INTEGRATED CONTROL MUST BE FLEXIBLE FOR BEST RESULTS

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Integrated control of insect pests has perhaps been most fully realised on protected crops in Europe, mainly as it has been forced upon the industry because of almost insuperable pesticide resistance problems. In its simplest sense, it means controlling pests by all reasonable means. This entails giving considerable attention to the way in which crops are grown, the pest complex and available potential control measures, both chemical and biological in operation.

The objective

The aim is to achieve reliable pest control, and such systems must be flexible enough to accommodate changes in cultural practice, unexpected pest invasions and so on. Certainly, it is not to replace chemical by biological control completely — this is considered impossible or impracticable — but to reduce chemical usage so as to avoid pesticide resistance.

Chrysanthemums

In the last four years, as a result of work by L. Wardlow and colleagues of ADAS and GCRI, a broad-based programme of integrated control has been developed around the use of the predator *Phytoseiulus persimilis.* A typical year-round crop (planted out after two weeks propagation on a rooting bench) is treated with ten adult predators per 100 plants three to four weeks after planting out. The predators will normally have controlled the spider population at the first signs of bud colour; otherwise a suitable acaricide should be applied at this stage.

How can the other pests be controlled without upsetting the balance between predator and prey in the latter's favour? Briefly, leaf miner *(Phytomyza syngenesiae)* can be controlled by introducing the parasitic wasp *Dacnusa sibirica* (three adults per 1,000 plants) during the first week after planting out.

Control of first generation leaf miners is usually satisfactory but a second introduction of parasites is recommended to clean up surviving progeny. The parasitic wasp *Diglyphus isaea* is preferred because development of a miner is arrested early in the development of a parasite.

The chemical pyrazophos has also been extensively tested for leaf-miner control; it is a mildewicide but also deters the leaf miner from laying eggs and kills young larvae. However, its use is still experimental and there are no label recommendations.

Minor pests such as onion thrips *(Thrips tabaci),* tarnished plant bug *(Lygus rugulipennis),* common green capsid *(Lygocoris pabulinus)* and glasshouse leafhopper *(Zygina pallidifrons)* are not easily controlled biologically and so pesticides must be used and timed carefully to avoid harming the parasites and predator described above. Carbaryl, diazinon or nicotine should be sprayed early in the second week after planting out; by this time, *Dacnusa* parasites will have laid their eggs in leaf miner larvae and so be protected from a chemical spray, and the spider mite predator will not have been introduced yet.

A recent modified version of the integrated programme incorporates a strain of the spider mite predator which is resistant to diazinon and carbaryl. This makes control of minor pests easier by chemical applications.

The major aphid species can be controlled by the fungus *Verticillium lecanii* (Vertalec), applied two weeks after planting out. Developed at GCRI and produced by Tate & Lyle Ltd, this needs high relative humidity to be effective. It is suited to the conditions in ayr chrysanthemums where daylength-restricting blackouts raise relative humidity to very high levels.

It is worth describing the fungus' mode of action in some detail so that the grower can use Vertalec as efficiently as possible. Vertalec contains spores of the fungus which, when sprayed on the insect cuticle, germinate and enzymically bore a hole to penetrate to the tissues within. This phase of the infection cycle is dependent upon high humidity.

Once inside the insect, the fungus disperses in the host's blood, colonising the whole insect which dies shortly after. This stage is independent of humidity. Following death, the fungus quickly grows over the insect — provided that the humidity is high — producing a dense mat of spores which remain viable for several weeks, infecting other healthy aphids.

To get the most benefit from the spore spray, Vertalec should be soaked for two to five hours before spraying, to accelerate spore germination. It is important not to allow soaking spores to overheat during this period in a hot glasshouse (temperatures at 35C will soon kill unprotected spores).

