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***"A Manual of Integrated Pest Management for Urban Landscapes for British Columbia"***
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# CHAPTER 1
# INTEGRATED PEST MANAGEMENT, A DECISION-MAKING PROCESS

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# CHAPTER 1
# INTEGRATED PEST MANAGEMENT, A DECISION-MAKING PROCESS

## INTRODUCTION

The concepts of Integrated Pest Management were first developed for use in agricultural crops. In 1959, four scientists at the University of California published an article outlining the concept of "Integrated Control" as the combination and integration of biological and chemical control. The scientists were then working on the spotted alfalfa aphid.

The IPM concepts were refined and tested on many agricultural crops during the 1960s and 1970s. The advent of IPM in urban landscapes is more recent. Some work was done in California in the 1970s, but most of the applied research was not formally conducted until the 1980s, when many scientists across North America began to develop IPM concepts specifically for use in urban landscapes.

In this chapter, the decision-making steps in Integrated Pest Management will be examined from the perspective of urban landscapes.

## A) MONITORING IN URBAN LANDSCAPES

The goal of monitoring is to observe the plants and the site for potential pest problems, at regular intervals.

### i) The elements of a monitoring program

Many municipalities in California initiated urban IPM programs in the early 1970s. In Berkeley and San Jose, for example, IPM methods were introduced by William and Helga Olkowski, who later helped establish the Bio-Integral Resource Centre. Their experience and suggestions are summarized in Box 2-1.

**Box 2-1: Developing a monitoring program**

**Purpose**

What is the purpose of the monitoring? It can be to inspect the plant damage, to assess the number of insects or to learn about a disease.

**Sampling**

Which populations are to be sampled? Although many pests can be assessed, it is important to concentrate on those likely to cause serious damage.

**Other variables**

What other variables will be assessed? Ambient temperature and humidity, the fertiliser and irrigation program, the time of year, and other factors influence the decision-making process.

**Frequency**

How often should there be an inspection? The frequency of visits can vary from once per day to once every 2 weeks, depending on the insect and the history of the site.

**Which sites**

Which sites should be visited? Sites can be classified as high priority on important streets to low priority in secluded areas of parks.

**Which plants**

How many plants will be sampled? The number of plants to be sampled should be determined for each site.

**Sampling procedure**

What sampling procedure will be used? The technique should be appropriate to the pest monitored and can vary with different circumstances.

**Record keeping**

What is the record-keeping system? It should be designed for ease of use in the field and clear display of information for reference in the office.

**Evaluation**

How will the evaluation be conducted? The treatment initiated for a pest should be evaluated for its success without creating other problems.

**Corrections**

Can corrections be made to the system? Fine-tuning can be a constant result of the information gained from monitoring.

Adapted from Olkowski, W., H. Olkowski and S. Daar, "What is Integrated Pest Management?", *The IPM Practitioner*, November / December 1991.

### ii) The concept of key plants

Using Integrated Pest Management techniques on a farm growing hectares of apples is quite different than using the same techniques in a city with a multitude of plant species. Even within a residential property, there could a high number of different plants, and to monitor each plant on a regular basis would require a large amount of time that often cannot be justified economically.

To make the monitoring program efficient, the landscape manager can focus on key plants in the landscape that are the most likely to incur problems year after year. To utilize the "key plant" concept, the personnel conducting field inspections must be able to identify trees and shrubs, so knowledge of the common regional plants is essential. Although plants are known by common names, most reference materials are organized with Latin names. Good reference materials for plant identification are available at libraries.

The "key plant" concept was demonstrated by a study conducted in Maryland between 1980 and 1982. Five Integrated Pest Management programs for landscape plants were conducted by extension specialists at the University of Maryland on residential and commercial sites, with more than 30,000 landscape plants monitored. The results showed that several genera such as *Malus, Pyracantha, Cornus, Prunus* and *Rosa* were highly prone to pest problems. Although *Malus* plants represented only 2.1% of all plants monitored, 100% of the plants showed a pest or cultural problem.

The opposite extreme included plants such as *Viburnum, Taxus, Thuja, Ilex, Forsythia*, and several others which were never found to be problem prone plants. The results do not imply that genera such as *Viburnum* or *Taxus* are free of problems, or that other genera such as *Rosa* and *Malus* will always have problems. It does imply, however, that over a variety of years and management approaches, several plant genera will be more or less problem free. The results of one I.P.M. program in the Maryland study are presented in Table 2-2.

The same researchers reported their results by tree species (Table 2-3).

**Table 2-2: The relative abundance and frequency of problems on landscape plants**

Results for the 20 most common genera found at 150 home site in Maryland in 1981

| Plant Genus | % of total plants examined | % of total pest problems | % of plants in genus showing pest problems |
|---|---|---|---|
| Rhododendron | 16.6 | 23.8 | 55.2 |
| Juniperus | 10.0 | 10.9 | 42.0 |
| Ilex | 6.2 | 2.6 | 16.5 |
| Rosa | 5.2 | 6.2 | 45.9 |
| Pinus | 4.7 | 6.6 | 54.4 |
| Taxus | 4.2 | 2.4 | 21.9 |
| Acer | 3.8 | 1.3 | 13.2 |
| Euonymus | 3.6 | 6.4 | 68.1 |
| Ligustrum | 3.3 | 1.2 | 14.7 |
| Forsythia | 2.9 | 2.0 | 27.2 |
| Prunus | 2.8 | 2.8 | 38.7 |
| Thuja | 2.6 | 2.9 | 43.7 |
| Cornus | 2.3 | 2.7 | 46.8 |
| Buxus | 2.1 | 2.2 | 40.3 |
| Malus | 2.1 | 8.6 | 100.0 |
| Pyrancantha | 1.6 | 5.0 | 100.0 |
| Tsuga | 1.2 | 4.6 | 15.5 |
| Quercus | 1.0 | 4.6 | 17.9 |
| Spirea | 0.9 | 0.4 | 17.9 |
| Picea | 0.9 | 0.4 | 16.0 |
| Total | 78.0 | 97.6 | |

Source: Raupp M.J., J.A. Davidson, J.J. Homes and J.L. Hellman, "The Concept of Key Plants in Integrated Pest Management for Landscapes", *Journal of Arboriculture*, 11(1): 317-322, 1985.

