, a 10x hand lens is used to see small insects.

BEST MANAGEMENT PRACTICES FOR MONITORING

There are several kinds of traps.

TRAPS	
PHEROMONE TRAPS	• sticky cardboard traps with a capsule containing synthetic sex attractants specific to the pest to be monitored • these tell us when the adult male flight of insects begins, when it peaks and its duration • also used to monitor the spread of a pest into a new area, e.g., Japanese beetle, gypsy moth
STICKY TRAPS	• the colour is specific to the pest being monitored – can be yellow, orange, blue or white panels, or red spheres • covered with an adhesive to catch the insects when they land
PITFALL OR INTERCEPTION TRAPS	• trenches or holes are constructed to catch insects as they walk by, e.g., Colorado potato beetle
BLACK LIGHT TRAPS	• many insects are attracted by UV light • useful for monitoring insects that are not easily attracted by pheromones, e.g., cutworms
BAIT TRAPS	• made of the crop itself, or may be bait recipes
SPORE TRAPS	• used to monitor fungal diseases of plants by catching spores that cause infections on the crop • information gathered tells us whether the spores are present and mature • need to monitor the spores, the weather and the growth stage of the crop to determine whether disease will result

Spores that infect plants and cause disease can be monitored with spore traps.

The black light trap attracts many species of flying insects.

Adult male moths of the oblique-banded leafroller can be monitored using a pheromone trap. In a commercial orchard, four traps per orchard are used to monitor adult activity.

BEST MANAGEMENT PRACTICES FOR MONITORING

The tentiform leaf miner male moth is attracted to the pheromone emitted by the rubber septum in this trap.

A carrot piece is used to attract carrot weevil.

INTERPRETATION OF TRAP COUNTS

From catches in the traps, we can track the seasonal development of the pest and determine when the population reaches action thresholds. Trap counts reveal activity patterns of a pest population. These counts only give a rough estimate and can be affected by placement, condition of the lure, competition from real females for the pheromone traps, and the density of the traps. Generally, professional help is required to interpret trap counts.

Trenches or pitfall traps are used to trap adult Colorado potato beetles as they return to the potato fields in the spring.

Sticky traps come in different colours because insect species have colour preferences. Orange sticky traps attract carrot rust fly. Yellow attracts onion maggot flies. Blue attracts thrips in greenhouses.

BEST MANAGEMENT PRACTICES FOR MONITORING

SWEEP NETS

Sweep nets consist of cloth nets on frames. They are used in the field to determine the presence and the numbers of many foliar insects that can be dislodged, such as leafhoppers on carrots, celery and alfalfa.

TAPPING TRAYS

A tapping tray is made of cloth stretched over a wooden frame. A stick is used to jar insects from the limbs of trees onto the tapping tray. Usually the cloth is white or black so that falling insects can be counted easily. Tapping trays are also useful for monitoring beneficial insects.

Carefully inspect each set of traps on a tapping tray to identify the insects.

A sweep net is used to sample for leafhoppers in a lettuce field.

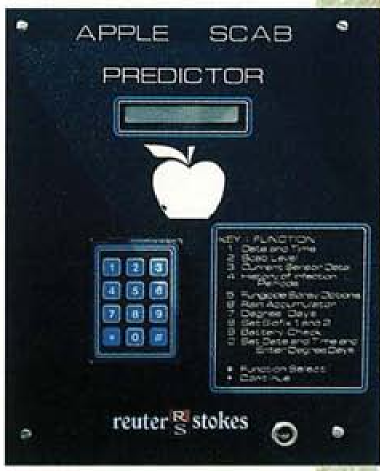
BEST MANAGEMENT PRACTICES FOR MONITORING

WEATHER MONITORING MACHINES

Insect, disease, weed and crop development is temperature- and moisture-dependent, and varies from season to season. This means that weather must be monitored continuously to predict the best timing for IPM practices. Weather data collected by machines are used to drive pest models. For some pests, weather data are very important to time controls.

This solar-powered weather station will monitor weather in a vegetable field.

Weather data form a key part of the IPM equation. This machine is used to forecast early and late blight diseases of potato.



Commercial disease predictors are available. This one measures leaf wetness and temperature, and indicates the occurrence of an apple scab infection period.

HOW TO IDENTIFY PESTS

Control measures will not be effective if they target the wrong pest. That's why correct identification is so important. Sometimes a problem that you might think is caused by pests is in fact due to nutrient deficiencies, air pollution or stress from other environmental factors.

Three types of information should be gathered to make the right identification.

What does it look like?

- the physical appearance of an insect or weed will differ depending on the species and the stage of development – for example, a weed seedling can be quite different from a mature weed, just as an insect in the caterpillar stage doesn't look at all like a butterfly or moth

The roots of the corn plant on the left have been eaten by corn rootworms. Compare them to those of the normal plant on the right.

