Integrated Pest Management
Pest Management versus Pest Eradication

Traditionally man has relied on chemicals to control both insects and mites. However before even the use of these was commonplace alternative means of control were available and today these are still effective if used properly. Adopting this approach will also reduce the impact of the overuse of chemical pesticides to the environment.

Contrary to popular belief the control of pests does not involve the complete eradication of all insect life but rather can be regarded as a reduction in pest numbers to more acceptable and manageable numbers. By more acceptable, for the sake of this article, this can be defined at levels whereby damage caused does not result in economic loss in the case of nursery crops or a deterioration in playing surface quality from the point of the turf manager.

In the case of nursery crops this is termed an economic threshold level.

Integrated pest management (IPM) is the selection, integration, and implementation of pest control (biological, chemical or cultural) taking into consideration economic, ecological, and sociological consequences. When adopting the IPM approach the following points must be considered:

1. No **single** pest control method will be successful. All control options must be used whether biological, chemical or cultural.
2. **Constant Monitoring** of the pest is needed in order to evaluate the status of a pest population.
3. The **mere presence** of a pest is not a reason to justify action for control.

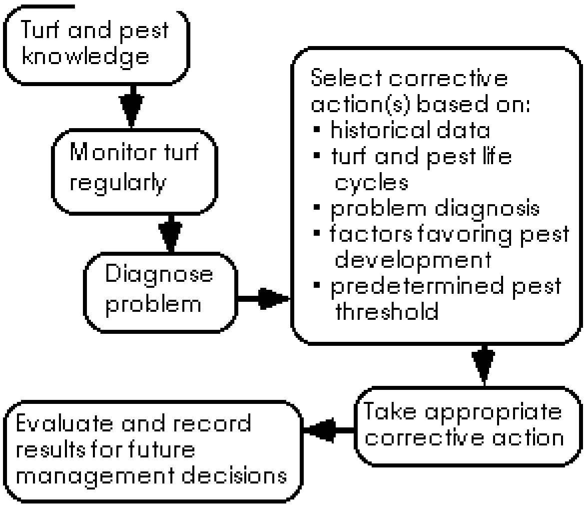
Considerable confusion appears to exist as to what IPM actually is. IPM can in simple terms be regarded as a decision making process which takes into account each particular set of circumstances. All natural environs differ to certain extent and so solutions to pest control problems must be specifically tailored to the problems as they develop. In order to achieve this a programme of constant monitoring must be initiated.

Biological control is not IPM but simply one of the options open to the grower along with chemical and cultural controls and it must also be realised that IPM is not an organic program although it can be used by organic growers if organic materials are used.

From an economic standpoint the cost of IPM usually equates to more traditional ‘pesticide’ based approaches with monitoring and sampling costs being traded for scheduled pesticide applications.

Whether a turf or nursery professional IPM comprises the following components:

Diagram showing the stages in an IPM programme



Monitoring

The absolutely crucial activity influencing the success or failure of an IPM programme is monitoring. This can be achieved by visual methods (counting pests present for example) to using temperature-dependent (degree-day) developmental models with similar principles being adopted for insect, fungus and weed control.

The total amount of heat required, between the lower and upper thresholds, for an organism to develop from one point to another in its life cycle is calculated in units called degree-days (°D). Degree-days are the accumulated product of time and temperature between the developmental thresholds for each day. One degree-day is one day (24 hours) with the temperature above the lower developmental threshold by one degree. For instance, if the lower developmental threshold for an organism is 24°C and the temperature remains 25°C (or 1° above the lower developmental threshold) for 24 hours, one degree-day is accumulated.

Because degree-days are temperature-independent, it is possible to use them to predict development time in experiments with variable temperature. In this case effective temperatures are accumulated day by day, and when the sum reaches *S*, then development is finished.

Example: t_{min} = 10 , S = 100.

Day No.	Average Temperature t	Effective temperature, $t - t_{min}$	Accumulated degree-days
1	15	5	5
2	18	8	13
3	25	15	28
4	23	13	41
5	24	14	55
6	18	8	63
7	17	7	70
8	15	5	75
9	18	8	83
10	15	5	88
11	22	12	100
12	25	15	115

Accumulated degree-days reach the value S = 100 on day 11. Thus, it takes 11 days to complete the development and this information can directly be used to influence when pesticide spraying will be at its most effective.