**Table 2-3: Five "most" and "least" pest prone trees and shrubs**

Selected from the 30 most common plants encountered in 6 Maryland communities in 1982

| Plant | % of plants with pests | Plant | % of plants with pests |
|---|---|---|---|
| **Trees** | | | |
| Peach | 100 | Black locust | 0 |
| Crabapple | 78 | Black gum | 0 |
| Apple (fruit) | 67 | White oak | 3 |
| Flowering cherry | 31 | Tulip poplar | 4 |
| Dogwood | 26 | Hickory | 4 |
| **Shrubs** | | | |
| Pyracantha | 67 | Yew | 0 |
| Lilac | 60 | Honeysuckle | 0 |
| Boxwood | 43 | Barberry | 6 |
| Rose | 37 | Arborvitae | 7 |
| Euonymous | 36 | Viburnum | 8 |

Source: Raupp, M.J. and R.M. Noland, "Implementing Landscape Plant Management Programs in Institutional and Residential Settings", *Journal of Arboriculture*, 10(6): 161-169, 1984.
"Pests" include insects, mites, diseases and cultural problems.

A similar study was conducted in Minnesota in 1987. A total of 2,136 plants were surveyed on 90 homesites. A list was prepared of the "key plants", the ornamental plants that have serious, persistent pest problems. Some plant species were found to be problem-prone (Table 2-4) and homesites containing those plants required additional time for monitoring.

In summary, the identification of key plants on a regional or local basis can assist by indicating which genera or species are pest prone and therefore will serve as the focus of monitoring and intervention activities on landscape sites.

**Table 2-4: Relative abundance of 10 woody ornamental plants most affected by pests.**

Data from 90 homesites in Owatonna, Minnesota (total of 2,136 plants)

| Plant Species | % of plants with problems | % of total plants |
|---|---|---|
| Birch (*Betula pendula*) | 100 | 0.3 |
| Elm (*Ulmus americana*) | 100 | 0.4 |
| Honeysuckle (*Lonicera tatarica*) | 95 | 5.6 |
| Hawthorn (*Crataegus* spp.) | 89 | 0.9 |
| Currant (*Ribes alpinum*) | 83 | 2.8 |
| Crabapple (*Malus* spp.) | 78 | 2.5 |

Ball, J., "Efficient Monitoring for an Urban IPM Program", *Journal of Arboriculture*, 13(7): 174-177, 1987.

### iii) The concept of key pests

Key pests of landscape plants have been determined for a variety of geographic regions and management systems. List of key pests serve important purposes: they clearly indicate that although the overall pest diversity is large in landscape systems, rather few insects and mites create the majority of problems. As with key plants, the concept of key pests will allow the landscape manager to concentrate monitoring efforts on the pest most likely to incur problems year after year.

In 1986, the Department of Forestry, Michigan State University, surveyed 2,861 municipalities across the U. S. regarding the most important pests in their landscapes. The survey revealed that a group of 10 species or groups accounted for 63% of the total insect problems encountered by municipal foresters.

**Table 2-5: The most important insect and disease pests in 1986 for the U.S.A.**

| Rank | Insect | Weighted value | Rank | Disease | Weighted value |
|---|---|---|---|---|---|
| 1 | Aphids | 947 | 1 | Dutch Elm Disease | 773 |
| 2 | Gypsy Moth | 546 | 2 | Anthracnose | 299 |
| 3 | Elm Leaf Beetle | 445 | 3 | Verticillium | 140 |
| 4 | Borers | 451 | 4 | Maple Decline | 135 |
| 5 | Tent Caterpillar | 351 | 5 | Oak Wilt | 133 |
| 6 | Scales | 335 | | | |
| 7 | Bagworm | 322 | | | |
| 8 | Webworm | 265 | | | |
| 9 | Ants | 218 | | | |
| 10 | Elm Bark Beetle | 196 | | | |
| Total value of above insects: | | 4076 | Total value of above diseases: | | 1480 |
| Value of all insects: | | 6502 | Weighted value of all diseases: | | 2186 |
| Percent of all pests: | | 74.8% | Percent of all pests: | | 25.2% |

Source: Wu, Z., S. Jamieson and J. Kielbaso, "Urban Forest Pest Management", *Journal of Arboriculture*, 17(6): 150-155, 1991

Note: The weighted value is done according to rank of listing: first = 6, second = 5, etc.

A less formal study conducted in 1993 by the trade magazine "American Nurseryman" asked ten entomologists working in various universities across the United States to list the worst pests in their regions for economic damage to woody ornamental nursery stock. The list of the 10 worst pests of ornamentals in the U.S. included some found in B.C. (Box 2-6).

**Box 2-6: The "Most Wanted List" of pests from American Nurseryman in 1993**

1- **Spruce Spider Mite** (*Oligonychus ununguis*), a serious cool-weather pest of conifers in nurseries, landscapes and Christmas tree plantations. With heavy infestations, the needles fade to brown and drop prematurely. A related pest is the two-spotted spider mite (*Tetranychus urticae*).

2- **Black Vine Weevil** (*Otiorhynchus sulcatus*), one of the most common and damaging pests of woody plants in nurseries and landscapes throughout the United States and Canada. The larvae feed in the spring on the roots of a wide range of woody ornamentals.

3- **Azalea Lace Bug** (*Stephanitis pyrioides*) and many other lace bug species attack various woody ornamentals. This insect injures azaleas by inserting its needlelike mouthparts into the leaves to extract plant fluids.

4- **Deer** (*Odocoileus virginianus*) inhabit the fields and edges of forests, which brings them into contact with ornamentals in nurseries and landscapes. They feed on the twigs and stems of a wide variety of plants.

5- **Aphids** (many species) are common on woody plants. They cause the distortion of new plant growth, secrete honeydew that drops on people and cars and some species carry viruses with them.

6- **Pine Needle Scale** (*Chionaspis pinifliae*) will infest urban plantings rather than natural forests. Other scale species are predominant in British Columbia, including Lecanium scale and oystershell scale.

7- **Peachtree Borer** (*Synanthedon exitiosa*) and other clearwing borers are some of the most aggressive and damaging borers of woody plants throughout North America. This insect feeds under the bark and may kill plants by girdling.

