Population Dynamics and Pest Status of Silverleaf Whitefly in the USA

Nick Toscano[1], Tom Henneberry[2] and Steve Castle[3]

(1) University of California, Riverside, Department of Entomology, Riverside, CA 92521, USA.
(2) USDA, ARS, Western Cotton Lab, 4135 E. Broadway Rd. Phoenix, AZ 85040, USA.
(3) USDA, ARS, Western Cotton Lab, 4151 Highway 86, Brawley, CA 92227, USA.

Abstract

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Bemisia has become a major insect pest of a wide range of warm-climate crops in many parts of the world. The ability to adapt to new hosts, wide host range, high fecundity rate, and ability to develop resistance to insecticides make this insect very difficult to manage. In some areas of the world *Bemisia* outbreaks are a natural consequence of increased cropping intensity and increase agricultural use of insecticides. The population dynamics of this pest are affected by multiple crop interactions. The host range of *Bemisia* includes many significant agricultural crops such as cotton, melons, tomatoes, cole crops, and many other ornamental and native plant species. Damage occurs in a variety of ways. Feeding whiteflies extract from the plant important nutrients, causing defoliation, stunting and poor plant yields. A sticky honeydew excreted by *Bemisia* renders cotton lint difficult to process. *Bemisia* causes several plant physiological disorders, such as tomato irregular ripening, squash silverleaf and light stalk in broccoli. The most economically significant of the whitefly transmitted viruses are the geminiviruses. Some of these viruses include tomato yellow leaf curl, the most severe disease of tomato in the Middle East, bean golden mosaic in Central and South America, and African cassava mosaic in Africa. Geminiviruses have already been identified damaging tomato, pepper and squash in the Southern United States. Research has shown that melons provides the best host for *Bemisia*, followed by cotton, cole crops, alfalfa and tomatoes. Parasitism rates on *Bemisia* varies dramatically from one susceptible crop to another. High levels of resistance to both organophosphate and pyrethroid insecticides were documented in *Bemisia* population in the United States and elsewhere in the world.

Key words: *Bemisia tabaci*, geminiviruses, host range, outbreaks.

Introduction

The past 15-20 years have seen the transformation of whiteflies from generally minor pests of field and greenhouse crops into major pests of various agricultural and horticultural plant systems. In particular, *Bemisia tabaci* Genn., the sweetpotato whitefly (SPW), and the recently described silverleaf whitefly, *B. argentifolii* Bell.& Perr., have become the predominant pest species throughout many subtropical -tropical zones of the world. The factors that have contributed to the shift in *Bemisia* spp. from minor to major pests have been the subject of much speculation. Additional research into virtually all aspects of the biology and management of *Bemisia* spp. must continue before we better understand its pest dynamics. However, accumulated knowledge to date allows us to begin to define a pattern of *Bemisia* spp. infestations and outbreaks and identify probable causes.

As an example of the development of *Bemisia* spp. into a primary pest species, it may be illustrative to consider the recent history of *Bemisia* spp. in the USA. Prior to the 1980's, few outbreaks had been recorded even though *B. tabaci* had long been resident in various agricultural regions throughout the southern U.S. In 1981, a serious outbreak of *B. tabaci* occurred in the Imperial Valley of California. Populations grew to enormous densities on cotton, leading to direct feeding damage and contamination of cotton lint with honeydew. Heavy dispersal out of declining cotton in the fall months led to epidemics of lettuce infectious yellows virus in both lettuce and melon fields. In subsequent years, *B. tabaci* continued to erupt into moderate to heavy population densities despite more aggressive management tactics.