A practical example of this technique is the use of degree-days to determine when to more accurately time the application of preemergent herbicides. In the USA it has been found that the major preemergence period is when the soil temperature reached an average of 14C and an average 73 degree days had accumulated.

Another method of solving the seemingly impossible task of monitoring pests in complex settings is the concept of **KEY PLANTS, KEY PESTS** and **KEY DISEASES**:

1. **Key Plants** are ones that frequently have diseases and should be monitored on a regular basis.
2. **Key Pests** are those that cause significant damage or may kill trees, shrubs or perennial flowers. These key pests often have special times (windows of opportunity) that they are susceptible to controls. A good example of this is African black beetle on Australian golf courses.
3. **Key Diseases** are those that frequently occur on the plants. Other diseases listed sometimes occur. If conditions at the planting site tend to favour the key diseases, the key plant should not be established there. This latter point is difficult to adhere to if for example a particular green is surrounded by trees and possesses poor air circulation.

In these circumstances the green cannot be replanted with an entirely new grass cover but efforts can be made to thin out the surrounding trees and improve the air circulation.

Cultural Controls

The cultural control option should be our **first** consideration. By cultural control I refer to any non-chemical option that gives a desired crop a competitive advantage over the pest in question. Cultural controls can be either preventive or curative.

Sanitation helps remove seeds, spores, or larvae of pests. Pruning, raking of leaves and destruction of heavily infested plant stock are sanitation techniques useful in nurseries.

Crop Rotation should be considered for ornamental tree and shrub production. Many nurserymen rotate growing areas by planting different types of stock after a rotation. Crop rotations radically alter the environment both above and below ground, usually to the disadvantage of pests of the previous crop. The same crop grown year after year on the same field will inevitably build up populations of pests that have a life cycle similar to that of the crop. More diversity also helps attract beneficial insects. This seems to help reduce attacks by borers and root infesting diseases.

Tillage. Aeration and mulching are important whether in the turf or nursery industries.

Host Resistance uses plants which are less susceptible to pest attack (tolerance) or produce actual toxins (antibiosis) which kill or stop pest growth.

Good Horticulture is one of the simple but commonly ignored methods of pest management. In other words, a "healthy" plant can generally fend for itself against insects, mites and diseases. This means for example not over fertilising to promote lush disease prone growth.

Chemical Controls

If using a pesticide in an IPM programme the aim must be to use no more than necessary to achieve the desired results - a material that only kills the target pest and possesses a high degree of selectivity.

Most of the pesticides are believed to have short residual life spans (this reduces accumulation in the environment), are more selective (this reduces the chance of killing non target animals), and are used at lower rates (this reduces the total chemical "load" used).

In reality this is not necessarily the case and with more traditional chemicals that have been available for a number of years this is generally not the case. Because of these characteristics, we need to be able to better target our applications in order to achieve satisfactory control.

Chemical controls used in IPM should be selected on their total attributes with the aim being to carry out curative ‘spot’ applications rather than preventative blanket applications.

Preventative blanket spraying for pests can extremely injurious as it usually kills beneficial insects and tips the ‘balance’ in favour of pests as these usually have good reproductive ability and can "rebound" faster than their natural controls. This results in what is termed **pest resurgence** and **secondary pest outbreak**.

Resistance is another potential problem that can develop.

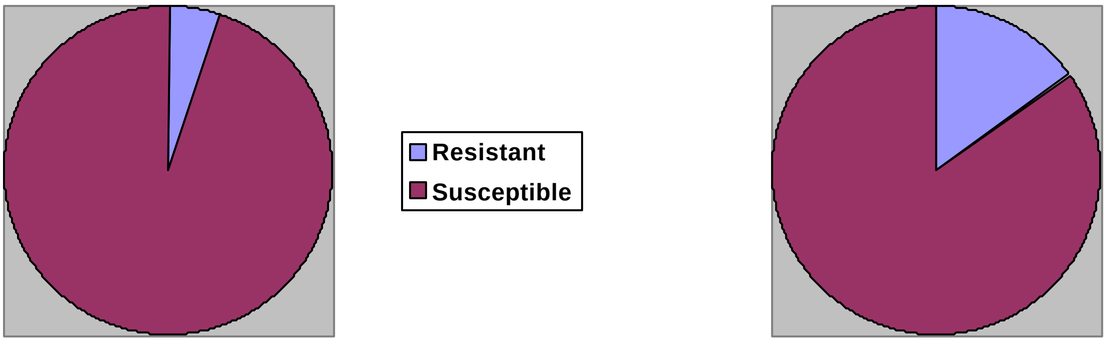


Figure 1. How the application of a pesticide can lead to the development of resistance