BEST MANAGEMENT PRACTICES FOR MONITORING

Where is it found?

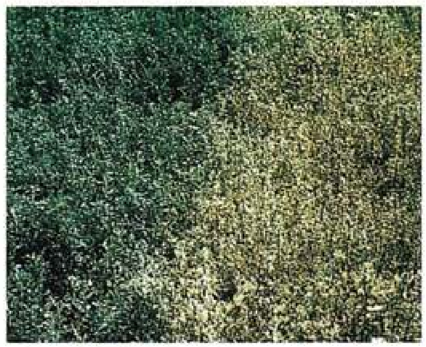
- understanding where to look for a particular pest helps to streamline monitoring
- most pests attack a particular part of the host plant, and observing damage may be a good indication of a pest's presence
- pests have a particular set of hosts that they attack – knowing these can help with identification

When is it found?

- knowing the time of year when you might encounter a particular life stage of a pest is useful
  - helps to determine when to spend time and resources on monitoring for the pest problem. For example, both the potato stem borer and the European corn borer tunnel in corn stalks. But the potato stem borer does it in the seedling stage, whereas the European corn borer tunnels in the mature plants.
- to control weed seedlings through cultivation, you need to know when seedlings are present, e.g., spring annuals versus winter annuals that germinate in the fall
- to control pests, you should be familiar with life cycles – see next section for more information
  - if a small caterpillar is found in an apple orchard at petal fall, you can eliminate the oblique-banded leafroller because you know that it would be a very large caterpillar at that time of the season
  - for corn rootworm, from mid-June to mid-July look for the larvae tunneling through and pruning the roots; in August, the adults feed on corn silks
  - for alfalfa weevil, the larvae should be checked from mid-May to June, with the peak of the larval attack coinciding with the flower bud stage of the first cut

To identify the European corn borer, look for pinhole feeding on the leaves, and stalk breakage due to seeding on the stalk and holes in the stalk.

The alfalfa weevil lays eggs in holes it has made in plant stems.



This alfalfa field has been seriously damaged by alfalfa weevils.

BEST MANAGEMENT PRACTICES FOR MONITORING

LIFE CYCLES OF PESTS

Most pest controls are aimed at a specific stage of the life cycle, when the pest is most susceptible. This makes monitoring of pest development very important. For example, pre-emergence herbicides only work if applied before the weeds germinate. Protectant fungicides won't work after the infection has taken place, Colorado potato beetle sprays are most effective on young larvae, and Colorado potato beetle trenches are only effective for adults.

Some pests require more than one host to complete their life cycles.

Alternate hosts may live on the farm in areas adjacent to the crop. For example, barberry is an alternate host for black stem rust of small grains such as wheat, oats, barley and rye.

Some pests have a wide **host range** and can survive on many different crops. You need to be familiar with the host range of particular pests, and consider it when you plan crop rotations and field locations.

The life cycle of the Colorado potato beetle begins with eggs, which hatch to produce tiny larvae.

Larvae grow quickly and eat a lot of foliage.

The adult is a beetle.

The Colorado potato beetle can inflict heavy damage on a potato field.

Apothecia of *Sclerotinia sclerotiorum* appear on the soil surface when conditions are moist and cool. Spores are discharged from the apothecia and carried by the wind to infect bean plants.

The *Sclerotinia* fungus infects bean plants, causing white mould symptoms to appear.

BEST MANAGEMENT PRACTICES FOR MONITORING

There are several pest models that are used in Ontario, such as Botcast, Tomcast, Machardy-Gadoury revised Mills system, Simweevil, Maryblyt, Blytcast, Bugwatch and Downcast.

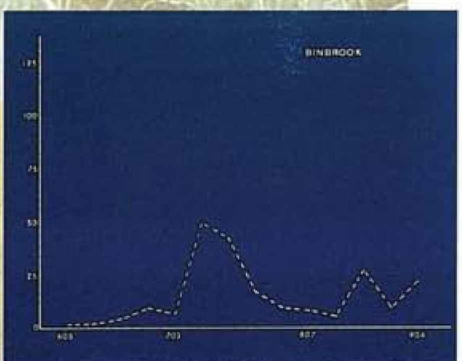
USING MODELS

Researchers build pest prediction models to predict the development of the crop and pests as affected by the weather. Researchers do not rely on calendar days to predict crop development, but on real events happening in the field.

Models can be simple or complex, and are driven by data obtained by monitoring the pest and weather. They use temperature, humidity and rainfall because insect, crop, weed and disease development is closely linked to environmental factors.

Development is related to accumulated heat units or degree-days. One degree-day is the heat experienced by the pest or crop when the temperature is one degree above the threshold temperature for development for 24 hours. A specific number of degree-days is needed for the pest to develop through each stage.