Source: Turner, C.B., "America's 10 Most Wanted", *American Nurseryman*, May 1, 1993, pages 28-35.

## B) IDENTIFICATION AND DIAGNOSIS IN URBAN LANDSCAPES

The goal of identification is to obtain the correct information about the pest and / or the problem. A good diagnosis is essential to recommend an effective treatment for the problem on site. Diagnostic ability results from a broad range of both academic and field experience mixed together with a great deal of common sense.

### i) Plant diagnosis in the field

A thorough understanding of the appearance and function of a healthy plant are necessary before a sick plant can be recognized. The appearance throughout the year of each common plant species in an area should be known.

**Plant Examination**

Plant examination should be a study of the total plant, including both below ground and above ground investigations, plus studies of the conditions around the plant and the plant's history. The examination can begin at any point on or around the plant but firm conclusions as to the cause of the problem should be deferred at least until the examination is finished.

Examine leaves, branches and the trunk for the presence of necrotic tissues, abnormal tissue growth and evidence of pathogens. Roots are more difficult to examine but may provide the information on the origin of the problem condition. The top soil surface can be carefully removed in one area close to the plant and the condition of the roots checked by removing a small section of bark with a small knife. Finally, the location of the tree, the soil, the proximity to roads or buildings can all give clues to stresses.

Box 2-7 provides a sample form for diagnosing problems. This can be adapted for use with any urban landscape plants. It is important to collect as much information as possible on the site and make a thorough examination of the affected parts.

**Box 2-7: Guide to diagnosing shade tree problems**

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In order to diagnose a tree problem, the pest manager needs much information. The answers requested in this guide may aid diagnosis. Please look at the tree and its surroundings carefully while you answer these questions. Any one point may be critical.

1: Date: ______________________________

Name and Address: ______________________________

2: Kind of tree: ______________________ Age: __________ Height: __________

3: Exactly what is troubling about the tree's condition? ______________________________

______________________________

4: Are more trees of the same kind nearby?______________________________

Are these or others similarly affected? ______________________________

5: Has the trouble appeared in previous years? ______________________________

6: Has this or nearby trees been sprayed or dusted for pest control?______________________________

If so, when? ____________________ What materials? ______________________________

7: Have chemical weed killers been used in the vicinity? If so, when? ______________________________

8: Is there any evidence of mechanical injuries from lawn mowers, automobiles, tools or machinery, or of heavy pruning or tree thinning?______________________________

9: Has the plant received special treatment for this or other troubles? ______________________________

10: Any comments on unusual local weather conditions, present or previous season? ______________

______________________________

11: Is the tree shaded by buildings or other objects, or in an exposed, windy location for part or all day?

______________________________

12: Is the soil generally sandy, heavy clay, intermediate? ______________________________

Wet or dry? Well or poorly drained? ______________________________

13: Has fertilizer or other material been added to the soil around or above the roots? ______________

If so, when? What materials? ______________________________

15: Has there been road construction or other construction near the tree in the past 15 years? ________

When? Describe: ______________________________

Has the soil near the plant been packed hard by automobiles or other traffic? ______________

16: Are gas, water, sewer or other pipes or conduits in the ground under or near the plant? ___________

Have tests for leakage been made? ______________________________

17: Describe any mushrooms, bracket fungi, mold, fungus growth, insect or mites on the tree. ___

Describe any wounds or unusual appearance of foliage, twigs, flowers, fruits, bark or roots.

Describe any projecting stubs of broken branches, any dead branch or any open wounds.

______________________________

18: Where possible, submit generous specimens of affected parts described in question 18. carefully chosen to include various stages of the trouble. Wrap them in newspaper or in heavy cardboard with name and address. Fruit, fungus and insect should be shipped in a rigid container, not in plastic.

19: Dig gently around the base of the tree, exposing the surfaces of the major roots without wounding them, by using a trowel and whisk broom. Anything unusual? ______________________________

______________________________

20: Send in a plastic container about 500 ml. of soil taken from a depth of about 15 cm at 4 or more separate points, each away from the tree trunk but not farther than the branches extend. Do not include the very surface soil.

21: Clip twigs, at least 1 cm thick and 15 cm long, whose wood is still moist, from any branches whose foliage is wilted. If there is brownish discoloration in the sapwood, wrap the twigs in waxed paper.

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Source: F.W. Holmes and D.S. Welch, cited in Tattar, T.A., "Diseases of Shade Trees", Academic Press, Inc. (New York, NY), 1978.

### Equipment

The equipment required for a proper diagnosis is not sophisticated. The tool box includes hand lens of 10 or 16 magnifications, commonly available and invaluable in the field for a better look at insects and disease signs and symptoms. A good pocket knife, hand shears and, if possible, pruning shears and a pole pruner, will be useful to cut off and examine plant parts. Cutting tools should be disinfected on a regular basis as they can transmit bacterial diseases from one site to the next.

A narrow trowel helps in removing soil for root examination and a soil probe helps in collecting soil samples. Vials, bags and other containers are needed to hold collected samples and coloured surveyors tape can be used to identify individual plants. Sticky traps and beating trays are useful for monitoring a variety of insects and mites. Report forms for notes and field guides for identification are also necessary.

### Sampling procedure

When it is not possible to diagnose a problem in the field, it may be necessary to collect a sample of the affected plant for further examination in the office or under a microscope. In some cases, the sample may be sent to a provincial, federal or private laboratory for further identification of the possible pathogens. For example, the B.C. Ministry of Agriculture, Fisheries and Food maintains a plant diagnostic laboratory to help commercial horticulturists, farmers and landscape companies in the diagnosis of problems. The laboratory is located in Abbotsford.

Pest managers who wish to submit a sample for analysis must first contact the laboratory to obtain the proper containers and instructions to follow during collection and preparation. Accurate records are kept of the area sampled, the appearance of the plant, and the history of the problem. Every sample is labelled with the name and location of the plant, the date of sampling and a brief description of the problem. The sample is hand-delivered or sent by courier.

For the diagnosis of leaf, shoot, branch or root problems, it is necessary to sample diseased and healthy specimens of the plant parts.  The sample should include the transition from diseased to healthy tissue, and be collected as soon as the symptoms are noticed. Samples are kept fresh and cool, as dryness or wetness may provoke decay or foster secondary organisms that mask causes or symptoms.

