Integrated Pest Management in Plant Display Houses: With Particular Reference to the Fernery and Display Houses, New Plymouth©

Jennifer Gleeson
New Plymouth District Council, Liardet Street, New Plymouth
Email: Jgleeson@ihug.co.nz

INTRODUCTION

"Battling the bugs and beasties in the war zone of a plant display house." This paper looks into the techniques and strategies that are available and used in controlling plant pests in the Fernery and Display Houses (The Fernery), Pukekura Park, New Plymouth. A coordinated approach evolved out of our desire to do things better. We wanted to reduce the use of toxic pesticides, because we were concerned about the development of pesticide-resistant populations, the nontarget effects pesticides can have, and the all-important public, staff, and environmental safety issues. We were also aware of the increasing public desire for a clean and green environment. Rather than rely on a prophylactic programme based on a calendar of spray applications, we looked for more environmentally friendly approaches sympathetic to the actual levels of crop damage. As horticulturists we found ourselves in the world of entomology, chemistry, ecology, and economics as we move into an integrated pest management (IPM) system. Although plant health depends on both the control of pests and the management of plant diseases, this paper only addresses insect and mite pests and their management.

BACKGROUND

The Fernery, Pukekura Park, New Plymouth, is on the west coast of the North Island of New Zealand and is managed by the New Plymouth District Council. New Plymouth city enjoys a temperate climate with approximately 1,500 mm of rainfall spread evenly throughout the year. Summer temperatures regularly reach 25 °C, and winters provide the occasional light frost.

Established in 1928 as a series of four glass houses linked by underground tunnels, The Fernery contains an extensive arrangement of potted plants displayed against a backdrop of fern-covered banks (total covered area of approximately 1000 m^2). There is about the same nursery area available for the growing of the plants before they go into the displays. Three of the public houses are maintained at ambient temperatures; the fourth is heated to allow subtropical and tropical plants to be displayed.

The primary aim is to display plants for the pleasure and enjoyment of all, and we attract over 30,000 visitors annually. There is also a botanical and educational role, so plants range from the rare and exotic to common house and garden taxa. The majority of the plants are grown on-site, with many forming part of significant plant collections. With over 25,000 plants in culture at any one time, the large range of plant genera, species, and selections attracts many different plant pests. This creates complex control issues, and active control measures are necessary. With the facility being open to the public daily, these measures need to be balanced with a safe environment for visitors and staff.

MANAGEMENT OF PESTS

The Fernery's pest management has, over the last 5 years, evolved into processes that include monitoring our pest numbers, the use of cultural methods, regular inundative release of beneficials (our insect and mite allies, generally natural predators or parasites raised commercially for this specific purpose), and a limited and controlled use of chemical sprays.

Monitoring. During normal cleaning and grooming of the plants and other cultural activities, we monitor pest levels. Blue and yellow sticky traps are used in the growing areas to assist with this. Blue sticky traps attract thrips, and yellow ones attract a range of insects. In early December (early summer) through to late April (mid-autumn), pheromone traps are set up in areas prone to green looper caterpillar (*Chrysodeixis eriosoma*). Capsules that attract male green looper moths are used (Zonda, 2006). This year, petunias have been used to monitor for western flower thrips (*Frankliniella occidentalis*).

Cultural Methods Available. Cultural practices and procedures for nonchemical control are simple and inexpensive and are carried out as part of our routine horticultural activities. They are used not only to reduce plant pest numbers but also to encourage the natural predators that can be found in mixed plant populations.

Cultural methods include:

- Using a combination of timely re-potting and re-propagating with simple manual hunting and killing of pests when plant grooming occurs. (Get physical in the war zone.)
- Checking all plant material that comes on site for the presence of pre-existing infestation. It may be necessary to set up a quarantine area. In the last few years three specific pest outbreaks have been traced back to a particular crop coming on site (poinsettia and white fly, gloxinia and western flower thrips, cineraria and aphids).
- Pruning out badly infested plant tissue together with manual removal of pests; heavily infested plants are discarded.
- Manual cleaning of plants with a damp cloth and a little mineral oil for shiny leafed species. An important note is to check phytotoxicity of plants to oil sprays. We test a few plants first (cycads, some palms, and some orchids have shown sensitivity to mineral oil). Recently cleaned plants are not exposed to direct sunlight.
- Expedient cleaning up of all old plant litter and weeds is desirable; however we consider weeds as a double-edged sword. They are potential sources of infestation but also potential sites for natural predators and parasites to camp out as a reserve army, able to launch an offensive should pest numbers build up within the crop.
- Maintaining appropriate soil moisture, atmospheric humidity levels, and good air movement to produce as healthy a plant as possible. Healthy plants are less prone to attack since their natural defences are maximised.
- Using high-health plant products to reduce plant diseases. This in turn reduces the need to spray with agrochemicals that may adversely affect beneficials. We use a liquid foliage fertiliser with SM6® (Chase Organics, 2002) at 160 ml per 320 L on all plants prone to powdery mildew. This product is a cold-compressed liquid seaweed-based product that encourages high plant health.

Release and Use of Commercially Available Beneficial Organisms. During summer, beneficials are released and relied upon for some control of pests. Our winters tend to be too cold for many of these beneficial organisms to function year-round. However, plant pests are more tolerant of the cold and continue to increase, albeit at a much slower rate, throughout the winter period. Nighttime temperatures in the warm houses will drop to 10 °C in winter and in the cooler houses temperatures will be below 5 °C for much of the night.

Pest levels are monitored, and the main beneficials are normally released in late November/early December (late spring/early summer), when temperatures are high enough for their survival, but before plant damage is visible. Repeat releases are also carried out in mid- to late January (midsummer). We also spray susceptible plants weekly throughout summer with *Bacillus thuringiensis* for caterpillar control.

The use of beneficials is increasingly possible since they became commercially available in New Zealand. The nature of our operation is such that the zero-tolerance regime of a commercial grower to plant pests is not required, and low levels are acceptable. The good insects need food and hosts to survive and reproduce — allowing a low level of pests to survive provides these. There is significant public interest in what we do to control plant pests. Low levels of infestation and the use of beneficials gives us an opportunity to demonstrate to the public alternative methods that can be used in the home garden for pest control. A degree of live and let live can still result in fabulous displays, and the beneficials we have used include:

- *Amblyseius cucumeris*. A thrip predator that feeds on the larval stage of most pest thrips including western flower thrips (*F. occidentalis*) (O'Connor, 2004; Lucas, 2005; Martin et al., 2005; Zonda, 2006); they are also reported to predate cyclamen mite (*Phytonemus pallidus)* (Lucas, 2005) and some mite species such as the two-spotted mite (*Tetranychus urticae*) in its early stages (O'Connor, 2004).
- *Aphidius colemani*. A parasitic wasp that lays its eggs inside green peach, cotton, or melon aphids (*Myzus* species) (O'Connor, 2004; Lucas, 2005; Martin et al., 2005; Zonda, 2006; Australasian Biological Control, no date supplied).
- *Bacillus thuringiensis*. Spores of the bacteria germinate and destroy the gut when ingested by caterpillar species (O'Connor, 2004). We find we achieve excellent control of caterpillars by spraying weekly through January and February (summer).
- *Encarsia formosa*. A parasitic wasp that parasitizes the larval stages of whitefly (*Trialeurodes vaporariorum*). The wasps are supplied as pupae on cardboard tags and must be introduced into the crop when whitefly numbers are low to allow wasp numbers to become established (O'Connor, 2004; Lucas, 2005; Martin et al., 2005; Zonda, 2006).
- *Gyranusoidea advena* (gyro bug). A parasitic wasp that parasitizes long-tailed mealy bugs (*Pseudococcus longispinus*) and needs to be introduced when pest numbers are low (Zonda, 2006).
- *Hypoaspis aculeifer*. A predator mite that feeds on fungus gnats larvae, bulb mites, thrip pupae, and nematodes (O'Connor, 2004; Lucas, 2005; Zonda, 2006).

