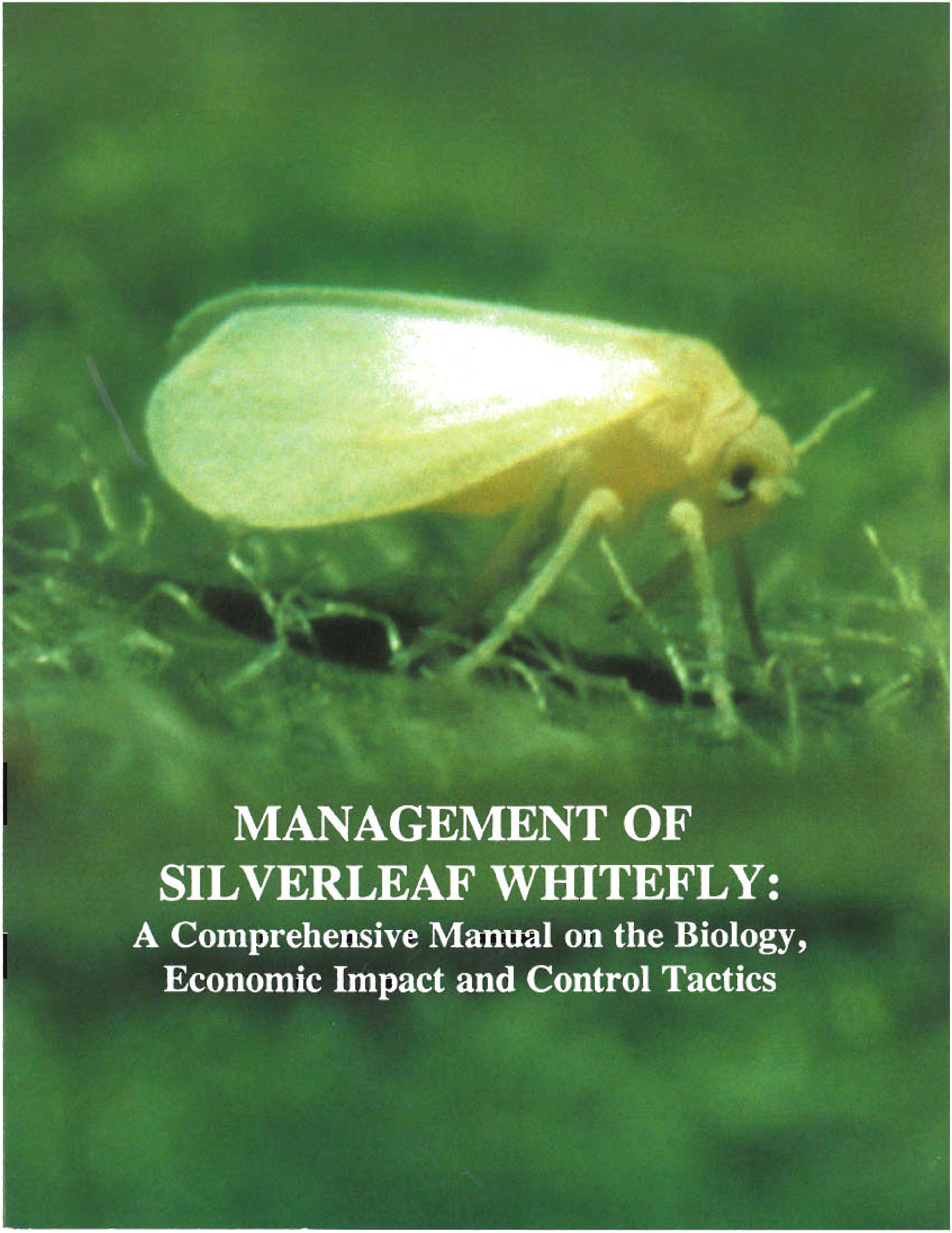

MANAGEMENT OF SILVERLEAF WHITEFLY:

A Comprehensive Manual on the Biology, Economic Impact and Control Tactics

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A Comprehensive Manual on the Biology, Economic Impact and Control Tactics

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INTRODUCTION

This manual will provide agricultural producers, Extension personnel, researchers and other agricultural interests with up-to-date management guidelines on silverleaf whiteflies in the U.S. The information herein has been compiled to give a thorough overview of the economic impact, identification, biology and control of silverleaf whiteflies with emphasis on an integrated approach to management. All aspects of management including cultural, biological, mechanical and chemical control are covered. This publication is intended to be updated as new research is conducted which leads to improvements in the database.

Management of Silverleaf Whitefly:

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Economic Losses Resulting from Silverleaf Whitefly Infestation

The silverleaf whitefly, *Bemisia argentifolii* (Bellows and Perring), formerly referred to as sweetpotato whitefly-strain B *Bemisia tabaci* (Gennada), has become an important pest of cotton, vegetables and ornamentals in the southern United States. Probably the main reason whiteflies suddenly increased in their economic importance was the introduction of this new, more aggressive whitefly species/strain and high levels of insecticide resistance associated with this new pest.

In 1986, the first recorded outbreaks of silverleaf whitefly in the U.S. occurred in the poinsettia industry of south-central Florida. Heavy infestations of south Florida vegetables occurred the following year, especially in tomatoes. Losses in tomatoes from whiteflies and the associated geminivirus for the 1990-91 season including control costs were estimated at $125 million.

In a 1991 outbreak of silverleaf whitefly in South Texas, cotton and vegetables sustained estimated direct losses of $24 million and $29 million, respectively. Losses to Texas in ornamentals that year were estimated at $23.8 million. In California, the insect caused $137 million in crop losses and the loss of more than 3,000 jobs. Since April 1992, crop losses in Imperial county alone have been estimated at $100 million, equivalent to $172 million in private sector sales, 2,787 jobs and $25 million in personal income. Unemployment in this agriculturally dependent region has been as high as 33.5 percent; much of this is attributable to the whitefly. Neither chemical, biological nor cultural controls used alone have successfully managed the silverleaf whitefly where it has become a predominant pest in field crops. However, the integration of several control tactics can be effective in reducing the overall impact of this pest and may lead to an acceptably low level of whitefly infestation.

