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WHITEFLIES - THE NEVER-ENDING BATTLE

Michael Brownbridge, Research Assistant Professor of Insect Pathology
University of Vermont
Entomology Research Laboratory, P.O. Box 53400,
Burlington, VT 05405-3400

Whiteflies are ubiquitous pests attacking everything from blooming to bedding plants, cotton to cucumbers. Of the major pest species, silverleaf whitefly (=sweetpotato, strain B)(SWF), *Bemisia argentifolii*, has been reported on more than 500 host plants, and the greenhouse whitefly (GHWF), *Trialeurodes vaporariorum* on around half that number. The apparent genetic plasticity of SWF enhances the insect's ability to thrive on a wide range of host plants, adapt to new ones, and rapidly develop resistance to chemical controls. Shipments of cuttings carrying insecticide-resistant whitefly can create additional problems. Several developmental stages in the whitefly life cycle are also naturally more tolerant to insecticides: the non-feeding egg and pupal stages, for example. Factor in too, the preference these insects have for the undersides of foliage, making them very difficult to target with sprays; their rapid life cycle; and the presence of overlapping generations within any cropping area, and whiteflies are one of a growers biggest headaches. An array of control strategies need to be adopted to combat the pest, as no single option will provide total control over the entire cropping period.

While SWF and GHWF are the most common and serious greenhouse pests, other species may be waiting in the wings. The banded winged whitefly, *Trialeurodes abutilonea*, has been reported in Pennsylvania, New Jersey, Florida, Kentucky and Maryland greenhouses on poinsettias; and the ash whitefly, *Siphoninus phillyrae*, in southern California on urban plantings and nursery stock. While not currently regarded as posing a threat to the industry, the incidence of these insects on greenhouse crops needs to be carefully monitored.

Whitefly Management

Poinsettias are perhaps the most widely grown and valuable of greenhouse crops, and SWF and GHWF are the most common and serious insect pests of these plants. Thus, while the information contained in this presentation largely deals with management of these pests on points, it also has applications for their control on other susceptible crops.

So what measures can be taken to prevent an infestation in your greenhouse? As indicated, no single strategy is satisfactory and, for a number of reasons, including new federal regulations and worker protection standards (and public opinion), it makes economic sense to adopt a variety of tactics. Integrated pest management (IPM) is a much used and a much misused term. In brief, it entails using a combination of control measures - cultural, physical, chemical and biological - to achieve the desired reduction in pest numbers.

Sanitation and Screening. The first component of any pest reduction strategy, is establishment of a strict sanitation program. For example, crops growing in adjacent greenhouses, open crops, or plants remaining in a greenhouse following a shipment, may act as hosts for residual whitefly populations which can then infest new plant material brought into the greenhouse. Whiteflies are also frequently found on weeds, or will survive in the pupal stage, to emerge as adults, on discarded leaves that have withered and died. Thus all weeds and plants from previous crops should be carefully disposed of. All new material plant should be thoroughly inspected for incidence of whiteflies surviving the controls used in their propagation. This should be followed by a vigorous scouting regimen. Use of insect screening can help prevent migration of whiteflies into a greenhouse.

Scouting and Monitoring. One of the most important components of any pest management strategy is knowing your pest. There are biological differences among the whitefly species, and in the susceptibility of the different life stages. Thus it is important to know which species and stages are present to obtain optimal control or to decide where, when or whether any control measures are warranted. A good scouting program forms the cornerstone of any IPM strategy. The more frequent these inspections can be made, then the sooner the beginning of any insect or disease problem will be observed. While there is no maximum limit to the number of plants that should be scouted to monitor the health of the crop, a sample size of 10 plants per 1000 sq. ft. is generally recommended as the minimum number that need to be scouted regularly. An improved sequential sampling plan has recently been developed by personnel at Cornell University and Cooperative Extension Service and is designed to provide information on whitefly population levels (whether the population is above or below a pre-determined population threshold) with minimal scouting, particularly vital when time and/or labor resources are limited; control decisions are then made on the basis of this information. Whichever system is adopted, scouting must be done in a regular and systematic fashion. Outbreak areas should be pinpointed and marked so that population development can be followed and treatments made if necessary. Marked plants can also be used to indicate the effectiveness of any control treatment. Yellow sticky traps should be used to complement a scouting program, to detect changes in whitefly populations and their incidence within a crop, as well as trapping other insect species such as fungus gnats, thrips and aphids. The traps should be placed at the rate of 1 to 4 per 1000 sq. ft., level with the top of the foliar canopy to trap adults seeking to oviposit on younger foliage. By keeping good records of scouting and sticky trap data, the information can be used to reveal infested areas, time pesticide applications, or release of beneficials, and assess the degree of control achieved.