- *Pseudaphycus maculipennis* (P.mac). A parasitic wasp that parasitizes obscure mealy bug (*Pseudococcus viburni*) (Lucas, 2005; Edwards, 2007).
- *Phytoseiulus persimilis*. Two-spotted mite (*T. urticae*) predator that feeds on all stages including pest mite eggs (O'Connor, 2004; Lucas, 2005; Martin et al., 2005; Zonda, 2006; Australasian Biological Control, no date supplied).

These insect and mite allies have given us varied results. Some seasons we have good control throughout and little spraying is required, whilst another season can be particularly challenging with pest hot spots developing that require chemical intervention. For us, mealy bug continues to be a major pest on a wide range of plants, with little help from the biological control organisms. Likewise, scale on the orchids may need chemical spraying, because no biological control organisms are as yet commercially available. However, it is possible to produce public plant displays using no toxic sprays. Wellington Botanical Garden's nursery production unit, which supplies plants to the public display houses, has in the last 12 months not used any toxic sprays. It has taken them 8 years of IPM to reach this point (Kidman, 2007).

When any type of agricultural chemical is used, it is crucial to ensure bug allies are not adversely affected. This includes some fungicides since they can be toxic to the beneficials, and pest numbers can rise rapidly after fungicide spraying. We have used two web sites to source information (Koppert, 2006; Biobest, 2007) as well as information found in the agrichemical manuals (O'Connor, 2006) and New Zealand Institute for Crop and Food Research IPM Manual (Martin, 1993).

Chemical Control Options. Plant pest spraying is only done when plant damage and pests are affecting plant display quality. When the beneficials together with cultural methods do not appear to be giving us the level of control we would like, we target-spray individual plants or crops. Some summers, chemical spraying may be required more often. A more blanket spray or fumigant may be used during winter if pest numbers have become high. It is during winter that our introduced bug allies may naturally disappear altogether. Chemicals of low toxicity are selected and only those that do not require tracking are used (ERMA, 2006).

We use mineral oil (1%) or imidacloprid/oil mix on affected plants showing major outbreaks of aphids, whitefly, greenhouse thrips, and mealy bugs. Repeat sprayings may be required. Spraying of oil compounds should be done with caution due to possible phytotoxicity. In summer, if possible, we use an imidacloprid soil drench rather than a spray as this is less toxic to the beneficials (Koppert, 2006). In early winter if pest problems seem to be evident, pyrethrins and piperonyl butoxide fumigant are used in affected houses as a cleanup. This however also kills many beneficials that may still be around. Scale on orchids can generally be removed with simple manual cleaning; however a spray programme with mineral oil or mineral oil with imidacloprid is used on those plants badly affected. Three repeat sprays are carried out at two weekly intervals and are timed to catch the crawler stages of the scale pests in spring and autumn. Also see earlier above about plant sensitivity to oil spray. Should mites be a problem and not being controlled by the predators, we will spray the affected plants with taufluvalinate.

Future Methods and Products Being Considered for Use. The Fernery is committed to continuous improvement, as well as to encouraging natural beneficials,

Table 1. Summary of major pests and non-cultural control measures used.

Major pest	Control measures used
Aphids mainly green peach aphids (*Myzus persicae*)	Imidacloprid, pyrethrins and piperonyl butoxide, mineral oil, taufluvalinate, and *Aphidius colemani*
Caterpillar: white butterfly (*Pieris rapae*) and green looper (*Chrysodeixis eriosoma*)	*Bacillus thuringiensis,* (for all species)
Mealy bugs: long tailed (*Pseudococcus longispinus*)	Imidacloprid, mineral oil, and *Gyranusoidea advena*
Mealy bugs: obscure (*Pseudococcus viburni*)	Mineral oil and *Pseudaphycus maculipennis*
Mites: broad mite (*Polyphagotarsonemus latus*)	Taufluvalinate and *Amblyseius cucumeris*
Mites: cyclamen (*Phytonemus pallidus*)	Taufluvalinate and *A. cucumeris*
Mite: two spotted (*Tetranychus urticae*)	Mineral oil, taufluvalinate, and *Phytoseiulus persimilis*
Scale: boisduval (*Diaspis boisduvalii*), brown soft scale (*Coccus hesperidum*), and cymbidium scale (*Lepidosaphes pinnaeformis*)	Mineral oil, imidacloprid (crawler stage all species)
Thrips: western flower (WFT) (*Frankliniella occidentalis*)	Mineral oil and *A. cucumeris*
Thrip: greenhouse (*Heliothrips haemorrhoidalis*)	Imidacloprid, pyrethrins, piperonyl butoxide, and mineral oil
Thrips: onion thrips (*Thrips tabaci*)	Taufluvalinate, imidacloprid, and *A. cucumeris*
Whitefly: green house (*Trialeurodes vaporariorum*)	Pyrethrins and piperonyl butoxide, mineral oil, imidacloprid, taufluvalinate, and *Encarsia formosa*
Weevil: garden (*Phlyctinus callosus*)	Diazinon (soil granules) and imidacloprid (soil drench)