To manage this pest, it is necessary to know what plants are affected and to understand the nature of crop damage, whitefly biology, and monitoring techniques (sites, population dynamics, action thresholds). Also, it is critical to understand the uses and limitations of various control tactics, which include cultural methods (altered planting practices and physical barriers), host plant resistance, chemical controls and biological controls.

Crops Affected by Whiteflies

Although the silverleaf whitefly attacks a wide range of host plants (more than 500 species representing 74 plant families) not all of these plants can support large populations of whiteflies. However, silverleaf whitefly is a pest on a wider range of host crops than the sweetpotato whitefly; for example, silverleaf whitefly reproduces well on cabbage while sweetpotato whitefly does not. Also, relatively low numbers of the silverleaf whitefly can cause striking plant disorders, such as silverleaf of squash, irregular ripening of tomatoes, and stem blenching of cole crops. Low numbers of sweetpotato whitefly do not produce noticeable direct damage. Crops that support large numbers of silverleaf whitefly include cotton, cabbage and other cole crops, cucumber, squash, melons, tomatoes, eggplant, okra, sesame, soybean, peanut and many ornamentals, including poinsettia, hibiscus, Gerber daisies, lantana, verbena, garden mum, salvia and mandevilla.

Crops grown in spring and summer and crops in large acreages, such as cotton, may produce very large whitefly populations. As cotton is defoliated, whiteflies seek new hosts and can then be found in higher numbers on a wider range of host plants. For example, in 1991 silverleaf whitefly migrations from the cotton crop in Texas' Lower Rio Grande Valley resulted in whitefly infestations of some citrus orchards, which do not have problems with this pest. In California's Imperial Valley, extensive surveys indicated a whitefly migration sequence of cucurbits in the spring, cotton in the summer, and alfalfa and cole crops in the late fall and winter. Major weed hosts include velvetleaf and sowthistle in the spring and sunflower and groundcherry in the early fall (summer in Arizona). In south Florida, whiteflies build up in fall vegetables such as tomatoes and move directly into overlapping spring crops. In south central Florida they use winter crops such as cabbage as a bridge. Survival over the fallow summer period is low, and in the absence of susceptible crops, is limited to weeds such as water primrose, hairy indigo and spurge where natural whitefly enemies are active and whitefly mortality is high. Susceptible crops grown in greenhouses that maintain warm temperatures throughout the year may experience whitefly outbreaks year-round, even as far north as New York.

Whitefly Damage

Direct crop damage occurs when whiteflies feed in plant phloem, remove plant sap and reduce plant vigor. The pests inject foreign enzymes into the host plant while feeding, which alters the normal physiological process. High whitefly populations may cause plants to die. Whiteflies also excrete honeydew, a complex mixture of sugars which promotes sooty mold growth that interferes with photosynthesis and may lower harvest quality. In cotton, honeydew makes the cotton fibers sticky and can promote growth of sooty mold, further reducing quality. Honeydew and sooty mold render cotton difficult to process and require washing of vegetables, thus increasing production costs. In some hosts, damage can result from toxins injected into the plant by feeding whitefly immatures (nymphs) that cause plant disorders such as silverleaf of squash and irregular ripening of tomato and peppers. Plant disorders, and especially virus transmission are of particular concern because they can occur even when a whitefly population is small. Other forms of damage include stem blanching, leaf and plant breakdown, chlorotic spots, yellowing, leaf and fruit shedding and abnormalities of fruiting structures.

Silverleaf whiteflies transmit plant viruses such as geminiviruses and clostroviruses, which can be extremely virulent. Geminiviruses damage tomato, pepper, cotton and squash in the southern United States. Affected plants may show vein clearing or yellowing, golden or yellow mosaic patterns, cupping, crumpling and distortion of leaves, and stunted or distorted plant growth. Tomato mottle geminivirus struck Florida in 1989, but has not yet been seen in California or Texas.

Tomato yellow leafcurl virus (TYLCV), long the major constraint to tomato production in the Middle East, appeared in the Dominion Republic in 1992 where it devastated the processed tomato industry. By 1995 the industry began to rebuild through the use of host-free periods, TYLCV resistant varieties and insecticidal control. In general, the later the infection with geminiviruses or the later the onset of plant disorders, the less damage to the crop, so preventive action is critical. Prevention is also crucial in managing whiteflies in highly cosmetic crops such as ornamental plants, where even low numbers of whiteflies can affect marketability.

Whitefly management in a given crop will depend greatly on the severity of damage caused in that crop and the number of whiteflies required to inflict this damage. Very few whiteflies are required to transmit viruses provided virus inoculation levels are high, so where virus is the major concern and virus sources are present, the grower will want to avoid even small numbers of whiteflies. A combination of selected cultural practices, intensive chemical treatments or physical controls, and/or the development of host plant resistance, may be most effective. Where low levels of whiteflies are tolerable, other methods such as biological control may be more effective.

Identification and Life Cycle of the Silverleaf Whitefly

There are several species of whiteflies in addition to the silverleaf whitefly that may infest the same crop. These include the banded-winged whitefly (*Trialeurodes abutilonea*) and the greenhouse whitefly (*Trialeurodes vaporariorum*). Banded-winged whitefly adults, as the name implies, have dark bands across white wings. The greenhouse whitefly adult looks similar to the banded-winged whitefly without the bands. Both hold their wings horizontally at rest whereas the slightly smaller silverleaf whitefly holds its wings tent-like over the body. It is important to be able to distinguish the silverleaf whitefly because its susceptibility to control measures and damage potential are quite different from that of the other whiteflies.