Outside of the southwestern U.S., *B. tabaci* remained as a mostly secondary pest. However, some unusual phenomena began to be reported in Florida around 1986 regarding apparent host shifts by *Bemisia* and the occurrence of virus-like symptoms in squash. No previous records of colonization or infestations of *B. tabaci* were known on pointsettia plants, a popular seasonal houseplant cultivated commercially in large greenhouse operations. Similarly, virus-like symptoms of squash that eventually were to be called squash silverleaf were previously unknown in Florida, but which were widely reported in 1986 along with infestations of poinsettia. Additional occurrences of these phenomena began to be reported in other states, and soon scientists were referring to the variant whitefly as the strain B biotype (a.k.a. poinsettia strain) in contrast to the standard strain A. Heavy infestaions of the new biotype in many vegetable and field crops occurred in Florida during the late '80s. Cases of biotype B occurrences also became known at this time in the western U.S. states of California and Arizona, but primarily in greenhouse ornamental crops. It wasn't until the benchmark year of 1991 in California's Imperial Valley that the full destructive potential of the new whitefly biotype was realized. Damage of unprecedented proportions occurred in many crops grown during the summer and fall months. These included heavily damaged cotton and alfalfa fields, complete destruction of fall melons, and intensive feeding pressure on lettuce and cole crops (broccoli, cauliflower and cabbage) leading to destruction or severe stunting and retardation of crop development.

Since 1991, whitefly populations have remained at extreme levels in the Imperial Valley, mandating intensive pesticide use to protect crops. Whitefly infestations have also escalated in neighboring Arizona with its similar arid, hot climate to Imperial Valley's, but without attaining the extreme densities seen in California. Texas and Florida continue to experience moderate whitefly pressure, but not at the levels experienced in the arid southwestern U.S. Other southern states in the U.S. such as Georgia and Mississippi have experienced whitefly problems in agricultural systems, while many northern states producing greenhouse crops of vegetables and/or ornamentals also contend with *Bemisia sppl* infestations. Available information suggests the culprit in all cases to be the type B strain of *B. tabaci*, now designated *Bemisia argentifolii*.

The argument for separating *B. argentifolii* from *B. tabaci* was put forth by Perring et al. (2) on the basis of the following criteria: a) reproductive isolation from *B. tabaci*, (b) and genetic variation as characterized by biochemical assays. In addition, other characteristics such as an expanded host range of *B. argentifolii* over that of *B. tabaci* and apparent differences in virus transmission specificities suggested basic biological differences between the two. More recently, Bellows et al. (1) identified subtle morphological differences between both types that, in combination with the above mentioned trait differences, were used in the definitive description of *B. argentifolii*.

Although debate continues over the question of whether differences between the two whiteflies indeed warrant separate species status, the facts are clear concerning the greater pest potential of *B. argentifolii* compared to *B. tabaci*. The silverleaf whitefly colonizes more crop hosts, causes various toxicogenic disorders on many of its hosts, and has a higher intrinsic rate of increase than *B. tabaci* (Betke et al. 1991). When combined with certain behavioral traits such as colonizing the undersides of leaves and possessing a tremendous capacity for dispersal from declining or perturbed habitats (e.g. cutting of alfalfa), control of silverleaf whiteflies in managed plant systems can rapidly be lost. This was the experience in 1991 in the Imperial Valley of California. Although potent new insecticides for whitefly control have been introduced since 1991, population densities have remained at economically damaging levels each year. A closer look at the situation in California may help to elucidate the tremendous pest potential of silverleaf whitefly within certain agricultural systems.

Siverleaf whitefly outbreaks in California

To appreciate the magnitude of the current situation in the Imperial Valley, it is useful to contrast silverleaf whitefly (*B. argentifolii*) infestations post-1990 with sweetpotato whitefly (*B. tabaci*) infestations pre-1990. The distinction between the two whitefly 'eras' is based upon the first observations in 1990 of colonizations of crops that previously were not considered hosts. One of the crops was melons, which was recognized as a host of *B. tabaci*, but not to the degree that was evident in 1990. Perhaps more noteworthy, substantial infestations of whiteflies were observed in various cole crops such as broccoli, cauliflower and cabbage. This was unknown in Imperial Valley populations of *B. tabaci* prior to 1990. Retrospectively, these observations are now recognized as the first indications of silverleaf whitefly invasions into the Imperial Valley, although conceding that infiltration may have been occurring even earlier than 1990. Not until the summer and fall of 1991 when whitefly populations exploded to unmanageable levels, infesting and multiplying on virtually every crop in the ground, was it realized there had been a significant shift in the pest potential of whitefly populations. Prior to 1990, *B. tabaci* occurred primarily as a pest of cotton crops, building to moderate densities in many cotton fields. Infestations were most often characterized by gradual growth of whitefly populations within cotton fields through the spring, approaching exponential growth during the hot months of June, July and August. However, infestations usually remained largely localized within cotton fields, the most spectacular exception being in 1981 when sweetpotato whitefly infestations grew beyond the capacity of cotton fields and spilled over into fall vegetables. After 1981, greater appreciation of the need to carefully manage whiteflies in the cotton crop helped to keep whiteflies in check. The threat to crops other than cotton was not so much direct damage resulting from whitefly colonization as it was the spread of whitefly-vectored viruses in fall-planted lettuce and melon fields. Consequently, almost all management efforts were targeted at whiteflies in cotton only.