Resistance costs money, as when insects develop resistance the immediate action is to increase the rate and frequency of applications to kill the pests. Eventually this results in the need to use a new pesticide to replace the old one. In addition, when insects become resistant the pesticide does not control them as well and they do more damage to the crop.

If an arthropod develops resistance to one pesticide, it has a gene that may allow it to be resistant to another closely related pesticide (or even one not so closely related) even if the population has not been exposed to it yet. For example, insects that become resistant to one organophosphate tend to be resistant to all organophosphates. Also insects that develop resistance to organophosphates usually have partial cross-resistance to carbamates.

This is an extremely important concept to understand as if you simply change the active ingredient of the pesticide that you are using you are quite likely to be worsening the problem if it belongs to the same group.

Key Factors aimed at reducing the development of resistance.

- Aim to limit selection pressure for the season; bearing in mind that spraying for one pest may directly influence other non-target pests.
- Do not rely on one chemical family when carrying out control measures.
- Rotate chemistries and/or modes of action
- Constantly monitor populations and what are termed economic thresholds.
- Aim to maintain good plant health
- Adopt all available tactics for management of a particular arthropod (insect or mite).

By adopting the above ‘rules’, management of insect/mite pests and delaying the onset of chemical resistance can be achieved.

Prevention is better than cure when it comes to resistance management and a resistance management program should be seen as one part of a larger integrated pest management (IPM) approach.
A more recently identified problem with preventative sprays of pesticides has been enhanced degradation and in Australia this ahs occurred with Nemacur (Bayer).

Since most of our current pesticides are organic compounds (i.e., containing carbon, hydrogen and oxygen), microbes are able to use the chemicals as foods or nutrients. Generally these microbes are beneficial in aiding in the removal of these pesticides from the environment. However, when constantly "fed" through general cover sprays, these microbes "learn" to "eat" these pesticides more rapidly than normal.

If using chemicals do so as a last resort only when needed and not habitually.

Pesticides can be classified as either organic or inorganic. Organic means they contain carbon in their molecular structures. Inorganic pesticides, the oldest used pesticides, do not.

Inorganics can be natural earth minerals or man-made compounds. Examples are:
a. **Boric Acid** - Boric acid is a stomach poison and causes insects to die from starvation
b. **Diatomaceous Earth** – this acts by scratching an insects waxy outer covering and causing it to dehydrate.

c. **Sulphur** - Do not apply to plants that have been treated with oil within the last 4 weeks. Don't apply at temperatures above 80° F. Corrosive to metal: use sprayer with plastic parts.

d. **Sodium Fluoaluminate** (=Kryocide, Cryolite) - forms sharp glass-like particles, which puncture insect gut cells if ingested. Since it is a stomach poison, it does not adversely affect beneficial predators and parasites. Good only against leaf feeding caterpillars and beetles.

e. **Mercury, Lead, Arsenates** – Examples of these would have been Comer or PMA which are now no longer used in Australia because of toxicity to mammals.

Oils are petroleum or plant based hydrocarbon chains that have insecticidal activity and are contact pesticides. They work by coating the pest, suffocating it by blocking the openings through which the insect or mite takes in air. Thorough coverage of the affected plant or plant part is necessary to assure that pests are in contact with the oil. Depending on population levels and weather conditions, oils may need to be reapplied regularly.

At least three different types of oil are used for pest control: petroleum, summer or horticultural oil, petroleum dormant oil and citrus oil.

i) **Petroleum summer** or **horticultural oil** is lighter weight oil applied during the active growth of a plant, when green plant foliage is present.

ii) **Dormant oil** is usually defined as heavier weight oil applied in spring prior to bud break or in the fall after leaf drop.

iii) **Citrus oil** is usually added to other pesticide formulations such as soaps and botanical pesticides.