The silverleaf whitefly adult is small, about 0.8 to 1.2 mm in length with a pale yellow body. The pest goes through four nymphal instars, ranging in approximate size from .3 mm (1/95 inch) as first instars and/or crawlers, to .6 mm (1/40 inch) as fourth instars. Immature stages begin with a pointed, oblong, smooth, yellow egg which darkens to brown at the apex just before hatching. The first instar or crawler is a greenish-yellow, flattened, oval nymph which attaches itself to the underside of a leaf near the empty egg case. The scale-like nymphs [eggs and nymphs] can become so numerous that they almost cover the entire undersurface area. Nymphs remain stationary, sucking plant sap through long, needle-like mouth parts and passing through three more molts [penetrating the tissue and removing plant sap with its pierce-sucking mouthparts]. Late third and fourth instars begin to develop distinctive eye spots and are often referred to as red-eyed nymphs. The fourth instar, or "pupal stage," has very prominent, red eye spots and is oval and flat with a rounded outside margin, tapering toward the leaf surface as viewed from the side although they may become more rounded on hairy leaves. In contrast, the pupae of *Trialeurodes* species have distinctly ridged outside margins with flat, vertical surfaces and waxy projections at the tops of the ridges as viewed from the side.

The life cycle from egg to adult requires 2 1/2 to 3 weeks in warm weather, but may take as long as 2 months under cool conditions. The number of eggs produced per female is also greater in warm weather than in cool weather. The rates of reproduction varies with the host plant, but an average is 160 eggs per female (range of 50 to 400), of which about two-thirds can be female. This high reproductive potential explains in part how whitefly populations can increase so rapidly (1 female..100 females..10,000..1,000,000 or the approximate number of adult females resulting from three generations assuming no mortality occurs).

Monitoring Whitefly Populations

Methods of monitoring for whiteflies include the use of sticky traps, leaf inspection, vacuum sampling, oiled-pan counts and others. The movement of whitefly adults can be monitored with yellow sticky traps. This method also can provide a relative measure of (1) general population trends for an extended area, (2) immigration rates into fields prior to planting, and (3) potential dispersal of adults from certain crop situations. Adults can both fly short distances within the plant canopy and be carried long distances on air currents. Some migrating adults can stay suspended for more than an hour and can be carried great distances. Even so, whitefly adults are usually more concentrated close to the ground and close to the source of infestation. Adults emerge from pupae during the morning and become more active as temperature increase. Thus, movement is greatest from mid-morning to mid-afternoon. Adults tend to settle randomly after a long-distance flight, but are able to perceive color and will preferentially select yellow/green objects. Adults congregate, feed and mate on the undersurfaces of the leaves of the host plant, in such numbers as to create "clouds" when disturbed.

Yellow sticky cards are regularly used to monitor the activity of migrating whitefly adults in Florida, Hidalgo and Cameron counties in Texas and statewide in Arizona. Since there is a diurnal change in the number of adults captured on traps, sampling is conducted over 24-hour periods in order to minimize daytime variation and focus on differences between locations. Increases of whiteflies occurred in Texas in a similar pattern in 1991, 1992 and 1993, with a measured peak in late July. By late August of these years, adult numbers were drastically reduced. This rapid increase, peak and decline in activity of migrating adults correlates with the maturation and defoliation of the cotton crop. A smaller peak in migration activity has been observed at the end of the spring melon crop. Those periods during the year when large acreages of host crops are removed tend to produce the largest migrations and subsequent crop infestations. Cotton defoliation, for example, causes a large migration of whitefly adults to other crops. Cotton stalk destruction in the fall contributes to a regional decline of whitefly numbers, as do cooler temperatures and a fall build-up of natural enemies. In south Florida whitefly catches on yellow sticky cards peak following harvests, especially the spring vegetable harvest which occurs from late May through early June. Numbers fall to lower levels by late summer in the absence of cultivated hosts then increase slowly in the fall crop. Senescence or destruction of fall crops following harvest releases a pulse of often viruliferous whiteflies which may settle in newly planted fields with dire consequences.

Eggs are laid and immature stages of silverleaf whitefly develop on the undersides of leaves of host plants. Adults usually congregate on younger leaves where oviposition is heaviest. Adult population densities within many susceptible vine or bush crops can be evaluated by counting the number of adults per fully expanded leaf (by gently turning over a leaf at the third or fourth node from the tip). Conversely, in cabbage; older leaves should be sampled. Sampling 100 leaves per field (one leaf on each of 25 randomly selected plants per quadrant) can provide a good estimate of average whitefly population density in the field, to make a control decision.

The location on the plant of the various stages of the silverleaf whitefly follows the development of the plant. Eggs and early instar nymphs are found on the young leaves and larger nymphs and pupae are usually more numerous on older leaves. For example, large nymphs are more noticeable at the sixth to eighth node from the growing point than on younger leaves in melons and tomatoes. On cabbage, higher concentrations of large nymphs occur on the oldest leaves (frame leaves). Thus, the age of leaves inspected affects the observed number of nymphs of each stage. In general, large nymphs are the easiest of the immature stages to sample because they can be counted with the unaided eye. Nymph samples can provide a better measure of actual whitefly population density in the field, especially when whitefly numbers are low. This sampling method also can be used to measure percent parasitism, which may be critical in a biological control program. However, nymphs may be more difficult to detect than adults with the additional disadvantage that an infestation may become well established prior to the detection of nymphs.

Action thresholds are levels of pest populations at which control should be implemented to avoid significant damage to the crop. Action thresholds help producers determine both the need for control actions, such as insecticide applications, and the proper timing of such actions. Unfortunately, there is little data with which to establish thresholds for silverleaf whitefly on most crops. For virus susceptible crops realistic thresholds would be based on viruliferous whiteflies which are not practical to sample. In this case the grower's only options to asses the damage potential of a particular whitefly population is to consider factors such as probable level of virus inoculum from outside sources or within the field, and the susceptibility of the crop to yield loss from virus which is correlated with crop age. In cucumber, an average of 30 nymphs per square inch of leaf completely stunts growth. In poinsettia, more than two to five immatures per square inch of leaf is considered a damaging level. In Arizona cotton, research shows that insecticide applications should begin once a threshold density of five whitefly adults per leaf has been reached. Data collected in 1992 at the Texas Agricultural Experiment Station at Weslaco suggest that an average of one large nymph per square inch of leaf at the sixth leaf node is a potentially damaging level in cantaloupe (resulting in approximately 10 percent yield loss). In 1993-94 thresholds of 0.4 nymphs per leaf between the sixth and ninth nodes and three adults per leaf at the third node were shown to be effective in melons at Weslaco, Texas. Sampling of adults is simpler and often more acceptable to growers than counting nymphs. In Arizona, 3 adults per leaf at the 3rd leaf node was shown to be effective in cantaloupe. Having samples of both adults and nymphs can help determine if the infestation is recent (adults present, but no nymphs) or established (nymphs present). With the limitations in available chemical treatments, the use of economic thresholds is essential for efficient whitefly management and economical production of susceptible crops.