The procedure for submission of samples to the B.C. Plant Diagnostic Lab is outlined in Box 2-8.

**Information from the client**

Much information may be gained by questioning the client on recent events or local conditions.  On mature trees, the damage may not show for many years.  Local conditions of weather and soil type are necessary for accurate diagnosis of plant diseases.  The extremes of temperature and normal range of moisture conditions are important factors in both infectious and non-infectious disease.  Knowledge of both recent history and past history of these conditions is needed, since plants often continue to respond to environmental stress after the stress has stopped.  The physical nature and chemical composition of soils are important because they determine which plant species adapt most successfully.

Finally, a note should be made about working on private property: a pest manager should always remember that they are a guest on the site.  The owner should be advised of the visit and notified of the planned activities.  In all cases, as few samples as possible should be taken to avoid changing the appearance of trees and plants.  Cleaning up any debris and replacing disturbed soil also shows a concern by the diagnostician for the client's plant and hence a concern for the client.

**Box 2-8: Submission of samples to the plant diagnostic lab**

1. Specimens must be fresh. Use plastic bags.
2. Send a much as possible of a typical diseased (not dead or badly decayed) plant, including roots. Do not include moist paper towels when sending samples.
3. Try to send several plants or plant parts showing the various stages of infection; include a healthy plant for comparison.
4. Dig up plants rather than pulling them from the ground to preserve the roots. If plants are potted, send the whole pot. Enclose roots and pots in a plastic bag or wax paper that is secured at the plant crown to prevent drying or roots and contamination of leaves with dirt. Please do not include moist paper towels with sample.
5. Enclose the top of the plant in a plastic bag secured at the plant crown or wrap carefully in newspaper.
6. Include roots with samples showing symptoms of dieback.
7. Turf disease samples must be at least 10 cm by 10 cm and as deep as the roots. Send two samples at least, with one sample per plastic bag. Include the margin of the affected areas in each sample.
8. Provide as much detail as possible (a form is available) and package securely.
9. Urgent samples can be sent by Greyhound to the Langley bus depot. These samples usually arrive the next day. Very urgent or perishable samples should be sent by courier. Send samples prepaid, door-to-door.

Adapted from: British Columbia. Ministry of Agriculture, Fisheries and Food, "Plant Diagnostic Lab Submission Form", Form AGR. 2612. Surrey, 1992.

### ii) Diagnosing plant problems caused by insects

Most feeding pests cause visible and predictable changes in the plant's appearance, enabling the trained observer to make an educated guess about the pest identity. Insect and mite damage symptoms can be grouped conveniently into five categories (see Table 2-9).

**Table 2-9: Symptoms or signs of attack by insects and mites**

| Category | Pests often responsible |
|---|---|
| I. Chewed foliage or blossoms | Larvae of Moth, Butterflies, Sawflies<br>Beetle larvae or adults<br>Grasshoppers |
| II. Bleached, bronzed, silvered, stippled, flecked, streaked, or mined leaves | Spider mites and Leafhoppers<br>Lace bugs and Plant bugs<br>Thrips, Aphids, Psyllids, Leaf miners |
| III. Distortion, swelling, twisting, cupping of plant parts | Thrips, Aphids, Psyllids<br>Gall makers, Eriophyid mites |
| IV. Dieback of twigs, shoots, or entire plant; stems, branches and exposed roots (sometimes with holes in bark that Exude wood dust, frass, gum, or pitch) | Wood borers<br>Bark beetles<br>Scale insects, Gall makers<br>Larvae of root-feeding beetle |
| V. Presence of insect, or insect-related, products on plants: | |
| Honeydew and sooty mold | Aphids, Psyllids<br>Soft scales<br>Leafhoppers, Mealybugs, Whiteflies |
| Fecal specks on leaves | Lace bugs and some Plant bugs<br>Greenhouse thrips<br>Some Leaf beetles, some Sawfly adults |
| Tents, webs, silken mats | Tent caterpillars<br>Leaf tiers and Webworms |
| Bags and cases | Case bearers |
| Spittle | Spittlebugs |
| Cottony fibrous material | Adelgids<br>Mealybugs, some Aphids, some Scales |
| Slime | Snails and slugs |
| Pitch tubes | Some bark beetles |
| Pitch or gum masses and sap flow | Larvae of certain moths, beetles, midges |

Source: Koehler, C.S., "Symptomatology in the Instruction of Landscape Ornamentals Entomology", *Journal of Arboriculture*, 13(3): 78-80, 1987
and Johnson, W.T. and H.H. Lyon, "Insects that Feed on Trees and Shrubs", Cornell University Press (Ithaca, NY), 1988.

### iii) Diagnosing plant problems caused by environmental disorders

To diagnose a plant problem, it is necessary to first determine whether the disease is caused by an environmental disorder or by a pathogen. In cases where typical signs or symptoms of a disease are present, it is fairly easy for an experienced person to determine the cause of the problem. In most cases, however, a detailed examination of the symptoms and an inquiry into characteristics beyond the obvious symptoms are necessary for a correct diagnosis.

The lack or excess of life-supporting elements is the common characteristic of non-infectious diseases of plants. Non-infectious diseases are caused by environmental conditions such as excessive heat or cold, lack of nutrient, over or under-watering, unfavourable soil, cultivation practices, traffic or a number of other hazards.

Many of these disorders involve the entire plant and will lead to poor growth, damaged appearance or even the death of plants. In many cases, plants weakened by environmental disorders are more susceptible to other diseases and insects.

**Box 2-10: Common causes of environmental disorders**

**Moisture**

Moisture disturbances in the soil are probably responsible for more plants growing poorly and being unproductive annually, over large areas, than any other single environmental factor. Lack of water stunts plants and causes pale green to light yellow leaves. If the drought continues, the plant wilts and dies.

Excess water is a serious problem in coastal landscapes. Poor drainage or flooding of planted sites result in quick and serious damage to plants. As a result of excessive soil moisture, the fibrous roots of plants decay, probably because of the reduced supply of oxygen to the roots. Once parts of roots are killed, more damage is done by disease organisms that may be greatly favoured by the new environment. Plants lack vigour, wilt, have pale leaves and may die.

