Integrated Pest Management for Ornamental Protected Plants©

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Integrated pest management (IPM) brings together all aspects of pest and disease control, cultural techniques such as general hygiene, ground cover materials for weed control, monitoring with sticky traps, and tracking plant movement being the first line of defense. Biological control should be the next strategy, introducing beneficial organisms as a preventive measure or at the first sign of a pest outbreak. Environmental preventative management of the growing area may help by inhibiting plant pathogens and by providing more suitable conditions for biological control agents to work more effectively. Pesticide use, preferably with selective products, should be used only when necessary; it is best to use a pesticide when pest numbers can be clearly seen on a plant or when leaf damage is evident. Biological control works best when pest numbers and leaf marking are low as a fully fed predator will take some time to digest its food before it starts eating again. This paper will describe the IPM practices currently used for several insects and mite pests on many nurseries in the U.K.

INTRODUCTION

All crops suffer pest outbreaks at some time or other. Numerous beneficial organisms can be used to control common pests such as aphids. There are also several pesticides with activity against aphids, for example, some of which can be integrated while others have a much broader range of activity, killing most natural enemies as well as the pest. Integrated pest management (IPM) is a more sustainable method of pest control using cultural techniques, biological control agents, and selective or short persistence pesticides to provide long-term pest management.

Pest identification and knowledge of basic biology is therefore essential for growers who want to manage a fully effective IPM programme. Sap-sucking pests such as aphids, mealybug, soft scale insects, and whitefly can excrete vast quantities of sticky, sugar-rich honeydew that, in addition to direct plant damage, will further disfigure plants with associated growths of sooty moulds and loss of plant vigour. Spider mites are also extremely common and severely damaging pests with a rapid rate of reproduction when conditions are hot and dry; predatory mites are available and frequently eradicate the pest completely. Various species of thrips can cause leaf damage as well as transmitting plant viruses. Vine weevil continues to be a major problem on protected nursery stock production units; granular pesticides incorporated into the growing medium can provide long-term protection, but remedial treatments may be required for unprotected plants or existing infestations. Nematode vine-weevil parasites, particularly the species active at low temperatures, now provide excellent curative activity for use through much of the growing season when ground temperatures are above 5 ^{o}C.

IMPORTANCE OF MONITORING AND RECORDING

Monitoring and recording pest outbreaks to build up a diary of trends and identify vulnerable locations helps to reduce the incidence of major pest problems by anticipating and responding to problems quickly. Nothing beats regular crop scouting (walking through a crop lifting pots and turning leaves) for finding and monitoring pest or disease levels. To aid crop scouting, yellow sticky traps hung vertically are useful for catching winged aphids, leafhopper, thrips, and whitefly. To trap adults of scatella, sciarid, and leaf hoppers the trap should be placed horizontally. Blue traps tend to catch more thrips but can also attract high numbers of predatory hoverflies (they are also useful to catch houseflies).

Pheromone lures are available for a wide range of adult moths; however, most of these lures use a sex attractant to catch male moths and are specific to each species so correct identification is critical. A recent development is the use of an aggregation pheromone lure for western flower thrips. These lures attract both male and female adults to a blue sticky trap and are a significant improvement over nonlured traps. A programmed approach to pest control with regular introductions of beneficials for major pest organisms is best. However, where large infestations are found and a rapid response is essential to prevent further damage and spread of the pest; selective pesticides can be integrated to counter this attack without long-term effects on natural enemies.

PESTS AND THEIR CONTROL

Root-zone Pests. The predatory mite *Hypoaspis miles* should be introduced into any plant propagation unit. It lives in soil, growing media, or capillary matting and feeds predominantly on sciarid larvae but will also eat thrip larvae and pupae, springtails, and other organisms in the soil. The mite is best introduced as a preventative treatment to all plants, ideally within 2 weeks of potting or striking cuttings, also at the very first sign of sciarid or scatella fly adults or larvae on the compost. Excellent results have been obtained by using *H. miles* at 100 to 150 mites per m^2 during propagation, as a single introduction on both seed- and cutting-grown material.