A model begins with an easily detected event such as a first catch of an adult insect in a pheromone trap. It is then used with heat units to predict difficult-to-detect events like egg hatch or peak moth flight. Models don't replace sampling, but help to predict when we need to sample or implement a control option.



European corn borer catches for the season can be graphed.

RECORD-KEEPING

IPM records should combine all of the information gathered on pest control methods, monitoring records, weather records, cropping practices and yield data.

Record-keeping is a daily job throughout the season. After the growing season is over, records should be analyzed to understand what happened and how things could be improved for the future.

Here are some of the benefits of record-keeping:

- helps you evaluate your results
- helps you plan pest control strategies for the next year
- assists with planting and harvesting schedules
- solves application or phytotoxicity problems
- documents your use and costs of pesticides and other alternative controls
- contributes to the information base for making the best IPM decisions in future
- helps you plan labour, marketing and equipment needs
- helps you evaluate your options for applying biological control agents.

BEST MANAGEMENT PRACTICES FOR IMPLEMENTING IPM

Monitoring is the first step in the IPM process. The second is interpreting the data and choosing appropriate control strategies for your operation. Ask yourself these questions:

Cost

- what is the value of the crop versus the cost of the solution?
- will you need to purchase new equipment?

Impact on the environment and fish and wildlife

- will there be negative effects on soil, water, wetlands or fragile areas?
- will there be negative effects on naturally occurring organisms such as invertebrates (e.g., insects), fish, amphibians, reptiles, waterfowl and mammals?

Timing

- will strategies fit in with your work schedule?

Success rate

- have the strategies been tested?

Availability of components

- are key components available, such as resistant varieties, registered pest control products and mechanical alternatives?

Versatility

- can the choice solve more than one pest problem?

Long-term consequences

- will the choice of control options affect economic competitiveness?
- will long-term planning prevent or delay problems with pesticide resistance?
- will the control option be acceptable to consumers?
- will the control reduce the risk of damage to the environment or wildlife?

Let's look now at pest control methods that make up an IPM system. They can be used alone or in combination, depending on the crop and the pest complex.

BEST MANAGEMENT PRACTICES FOR IMPLEMENTING IPM

SITE SELECTION

Site selection involves choosing a field or growing area that is best suited to growing and maintaining healthy, stress-free plants, and is least hospitable to pests.

Factors to consider include:

Soil type

- clay, silt, sand and organic matter content is important, since each crop has an optimal soil type. Some pests also prefer certain soil types. For example, nematodes prefer sandy soils.

Water drainage

- poor drainage leads to root rot problems, such as phytophora and pythium root rots on alfalfa

Isolation

- for many crops, it's advantageous not to be near a large, established pest reservoir

Exposure and slope

- maximum air drainage is important for many berry and tree-fruit crops to minimize disease infection periods

Previous crop

- need to anticipate problems presented by the previous crop, such as herbicide residues or pest carryover
- many diseases are soil-borne, such as wilts caused by fungi. Fungi (e.g., verticillium) can infect a very broad spectrum of crops, such as a potato-tomato-alfalfa rotation.

This alfalfa plant has been infected with verticillium, causing wilt symptoms.

An apple orchard planted on rolling land has good air drainage, which lowers the incidence of disease.

BEST MANAGEMENT PRACTICES FOR IMPLEMENTING IPM

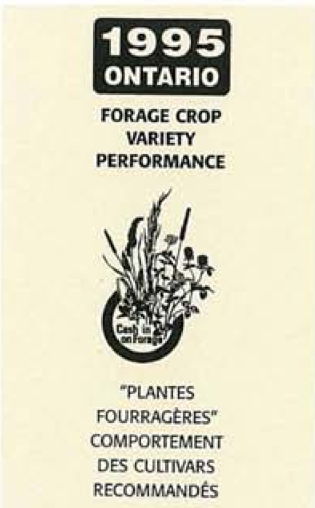
CULTIVAR SELECTION

Cultivar selection involves choosing a cultivar or variety based on its genetic characteristics and ability to tolerate or resist a pest. Resistant seed or plant material is usually inexpensive, and can eliminate the need for other costly methods of pest control.

The cost of developing a new soybean variety is in the $250,000 to $1-million range, and is recouped through the sale of seed as long as the variety is accepted by the market. For field crops, this cost is spread over large areas, whereas the initial cost of developing a variety for a small-area horticultural crop cannot be spread out. This makes new varieties very expensive on a per-unit basis.