**Temperature**

The minimum and maximum temperatures at which plants produce normal growth vary greatly with the plant species and with the stage of growth of the plant. Plants are generally injured faster by high temperature, causing sunscald, scorching and burn injuries. Sunscald symptoms on leaves include irregular areas that are first pale green, then collapse to form brown, dry spots.

Sudden low temperatures in the fall or in the spring may kill roots or flower buds. Plants most susceptible are those in poorly drained soils, in wind-swept areas, or making considerable growth in late fall. Winter cold followed by warm temperature causes bark cracks on the sun-exposed south-west side. These cracks are most common on Norway maple, elm, linden, oak, and planes.

**Nutritional deficiencies**

Plants require several mineral elements for normal growth. When these are present in the plant in amounts smaller than the minimum levels required for normal plant growth, the plant becomes diseased and exhibits various external and internal symptoms.

The foliage of rhododendrons and mountain-laurel may turn yellow because of iron unavailability, due to excessive lime in the soil. This condition commonly occurs when these acid-loving plants are planted near a cement wall.

**Toxic soil minerals**

Soils often contain excessive amounts of certain elements, which at high concentration may be injurious to the plants. For example, salts used in the winter for the melting of snow on roads and sidewalks may accumulate in the landscape soil and cause stunting, leaf burn, wilting and eventually plant death.

**Herbicide injury**

Much of this damage is caused by direct application of the wrong herbicide, drift of herbicide onto the plant or the wrong dose of the pesticide. The affected plants show various degrees of distortion or yellowing of leaves, browning, drying and shedding of leaves, stunting and even death of the plant.

Herbicides can also affect landscape plants by causing an increase in disease organisms. Soil microorganisms associated with root diseases will colonize and multiply on the tissues of weeds dying from herbicide treatment: this may lead to an increase of the same disease on susceptible plants near-by.

**Air pollution**

Almost all air pollutants causing plant injury are gases, but some particulate matter or dusts also affects vegetation. Ozone from automobile exhausts is the most destructive air pollutant of plants and causes stippling, mottling and chlorosis of leaves, primarily on the upper leaf surface. Premature defoliation and stunting may occur.

Maples exposed to sulphur dioxide show ivory-white markings on the leaves, whereas Douglas-firs exhibit a reddish discoloration of the needles.

**Other human activities**

An impact on the overall health of the tree can result from branches broken by energetic children, scars from automobile impact, girdling of the trunk from string weeder or lawnmower injury, contamination of the soil with construction materials, or vandalism in urban areas.

Adapted from: Agrios, G.N., "Plant Pathology", Academic Press Inc. (San Diego, CA), 3rd Edition, 1988. and Pirone, P.P., "Diseases and Pests of Ornamental Plants", John Wiley and Sons, Inc. (New-York, NY), 5th Edition, 1978.

### iv) Diagnosing plant problems caused by diseases

A uniform decline in a mixed planting is caused by environmental disorders. When the decline affects only one genus or species in a mixed planting, or only one plant in a same-species planting, the cause is an attack by an infectious organism, or disease.

The presence of pathogens in an active stage on the surface of a plant indicates that they are probably the cause of the disease. If no such signs are present on the surface of a diseased plant, then it is necessary to look for additional signs and symptoms of pathogens inside the diseased plant. These are usually at the margins of the affected tissues, at the vascular tissues, at the base of the plant, on or in the roots.

A key point in diagnosis is to be able to differentiate between organisms that attack living plant tissues and organisms that grow on dead tissue. In some cases, the organism responsible for killing the plant tissue is replaced by another organism feeding on dead tissue: an improper examination of the affected plant will lead to an incorrect disease diagnosis. The best place to look for pathogens in a pure state is in the most recently killed tissues. In some cases, the plant will be attacked by two or more pathogens and may develop many types of disease symptoms.

Plant diseases may be classified according to the symptoms they cause (leaf spots, root rots), according to the plant organ they affect (root diseases, fruit diseases) or, more appropriately, by the type of pathogen that causes the disease (bacteria, fungi, nematode). Some common plant diseases in Box 2-11 are listed by the symptoms they cause.

**Box 2-11: Some signs and symptoms of infectious diseases**

**Foliage diseases**

Various foliage diseases affect the photosynthetic activity of trees, resulting in subtle color changes such as mottling, chlorosis or necrosis.

Examples include the powdery mildews, affecting a wide range of ornamental plants. This disease is recognized by white or grey powdery growth on leaves and shoots. Another example is the dogwood anthracnose, now widespread in south coastal B.C.

Conifers do not have the ability to regrow needles, therefore foliage diseases are important because they reduce growth and may cause death. Examples include needle cast on pines and rust disease on white pine.

**Shoot blight**

Caused by fungi and bacteria that aggressively parasitize succulent, rapidly growing shoots. For example, crab apple, cotoneaster, firethorn, hawthorn, quince and mountain ash are susceptible to the bacterial disease fire blight. Foliage and branches rapidly darken, wilt and die. Blighted foliage often remains attached to the tree after autumn leaf fall.

**Fruit diseases**

Spots, rots or deformity of fruit may spread to the twigs and branches. Examples include brown rot on cherries, plums and other *Prunus*, or botrytis on greenhouse crops and flowers.

**Vascular wilts**

The water transport is disrupted inside the tree, resulting in wilt and death. Examples include Dutch Elm Disease and a wilt caused by *Verticillium* that affects many ornamental plants.

**Stem cankers**

Localized diseases of woody plants, they result in a shrinking and dying of the tissues, which later crack open and expose the wood underneath. Examples are brown canker of roses, chestnut canker, and apple nectria canker.

**Root rot**

Initial symptoms of root rot are similar to nutrient deficiencies, with the foliage becoming smaller and yellowed. Mushroom may grow on the soil. Excavation of root systems reveals discoloured tissue and / or absence of feeder roots. Examples include Armillaria root rot and Phytophthora root rot.

Adapted from: Manion, P.D., "Tree Disease Concepts", Prentice-Hall Inc. (Englewood Cliffs, NJ), 1991.

## C) INJURY LEVELS IN URBAN LANDSCAPES

The goal of the injury level is to determine when the pest problem is likely to require some action.

The site monitored determines what type of injury level should be applied. For example, the main focus of a nursery operation is to sell healthy plants. The pest management program should consider the value of the crop, the damage associated with a pest and the cost of treatment. The injury level should be established to ensure limited economic damage to the crop.