Whiteflies. Whiteflies should not be a significant pest in most propagation units. However, weaning units and subsequent growing-on areas are at risk from whitefly infestation that can be controlled biologically. The whitefly parasite *Encarsia formosa* is well known and widely used on many nurseries, particularly those producing fruiting salad crops. For ornamental plant production introduce *E. formosa* at 2 to 5 wasps per m^2 weekly for about 8 weeks to "seed" the area with parasites as a preventive measure. However, should a population of whitefly establish it might be necessary to spray with a contact insecticide such as Agri 50E (alginate and polysaccharides) or Stalwart (nico-soap). These are nonselective, but are of very short persistence and hence will integrate reasonably well. After reducing the pest population with a couple of sprays, *E. formosa* should be introduced at 5 to 10 per m^2 weekly for about 8 weeks.

In the U.K. there is now a SOLA (Specific Off-Label Approval) for the use of Chess™ (pymetrozine) at up to 6 g in 10 L for control of adult whitefly and their eggs on tomatoes. Under the current Long Term Arrangements for Extension of Use it is permissible (at grower risk) to use this rate of Chess on protected, non-edible crops. The product should be applied as a high volume wet spray and repeated after 10 to 14

days for best results. Although Chess may be slow to provide a full kill of the target pest it is remarkably safe to most beneficials, including parasitoid wasps.

Several growers have used a tank mix of Chess and Nemolt™ (teflubenzuron) to control whitefly with good results. However, this is a non-approved tank mix and is done entirely at grower risk. Growers have also tank mixed Chess with Dynamec™ (abamectin) making a very useful clean-up treatment for use on most plants to control a wide range of pests including aphids, leaf hopper, leaf miner, spider mites, thrips, and whitefly while having only a 1 to 2 week persistence against beneficials. It should be stressed that the use of any tank mixes, unless specified on the product labels, is entirely at grower risk; to minimize any potential damage always test on a few plants before widespread use.

Aphids. This pest can be a potential pest problem through all stages of plant production. *Verticillium lecanii* (an insect fungal pathogen) is ideally suited for use in propagation units and will provide excellent control of several pest species. This fungus needs specific environmental conditions for its activity: temperature of 12 to 28 °C and relative humidity of 85% or more. This high humidity requirement need not be permanent; approximately 6 h per day or 42 h per week will suffice so fungal activity can persist after plants leave the propagation unit. Periods of still air around plants help raise the humidity at the leaf surface and can be used to provide the necessary conditions for further fungal infection of the pest.

The parasite *Aphidius* and predator *Aphidoletes* will easily control most aphid species; these should be introduced fortnightly at the first sign of aphids at a rate of 500 *Aphidius* per 1000 m^2 and 1000 *Aphidoletes* per 1000 m^2. This rate should provide adequate aphid control for much of the growing season and can allow a breeding population of control agents to establish over the site. *Aphidius colemani* attack small, round-bodied aphids such as *Aphis gossypii* and *Myzus persicae*, which are usually the first aphids to be found in the spring. *Aphidius ervi* is larger and thus better suited to target the larger species of aphids such as *Aulacorthum* and *Macrosiphum* species; these can be green or pink in colour and usually occur from mid summer onwards.

To broaden the scope of aphid parasites, which can be fairly specific in the aphids they control, an exclusive mix of the parasite species: *Aphelinus abdominalis*, *A.* colemani, and *A. ervi* sold as ACE mix or CE mix (250 *A. colemani* + 250 *A. ervi*) has been developed. One unit of ACE mix or CE mix will treat up to 500 m^2 and should be introduced fortnightly through the period when aphids are likely to occur. Although they are able to establish, localized introductions may be required through the season depending on plant movement through and off site.

Lacewing larvae (*Chrysoperla carnea*) will devour most aphid species and can be used to control quite large infestations. They will feed on other soft-bodied organisms including leafhopper nymphs, mealybugs, scale insects, spider mites, thrips, and developing whiteflies. Several nurseries have introduced lacewing larvae to hedges close to their glasshouses and tunnels in May and again in June. This has helped reduce the numbers of pests in the local environment before they migrate into the production area and establish a breeding population on site. Lacewing larvae can be cannibalistic if food supplies run short, so they need to be distributed thinly, rather than many in one place.