In contrast, *B. argentifolii* infestations since 1990 have required management inputs into spring melons and squash, summer cotton and alfalfa, and fall melons, lettuce and cole crops. The greater capacity of the silverleaf whitefly to colonize various crops, weeds and ornamentals has produced higher population densities of whiteflies that are sustained for longer periods through the annual crop cycle. Proximity of diverse crops to one another in overlapping phenological states ensures a large, stable resource base that the silverleaf whitefly maximally exploits. Its well-developed ability to disperse from declining crops to those in an earlier developmental stage helps in avoiding population crashes. This is perhaps a central issue for an organism that lacks an adaptive resting stage and must therefore always be closely associated with its plant hosts. As long as a sequence of hosts are present in abundance, chances are that silverleaf whitefly populations will also be present. Just what level of infestation is acheived depends on any number of important factors. We will next examine some of these factors that have contributed to outbreaks of silverleaf whiteflies in the Imperial Valley, and where appropriate contrast to other regions where silverleaf whitefly infestations occur, but in a more moderate and controllable fashion.

Silverleaf whitefly outbreaks: potential factors

The level of infestation of crops attained by silverleaf whitefly populations, or for that matter by any potential pest colonizer, may be considered to be driven by inputs belonging to the following three categories:

- Biological — those traits of an organism which, under environmental influence, characterize its intrinsic potential to utilize a given resource.
- Agri-cultural — the crops grown, including relative acreages, spatial and temporal proximity to one another, etc.
- Management — efficacies of chemical, biological and cultural controls.

Biological factors

This concept has already been alluded to in comparing the silverleaf whitefly to the sweetpotato whitefly. Although both species are very similar in many of their basic traits, the silverleaf whitefly is exceptional in its ability to colonize more crops, weeds and ornamentals than was ever observed for the sweetpotato whitefly. To some extent the apparent greater host range of the silverleaf whitefly may be due to much higher population densities which 'force' colonization of marginal hosts as a spillover effect. This is not to minimize, however, the very real capacity of the silverleaf whitefly to multiply on crops such as broccoli, cauliflower, alfalfa and especially melons, all of which contribute to increase whiteflies during the annual cropping cycle.

Besides its capacity to utilize more hosts, studies also suggest silverleaf whiteflies possess a higher rm, or intrinsic rate of increase value compared to sweetpotato whitefly (Betke et al 1991). If generally true, then *B. argentifolii* would be able to more rapidly exploit a particular crop than *B. tabaci*. This could be important in the interactions of silverleaf whitefly populations with populations of their natural enemies. It may be more difficult for natural enemies to regulate a prey population with a higher rm than one that increases at a slower rate. Indeed, silverleaf whitefly populations in the Imperial Valley often appear to increase faster than their natural enemies, with predation and parasitism rates lagging well behind the growth of whitefly populations.

A trait of many whitefly species including *B. argentifolii* is the production of unequal numbers of male and female offspring. There are many unanswered questions concerning sex ratio dynamics of whitelfies, but field surveys af *B. argentifolii* populations suggest a mostly female-biased sex ratio throughout their annual cycle (Fig. 1). This could be an integral part of the reason silverleaf whiteflies have such high capacity for rapid increase.