On public boulevards, the cost of replacing a dead tree is hundreds of dollars. On private property, a mature landscape tree provides shade and added value to the property. In such cases, the injury level takes into account the cost of maintaining healthy trees versus the cost of replacing sick trees.

In other situations, plants are not grown or maintained for direct economic profit. The visual appearance of the plant is the most important factor and constitutes what is often called an "aesthetic" value. Different clients have different tolerance levels for visible insects or visible damage.

The "aesthetic" injury level is based on various factors:

1- The pest species (is it controllable? does it only feed or does it transmit viruses?).

2- The characteristics and location of the plant (Is it bordering a footpath? Is it a show garden?)

3- Public attitude (is the treatment to protect the plant or to satisfy the public?).

For example, aphids feeding on a boulevard tree may cause only minimal damage to the plant, but the honeydew secreted by the aphids and falling on cars is unacceptable to the car owner. Such trees may require treatment, whereas similar trees located in a vacant field will not require treatment.

In recent years, researchers have attempted to quantify the relationship between plant injury and aesthetic perceptions. Some studies indicate the majority of people discriminate injury at or below 10% of the affected plant or landscape. For example, attendees of floriculture trade shows were surveyed regarding their perceptions of injury caused by a serpentine leaf miner on chrysanthemums. The most rapid decrease in the willingness to buy injured plants occurred at injury levels around 10% (Raupp et al, 1992).

Other studies have showed that complete control of certain pests is not required to sell some plants in nurseries. During a one-day plant sale in California in 1991, some customers ignored or did not recognize some types of pest damage. Plants of the coyote bush (*Baccharis pilularis*) affected by lace bug feeding sold faster than plants less affected, possibly because customers were attracted to the silvery appearance of the stippled foliage. On other plants, sales were adversely affected by customer disdain of plant injury, such as valley oaks (*Quercus lobata*) affected by oak leaf phylloxera (Flint et al, 1993).

A comprehensive effort to develop an aesthetic injury level was conducted in the city of Norfolk, Virginia. The orangestriped oakworm had become a major pest, but pesticide application on trees with little defoliation resulted in needless pesticide use. In 1987, a survey indicated a majority of residents were willing to tolerate some defoliation of the street oak trees. The effect of defoliation on root starch reserves was examined as an indication of tree vigour, establishing that 25% defoliation did not result in a significant reduction of starch content.

In 1988, a recommendation was made to spray only trees that had over 25% damage at the time of monitoring: this level of defoliation was aesthetically acceptable to many residents and did not affect tree health. The result was an 80.3% decrease in pesticide use compared with 1987. The total cost of this program for 1988, including monitoring, was 55% lower than in 1987 (Coffelt and Schultz, 1990).

## D) ACTION LEVELS IN URBAN LANDSCAPES

The goal of the action level is to determine when the treatment must take place to prevent pest numbers from reaching the injury level.

Woody plants can support a low-level pest infestation without suffering serious physical or aesthetic injury. Thus, the IPM approach will accept some level of pest presence, and an action threshold determined to prevent serious physical or aesthetic injury. This approach is used commonly in landscape situations, when pests are detected but no treatment applied because of the low pest numbers.

At this time, the action threshold for most landscape pests has not been determined through experimentation and validation. Thus, in a new IPM program, the action threshold for each pest or problem will be an arbitrary decision. Careful record-keeping during monitoring, a correlation of plant vitality and pest numbers, and experience over time will allow the development of meaningful thresholds for each problem. The objective is to become skilled and comfortable at estimation of pest density and plant damage, about how various levels of pest density affect the plant, and when the treatment should be initiated to prevent excessive damage.

A presentation at the annual conference of the International Society of Arboriculture, held in Vancouver in 1988, discussed the concept of action threshold. Frequently, the visual threshold replaces the action threshold: when the pest can be seen, a treatment is applied. However, vigorous plants can tolerate some pest activity and the aesthetic damage occurs before the pest population causes measurable plant stress This approach can be modified so treatments are applied on a need-only basis through monitoring of the plant for pests or problems, a systematic assessment of plant vitality, and the effect of the pest on plant performance over time (Nielsen, 1989).

## E) TREATMENT STRATEGIES IN URBAN LANDSCAPES

The goal of the treatment strategy is the selection of planned tactics or methods to prevent or suppress the pest populations with a minimum of ecosystem disruptions.

Many of the "softer" pesticides have received considerable attention for use in urban landscape situations in recent years and are available in commercial formulations.

### Horticultural oils

They are applied in the late dormant season, function as insecticides and miticides primarily by suffocating eggs. Good control is achieved of scale insects, mites and mite eggs, aphid eggs, and caterpillar eggs. The use of dormant oil presents many advantages. They are relatively safe for the environment and dissipate quickly by evaporation. Most predators and parasites are killed on contact, but the population can rebuild because of the short-term residual activity of oil. Dormant oil provides a wide range of pest control, well suited for IPM.

Recently, the manufacture of highly refined, lighter oils has made possible the summer use on ornamental plants. However, few products are registered for this use in Canada. Also, oil application on growing foliage may result in phytotoxic side effects such as leaf drop and dead twigs. The phytotoxicity is increased when plants are stressed. Lack of moisture, extreme temperatures, prolonged winds or other poor conditions predispose spray damage.

Horticultural oil registered for summer use is part of the pest management tools of Mac McNear, Arbour-Care Tree Service in Vancouver. A mixture of 1% summer oil with 1% insecticidal soap gives good control of rhododendron lacebugs, boxwood psyllid and spider mites on junipers, without phytotoxicity to the plant. The mixture is especially good where eggs are protected with a cottony coating, such as with cottony scale and woolly adelgids. Thorough coverage is essential.

In all cases, instruction on the label must be followed.

**Insecticidal soaps**

Soaps penetrate and disrupt the cellular membranes of certain target pests and kill them. They are used to control soft-bodied pests such as aphids, scales, psyllids and mites. Slow-moving insects are more susceptible than mobile insects. Many winged beneficial insects can fly away from the spray. This product is essentially non-toxic to humans, making it appropriate when insecticide drift is a problem. Phytotoxicity is usually not a problem except for some hairy plants holding the soap solution, which causes leaf burning.