The aphicides, Aphox™ (pirimicarb), and Chess will integrate well with most biological control agents and can be used as clean-up sprays for any difficult or large outbreaks.

Spider Mites. Spider mites can survive throughout the year in a moderately heated house and increase rapidly when hot weather persists. A new development in spider mite control or prevention is the predatory mite *Amblyseius andersoni*, a U.K. sourced and produced mite available in controlled-release system (CRS) sachets that hang on plants and release mature mites continuously over a 6 to 8 week period. *Amblyseius andersoni* may also provide control of fruit-tree spider mites, russet mites, and other small prey but do not perform well on spider mite webbing. However, they survive well in surrounding areas, often ambushing straying spider mites and limiting their spread. Due to their ability to survive on other food sources, they are ideal to use as a preventive measure on susceptible plants.

The more voracious predator *Phytoseiulus persimilis* can be used alongside *Amblyseius* species as a curative treatment. The licensed predatory mite *Amblyseius californicus* is tolerant to high temperatures and lower humidities; it can also feed on pollen, other mites, and small prey making it ideal to "seed" a susceptible crop before spider mites appear. *Phytoseiulus* continues to provide excellent curative control and will frequently eradicate a pest colony. The predator should be introduced at the first sign of spider mite damage, and a repeat application made a fortnight later. Further introductions may be necessary during the summer months.

Should spider mites not be noticed until plant damage is more evident, a rapid response is required to minimize further damage and pest spread. Spray with Dynamec followed 1 to 2 weeks later with an introduction of *Phytoseiulus* at 10 to 50 mites per m^2 of infested crop. Dynamec may be used for any early season outbreaks and as an emergency treatment in summer, up to 1 week before predator introduction. It also makes an excellent end of season clean-up treatment to prevent mites entering diapause. This pesticide is not photostable and will break down in bright sunlight conditions (May to August in GB&I) in about 5 to 7 days or less if continuously hot and bright. When the high rate is used (50 ml per 100 L), Dynamec has activity against leaf miners, thrips, other mites, and leaf nematodes. It can be harmful to biological agents for up to 2 weeks in the winter but less in summer or high light conditions. Torq™ (fenbutatin oxide) will integrate well with biologicals and should be used during spring and summer for any "hot spots" of mites along with *Phytoseiulus* or *A. californicus* to speed up mite control. Increased humidity around the plants helps to decrease spider mite reproduction and also improve predator activity. All predatory mites struggle to move between well-spaced leaves and plants. To improve their activity, strips of fleece can be draped over and between plants that improve mite mobility by acting as a bridge.

Thrips. The other major pest of protected ornamentals is thrips; usually western flower thrip and onion thrip although cereal thrips can cause widespread plant damage in late summer. The recently identified black "T" thrip *Echinothrips americanus* may be found on many houseplants and in interior landscaped atriums. Several thrips species are able to transmit plant viruses (tomato spotted wilt virus and impatiens necrotic spot virus in particular) to a wide range of plants potentially causing severe infection symptoms on the whole plant. Thrips also rasp the leaf surface causing distorted growth and loss of colour from flowers, followed by premature senescence.

Thrips are best tackled preventatively by introducing the predatory mite *Amblyseius cucumeris*, particularly to flowering plants. The mite can be introduced in

loose vermiculite carrier material weekly to keep thrips populations low. Alternatively use the CRS — a breeding population of predatory mites in a sachet. The CRS sachets last about 8 weeks and release mated females that distribute themselves over an area of about 1 m^2. The CRS system is very good for use across a range of crops, in particular bench- or floor-grown crops where leaf contact between plants can be maintained. The waterproof sachets can also be hung on larger plants; they come in units of 40 or 200 and 500 CRS sachets.