How distillation temperature effects oil classification

DISTILLATION TEMPERATURE	PRIMARY USE	RATE PER 100L
211 degrees C	Summer	1.5-3.0 L
224 degrees C	Summer / Dormant	1.5-2L/Summer
		3-4L/Dormant
226 degrees C	Dormant	2-4 L

Fatty Acid Salts or **Soaps** are contact insecticides specially formulated not to strip plant surfaces of their protective wax coating. Insecticidal soaps can control mites and soft-bodied insects like aphids and other sap-feeders. Like horticultural oils, thorough coverage of the plant is necessary to ensure contact with the pest(s) and reapplication may be necessary depending on weather conditions. Soaps tend to be very good at controlling soft-bodied insects such as aphids, mealybugs, soft scales, caterpillars, beetle larvae and spider mites.

Microbial Toxins are molecules produced by bacteria, fungi, protozoa and other microbes which are toxic. Examples are:
a. ***Bacillus thuringiensis*** **(Bt)** – This is sold under the Trade Name BIOBIT HPWP (Nufarm) or DELFIN WG (Novartis) in agriculture. DELFIN WG is registered for the control of insect pests on ornamentals and if it does not offer complete control of pests by itself, acceptable levels of control can be achieved in conjunction with pesticides.

B. thuringiensis is an insecticidal bacterium, marketed world-wide for control of many important plant pests - mainly caterpillars of the *Lepidoptera* (butterflies and moths) but also for control of mosquito larvae. Bt products represent about 1% of the total ‘agrochemical’ market (fungicides, herbicides and insecticides) across the world.

The commercial Bt products are powders containing a mixture of dried spores and toxin crystals. They are applied to leaves or other environments where the insect larvae feed. The toxin genes have also been genetically engineered into several crop plants.

b. **Avermectin-B** e.g Vertimec (Syngenta) - a powerful toxin (LD50 = 10mg/kg) derived from Streptomyces fermentation.

c. **Chitin** e.g Clandosan® (Igene) is a natural nematicide made from crab and crawfish exoskeletons and processed into pellets or granules. The product acts in soils as a biological control agent by stimulating the growth of normal soil microorganisms, which produce chitinase and other enzymes that degrade chitin present in cuticles, and eggs of plant-pathogenic nematodes. It has secondary effects as a slow release fertilizer.

Botanicals are plant extracts, usually alkaloids, which have insecticidal properties. Most people believe that since these are "natural" products, they are " safer" than other pesticides. However, many cause severe allergic reactions (i.e. pyrethrin and sabadilla), have high toxicity (nicotine), or are even suspected carcinogens (nicotine). Examples are:

a. **Pyrethrin** (LD50-200). The natural product is mainly an irritant to insects having a very fast knockdown activity, causing rapid paralysis in the target insects. However, unless a synergist is added to enhance the activity of the pyrethrum, the paralysis may be only temporary. Pyrethrum has low mammalian toxicity although some people are very allergic to the compounds.

b. **Rotenone** (LD50=132) Rotenone is an insecticide which breaks down easily in the environment although research is now indicating that there may well be a link between it and Parkinsons disease in humans. It is not toxic to honeybees, but will kill some beneficial insects.

c. **Sabadilla** (LD50=2500-4000) is an alkaloid, which though having low dermal toxicity is a powerful irritant which if inhaled can cause severe circulatory and respiratory failure. Sabadilla is a broad-spectrum contact poison, and may have some action as a stomach poison also. Sabadilla is toxic to honeybees. It is most effective against leafhoppers and true bugs. It degrades rapidly on exposure to air and sunlight, leaving very little residual toxicity.

d. **Nicotine** (LD50=55) is an alkaloid derived from tobacco which high toxicity and is a suspected carcinogen.

e. **Neem** (Azadirachtin)(LD50 >3000) is an interesting botanical derived from an Asian tree grown in India. It seems to act as a systemic with repellent and growth regulator effects on insects and mites.

f. **Ryania** (LD50=750) is an alkaloid which although acts as a stomach poison, often depresses the insects feeding initially, so that it undergoes a long period of inactivity before death. Its residual period is longer than the other botanicals. Relative to rotenone, ryania is moderate in acute or chronic oral toxicity in mammals.