**B.t. (*Bacillus thuringiensis*)**

This is a microbial insecticide effective against the larval stage of many caterpillars such as leaf rollers, tussock moth, apple-and-thorn skeletonizer, etc. Current formulations of B.t. lose their effectiveness in a short period of time. Caterpillars will stop feeding immediately but may take several days to die.

Many other products are available and can be regarded as a least-toxic option, while others are currently being tested and may become helpful in the future. These include sulphur, copper, silicon dioxide (diatomaceous earth), boric acid and borate products, insect parasitic nematodes and insect growth regulators.

A general look at available treatment strategies can be obtained from Box 2-12.

**Box 2-12: Summary of treatment strategies**

Type of strategy and examples

A) DESIGN OR REDESIGN OF THE LANDSCAPE OR STRUCTURE

1. Selection of plants that are resistant to pests and attractive to beneficial species.
2. Structural designs that are conducive to plant health, appropriate to the weather, soil, water and human resources of the site.

B) HABITAT MODIFICATION

1. Reduction of pest harbourage, food or other life support requirements.
2. Enhancement of the environment required by the predators, parasites, competitors.

C) HUMAN BEHAVIOR CHANGES

1. Horticultural controls and maintenance practices such as mowing, cultivating, watering, fertilizing, pruning, mulching, waste management, etc.
2. Education:
   of the public, landscape and building maintenance personnel, policy makers;
   to modify the judgment on aesthetic damage and value of predator insects.

D) BIOLOGICAL CONTROLS

1. Conservation of pests' natural enemies through the proper selection of materials.
2. Augmentation of existing natural enemies by releasing additional numbers of same.
3. Inoculation by the repeated reintroduction of effective natural enemies.
4. Importation of the host-specific natural enemies of exotic, invading pests.

E) PHYSICAL CONTROLS

1. Barriers, trunk wraps.
2. Traps or sticky traps.
3. Mechanical action such as plowing, hand weeding, etc.

F) CHEMICAL CONTROLS

1. Pheromones to lure and / or confuse the pest.
2. Juvenile hormones that arrest pest development.
3. Repellents, fumigants and sterilants.
4. Pesticidal soaps and oils
5. Contact, stomach and other poisons.

Source: Olkowski, W., H. Olkowski and S. Daar, "What is Integrated Pest Management?", *The IPM Practitioner*, November / December 1991.

## F) EVALUATION IN URBAN LANDSCAPES

The goal of the evaluation is to inspect the site after the treatment to verify the effect on the problem.

An important component of IPM is to evaluate whether or not it is working, and fine-tuning when necessary. The need to regularly apply a toxic material is an indication the program is not working and that other solutions should be sought to reduce pesticide use.

Using the monitoring data, a number of questions are asked at the end of the season. These are summarized in Box 2-13.

**Box 2- 13: Questions to evaluate an IPM program**

1- Was the pest population adequately suppressed?
2- Was the pest population suppressed in a timely manner?
3- Was the planned procedure used? If not, what was different?
4- How did the cost of suppression compare with the potential value of damage?
5- What damage occurred? What damage was tolerable?
6- Were natural enemies affected by treatments? How?
7- If natural enemies were killed by treatments, will it cause problems elsewhere or at a later period?
8- Were there any other side effects from the treatments?
9- Were the side effects added to the cost of treatments?
10- If ineffective, should the treatments be repeated?
11- If ineffective, should another kind of treatment be evaluated?
12- Is the plant or structure worth maintaining?
13- Can the site be changed to eliminate or reduce the problem for the same cost of treatment?
14- Were there unanticipated consequences of old or new methods used?

Source: Daar, S., H. Olkowski and W. Olkowski, "IPM Training Manual for Landscape Gardeners", Bio-Integral Resource Center ( Berkeley, CA), 1992.

Cost effectiveness is central to a decision to continue an IPM program. Thus, a calculation of the change in pesticide use and related cost is an important part of the final evaluation.

Earlier in this chapter, we discussed the "key plant" concept with a study conducted in Maryland between 1980 and 1982. The same researchers conducted another demonstration in 1983 and 1984 within a city of 27,000 people. The project documented 354 acres inhabited by 1,661 residents under IPM management in 1983, expanding to 476 acres in 1984. Table 2-11 provides economic information from this study.

Over the first two years of the program, pesticide sprays were reduced by an average of 83% and the overall cost associated with pest management was reduced by 22%. In 1985, the program was transferred to a private consultant and not all data was made available. However, economic information indicated that costs continued to be reduced. The mean savings resulting from the adoption of IPM was $12.90 per acre.

**Table 2-14: Economic assessment of traditional vs. IPM programs in Maryland, U.S.A.**

| Community | Cost (in $) | | | | Size of site |
|---|---|---|---|---|---|
| | 1982 | 1983 | 1984 | 1985 | |
| 1 | $2895 | $ 784 | $ 822 | $ 211 | 131 acres |
| 2 | $3750 | $1663 | $2986 | $ 420 | 56 acres |
| 3 | $1325 | $ 510 | $ 401 | $ 0 | 17 acres |
| Pesticide total: | $7970 | $2957 | $4209 | $ 630 | 204 acres |
| Labour total: | $ 0 | $2505 | $2779 | $2920 | |
| Total cost: | $7970 | $5462 | $6988 | $3550 | |

1982: traditional management program, including cover spray, no monitoring.
1983, 1984: IPM management program conducted by Maryland University Extension Service.
1985: IPM management program conducted by private consultant.

Source: Raupp, M.J., M.F. Smith and J.A. Davidson, "Educational, Environmental, and Economic Impacts of Integrated Pest Management Programs for Landscape Plants", in: "Integrated Pest Management for Turfgrass and Ornamentals", United States Environmental Protection Agency (Washington, D.C.), 1989.