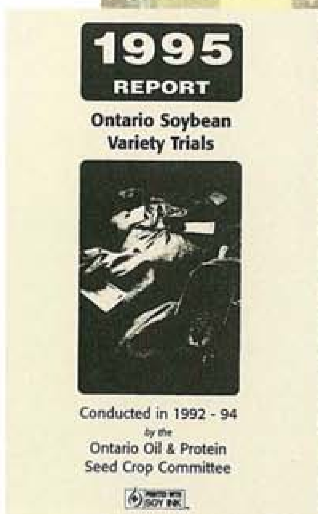
Cultivar selection has worked especially well with field corn. Breeders have selected for stalk strength so that European corn borer may be present, but the stalks are strong enough to stand in spite of the feeding damage.

However, some challenges remain. One is that the variety must be marketable. Scab-resistant apples, for example, have never become established in the marketplace. Another challenge is that pests can overcome resistance. Despite the development of crown rust-resistant oat varieties, rust returned within two years. In this case, genetic change in the crop was not sufficient to overcome the huge pool of alternate hosts in adjacent areas. Also, there are many strains of rust.



You can use the most recent *Ontario Forage Crop Variety Performance* report to choose varieties that are resistant to diseases.

The findings of the *Ontario Hybrid Corn Performance Trials* can be used to identify varieties that are most resistant to corn borer. These are determined by percent broken stalks.



The *Report of the Ontario Soybean Variety Trials* can be used to choose varieties most resistant to Phytophthora root rot.

BEST MANAGEMENT PRACTICES FOR IMPLEMENTING IPM

CROP ROTATION

As an IPM strategy, crop rotation involves alternating crops to meet specific objectives such as reduced pest habitat, soil improvement, and reduced pest food source. It can be successful under the following conditions:

- a marketable alternative crop is available
- sufficient land base exists
- alternative crop has a different set of pests and will not act as a food source for the resident pests in the field
- target pests are resident in the field and don't fly in from a great distance.

In Ontario, the use of corn rootworm insecticides has been cut by 50 percent since 1986 due to rotation. The rootworm adult lays its eggs in the fall, and if the crop is rotated to wheat or soybeans, there is no food source for the rootworm the next spring.

Soybeans are another success story. The soybean cyst nematode has been spreading in Ontario since 1987. A five- or six-year crop rotation using non-hosts and resistant soybean varieties has reduced the population in infested fields.

Crop rotation has its limitations. Vegetable growers, for example, don't have a big enough land base to use a long rotation. Also, perennial crops like tree fruits are in the ground for up to 20 years. Low prices for crops such as winter wheat make it a difficult choice in the traditional corn-wheat-soybean rotation.

A healthy cornfield is largely the result of crop rotation and choosing the best variety to plant.

BEST MANAGEMENT PRACTICES FOR IMPLEMENTING IPM

SANITATION

Pest numbers can be controlled in part by eliminating materials or places where pests live and reproduce. Sanitation can also involve the purchase of clean seed complete with a phytosanitary certificate, and the removal of contaminated crop refuse from past crops to reduce problems in future crops. Many bacterial diseases result from the use of infested seed stock.

Sanitation practices can have many benefits. In the Bradford Marsh area, onion cull piles are diverted from landfill sites to highland farms for spreading.

By cleaning storages and seed-handling equipment, seed potato growers are eliminating the carryover of disease-causing organisms on surfaces or in potato debris. Pressure washing and disinfecting surfaces help control ring rot bacteria, which can live for two to five years on dry surfaces and survive freezing temperatures.

Farmers who store grain are able to exclude pests and prevent their re-entry. Measures include vacuuming storages and maintaining tight seals on all entry points.

Manure piled outside for long periods can create a perfect breeding environment for flies.

If onion cull piles are left near fields, they become sources of insects and diseases for the next crop.

BEST MANAGEMENT PRACTICES FOR IMPLEMENTING IPM

BIOLOGICAL CONTROL

By utilizing a pest's natural enemies – predators, parasites and pathogens – it's possible to keep pests below treatment thresholds. There are two approaches:

Encouraging natural enemies

- using selective pesticides that aren't harmful to the beneficials, while killing the target pest
- knowing life cycles of beneficials – allows you to time operations such as spraying, cultivating, mowing and harvesting so that most beneficials can survive
- providing food for them by not eradicating the pest populations, but rather allowing a low level of pests to act as a food source
- being patient by allowing up to two years for their establishment, once broad-spectrum pesticides have been eliminated from the spray program
- sampling periodically for beneficials to track the beneficial:pest ratio and to recognize changes in it as a consequence of operations in the crop

Releasing natural enemies

- classical – introducing natural enemies from a pest's native range into a new area where natural enemies don't provide control, e.g., alfalfa weevil and blotch leaf miner in Ontario
- inoculative – releasing natural enemies periodically to re-establish a balance that hasn't been maintained naturally, e.g., in greenhouse tomatoes, release the parasitic wasp, *Encarsia formosa,* for whitefly control with each new crop.