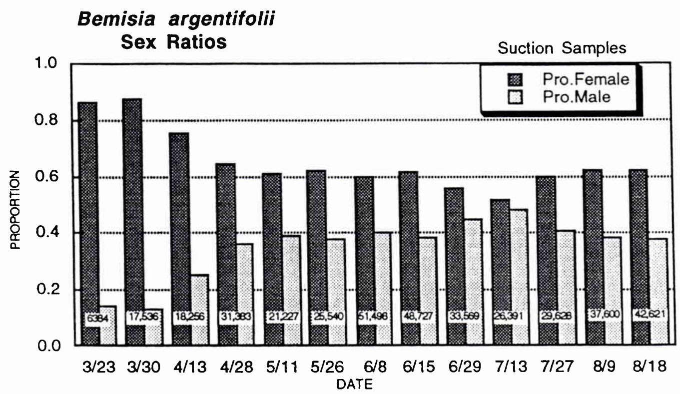

Figure 1. Suction samples of male vs. female whiteflies in melon (3/23-5/26) and cotton fields (6/8-8/18) in the Imperial Valley during 1994. Numbers within bars represent sample size for each date.

A basic biological capacity for explosive increase is meaningless in an inhospitable environment. Assuming for the moment all crop systems to be equal, silverleaf whitefly populations would likely demonstrate greater growth in environments similar to the Imperial Valley's than elsewhere. Daily maximum temperatures exceed 40°C 3-4 months of the year, the time of year that silverleaf whitefly populations increase most rapidly. In California's San Joaquin Valley 500 km to the north of the Imperial Valley, silverleaf whitefly populations occur on similar crops, but do not increase to extreme densities as in the Imperial Valley. Temperatures in San Joaquin are not as high and consequently whitefly generation time not as fast as in the Imperial Valley. The absence of rainfall also appears to benefit whiteflies, as depression in their populations has frequently been reported following intense rainfalls or extended periods of rain. Whitefly populations in Texas' Rio Grande Valley have never approached the level experienced in the Imperial Valley despite having a similar agriculture, but annual rainfall in the Rio Grande Valley exceeds 40 cm compared to <8 cm in Imperial Valley. These contrasts between the different valleys are only anecdotal, but a consistent pattern from year to year argues for the importance of the physical environment in rapid population increases of silverleaf whiteflies.

Another aspect of silverleaf whitefly biology that is manifold to understanding the pest potential of this species is dispersal. Movement of whitefly populations from one field to another as well as from one crop to the next enable whitefly populations to sustain high densities. Dispersal events during the hot summer months occur from sun-up until 0900-1000. Temperatures become too high beyond mid-morning and whiteflies stop flying. Those dispersing whiteflies that do not locate new hosts are often observed sheltered in vegetation or in moist habitats at ground level during the heat of the day. Research on flight endurance of whiteflies is currently being conducted in Arizona. Experience in the Imperial Valley suggest that substantial numbers of whiteflies are capable of moving distances in excess of 10 km based on observations of whiteflies moving over desert terrain from a crop source. It is possible that dispersing whiteflies make incremental movements over a period of days prior to locating a suitable plant host. Presumably some nutritional benefit is acquired by dispersing whiteflies that feed upon non-hosts or marginal hosts during holding periods in between dispersal flights.

Agricultural Factors

The importance of the agricultural system in driving silverleaf whitefly populations to extreme densities should not be underestimated. The types and sequences of crops grown in the Imperial Valley provide a lush, stable resource for whitefly populations. The spring melon crop is planted from January-March at a time when whitefly populations are at their lowest point because of cooler winter temperatures. Movement into melon fields from surrounding winter annual weeds, late-season cole crops and ornamentals is barely detectable due to the low whitefly numbers. With increasing early spring temperatures, however, silverleaf whiteflies begin to increase on fast growing melon vines, by far its most suitable crop host. By the time melons are harvested from May-July, whitefly populations in the Imperial Valley have increased by orders of magnitude, predominantly in melon fields. Dry-down and harvest of the melon fields send clouds of dispersing adults to all corners of the valley, infesting young cotton fields and vast acreages of alfalfa. This major dispersal event out of melons has been fundamental to the problems encountered in controlling silverleaf whiteflies in the Imperial Valley the past four years. From June through October there is a perpetual swarm of whiteflies immigrating into crops, forcing heavy reliance upon insecticides. During the summer months cotton and alfalfa fields become the major sources of whitefly multiplication. Periodic cuttings of alfalfa fields and defoliation and harvest of cotton in August and

September send more swarms of dispersing whiteflies into young fields of lettuce and cole crops. Fall melons can no longer be grown in the Imperial Valley because of the extreme whitefly pressure at this time of year.