## G ) REFERENCES


- Agrios, G.N., "Plant Pathology", Academic Press Inc. (San Diego, CA), 3rd Edition, 1988.
- Ball, J., "Efficient Monitoring for an Urban IPM Program", *Journal of Arboriculture*, 13(7): 174-177, 1987.
- British Columbia. Ministry of Agriculture, Fisheries and Food, "Plant Diagnostic Lab Submission Form", Form AGR. 2612. Surrey, 1992.
- British Columbia. Ministry of Agriculture and Fisheries, "A Gardener's Guide To Pest Prevention And Control". Gerber, H.S. editor. Victoria, 1990.
- Coffelt, M.A. and P.B. Schultz, "Development of an Aesthetic Injury Level to Decrease Pesticide Use Against Orangestriped Oakworm (Lepidoptera: Saturniidae) in an Urban Pest Management Project", *Journal of Economic Entomology*, 83(5): 2044-2049, 1990.
- Cordell, C.E. et al, "Forest Nursery Pests", Agriculture Handbook No. 680, U.S. Department of Agriculture, 1989.
- Daar, S., H. Olkowski and W. Olkowski, "IPM Training Manual for Landscape Gardeners", Bio-Integral Resource Center (Berkeley, CA), 1992.
- Davidson, J.A., S.A. Gill, M.J. Raupp, "Foliar and Growth Effects of Repetitive Summer Horticultural Oil Sprays on Trees and Shrubs Under Drought Stress", *Journal of Arboriculture*, 16(4):77-81, 1990.
- Davidson, N.A. et al, "Managing Insects and Mites with Spray Oils", Publication 3347, Statewide Integrated Pest Management Project, University of California (Oakland CA), 1991.
- Derr, J.F. and B.L. Appleton, "Herbicide Injury to Trees and Shrubs: A Pictorial Guide to Symptom Diagnosis", Blue Crab Press (Virginia Beach, VA), 1988.
- Flint et al, "IPM Reduces Pesticide use in the Nursery", *California Agriculture* (Oakland, CA), 47(4): 4-7, 1993.
- Gill, S.A. and D.C. Smith, "Survey Finds IPM Works in Urban Areas", *Grounds Maintenance*, August 1988.
- Harris, R.W., "Arboriculture: Integrated Management of Landscape, Trees, Shrubs, and Vines", Prentice Hall Inc. (Englewood Cliffs, NJ), 2nd Edition, 1992.
- Hitchcock, C.L., and A. Cronquist, "Flora of the Pacific Northwest", University of Washington Press (Seattle, WA), 1978.
- Johnson, W.T. and H.H. Lyon, "Insects that Feed on Trees and Shrubs", Cornell University Press (Ithaca, NY), 1988.
- Keim, R. and W.A. Humphrey, "Diagnosing Ornamental Plant Diseases", University of California (Oakland, CA), 1987.
- Koehler, C.S., "Symptomatology in the Instruction of Landscape Ornamentals Entomology", *Journal of Arboriculture*, 13(3): 78-80, 1987.
- Koehler, C.S., "Insect Pest Management Guidelines for California Landscape Ornamentals", Cooperative Extension, University of California (Oakland, CA), 1987.
- Levesque, C.A. and J.E. Rahe, "Herbicide Interactions With Fungal Root Pathogens, With Special Reference To Glyphosate", *Annual Review of Phytopathology*, 30:579-602, 1992.
- McNair, Mac. Arbour-Care Tree Service (Vancouver, B.C.) Personal Interview. December 8, 1993.
- Manion, P.D., "Tree Disease Concepts", Prentice-Hall Inc. (Englewood Cliffs, NJ), 2nd Edition, 1991.
- Miller, F.D., "The Use of Horticultural Oils and Insecticidal Soaps for Control of Insect Pests of Amenity Plants", *Journal of Arboriculture*, 15(11):257-262, 1989.
- Neely, D. and G.R. Smith, "IPM Strategies Used By Arborists", *Journal of Arboriculture*, 17(1): 8-12, 1991.
- Nielsen, D.G., "Integrated Pest Management in Arboriculture: From Theory to Practice", *Journal of Arboriculture*, 15(2): 25-30, 1989.
- Ohlendorf B.L.P. et al, "Integrated Pest Management for Apples and Pears", Publication 3340, Statewide Integrated Pest Management Project, University of California (Oakland, CA), 1991.
- Olkowski, W., S. Daar, H. Olkowski, "Common-Sense Pest Control", The Taunton Press (Newtown, CT), 1991.
- Olkowski, W., H. Olkowski and S. Daar, "What is IPM?", *Common Sense Pest Control*, 4(3), 1988.
- Perkins, J.H., "Insects, Experts, and the Insecticide Crisis", Plenum Press (New York, NY), 1982.

- Pirone, P.P., "Diseases and Pests of Ornamental Plants", John Wiley and Sons, Inc. (New York, NY), 5th Edition, 1978.
- Raupp M.J., C.S. Koehler, J.A. Davidson, "Advances in Implementing Integrated Pest Management For Woody landscape Plants", *Annual Review of Entomology*, 37: 561-585, 1992.
- Raupp, M.J., M.F. Smith and J.A. Davidson, "Educational, Environmental, and Economic Impacts of Integrated Pest Management Programs for Landscape Plants", in: "Integrated Pest Management for Turfgrass and Ornamentals", United States Environmental Protection Agency (Washington, D.C.), 1989.
- Raupp M.J., J.A. Davidson, J.J. Homes and J.L. Hellman, "The Concept of Key Plants in Integrated Pest Management for Landscapes", *Journal of Arboriculture*, 11(1): 317-322, 1985.
- California Fertilizer Association, "Western Fertilizer Handbook", Sixth Edition, The Interstate Printers and Publishers, Inc. (Danville, Il), 1980.
- Stern V.M., R.F. Smith, R. van den Bosch, K.S. Hagen, "The Integrated Control Concept", *Hilgardia* 29(2): 81-101 1959.
- Sutherland, J.R. and E. Van Eerden, "Diseases and Insect Pests in British Columbia Forest Nurseries", Joint Report No. 12, B.C. Ministry of Forests and Canadian Forestry Service (Victoria, B.C.), 1980.
- Tattar, T.A., "Diseases of Shade Trees", Academic Press, Inc. (New York, NY), 1978.
- Turner, C.B., "America's 10 Most Wanted", *American Nurseryman*, May 1, 1993.
- Whalon, M.E., B.A. Croft, "Apple IPM Implementation in North America", *Annual Review of Entomology*, 29: 435-470, 1984.
- Wood, C., "Distribution Maps of Common Tree Diseases in British Columbia", Canadian Forestry Service (Victoria, B.C.), 1986.