The whitefly is one of the most important pests of greenhouse tomatoes.

BEST MANAGEMENT PRACTICES FOR IMPLEMENTING IPM

MINI CASE STUDY

***Amblyseius fallacis* to control mites in Ontario apple orchards.**

Problem

Mites are normally controlled by predators, but broad-spectrum insecticides used to control other apple pests often kill predators. Mite populations explode when broad-spectrum insecticides kill their natural predators.

Solution

Re-introduce a mite predator. This required:

- ▸ grower awareness of the problem and growers using fewer, better timed pyrethroid sprays
- ▸ rearing of organophosphate resistant mite predator, *A. fallacis*
- ▸ 1993 commercial availability of mite predator to re-establish predator numbers
- ▸ available list of pesticides least toxic to the predators.

The mite predator, *Amblyseius fallacis*, travels along the underside of an apple leaf, where the pest mites accumulate.

NUTRITION AND WATER NEEDS

Generally, a healthy plant or animal can withstand more pest pressure and higher thresholds for control. Be aware that some nutritional disorders and other stresses can look like pest damage. Ensure correct diagnosis.

Overfertilizing plants can cause pest problems. For example, too much nitrogen causes excessive sucker growth, favouring infestations of aphids on apple, and psylla on pear. Excessive nitrogen may also increase disease problems such as Botrytis grey mould on strawberry.

Take soil and leaf samples regularly to monitor nutrient balance, and be aware of water requirements of the crop.

Blossom end rot on tomatoes may look like a disease. In fact it's caused by a calcium imbalance.

Nutrient deficiency, e.g., magnesium deficiency, may be mistaken for leafhopper or other insect damage.

BEST MANAGEMENT PRACTICES FOR IMPLEMENTING IPM

REMOVAL

DISEASES

Proper management of grapevines results in less disease.

The physical removal of infection sites, such as black knot of plum and fireblight of pear, and removal of alternate hosts from fencerows can help to control diseases without chemicals.

Proper canopy management through pruning, plant spacing and trellising in some crops can make the crop less likely to become infected because of better air movement.

WEEDS

The physical removal of weeds by cultivation can replace a herbicide. However, you must factor in the cost of fuel, machinery, time and the potential for soil erosion or degradation.

To control weeds through hoeing or hand weeding, consider availability of the labour force, value of crop and time involved.

Mulching can be used to smother weeds, prevent weed germination and help conserve soil moisture. Mowing can be important in pasture management to prevent the unwanted establishment of perennials.

BEST MANAGEMENT PRACTICES FOR IMPLEMENTING IPM

INSECTS

The physical removal of insects is done on a small scale in home gardens and on a large scale in some commercial potato fields in Ontario. Propane flamers are used where the problem of resistance has meant that chemicals no longer work to control Colorado potato beetles. Plastic-lined ditches around potato fields are used to prevent the entry of Colorado potato beetles in the spring. These expensive and difficult procedures are done as a last resort.

Cedar-apple rust spends part of its life cycle on cedar, where it produces these orange telia.

The disease infects apple foliage, producing characteristic lesions.

Cedar-apple rust also attacks apple fruit.

Tarnished plant bug attacks many fruit crops, and has a wide host range.

Two-spotted spider mites use many crops – from tree fruit to soybeans – as a food source.

BEST MANAGEMENT PRACTICES FOR IMPLEMENTING IPM

PLANTING AND HARVESTING DATES

Planting and harvesting dates can be manipulated to avoid some pests. However, only some pest-crop combinations can benefit from this practice. There are three approaches:

Planting late

- early generations of pests can be avoided by late planting
- challenge: planting late may result in soil moisture problems, poor germination, lower yields, and not enough heat units to mature the crop

Planting early

- resistant varieties of field corn are planted early so they will be unattractive to second-generation European corn borer in Southwestern Ontario

Early harvest

- used in alfalfa to control both alfalfa blotch leaf miner and alfalfa weevil. The benefit to producers is that the early harvested crop has higher digestible protein for livestock.
- challenge: harvesting early may result in lower yields, poor storage ability and a product that is less marketable and not mature.

BEST MANAGEMENT PRACTICES FOR IMPLEMENTING IPM

A row of potatoes has been planted in a tomato field to act as a trap crop for Colorado potato beetle. This row was not sprayed.

This trap crop row was sprayed to control Colorado potato beetle.

TRAP CROPS

Trap crops lure pests away from primary crops. A trap crop can be planted to surround a crop, or be interspersed in it. Here are some examples:

Colorado potato beetles in processing tomatoes

- ▸ Colorado potato beetles prefer potato to tomato. Potatoes are planted and ground in the tomato field. When beetles attack the potatoes, they can be managed with insecticides or propane flamers. This reduces the area of the field requiring controls.