In contrast to the Imperial Valley, the Coachella Valley 100 km to the north is also an intensively-farmed irrigated desert valley with an identical climate to the Imperial Valley's. The predominant crops grown in Coachella are perennial crops of dates, citrus and grapes. Only limited acreages of melons and alfalfa are grown and no cotton. Consequently, the vast resource base for exploitation by silverleaf whitefly does not exist, and only small to moderate populations of whiteflies occur. These are easily managed with chemical sprays because there is no constant pool of dispersing whiteflies to immigrate back into a treated field.

Elimination of spring melons in the Imperial Valley would probably help to diffuse the explosive potential of *B. argentifolii*. This is the case in many irrigated regions of Arizona where few crops other than cotton are grown. Silverleaf whitefly infestations of cotton in such regions of Arizona are characterized by gradual buildup of whiteflies in the cotton without the major dispersal events experienced in the Imperial Valley. Close management of building whitefly populations allow for timely treatments of insecticides to maintain the population below damaging levels. These regions also have crop free periods through late fall-winter months which help to drive whitfly numbers very low. In contrast, year-round crops in the Imperial Valley help to sustain whitefly densities at relatively high levels even during the cool winter months.

Management Factors

Chemical treatments of silverleaf whitefly infestations have been the rule in the Imperial Valley. Many pyrethroid and organophosphate chemicals remain highly effective at knocking back whitefly infestations, especially when used in a tank mix with one another. Insecticide resistance monitoring of several compounds over the past two years has not detected any strong trends toward resistance buildups (Fig. 2). However, there are some indications of resistance building in Arizona cotton fields where a larger proportion of the total acreage is treated with insecticides relative to the Imperial Valley, where much of the alfalfa acreage (nearly half of the entire valley) is not treated for whitefly infestations. Conceivably, the lack of significant insecticide resistance in the Imperial Valley is in part due to a large reservoir of susceptible genotypes maintained in untreated areas and which act to dilute resistant genotypes as a consequence of the constant mixing of populations through dispersal.

Research into biological control agents is being pursued, but many parasitoids and predators evaluated thus far have one or more severe limitations. There is a problem of seasonality in that many of the natural enemy populations are not very well developed at the time whiteflies are beginning to increase on melons. Also, it is uncertain how adept natural enemies are at dispersal relative to whiteflies. Dispersal to new crops by whiteflies help to perpetuate their numbers, whereas some of the natural enemies may be left behind by emigrating whiteflies.