Nemasys F™, the foliar spray application formulation of the parasitic nematode *Steinernema feltiae*, has given excellent and reliable control of western flower thrips on chrysanthemum and other flowering plants such as gerbera and *Saintpaulia.* The nematodes should be applied weekly as a high-volume spray to leave a wet residue on the plant surface. Nematodes swim through this film of water to attack and kill various prey insects. Once the spray has dried, the nematode activity ceases so the application should be timed to allow a film of water to remain on the leaf for as many hours as possible. Some cut chrysanthemum growers are using the nematode only at certain stages of plant growth, i.e., Weeks 2 and 3 after planting and again at Weeks 7 to 12 or until harvest. Nemasys F comes in two unit sizes: one box of 5×50 million and one of 5×250 million. The suggested rate is 50 million in 40 L water per 400 m^2 as preventive treatment and 50 million in 20 L water 200 per m^2 as a curative for heavier infestations. The larger unit size of 250 million nematodes will treat up to 2,000 per m^2 per tray.

Should thrips become a problem Conserve™ (spinosad) will provide excellent control of all thrips stages and is safe to all predatory mites and nematodes; two sprays at a 5 to 7 day interval will usually correct an outbreak. Conserve has contact and translaminar activity and, from grower observations, will also provide incidental control of caterpillar, including tortrix moth larvae, although there is no label approval. When using Conserve, the whole crop should be treated so as not to allow any refuge for survivors. A maximum of six applications per structure per year is permitted as part of a resistance management strategy. Nemasys F can be tank mixed with several pesticides, a full and updated list is available from the supplier, Becker Underwood.

Mealybug and Scale Insect. These pests can establish on many plants, particularly woody ornamentals, slow-growing ornamentals, and even tomatoes. An unmated female mealybug can survive on an inert surface for 6 months or more before mating with a winged male and returning to a plant to reproduce. Biological control with the Australian ladybird *Cryptolaemus montrouzieri* works well on egg-laying species of mealybug such as *Planococcus citri* and some *Pseudococcus* species but these ladybirds can be slow to establish on long-tailed mealybug. *Cryptolaemus* also feeds on scale insects but will not establish without mealybug; also their larvae can be very noticeable on display plants, which has led to the preferred use of lacewing larvae for mealybug control.

Lacewing larvae are small predatory insects that will remain close to their release point, unlike *Cryptolaemus* adults that can easily fly away; a rate of 10 to 15 larvae per m^2 on a 2 to 4 weekly cycle is suggested, if needed. The parasitic nematode *S. feltiae* will control scale insects when sprayed on leaves; the nematodes swim through the film of water and enter under the scale to kill it. Specific parasites are seasonally available for mealybug and scale insect; contact Fargro for availability and advice.

Applaud™ (buprofezin), off label use at grower risk, will give good control of young mealybug and developing scale insects but has little effect on adults. White oils and soft soap sprays will also control mealybug, including adults if good contact can be made—watch out for phytotoxicity on some plants. Agri-50E™ applied as a contact spray will also suppress scale insects, particularly soft scale, and can be used on most plants with good results. Chess, a systemic insecticide with translaminar activity against most sucking insects, also has incidental activity against mealybug, psyllids, and scale insects while being safe to the majority of beneficials. Although these pesticides are approved on several crops, some uses are at grower risk, and it is still safer to test on a few plants first.

Caterpillar. Butterfly and moth larvae, in particular tortrix, can be controlled with routine sprays of the bacterial parasite *Bacillus thuringiensis* as DiPel DF™, which has given excellent results. The parasitic wasp *Trichogramma* will give reasonable parasitisation of eggs from most moth species; these are introduced on cards when moths are flying mid spring to later summer, depending on weather conditions. Pheromone traps are a very useful addition to the IPM programme and will attract tortrix moths from a wide radius, indicating when to begin a spray programme and often providing a degree of pest control.

Vine Weevil. These days vine weevil should not be a problem due to the use of compost incorporated insecticides. However, if larvae are found on any plants, the insect parasitic nematode *Steinernema kraussei* as Nemasys L can provide excellent curative activity. This species of nematode is active from 5 °C up to 25 °C and is applied as a drench to the compost. None of the currently used soil-incorporated pesticides have any effect on these nematodes except Temik™ (aldicarb).

CONCLUSION

The key points to a successful, sustainable IPM programme is to use cultural techniques to start clean, keep the system clean, and finish the crop cycle clean. Biological control will keep a pest population low and can frequently eradicate pests completely. Selective pesticides can be integrated to control troublesome outbreaks.