Flea beetles in cole crops

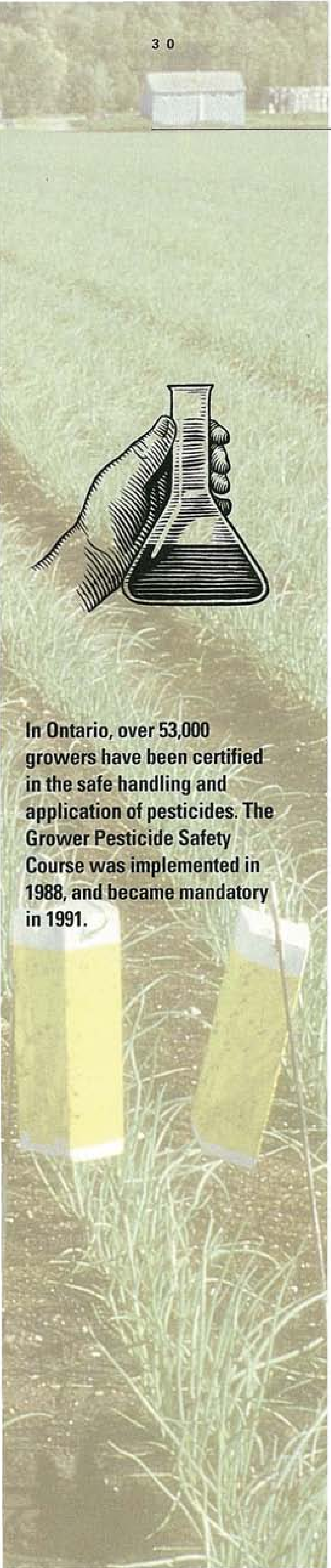
- ▸ Indian mustard var. crispafolia is planted at the edge of broccoli fields and along laneways, and eliminates sprays for flea beetles – from four sprays to zero in 1994.

There are some problems with trap crops. They take up space and nutrients, and won't work if pest pressure is too severe. For example, the Colorado potato beetle may eat all of the potato plants, then move to tomatoes if the population is high.

Growers need to be able to manage both the trap crop and the commercial crop. The trap crop should not become a weed problem, and it needs to be inexpensive and easy to obtain.

Indian mustard has been used as a trap crop and shows damage by flea beetles.

Flea beetles attack the row of mustard on the right, leaving the crucifer crop on the left undamaged.



BEST MANAGEMENT PRACTICES FOR IMPLEMENTING IPM

PESTICIDE REGISTRATION AND SELECTION

A pesticide is a chemical that kills pests, and can be synthetic or natural in origin. The pest could be a weed, disease, nematode or rodent. The Government of Canada has defined the following pest control products as pesticides: insecticides, fungicides, herbicides, rodenticides, miticides, plant growth regulators and fumigants. There are currently no defined protocols for new types of pest control products such as beneficials and biotechnology products.

Before pest control products can be sold in Canada, they must be registered by the federal government. This can take up to 10 years for a new chemical, and can cost between $50- and $100-million.

In Ontario, over 53,000 growers have been certified in the safe handling and application of pesticides. The Grower Pesticide Safety Course was implemented in 1988, and became mandatory in 1991.

Once registered, some provinces review the data and the pesticides are classified into schedules to control who may buy and use each product. In Ontario, farmers must be certified in the safe use and handling of pesticides through the Grower Pesticide Safety Course. Vendors must also pass a course. Vendors must have an employee who has passed the Vendors Certification course at each sales location during business hours.

Pesticides are highly regulated when they are transported and distributed.

Health Canada establishes maximum residue limits on crops and conducts residue testing on our food. Crops can be seized if excessive residue levels are found at harvest and the crops may not be marketed.

BEST MANAGEMENT PRACTICES FOR IMPLEMENTING IPM

SELECTION

When deciding to use a pest control product, try to ensure:

- it's effective against the pest problem
- it's registered for the intended use in your area
- it's compatible with your work schedule, labour costs and harvest dates
- it's easy on beneficials and other non-target fish and wildlife
  - you understand the effects of a product on non-target organisms, such as those in sensitive areas near ponds or streams (fish and wildlife), and around farm buildings (humans, pets, livestock)
- it's least hazardous to applicator, e.g., soluble packaging, lower mammalian toxicity
- it's least hazardous to the environment, i.e., not easily moved into ground water, not persistent in soil
- it can be alternated with other pest control methods to discourage the development of pesticide resistance
- the selected pest control product will not encourage the development of secondary pests
- chemical persistence will not be harmful to future cropping plans
- affordability – some new IPM-compatible products can be more expensive than traditional ones
- you know whether the pesticide will be applied as a broadcast, spot or border spray
- you know the best timing for its use – every pest has a part of its life cycle that is most vulnerable to controls.