and we are actively investigating the use of alternative sprays and other commercially available beneficials. Additional biological control organisms are being considered for use in the houses, and they include:

- *Cryptolaemus montrouzieri*, a dark brown ladybird with a tan to orange head and posterior, which feeds on mealy bug at both larval and adult stages as well as some scale insects including hemispherical scale and brown soft scale (Australasian Biological Control, no date supplied; Lucas, 2005). We have not been able to find a commercial source of this; however it is being used successfully in the Wellington Botanic Gardens where a colony is maintained on mealy-bug-infested sprouted potatoes (Kidman, 2007).

- *Heterorhabditis bacteriophora*, a nematode, marketed as the formulation Otinem (Carran, 2005) for the control of garden weevil (*Phlyctinus callosus*) (Lucas, 2005).

We are also becoming concerned about resistant populations developing due to our heavy reliance on imidacloprid. We are investigating using buprofezin, an insect growth regulator, as an alternative for the control of mealy bugs, white fly, and scale. It is reported as safe with beneficial bugs (O'Connor, 2004; Koppert, 2006). We are also considering a specific miticide, abamectin, to control heavy infestations of two-spotted mite and cyclamen mite. It has systemic action because it is absorbed into young developing foliage, giving some weeks of control. Unfortunately it is reported to be toxic to a number of beneficial bugs as well as having a 2 to 3 week residual effect (Koppert, 2006). Alternative fungicides are also being investigated with the increased use of dilute mineral oils to reduce some problems such as powdery mildew. We hope these new incentives will give better pest control with reduced adverse effects on our bug allies. We do not undertake formal monitoring, nor are records of pest levels kept. This needs to be initiated to enable data on the results to be used to establish patterns and further develop control standards.

CONCLUSIONS

Integrated pest management is a coordinated approach to managing plant pests and diseases in a particular horticultural operation. It involves knowledge of pest population numbers, species and life stage; the crop's condition; and the environmental factors; including the season. This information is matched with pest control methods available, which give a level of control acceptable for this particular horticultural operation. There is an increasing range of off-the-shelf beneficials and we are trying to use these together with cultural controls as our first line of defense. Agricultural chemicals are used sparingly. These strategies are good for the environment, and reduce the risk of staff and public exposure to toxic chemicals. Integrated pest management is also important in the reduction of pesticide resistance development, as a range of options is used throughout the growing year and the opportunity for resistant pest population development is minimised. An additional up side to using beneficials is in the important area of public education of these practices. We are achieving varying degrees of success with the IPM and at times find we have to resort to a calendar spray programme to get on top of a particular pest. Plant pests will always be present in low numbers in the houses and need to be tolerated as they are the natural requirements of the parasites and predators we are trying to encourage. It is important to minimize effects of the pests and ensure the displays are maintained to the world-class standards that The Fernery is renowned for.

With our bug allies (those that are naturally found as well as those we introduce), we attempt to restore Nature's balance. Rather than a war zone in the battle ground of The Fernery we endeavour to create a jungle where the game of survival is played more according to the laws of Nature rather than the chemically weighted hand of man.

Disclaimer. This paper should not be seen as endorsing any particular product. Any that are named are simply those we have used in The Fernery. We have drawn information from product labels and various published sources before any control programme has been undertaken. Any lack of control of a problem does not neces-

sarily reflect on the product used, but may be due to our methods, or other outside circumstances. In all pest control programmes growers need to seek acknowledged professional advice before committing to any action.

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