Geographic Location and Migratory Patterns of Whiteflies in Southern U.S.

In California, the silverleaf whitefly was found recently in the San Joaquin Valley and as far north as Sutter and Yuba counties. This whitefly overwinters in the San Joaquin Valley, but lower temperatures in this region may prevent numbers from reaching the levels experienced in the warmer southern deserts. Nevertheless, serious problems threaten Central Valley growers. Silverleaf whitefly is consistently the key pest of susceptible vegetable crops in south and south-central Florida, but only an occasional field pest in north Florida and South Georgia, depending on overwintering conditions. However, it can occur as a greenhouse pest much further north.

Cultural Control of Whiteflies

One solution to any pest problem is to prevent or avoid it through cultural manipulation of crops. Cultural controls are modifications of management practices that make the environment less favorable to pest reproduction, dispersal, survival and/or damage. Cultural control options for silverleaf whitefly include using physical barriers or other barriers that prevent the pest from reaching the crop, adjusting planting dates to avoid the pest, cleaning transplant materials, planting in low infestation areas, rotation with non-susceptible crops destroying crop residues and selecting resistant crops or cultivars. Fields relying on cultural rather than chemical controls are likely to get the most help from natural enemies.

Physical Barriers

Physical barriers, such as fine mesh screens, can be used in greenhouse production to reduce the potential for infestation. Under field conditions, there are several types of barriers that can reduce whitefly problems. These include reflective mulches that tend to repel whiteflies, oil-coated yellow mulches that act as a trap for whiteflies, floating row covers (generally made out of a light fiber mesh and placed over newly planted crops) that exclude whiteflies during the vegetative growth of the crop, and trap crops. Floating row covers work exceptionally well for early-season protection, but can be expensive and often have to be removed at flowering for proper pollination. Other barriers may be only partially effective and should be considered in conjunction with other control tactics.

Planting Dates

Another way to avoid or reduce whitefly infestations is to adjust planting dates to avoid the heaviest insect migration periods or crop overlap. Early planting can be an effective way to avoid whiteflies because they reproduce more rapidly under hot, dry conditions. Thus, early planting of spring and summer crops allows them to mature before conditions are favorable for rapid whitefly population increases. Highly susceptible crops such as cucurbits, crucifers and tomatoes should not be planted when whitefly migration is expected (such as at the end of cotton season). In Texas, cucumbers planted in mid-June 1991 could not withstand the high infestations of silverleaf whitefly despite the large number of insecticide applications. However, cucumbers planted in August, after migrations had diminished, were much less affected. In Florida, tomato growers are advised not to plant spring tomatoes until the fall harvest has been completed and whiteflies have had time to disperse. Fall melon production has been curtailed and/or eliminated in many parts of Arizona and southern California. Delayed planting in the fall, after peak migration has diminished, can help to reduce heavy infestation pressure. Terminating cotton by August 31 and drying down alfalfa in the Fall in Southern California also will decrease whitefly population. An alternative option to not planting anything during this period is to plant a less susceptible crop such as pepper.

Clean Transplants

Cleaning any plant material that has been shipped into the U.S. will help to reduce whitefly populations. Growers or landscapers should thoroughly inspect new plants for whitefly infestation. Before making a purchase, investigate or view greenhouses where transplants are grown. If whiteflies are found, they should be identified; plants infested with invading whiteflies should be returned or destroyed and suppliers and county agricultural commissioners notified. Vegetable transplants should be inspected and infested plants treated immediately or rejected, especially if potentially infected with virus. Transplants grown outside of major crop production areas will be less likely to be infected.

Removal of Infested Plants

Field location also can affect the potential for whitefly infestation. The earliest and heaviest whitefly infestations most often occur in fields located near crops with prior or current infestations. This has been observed in spring melon crops located near infested cabbage or cucurbit fields and in spring tomato next to fall tomato. Susceptible crops should not be planted near infestation sources. Avoid planting cotton near melons, and neither cotton nor melons should be planted near urban landscaping or weed grasses.

To combat the problem of whitefly-transmitted viruses,[All infected plants should be removed and destroyed] susceptible crops should not be grown continuously because they provide a constant source of inoculum.

Roguing may not be practical and effectiveness has not been demonstrated. Neither has weed removal been demonstrated to be effective unless the weeds are virus sources, which they usually aren't. Since crop residues can harbor silverleaf whiteflies and virus inoculum, they should be rapidly and completely destroyed after the final harvest. Subsequent planting of susceptible crops should be avoided until migration has ended. This practice can reduce whitefly infestation as well as carryover of viral inoculum. Most weeds do not harbor geminiviruses that effect crops. An exception is tropical soda apple (*Solanum viarum*) which is a host of tomato mottle geminivirus in Florida. Vegetation along field edges, ditch banks, roadsides and other noncrop areas that may be overwintering sites for whitefly should be controlled.

Establishing a host-free period by careful choice of planting site and date is now a commonly accepted recommendation for reducing whitefly populations in many areas of the southern U.S. that are severely affected by this pest. This practice requires regional cooperation to be effective.

Although these practices may not completely eliminate whitefly problems, they can help to reduce pest populations and damage to manageable levels. These practices should be modified only to preserve known populations of natural enemies of whiteflies.