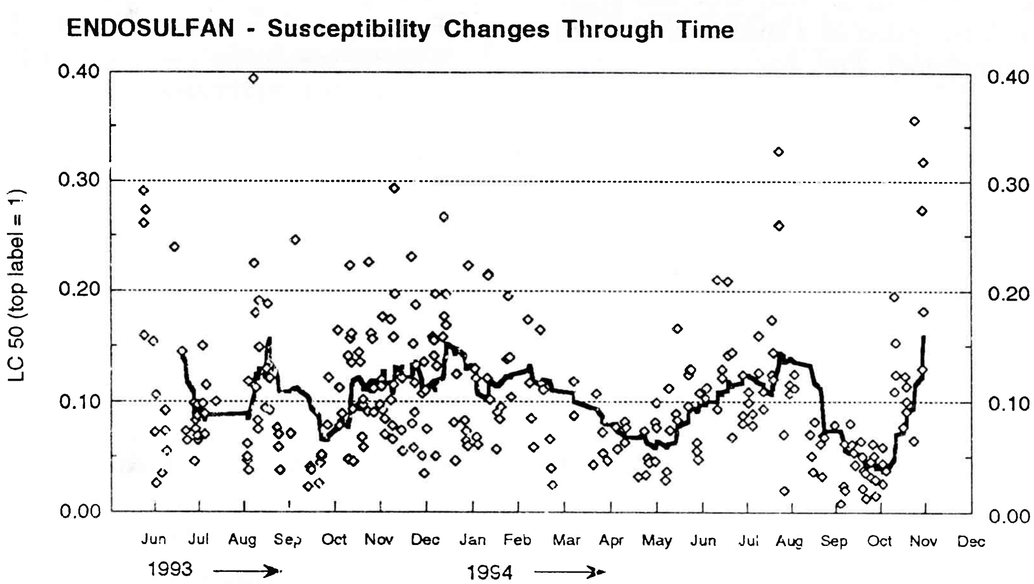

Figure 2. Toxicity of endosulfan to field collected whiteflies throughout the Imperial Valley on assorted crops. Each point represents an individual bioassay from a field population. The solid line represents the 14 point moving average of all LC50s.

الملخص

توسكانو، نيك، توم هنبري وستيف كاستل. 1994. ديناميكية مجتمعات أنواع الذباب الأبيض في النظم الزراعية في الولايات المتحدة الأميركية. مجلة وقاية النبات العربية. 12 (2): 137-142.

أضحت أنواع الذباب الأبيض آفة رئيسة لمدى واسع من محاصيل المناطق الحارة في أصقاع عديدة من العالم. ويصعب جداً إدارة هذه الآفة نظراً لمقدرتها على التكيّف مع عوائل جديدة، ولمداها العائلي الواسع، ومعدّل خصوبتها المرتفع، ولمقدرتها على تطوير مقاومة لمبيدات الحشرات. وفي بعض المناطق، يعتبر تفشي هذه الآفة نتيجة طبيعية للتكثيف الزراعي المتزايد والإستخدام اللاعقلاني لمبيدات الحشرات. وتتأثر ديناميكية مجتمعات هذه الآفة بعديد من التأثرات المحصولية. ويشتمل المدى العائلي للآفة على عدة محاصيل زراعية هامة كالقطن والبطيخ والبندورة/الطماطم ونباتات العائلة الصليبية بالإضافة لعديد من أنواع نباتات الزينة والنباتات البرية. وتحدث الآفة أضرارها بطرائق عدة، إذ تستنزف عناصر غذائية هامة أثناء تغذّيها على العائل، محدثة له تساقطاً للأوراق وتقزماً وانخفاضاً في الغلّة. كما تؤدي الندوة العسلية التي تفرزها الحشرة إلى صعوبة في تصنيع ألياف القطن. وتحدث الآفة عدة اختلالات فسيولوجية، كالنضج غير المنتظم في البندورة، والورقة الفضية في الكوسا، والساق الخفيف في "البروكلي". ومن بين الفيروسات المهمة إقتصادياً التي ينقلها الذباب الأبيض تأتي مجموعة الفيروسات التوأمية. وبعضاً من فيروسات هذه المجموعة يضم فيروس التفاف واصفرار أوراق البندورة، الذي يعتبر أشد أمراض هذا المحصول خطورة في منطقة الشرق الأوسط؛ والموزاييك الذهبي للفاصولياء في أمريكا الوسطى والجنوبية؛ والموزاييك الأفريقي للكاسافا في إفريقيا. وقد تمّ تعريف فيروسات توأمية تُحدث أضراراً للبندورة والفليفلة والكوسا في الولايات الجنوبية من الولايات المتحدة الأمريكية.وأظهرت نتائج البحوث أن البطيخ يعتبر أفضل عائل للذبابة يتلوه القطن، ونباتات العائلة الصليبية، والفصة، والبندورة. ويختلف معدل التطفل على الذبابة، على نحو كبير، من عائل حساس إلى آخر. وقد سجلت مستويات عالية من المقاومة لمبيدات الفوسفور العضوية ومجموعة البيروثرويدات في مجتمعات *Bemisia* داخل الولايات المتحدة وفي أماكن أخرى من العالم.

كلمات مفتاحية: *Bemisia tabaci*، المدى العائلي، الفيروسات التوأمية، جائحات.

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