Synthetic Organics are human made compounds containing carbon and are usually synthesized from petroleum products. This is the group most people refer to when they mention pesticide.

a. **Organochlorines** possess serious problems such as: fat solubility, long persistence and a tendency to accumulate in predators at the end of food chains. If they are frequently or excessively used residues can accumulate in the soil.
b. **Organophosphates** have two distinctive features: they are generally much more toxic to vertebrates than other classes

of insecticides, and most are chemically unstable or nonpersistent.

c. **Carbamates** are anti - cholinesterase inhibitors that possess some degree of systemic activity and persistence and are rather selective in action..
d. **Pyrethroids** have highly specific effects on insects' nerve cells, so that only a very small quantity is needed to produce the required effect. Their action on warm-blooded creatures is 1,000 to 10,000 times weaker than on insects. This selectivity is attributable to the fact that the design and functioning of the nervous system and metabolism of warm-blooded animals - that is mammals including humans - and insects are completely differ.

Insect Growth Regulators (IGR) are synthetic chemicals which look and act like insect hormones and act by upsetting insect hormones that are used to grow and develop in their larval stage.

Insect growth regulators (IGR) interfere with the insects normal process of molting. At high dosages, IGR's cause rapid insect mortality, while sub-lethal doses cause rapid maturation, deformation of larvae and additional molts instead of pupation. Death of the insects occurs within 2-3 weeks because the normal molting process has been interrupted.

However, there are concerns with the use of these due firstly to the potential for these chemicals to disperse in the environment and secondly for the development of resistance.

Evidence of the former arose in 1989 with the incapacity of *Bombyx mori* Lepidoptera larvae (silkworm) to spin their cocoon and pupate. This followed the use of fenoxycarb in agriculture. (Arzone, Alessandra, et al, 1995). Other non-target insects have also shown sensitivity to fenoxycarb use. A study was performed in May 1991 to examine the potential for fenoxycarb to translocate, allowing contact with non-target species.

Airborne drift of the product during crop treatment resulted in its accumulation on foliage at a concentration which could easily prevent the regular development of sensitive species. This property allows for alarming consequences if care is not taken during treatment.

Pesticide resistance is also a problem and has been observed both with traditional neurotoxin pesticides and with these IGR's. A study performed in 1992 showed that certain strains of Codling Moth were resistant to treatment with Insegar (a JH-Analogue). The study also showed that these IGR resistant strains also had cross-resistance to neurotoxic pesticides. These findings suggest that more than one mode of resistance action is responsible for the organisms' ability to resist Insegar. (Welter, Stephen. 1992).

Biological Controls

Biological control is using **parasites**, **predators** and **pathogens** (diseases) to control pests. The whole basis of IPM is to limit pesticide use and allow naturally occurring predators to thrive. An alternative to this is to physically introduce, conserve and augment these organisms. Suitable biological controls possess: a high ability to reproduce, good Mobility, be host Specific, a high level of persistence, are easily reared or encouraged and tolerant of other controls.

Efforts can be made to encourage natural predators by growing plants that attract them.

Plants that attract beneficial insects

Plant	Attracts
Berseem clover	Big-eyed bugs
Black locust	Lady beetles
California lilac	Hoverflies
Caraway	Lacewings, hoverflies, insidious flower bugs, spiders, parasitic wasps
Common knotweed	Big-eyed bugs, hoverflies, parasitic wasps, soft-winged flower beetles
Cowpea	Parasitic wasps
Crimson clover	Minute pirate bugs, big-eyed bugs, lady beetles
Flowering buckwheat	Hoverflies, minute pirate bugs, predatory wasps, tachinid flies, lacewings, lady beetles
Hairy vetch	Lady beetles, minute pirate bugs, predatory wasps
Queen Anne's lace	Lacewings, predatory wasps, minute pirate bugs, tachinid flies
Soap-bark tree	Hoverflies, green lacewings, brown lacewings
Spearmint	Predatory wasps
Sweet alyssum	Tachinid flies, hoverflies, chalcids
Subterranean clover	Big-eyed bugs
Sweet fennel	Parasitic wasps, predatory wasps
Toothpick ammi	Hoverflies, minute pirate bugs, soft-winged flower beetles, tachinid flies
Tansy	Parasitic wasps, lady beetles, insidious flower bugs, lacewings
White sweet clover	Tachinid flies, bees, predatory wasps
Wild buckwheat	Hoverflies, minute pirate bugs, tachinid flies
Yarrow	Lady beetles, parasitic wasps, bees

In the case of releasing the insects proper timing of relative to pest populations is critical even when limited insect damage is acceptable. Beneficial insects need time to increase their populations sufficiently to reduce pest populations. They must be released before severe damage occurs, but releases when no pests are present or populations are very low are rarely effective either because the parasites need hosts to survive. If pest populations are low, predators may simply fly away from the release site in search of better hunting grounds.