Host Plant Resistance

Host plant resistance (HPR) is one of the preferred methods for minimizing the damage caused by the silverleaf whitefly and associated viruses, because it does not require the complete elimination of the pest to be effective. Resistance and/or tolerance to many plant viruses, including the whitefly-transmitted tomato yellow leafcurl virus, is already available in commercial varieties. HPR can also protect the crop by making it less suitable for the pest or because the crop is tolerant to the pest. The result is less crop damage. Examples of this are (1) the use of smooth-leaf (glabrous) cotton rather than hairy-leaf cotton to reduce the impact of silverleaf whitefly on yield, and (2) resistance to cotton leaf crumple virus in the 'Cedix' cotton variety. Possible resistance to the silverleaf whitefly is also being developed in certain tomato, peanut, squash and pepper varieties. Also, cantaloupe varieties such as 'Cruiser,' 'Primo' and 'Hymark' tolerate low whitefly infestation with less damage than 'Perlita.'

Commercial producers should note that the resistance of a crop can be affected by the level of pest infestation, with even some resistant cultivars damaged by large whitefly populations. Also, crops resistant to one pest may not be resistant to another. For example, smooth leaf cottons are less attractive to silverleaf whitefly but more attractive to cotton fleahopper. Finally, resistant commercial cultivars take time to develop and are not currently available for many crops.

Chemical Control of Whiteflies

Chemical control of whiteflies is both expensive and increasingly difficult. If the rate of whitefly re-infestation is great enough, as it was in June and July, 1991 in Texas and July and August, 1992 in Arizona, the cost of effective insecticide treatments may be prohibitive. Besides the cost of treatment, other factors involved in chemical control decisions are the need for thorough coverage on underleaf surfaces, the risk of secondary pest outbreaks, the risk of whiteflies developing insecticide resistance, and regulatory factors that have to be weighed against the expected returns for a given crop at a given planting date.

Many systemic and contact insecticides have been tested for control of silverleaf whitefly, but few give effective control. Previously registered systemic insecticides, such as oxamyl, have been only partially effective. Imidacloprid has limited availability, may be difficult to apply and is costly, but it is quite effective. Certain contact insecticide combinations, such as fenpropathrin or bifenthrin plus acephate, have provided excellent control in initial greenhouse and field studies as long as there was thorough coverage of the foliage. Other products with contact activity, such as oils, detergents and soaps have good activity against whitefly, but in field tests are often less effective because of poor coverage or other reasons. Oils are effective against all stages of whitefly but are most dependent of all insecticides on complete coverage of underleaf surfaces. Also, oils can be detrimental to tiny parasitic wasps, although not really to the extent of broad-spectrum insecticides. Soaps and detergents are most effective against young whitefly nymphs and have little activity against adults. They do not harm parasitic wasp adults but can kill larvae of predaceous beetles such as Delphastus and Nephaspis which come in direct contact with the spray. Soaps and detergents are only effective when wet so are best used under humid conditions to lengthen activity. Soaps tend to precipitate in hard water so should be mixed with soft water or substituted with a detergent. Soaps, oils, and detergents may all cause phytotoxicity at high concentrations, especially in hot weather.

Good coverage of the foliage with contact insecticides is essential for best results. Most whiteflies are located on the undersides of leaves where they are protected from overtop applications, and the immature stages (except for the crawler) are immobile and do not increase their exposure to insecticides by moving around the plant.

The most effective time to control whiteflies by aerial application is when adults are active, and, therefore are better exposed to the insecticide.

Specific insecticides should be selected according to the stage(s) of whitefly to be controlled. For example, growth regulators often control immature stages by affecting nymphal development, but do not provide good adult control. On the other hand, short residual contact insecticides (nicotine, endonsulfan) may control adults, but not affect immature stages.

Silverleaf whiteflies have become resistant to many insecticides in parts of the U.S. and resistance could threaten traditional chemical control techniques. The effectiveness of the few currently registered insecticides could be lost if they are excessively and repeatedly applied. There are techniques for monitoring resistance to determine which insecticides are still active against whiteflies. Generally, if an insecticide treatment is properly made with sufficient coverage and yet is ineffective, then that whitefly population should be tested for resistance to the product. An ideal way to prevent or slow development of resistance is to rely on alternative control methods such as biological or cultural control, which reduce selection for resistance. Another method, currently recommended when treatments are made for control is to rotate between chemicals with different modes of action between approximate whitefly generations.

There is a possibility that treating a resistant whitefly population with certain insecticides could actually accelerate population increases because the insect is under biochemical stress, or because beneficial arthropods are eliminated. Resistant populations have been shown to have accelerated reproductive potential in some cases. To minimize this potential problem, insecticide applications should be used judiciously and combined with non-chemical control tactics.

Biological Control of Whitefly

Whiteflies are attacked by predatory insects such as green lacewing or coccinelid larvae and by parasitic wasps such as *Encarsia* or *Eretmocerus* species. They are also subject to mechanical injury; desiccation; diseases such as *Beauvaria*, *Paecilomyces* or *Verticillium* species. Researchers are studying the use of natural enemies and control factors in field situations.

Parasitic wasps have a prolonged and specialized relationship with their host, the larvae usually parasitizing only one or a few hosts in their lifetime. Parasites usually are more effective at low pest population densities. Parasitism can be quantified by counting the number of empty whitefly pupal cases with a circular exit hole (created by the parasite) rather than a "T" shaped split (created by the normal adult whitefly emergency).

A predator is an animal that attacks, kills and feeds on many other animals in its lifetime. Some predators are quite specialized and feed on only one or a few closely related species. However, most predators are more generalized and feed on a variety of species of similar types of organisms. They are more effective at high population densities.

Pathogenic fungi can be applied as a spray treatment and are effective at any population density. Insect pathogens used for silverleaf whitefly control must be applied with good coverage and under proper environmental conditions to be effective. These products are being tested in commercial production fields and commercial greenhouses, and the economic feasibility of their use has not yet been determined. Naturally occurring biological control in weeds during the summer fallow period is a key component of whitefly management in south west Florida. Monitoring of a large but isolated organic vegetable farm there has shown that biological control of whiteflies can also work with in the crop in the absence of broad spectrum insecticides.