CASE STUDIES

POTATOES

Growing potatoes in Ontario in the 1990s has been especially challenging, due to extreme pest pressure and a lack of new pesticides. Here's how the industry in Alliston has responded.

Potatoes are grown on sandy loam soil in three areas of the province – Essex-Kent, Alliston and Shelburne. In the Alliston area, roughly 6,000 hectares are grown mainly for the processing market. It is a concentrated area with minimal crop rotation and intensive pesticide use. Growers have invested heavily in specialized equipment and storage. Crop rotation is practised, but often the rotated fields are right beside non-rotated fields.

PEST COMPLEX

INSECTS	DISEASES	WEEDS
Colorado potato beetle	Late blight	Pigweed
Aphids	Early blight	Nutsedge
Leafhoppers	Verticillium wilt	Horsetail
Wireworms	Bacterial ring rot	Barnyard grass
Tarnished plant bug	Scab	
Flea beetles	Blackleg	
	Seed piece decay	
	Fusarium dry rot	
	PVYN	
	Rhizoctonia	

IPM PRACTICES

Monitoring
- 90 percent of hectares is scouted in the Shelburne and Alliston areas
- 1 scout can look at 200 hectares
- cost is about $5 per hectare

Sanitation – used to reduce disease incidence
- late blight: destruction of cull piles, roguing volunteer plants
- verticillium: burning of vines after top killing
- ring rot: disinfection of planters, cutters, graders and diggers

Crop rotation
- used by 85 percent of growers, but since most of area is in potatoes, there is significant pest pressure

CASE STUDIES

Resistance management

- Colorado potato beetle is the major potato production problem due to insecticide resistance
- regular scouting leads to well-timed insecticide applications that control small larvae
- dip tests done before insecticide treatments determine which insecticides are likely to be most effective
- rotate chemical families

Models

- Blytcast is used as a predictive model to help growers deal with all of the major potato diseases

Biotechnology

- potato plants with the transgenic gene for the B.t. toxin are being tested in Canada
- these plants will be resistant to Colorado potato beetle because they carry the insecticide gene and manufacture their own B.t., which is toxic to various stages of the pest

BARRIERS TO IPM

- limited potential for rotation because:
  - farms are highly specialized – most of entire region is potatoes
  - the crop is best adapted to a narrow range of soils
  - at least three kilometres are required for effective Colorado potato beetle control by rotation, but farms are fairly small
- few new pesticides
- few resistant cultivars

APPLES

Apples have an extensive pest complex, and are one of the first crops in Canada for which IPM programs were developed. Nova Scotia growers have been practising IPM since the 1950s; since the 1980s, all apple-growing areas in Canada have had IPM programs.

Ontario's orchards are concentrated in several regions close to the Great Lakes. Pest biology and threshold levels have been well-documented, and provincial coverage has been relatively easy, even with regional differences in the pest complex.

Nonetheless, the pest complex is constantly changing as the industry evolves to high-density systems with many new cultivars. In the 1970s, apple maggot, codling moth, plum curculio, mites and scab were the main pests and growers sprayed weekly. In the 1980s, orchards were monitored and sprayed only every three weeks for major pests.

Some of the pests live in the orchard; others come in from abandoned or wild trees.

CASE STUDIES

PEST COMPLEX

INSECTS	DISEASES	MITES
Apple maggot	Apple scab	Apple rust mite
Codling moth	Fireblight	2-spotted mite
Plum curculio	Powdery mildew	European red mite
White apple leafhopper	Rusts	
Woolly apple aphid	Blister spot	
Green apple aphid		
Tentiform leaf miner		
Mullein bug		
Oblique-banded leafroller		

IPM PRACTICES

Cultural

- nutrition of trees is carefully monitored through leaf analysis to avoid excessive growth and related pest problems (woolly apple aphid and green apple aphid)
- trees are pruned twice annually to maintain open, easy-to-spray trees, resulting in fewer insect and disease problems
  - prunings are removed from the orchard to reduce disease
- apples are picked up from the ground in autumn to remove pest pressure; wild trees growing in close proximity are removed because they can be pest reservoirs
- scab-resistant cultivars can be grown to lower the need for fungicides

Models

- used to predict the timing of sprays for some of the major pests
- degree days and pheromone trap catches are used for insects
- action thresholds are used to determine when controls are needed
- scab predictor machine measures leaf wetness and temperature, and indicates whether a scab infection period has occurred

Scouting

- hundreds of hectares are scouted weekly in all of the major apple-growing areas
- leaf and fruit sampling is used, as well as tapping trays, pheromone traps and sticky traps
- controls are based on findings and action thresholds