Release of beneficials can take two forms. The first is inoculative releases of low numbers of natural enemies in the hope that they will become established and provide future control. The second, mass releases designed for immediate control, may or may not result in permanent establishment of the beneficials, even if the insects released actually control the pest as planned.

Predators

a) **Lady Beetles** are one of the most widely ranging and well known predatory insects. Although both adults and larvae of the lady beetle feed on soft-bodied insects, insect eggs and mites, beetles must reproduce in a field to be effective. If prey is not abundant, introduced adults will move to another area to lay eggs, often before significantly reducing aphid populations. They may fly away even if prey is available. Spraying plants in the release site with water or a sugary solution will help slow their immediate dispersal.

b) **Green Lacewings** larvae feed on aphids, scales and mites. Eggs are purchased and sprinkled where small pests are noted to be active. The larvae must search for the pests because they do not have wings.

c) **Ground and Rove Beetles** are active predators present in most soil/turf habitats. Both the adults and larvae feed on a wide variety of pests but are highly intolerant of pesticides.

d) Syrphid Flies (=Hover Flies)

Parasites possess larvae that feed on the inside of their host, usually killing or sterilizing it.

a) **Trichogramma Wasps** (=Egg Parasite Wasps) are microscopic (usually less than 0.5mm long) and lay their eggs in the eggs of other insects. They are usually very host specific and generally limited to butterfly or moth (caterpillar) pests.
b) **Ichneumonid and Brachonid Wasps** are small wasps which commonly attack caterpillars and aphids. The larvae usually emerge from the dying host and spin small white or yellow cocoons.
c) **Tachiniid Flies** are generally medium to large flies which lay eggs on caterpillars or various leaf feeding beetles. The eggs hatch into maggots which feed on and eventually kill the host insect.

Pathogens are usually bacteria, virus, fungi and protozoa. Insect pathogens are fairly ideal in that they are very host specific. They are also very non-infective to vertebrates.

Bacteria have been the easiest of the pathogens to utilize because they can often be reared "in vitro" (in artificial culture) and form spores fairly resistant to adverse environments. Examples are:

1. ***Bacillus thuringiensis*** (Bt) - has several strains which produce toxins lethal to various insect groups (and are thus technically a chemical control). The most common types are:
a. Bt 'Kurstaki' - which affects only young caterpillars.
b. Bt 'Israelensis' - which affects aquatic fly larvae such as mosquitos and black flies.
c.Bt 'Tenebrionis' - which affects some leaf feeding beetles.
2. ***Bacillus popilliae*** (= white grub milky disease) - has one strain available which kills Japanese beetle grubs. Other strains have been identified which kill other species of grubs but these strains are not commercially available.

Fungi have been identified but are difficult to utilize because the spores are easily dried out or need high moisture and/or water to germinate. Examples are:

Viruses are common pathogens of insects but are one of the most difficult to use because they require living insects to grow.

Entomopathogenic Nematodes There are many factors that in theory make nematodes the ideal microbial control agent: they have a broad host range, will not attack plants or vertebrates, are easy to mass produce, and can be applied with most standard equipment. Additionally, some species of nematodes can actively seek out their hosts and kill them rapidly. They multiply quickly within the host and release thousands of mobile offspring. Although there have been many successful field applications of entomopathogenic nematodes, applications do not always yield the desired results.

Adverse environmental conditions at the time of application and for several weeks after can cause poor results. Nematodes are sensitive to sunlight and they are prone to desiccation. Nematodes require high relative humidity, as well as a film of water on leafs and soil on which to move. Nematodes should be applied early in the morning followed by a half inch of water applied through irrigation.

In summary, there are multiple alternative control methods which can be used in the both the turf and nursery industries. The concept of integrated pest management provides a framework in which to use all of the alternatives in a systematic fashion.

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