For application, thorough coverage with conventional high-volume spraying techniques is recommended, although not essential since, once established, the fungus will spread from spores on the aphid bodies. Timing of the spore spray is important; aphids killed by fungi are white in appearance and stick firmly to foliage. Too many of them on prominent foliage disfigure an ornamental plant. Sprays in the ADAS/GCRI integrated programme are timed so that spore populations of aphids are controlled early in the crop.

The fungus is compatible with various insecticides and fungicides but recent evidence suggests that it is best to avoid applying spores in the same tank mix and for at least a week after any fungicide sprays. In the glasshouse, *V lecanii* is totally compatible with other control agents, non-phytotoxic, and harmless to users and beneficial insect populations.

In 1982 and 1983 Vertalec gave excellent control of *Myzus persicae* and *Brachycaudus helichrysi,* another green aphid. The chrysanthemum aphid *(Macrosiphoniella sanborni),* an occasional pest, cannot be controlled by Vertalec sprays and must be curbed either by the specific aphicide pirimicarb or any other insecticide which can be incorporated into the integrated programme.

One of the most troublesome aphids in recent years is a black aphid (probably *Aphis gossypii),* which is resistant to pirimicarb and on some holdings could not be controlled even by diazinon. *V lecanii* typically kills 80 to 90% of populations of this aphid but this is inadequate on an ornamental crop like chrysanthemums.

However, this level of control prevents damage until just before flowering, when the aphids can be sprayed with an insecticide like dichlorvos. By this time red spider mites will have been controlled and so predator mortality is not too important.

To control caterpillars, sprays of *Bacillus thuringiensis* are recommended (available under various trade-names — Biobit, Thuricide, Bactospeine, Dipel). *B thuringiensis* is a bacterium containing a powerful stomach poison (specific for caterpillars) which paralyses caterpillar mouthparts and gut so that feeding ceases rapidly although, to the casual glance, caterpillars may appear normal for some time. The bacterium must be eaten to be effective, and so good spray coverage is essential, particularly on the undersides of foliage where young caterpillars, at their most susceptible stage, feed.

Species of caterpillar differ in susceptibility to *B thuringiensis.* The tomato moth is the most susceptible and is controlled by an HV spray concentration of 0.1% w/v. Other species normally found on chrysanthemums are less susceptible and require a concentration of 0.3%. *B. thuringiensis'* failure to control caterpillars is usually due to incorrect concentration. Inadequate leaf coverage can also lead to failure, so the bacterium is best applied as a high volume spray. Other methods, like thermal fogging, give poor under-leaf coverage unless the foliage is not dense, as with tomatoes.

Other ornamentals

Many types of ornamental pot plants may be grown under glass and can suffer from most of the previously mentioned pests on chrysanthemums. Each case must be considered separately.

Vine weevil *(Otiorhynchus sulcatus)* is a common and serious pest. The larvae feed in the soil on roots and are difficult to control. The insecticide aldrin has been used but now it has been banned in many countries and could be in the UK in the future, so alternative methods of control must be found. GCRI, in collaboration with ADAS, is evaluating the prospects of using a fungus, *Metarhizium anisopliae,* and/or a nematode parasite, *Heterorhabditis* sp. The research is in its early stages but so far results have been encouraging.

Cucumbers and tomatoes

The major pests are red spider mite, whitefly, aphids and thrips. Red spider mite is controlled adequately by predator. Use of the chalcidoid parasite, *Encarsia formosa,* to control whitefly has more limitations often leading to an imbalance in the pests' favour. Because of this, an additional selective method of whitefly control was needed which would not interfere with the successful spider mite/predator relationship.

The fungus *Verticillium lecanii* — described in the previous section as an aphicide — will also kill whitefly. In the first experiments on cucumbers, this "aphid" strain of *V lecanii* was found to kill all stages of whitefly except the eggs and could be used in conjunction with *Encarsia* to regain control.

However, this strain on its own could not provide control unless repeated applications were made. The fungus did not spread to healthy scales and new infestations remained healthy, in contrast to the "one shot" aphid control on chrysanthemums. Consequently, a screening programme was undertaken to find a strain which would spread successfully.

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