CASE STUDIES

Pesticides

- selection is based in part on whether these are benign to beneficial insects
- resistance management is practised by alternating pesticide families and avoiding multiple applications through better timing

Biological control

- predatory mite *A. fallacis* is purchased and seeded into an orchard block to help control pest mites
- in British Columbia, sterile male codling moths have been released

Disruptive pheromone technique

- synthetic female moth scent is released from pheromone dispensers, making it very difficult for males to find a potential mate

BARRIERS TO FURTHER REDUCTIONS IN PESTICIDES

Dependence on fungicides will continue until a disease-resistant variety that is acceptable to consumers is developed. Also, many existing pesticides don't work well in an IPM program – Canada lags behind the United States by five years, and 15 years behind Europe in pesticide availability. Organic production is not yet supported by the marketplace.

TURFGRASS

Most lawn care companies serve urban customers who want a perfect lawn. At the same time, an increasing number of customers would prefer to reduce pesticide use on their lawns. Currently there are no independent companies that monitor for pests.

Here are treatments typically provided by lawn care companies:

- fertilizer treatments – (2) spring and late summer
- herbicides – (1) pre-emergence for crabgrass; (2) applications for broadleaf weeds
- insecticides – (1) midsummer for chinch bugs
- cultural practices – core aeration and overseeding.

PEST COMPLEX

INSECTS	DISEASES	WEEDS
Hairy chinch bug White grub Japanese beetle	Necrotic ring spot Dollar spot Rusts	Dandelion Plantain Other grass

CASE STUDIES

IPM PRACTICES

Many IPM principles are new to this industry. However, some companies may be trying some of them.

Nutrition

- healthy, dense lawns promoted through fertilization and raised mowing height can compete better with weeds

Spot spraying

- spot treatments of herbicides can replace treatment of the entire lawn
  - post-emergent crabgrass control allows for spot treatment

Monitoring

- methods are available for hairy chinch bug and European chafer grubs

Timing sprays

- plant growth stages can be used to time sprays for some turf pests

Resistant varieties

- these are resistant to disease and insects, and should be planted
- varieties are available for different growing conditions (shade, sun, drought)

GREENHOUSE CUCUMBERS

An increasing number of vegetable greenhouses in British Columbia and Ontario are using IPM. Current IPM programs use chemical and biological controls, as well as cultural practices.

The average greenhouse in Ontario is 1.5 hectares. There are approximately 70 hectares in greenhouses in the province. Biocontrol is practised on 28 percent of the area, and 25 percent is monitored. Growers usually plant a spring crop (late December or early January) and a fall crop (July to August).

Growers tend to be well-organized, informed and geographically concentrated, making IPM delivery relatively easy.

CASE STUDIES

PEST COMPLEX

INSECTS	DISEASES	MITES
Western flower thrips Fungus gnats Cotton aphids Greenhouse whitefly Sweet potato whitefly *(also known as silverleaf whitefly)* Cucumber beetle Lepidopteran species	Virus complex Gummy stem blight Root rots Powdery mildew	2-spotted spider mite

IPM PRACTICES

Sanitation

- very important IPM practice – heat is used at end of spring crop; greenhouses are closed for seven days and heated to 54-60° C to kill pests; weeds are removed from inside and outside
- weeds can be a year-round important source of mites and insects
- insect screens are used to keep out pests
- steam sterilization is used to reduce the carryover of thrips, mites and diseases in the growth media

Monitoring

- yellow and blue sticky boards are used to detect populations of whitefly, thrips and fungus gnats
- trap monitoring will detect the pests before they are noticed on the plants
- direct observation of foliage is also used to detect pests such as mites and aphids

Biological control

- use of predators and parasites to control major pests has been successful
- greenhouses are conducive to biocontrol because they are enclosed and environmental conditions are controlled
- predators are introduced to the crop as soon as the pest is detected
  - predator release rates aren't exact, and are customized for each situation depending on the pest, the biocontrol agent and the region

BARRIERS TO IPM

The quality of biological control agents needs further improvement. Also, growers need education in handling the living pest control agents. Finally, there is no registration protocol in place for biological control agents.

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Contact your local ministry office. See the blue pages of your telephone directory for the office nearest you.

References

The following publications are available through the Ontario Ministry of Agriculture, Food and Rural Affairs:

Integrated Pest Management for Onions, Carrots, Celery and Lettuce in Ontario, 1993

Integrated Pest Management for Apple Orchards in Ontario, 1990

Fruit Production Recommendations, Publication 360

Vegetable Production Recommendations, Publication 363

Field Crop Recommendations, Publication 296

Insect and Disease Control in the Home Garden, Publication 64

Guide to Weed Control, Publication 75.

Numerous factsheets that address specific pest biology, controls and integrated pest management strategies are also available. These factsheets are crop- and pest-specific.

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