Integrated Management of Silverleaf Whiteflies

A combination of cultural, biological and chemical controls can be effective in managing silverleaf whitefly and reducing the overall impact of this pest. Different strategies will be necessary for different production systems, growing conditions and geographical areas. Greenhouse growers can take advantage of the enclosed environment by using screens to exclude whiteflies and by releasing beneficial insects. In field situations, one general approach is to use: 1) cultural practices to avoid or at least reduce infestations; 2) biologically mild treatments such as insecticidal soaps or highly selective insecticides to suppress whiteflies while preserving beneficial insects; and 3) broad-spectrum pesticides only when necessary (based on action thresholds) preferably waiting to the later stages of the crop in order to minimize detrimental effects on beneficial organisms.

When planning whitefly management in vegetable and field crops, the following factors should be remembered: (1) whitefly populations begin with low numbers following winter or host-free periods, increase through the season and decline with crop removal or unfavorable weather. (2) hot, dry weather favors rapid whitefly reproduction; cool or wet weather has the opposite effect. (3) a decline of host crop quality and availability, such as after harvest, increases the likelihood that whiteflies will migrate to adjacent crops; (4) different crops and crop varieties can vary greatly in their susceptibility to whiteflies; and (5) fallow periods prior to planting will reduce whitefly populations to manageable levels. Early planting of susceptible spring crops in Texas and California and the use of short-season varieties will help crops escape the greatest whitefly pressure. Following cotton, whitefly numbers in fall vegetables begin high and eventually decrease with time, presumably because of the smaller acreage of available host crops, cooler weather and greater numbers of natural enemies in the fall. Therefore, delaying fall planting until the threat of heavy migration has diminished can help to reduce whitefly problems.

Working with these considerations in mind, a multi-tactic approach can be used to effectively manage the silverleaf whitefly in agricultural situations.

Suggestions for Whitefly Management

1. Destroy old crop residues that harbor whitefly infestations.
2. Plant resistant varieties where available.
3. Plant early to avoid high infestations late in the season and use short-season varieties.
4. Avoid planting next to crops infested with whitefly and avoid carry-over from infested plant material.
5. Delay the planting from previous crops until whitefly migration have diminished; use physical barriers during heavy migration; or, plant tolerant crops during these periods.
6. Adopt spraying methods that improve coverage, especially on the under surface of leaves.
7. Avoid the use of broad-spectrum insecticides as much as possible, especially early in the crop cycle to allow buildup of beneficial insects.
8. Use all insecticides in accordance with action thresholds and rotate modes of action to delay the selection for insecticide resistant whiteflies, and maximize field efficacy.
9. Consult your state's IPM Pest Management Guidelines or state Extension Service for the effectiveness of chemical and nonchemical management tactics.

Whitefly Resources

Numerous research articles and extension publications are available on silverleaf whitefly. The sources listed below provide a good starting point for locating information on whiteflies.

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World-Wide Web Sites on the Internet

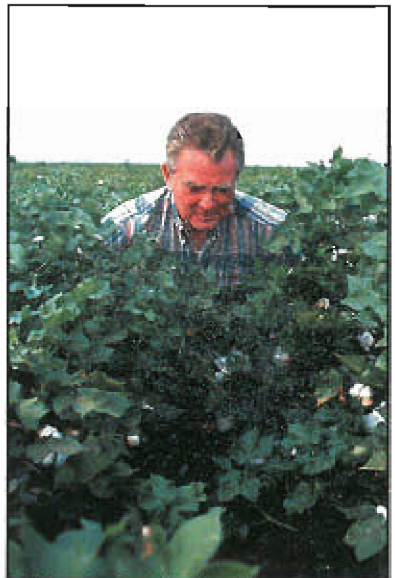
USDA Whitefly Knowledgebase: http://gnv.ifas.ufl.edu/~ent2/wfly0002.htm

University of Arizona Whitefly Working Group:
http://gears.tucson.ars.ag.gove/wcrl/wwghome.html

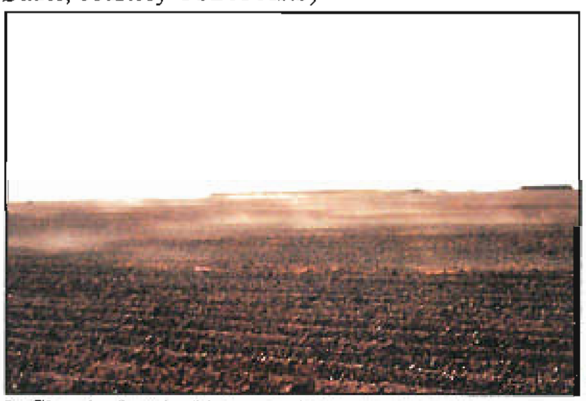
Cooperative Research on *Bemisia tabaci* -- Texas: http://rsru2.tamu.edu/bcpru/sweetpot.htm

Silverleaf Whitefly Page -- California: http://www.uckac.edu/whitefly/index.htm

1. Silverleaf whitefly (*Bemisia argentifolii*) a.k.a. sweetpotato whitely (*B. tabaci* strain B) adult. (S. Bauer, courtesy USDA-ARS)



2. Cloud of whiteflies in cotton. (E. McCain, courtesy of USDA-ARS)



3. Cloud of whiteflies over field, Imperial Valley California. (Courtesy of N. Toscano)

4. Cotton leaf infested with whiteflies. (P. Ellsworth)

5. Melon plant infested with whiteflies. Note immatures on undersides of leaves near base of plant and adults near terminal. (J. Palumbo)