Chemical Control. Traditionally, whiteflies have been controlled using contact or systemic pesticides. Selection of the most appropriate pesticide will depend upon the whitefly species present, and which life stage is predominant. Few insecticides are active against all life stages. Products registered for whitefly control will vary over time and from state to state. Lists of those products recommended for whitefly control can generally be obtained from local extension service personnel. Better control of a mixed whitefly population may be obtained when tank mixes of two different classes of insecticide are applied than if either chemical was used individually. However, when using mixtures the risk of phytotoxicity is increased, and development of multiple insecticide resistance may be enhanced if such combinations are overused. Use of spray rotations where different classes of insecticides are used are recommended to obtain good control in the long term, and to prolong the active lifetime of the various chemical control options.

A number of so-called 'biorational' insecticides are also now available, or under development for registration; so-called because of the reduced impact such treatments have on other, biological control strategies, their low mammalian toxicity, and the brief re-entry times generally associated with their use, e.g. insecticidal soaps (Safers®, M-Pede®); horticultural oils (Sunspray®); insect growth regulators (Enstar®); botanicals containing the neem seed extract azadirachtin (Margosan-O®); and abamectin (Avid®), an insecticide derived from naturally occurring soil microorganisms. Marathon®, a new synthetic, systemic insecticide currently undergoing efficacy trials, appears to show considerable potential for whitefly control. Residual effects up to 15 wk. after application have been reported, and activity has been shown to persist in cuttings taken from treated plants up to 4 wk. after propagation. This may provide a viable replacement for Temik[R], and registration for use on poinsettias is being sought. If registered though, such a pesticide needs to be used with restraint and within an IPM framework. While the long-term residual activity may seem to be a growers dream come true, prolonged exposure of a pest population to a pesticide will doubtless promote development of resistance.

For all insecticides, repeated applications may be necessary to bring whitefly populations under control, so good crop monitoring is essential to determine pesticide efficacy. This can save time, money and insecticides, and will help attain the best returns on such inputs. For example, if scouting reports reveal few or no whiteflies toward the end of the crop, there may be no need to continue a spray regime, especially if there is insufficient time for a detectable infestation to develop before the crop is sold.

Application Techniques. Whitefly control efforts seem to be most efficient when targeted to young immatures, particularly when the crop is in its early stages before the leaf canopy becomes too dense and good underleaf coverage can be obtained. Hydraulic and ULV sprayers - including electrostatic sprayers - may be used with good effect. Thermal and cold foggers, while allowing pesticides to be applied to a large area within a short time, seem to be primarily effective against the adult stages and show little activity against immatures. Knowing the pest status will allow selection of the most suitable application method, and will determine how often treatments need to be reapplied.

Biological Control. ***Beneficials.*** Suppression of whiteflies with insect parasitoids and predators is becoming increasingly popular within an IPM framework. Three beneficial species are commonly available from commercial distributors. Good control of GHWF immatures can be obtained with *Encarsia formosa*, a parasitic wasp, but it is demonstrably less effective against SWF. For SWF, *Eretmocerus californicus* may be a better option. Unfortunately, this species does not seem to reproduce on poinsettia and repeated innundative releases may be necessary to obtain control. *Delphastus pusillus*, a minute black lady beetle, feeds on whitefly eggs, nymphs and adults. This predator must be released in areas of high whitefly population density, and close enough together for successful reproduction and establishment. Subsequent generations will then disperse through the greenhouse to provide control in other areas. Releases of beneficials must be made early enough to ensure success and before pest numbers reach critical levels. They will not cause a rapid crash in the pest population but will suppress moderate infestations and then maintain them at low levels. Timing of release is thus crucial to their successful utilization.

The potential of a range of other parasitoid and predator species remains to be established. Each have been recovered in abundance in field populations of SWF. While the most common approach to their use would be to buy in natural enemies from commercial producers, and release them into an infested crop, there are increasing reports documenting the 'natural' incidence of whitefly biocontrols. This usually occurs when insecticide use in a crop is reduced, permitting the beneficials to flourish within the greenhouse. The influence of chemical pesticides on beneficials is an important factor to consider in their use. Some are very sensitive to certain insecticides, especially those that persist on foliage, so it is important to record which pesticides have been used and when they were applied, and to know their persistence and compatibility with the natural enemies being contemplated for release. Information on the bio-compatibility of beneficials with chemical pesticides is generally available upon request from the producers of these agents.

Host Plant Resistance. Certain plant cultivars are known to be more resistant/tolerant to damage or infestation by whiteflies. Cultivars showing these characteristics could be used in breeding programs, using traditional crossing or molecular techniques, to develop new varieties and hybrids showing enhanced levels of resistance. While breeders have worked to develop new plants with altered characteristics, e.g. color of blooms, disease resistance, those traits conferring insect resistance have not been studied thoroughly, or utilized, in potted, flowering or bedding plant production.