6. Whiteflies and aphids on alfalfa leaflets (P. Ellsworth & J. Diehl)

7. Sunflower, a host of silverleaf whiteflies. (Courtesy of P. Ellsworth)

8. Peanut, a host of silverleaf whiteflies. (P. Ellsworth)

9. Whiteflies on grape, an occasional host plant. (P. Ellsworth & J. Diehl)

10. Poinsettia in the greenhouse, a frequent host of silverleaf whiteflies. (O. Minkenberg)

11. Lantana, an ornamental plant which is a major host of whiteflies in some areas. (J. Diehl)

12. Whiteflies on passion vine (*Passiflora* sp.), an ornamental host. (P. Ellsworth)

13. Sowthistle (*Sonchus* sp.), a weed which hosts whiteflies. (J. Diehl)

14. Wright groundcherry (*Physalis wrightii*), a weed which is a frequent host of whiteflies in the southwest. (P. Ellsworth)

15. Whiteflies on pigweed, *Amaranthus* sp. (P. Ellsworth & J. Diehl)

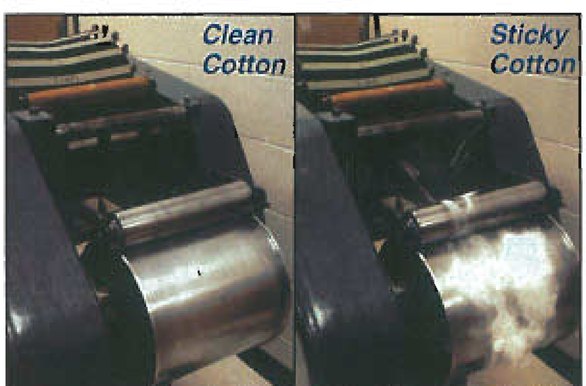
16. Whiteflies on mallow (*Malva* sp.) a common weed host of whiteflies. (E. Natwick)

17. Whitefly damaged (left) vs. insecticide protected lettuce. (J. Palumbo)

18. Sooty mold on melons. (E. Natwick)

19. Sooty mold and stickiness on cotton lint. (J. Norman)

20. Sticky cotton plants. Whiteflies may be seen stuck to some of the leaves. (E. McCain, courtesy of USDA-ARS)



21. Minicard running clean and sticky cotton. Sticky cotton will stick to the card. (Courtesy T. Henneberry)

22. Squash silverleaf disorder. (A. Sparks)

23. Irregular ripening of tomato caused by whitefly feeding. (D. Schuster).

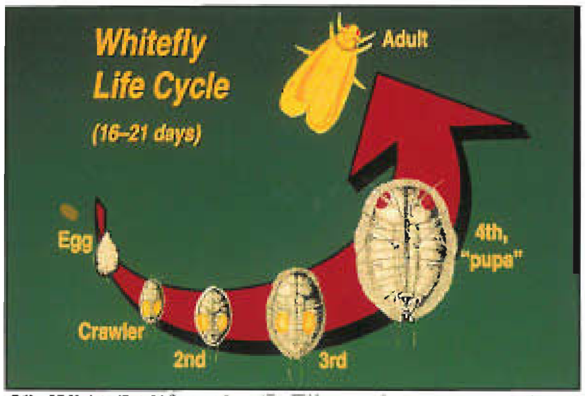
24. Stem blanching in broccoli caused by whitefly feeding. (E. Natwick)

25. Chlorosis of upper leaf and whiteflies feeding on lower leaf of ?. (P. Ellsworth & J. Diehl)

26. Gemini virus in tomatoes. (D. Riley)

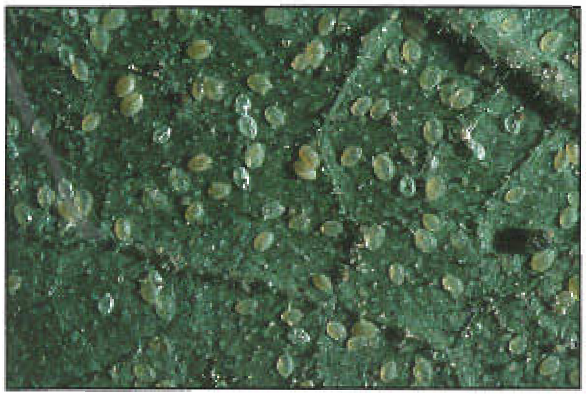
27. Gemini virus in peppers. (B. Villalon)