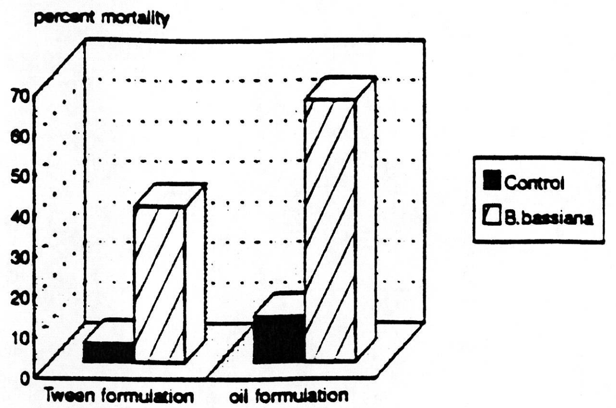
Pathogens. Fungal pathogens show excellent potential for whitefly management. The greenhouse provides a particularly attractive environment to target with fungi, being relatively protected and, in some instances, the environment may be manipulated to enhance performance. Fungi would probably be used as mycoinsecticides in greenhouse crops, with the aim of maximizing mortality rates from a single application in the same way as a chemical pesticide. *Verticillium lecanii*-based products (Mycotal[R], MicroGermin[R] Plus) are available in Europe for control of GHWF in cucumbers, tomatoes and other greenhouse-grown vegetable and ornamentals.

Our own research program is seeking to develop fungi for control of SWF and other greenhouse pests such as thrips and aphids. Of 120 plus indigenous fungal isolates tested against SWF, strains of *B. bassiana, P. farinosus, P. fumosoroseus* and *V. lecanii* were significantly more pathogenic than strains of *M. anisopliae* included in the study.

The susceptibility of different SWF life stages to selected strains was then investigated. The infection rate obtained in treated eggs was negligible for all strains tested but spores persisted on the leaf surface long enough to initiate high levels of infection in the emerging nymphal population. All nymphal stages were susceptible. First instars appear to be particularly sensitive although fourth instars, which represent the longest developmental stage in the life cycle, potentially provide the largest 'window of opportunity' for targeting with a fungal preparation. Adults are also susceptible and a fungal treatment may cause high levels of mortality if direct host contact is obtained. Infection also occurs when the adults move over a treated leaf surface, picking up spores as they do so; infection rates obtained in adults exposed to fungi in this way though, were relatively low. In addition, numbers of eggs laid by a treated population did not seem to be affected when compared to numbers laid by the control groups, presumably because the time from exposure to death was long enough to permit gravid females to produce most of their eggs. However, at the higher dose levels used, sufficient numbers of spores persisted on the leaves to infect a significant proportion of the emergent nymphs.

Laboratory assays have provided several virulent isolates. These are presently under evaluation in a series of small-scale greenhouse trials vs. SWF infesting poinsettia, as we move to develop their potential into a practical product. In these trials we are currently investigating effects of strain, dose rate and formulation on efficacy. Some strains appear to be more versatile than others, and perform well over a range of environmental conditions. Certain *B. bassiana* isolates, for example, appear to provide high levels of infection even under conditions of low relative humidity. Knowledge of suitable dose rates is important to ensure that growers obtain high levels of control of a range of developmental stages, and to prevent waste. In addition, under conditions of low RH, spore germination is inhibited in some species such as *V. lecanii*; this negative effect might be countered by use of higher dose rates. The type of formulation used, important for maintenance of virulence in storage and application, can also affect efficacy. We have been testing *B. bassiana* formulated in emulsifiable oils and a variety of surfactants. Results indicate that, when applied as an emulsifiable concentrate vs. a Tween[R] suspension, higher levels of infection are obtained, probably as a result of the superior leaf and insect coverage obtained (Fig. 1).

Fig.1 SWF mortality on poinsettia treated with B.bassiana formulated in oil or Tween



Another factor affecting field performance of all pesticides is the way in which the treatments are applied. Entomogenous fungi are analogous to contact insecticides, and fungal spores must contact the insect host to initiate an infection. Different application technologies, combined with good product formulation, undoubtedly provide better underleaf coverage than others. Thus, in the next phase of our research, we plan to evaluate a variety of sprayers (mist blower, electrostatic and hydraulic) to determine the most effective way to treat whiteflies on poinsettia. We also intend to continue work to refine dose rates and application timing to provide growers with a practical set of guidelines for implementation of a fungal-based whitefly control strategy. Fungi represent another weapon in the IPM arsenal, and as such, information on their compatibility with other crop protection and plant production practices has to be generated; they will not simply replace chemical pesticides, and should not be viewed as a cure-all for whitefly problems.

Whitefly Management - Where do we go From Here?

The future for successful whitefly management undoubtedly rests in the adoption of an IPM approach. But with all the information on current and new control strategies, how best to go about the business of making an IPM program work in your individual operation? The approach selected will ultimately depend upon, among others, the location and size of the operation, the types of plants being grown, the rotational cycle of plants into the greenhouse, and the type of market outlet for the plants being grown there. The resources a grower can afford to devote to the implementation of an IPM strategy will also influence its complexity. Perhaps, in the short term, the adoption of existing IPM practices - sanitation, monitoring and scouting - may be the first steps all growers must take in order to reduce pesticide use through more efficient timing and targeting of insecticide applications. Introduction of more diverse management practices can then be pursued over time, in collaboration with extension personnel, and with information gleaned from grower meetings and trade journals. As in many other things, diversity will be the strength that enables growers to come out on top in the whitefly war.

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