28. Leaf with cotton leaf crumple virus vs. undiseased leaf. (J. Dykinga, courtesy of USDA - ARS)



29. Whitefly lifecycle. (P. Ellsworth, drawings of nymphs by T. Liu)

30. Silverleaf whitefly adults and eggs on squash leaf. (Courtesy of USDA-ARS)



31. Silverleaf whitefly nymphs. (D. Riley)

32. All stages of sweetpotato whiteflies (*Bemisia tabaci*). (J. Clark, courtesy of UCIPM)

33. All stages of greenhouse whiteflies (*Trialeurodes vaporariorum*). (J. Clark, courtesy of UCIPM)

34. All stages of bandedwing whiteflies (*Trialeurodes abutilonea*). (J. Clark, courtesy of UCIPM)

35. All stages of ash whiteflies (*Siphoninus phillyreae*). (J. Clark, courtesy of UCIPM)

36. Leaf turn method for sampling whiteflies in cotton. (P. Ellsworth & J. Diehl)

37. Leaf turn method for sampling whiteflies in melons. (J. Palumbo)

38. Yellow sticky trap for monitoring whitefly populations. (P. Ellsworth)

39. Pan technique for sampling whiteflies. (P. Ellsworth)

40. Hand vacuum technique for sampling whiteflies. (J. Palumbo)

41. Floating row covers in vegetables. (D. Riley)

42. Deep plowing of cotton. (J. Palumbo)

43. Ground application of insecticides for whitefly control. (E. Natwick)

44. Mist sprayer. (E. Natwick)

45. Thorough insecticide coverage using nozzle extensions and drops. (J. Dykinga, courtesy of USDA-ARS)

46. Aerial application of insecticides for whitefly control in cotton. (I. Kirk)

47. Insecticide treated (background) vs. untreated (foreground) lettuce. (J. Palumbo)

48. Insecticide treated (background right) vs. untreated (foreground) cabbage. (E. Natwick)

49. Insecticide treated (foreground) vs. untreated (background) melons. (D. Riley)

50. Insecticide treated (background) vs. untreated (foreground) cotton. (P. Ellsworth)

51. Big-eyed bug (*Geocoris* sp.) a native predator of whiteflies. (Courtesy of USDA-ARS)

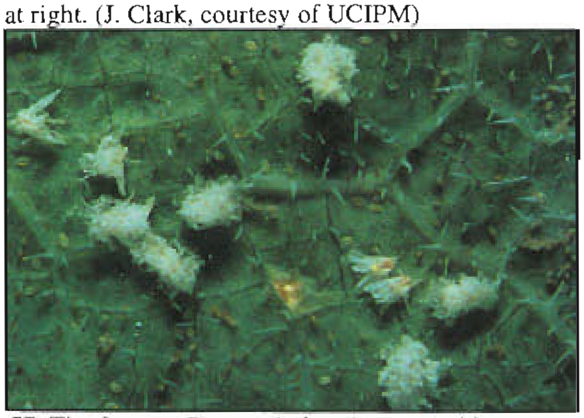
52. Green lacewing larva (*Chrysopa* sp.) a native predator of whiteflies eating an apid. (Courtesy of UCIPM)

53. Dance-fly (Empididae: *Drapetis* sp.), a native predator of adult whiteflies in the southwest. (D. Meade)

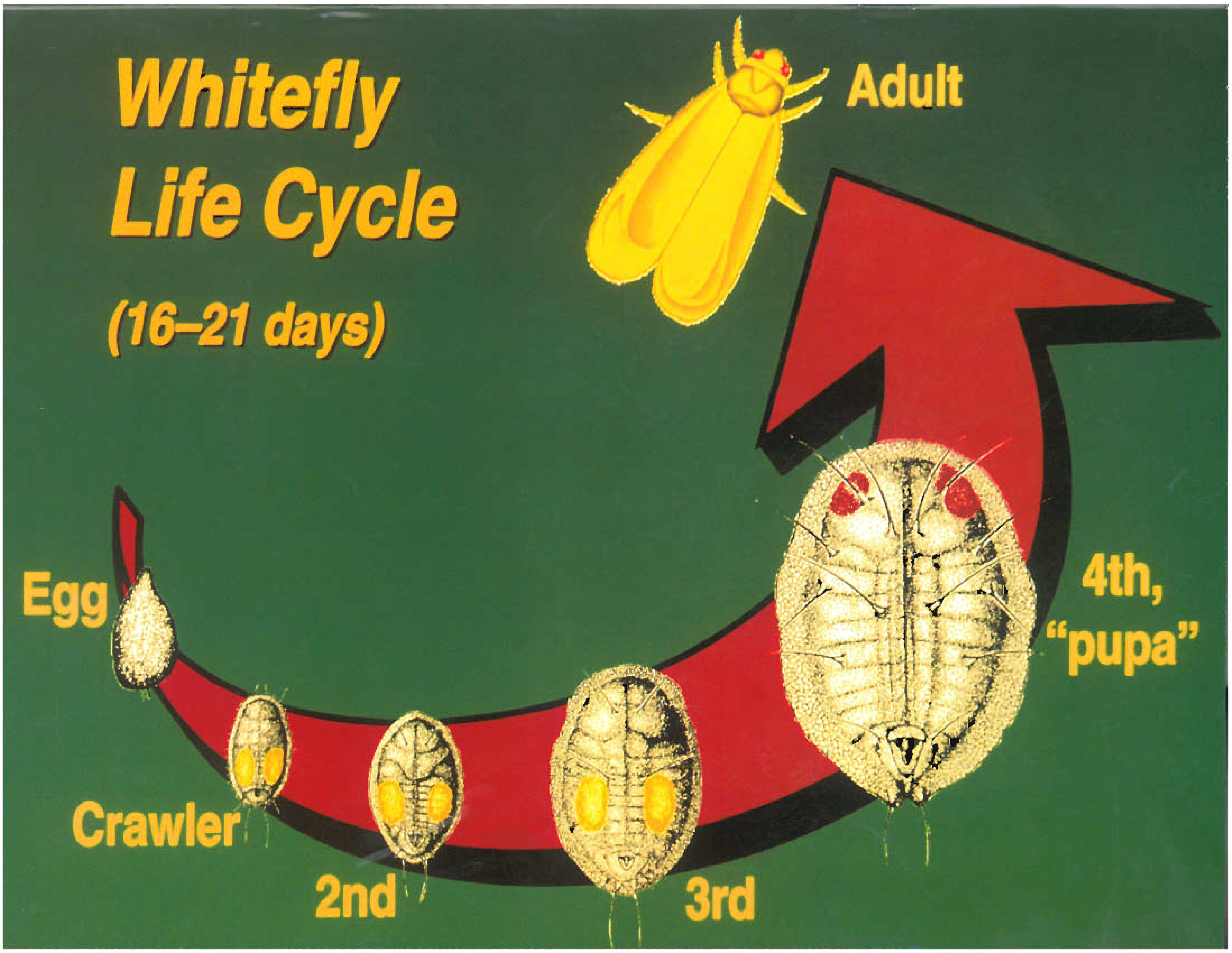
54. The beetle, *Delphastus pusillus,* feeding on whitefly eggs. (R. Smith, courtesy of USDA-ARS)

55. *Eretmocerus* wasp emerging from whitefly exuvia with circular exit hole. Nonparasitized exuvia at right. (J. Clark, courtesy of UCIPM)

56. *Encarsia formosa*, a parasitoid of whiteflies. (J. Clark, courtesy of UCIPM)



57. The fungus, *Beauveria bassiana,* attacking whitefly adults. (S. Bauer, courtesy o f USDA-ARS)



Whitefly
Life Cycle
(16–21 days)
Adult
Egg
Crawler
2nd
3rd
4th,
"pupa"