The Status of *Bemesia* as a Cotton Pest: Past Trends and Future Possibilities

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ABSTRACT

Bemesia tabaci was first recognized as a cotton pest in India early in the 20th Century. Between 1970 and 1980, severe outbreaks occurred in Sudan, Turkey and Israel, followed by California, on vegetable crops and cotton. In 1989-90, epidemic infestations occurred on cotton in the USA, followed by Mexico and then South America and Asia. They were attributed to a new whitefly called B. tabaci strain B or B. argentifolii. Bemesia damage to cotton is expressed in direct crop loss, contamination with honeydew leading to stickiness problems in the spinning mill and transmission of viral diseases. The latter is primarily a problem in Pakistan and India where cotton leaf curl virus has taken on very serious proportions. Bemesia suppression relies heavily on chemical control, leading to excessive use followed by resistance and failure of control measures. Population levels are influenced by cultivar, environmental factors and the efficacy of natural enemies. Heavily infested cotton fields may exist near lightly infested fields where less susceptible cultivars, cultural practices and natural enemies suppress the infestation. Effective whitefly management should utilize suitable cotton cultivars, insecticide resistance management (IRM) to reduce insecticide use, improved natural enemy efficacy and effective grower/extension worker co-operation. Supporting research is essential to provide explanations for favourable plant/whitefly associations and success or failure of natural enemy activity.

Background

Bemisia tabaci was described by Gennadius from tobacco plants in Greece in 1889. A statement emphasizing its potential to develop extensive infestations accompanied the taxonomic description. Infestations on cotton were first reported from India in 1932 by Husain and Trehan (1933), and Husain *et al.* (1936), and *B. tabaci* continues to be a serious pest there (David and Jesudasan, 1985). Concurrently, *B. tabaci* was recognized as a cotton pest in the Sudan, first as a virus vector (Kirkpatrick, 1931) and later as a general cotton pest (Cowland, 1934). Severe infestations during the late seventies and early eighties promoted *B. tabaci* to the number one cotton pest in the Sudan (Dittrich *et al.*, 1985, 1990). Outbreaks also occurred in Turkey and Israel from about 1976 (Gerling *et al.*, 1980), when high level infestations were found on numerous crops, including cotton. In the New World, *B. tabaci* was first identified on cotton in 1925 at Gila Bend, Arizona, USA (Russell, 1957). It remained a minor cotton pest until ca. 1950 when it became a major concern in the transmission of cotton leaf crumple (Dickson *et al.*, 1954). Thereafter, outbreaks on cotton continued to be sporadic through the late 1970s. From about 1988, new and very severe outbreaks began to occur in numerous cotton growing regions, including both North and South America. These outbreaks were attributed to a new strain or species of *Bemisia*, that was described as *B. argentifolii* Bellows and Perring, or the silverleaf whitefly (Bellows *et al.*, 1994). Concurrently, outbreaks were reported in several Asian cotton-growing areas, including the republic of Turkmenistan, where severe infestations in 1990 caused cotton wilting (Gerling, personal observations). While many of the previously infested cotton growing countries had developed IPM programs and were learning how to cope with silverleaf whitefly, very severe outbreaks developed in additional locations. For example cotton and numerous other crops are now being severely attacked in Brazil, where economic losses vary from 30 to 100% (Vilarinho de Oliveira, 1998). Many of these outbreaks of *Bemisia*, thus show the characteristics of an invading pest: they reach very high numbers in a short time; have a wide host range; and seem to defy the previously established balance with the local natural enemies. Moreover, laboratory tests of these pests often show higher reproductive rates than those of the previously established conspecifics (or of closely related previously recognized species) (e.g. Dittrich *et al.*, 1990). However, like other invaders, their attacks abates after a number of generations and although damage caused by these populations of *B. argentifolii* may still be considerable and require human intervention, its populations are often much lower than those observed shortly after the initial attacks.

A grower whose cotton is heavily infested by whiteflies, cannot absorb crop losses until natural

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processes occur. Consequently, whitefly-generated cotton problems must be dealt with in different ways, depending on whether they occur during the first invasion stages of the pest, or once the pest had become established and its levels have abated. Infestations that are accompanied by viral diseases must be considered by both plant- pathologists and entomologists. The characteristics of these three possible scenarios are considered:

Management Scenarios

Severe outbreaks. These are usually accompanied by large whitefly migrations, relatively low natural enemy populations and extensive crop damage. This is a transient situation that must not only be controlled, but also be properly managed to reduce associated insecticide-caused problems. Thus while developing the proper insecticidal tools to alleviate the damage caused by whitefly, efforts must also be made to increase total environmental resistance to the pest, and to set up the proper long-term infrastructure to combat it. Essential strategies for this include the introduction and augmentation of natural enemies; encouragement of other natural mortality factors; manipulation of pest levels through agrotechnical methods; the right choice of crop plants, varieties and planting times; a thorough study of the factors limiting and/or encouraging pest outbreaks; and educating advisors and growers about the new pest.

The American experience is instructive in this respect since the severe outbreaks of the pest in the USA have brought about a co-ordinated effort to provide short and long-term solutions to the problem. The "Sweetpotato whitefly: 5-year Plan for Development of Management and Control Methodology" was initiated in 1992. The program priorities provided for input to develop immediate control methods and the improvement of insecticidal solutions. Concurrently, new parasitoids were introduced and numerous technology transfers were documented (Heinz, 1996). Moreover, specific IPM projects were conducted demonstrating the viability of the concept of community-based action programs. The program infrastructure consisted of three interacting components: education- in which the growers learned about the pest and what could be done about it; validation - in which sampling and control method effectiveness were validated; and implementation - in which the actual sampling and control took place. This latter component, implementation, also included the associated research that was necessary in order to continually improve the sampling and control methodologies (Ellsworth *et al.*, 1996). Research brought about a shift from treatment regimes that were based on conventional insecticides to those that incorporated insect growth regulators (IGRs) that were, in general, more efficacious, less disruptive, and less costly than the conventional insecticide regimes. The risks of secondary pest outbreaks and pest resistance buildup were reduced and the opportunity for natural enemy conservation increased (Ellsworth *et al.*, 1996; 1997).

Stabilized whitefly populations. These are usually less eruptive in nature. The Israeli experience has shown that stabilization of silverleaf whitefly is accompanied by low population occurrences on many non-cultivated plants, like hedges and ornamentals that were previously heavily infested, and by a measurable reduction in whitefly population increases in many cotton fields. These instances are usually associated with the absence of insecticidal treatments. Determining the reasons for such population stabilization, and for the reduction of whitefly economic pest status, could provide important clues about the driving factors behind the rise and decline of whitefly populations. These factors are often better observed on noncultivated plants that are of little economic importance, rather than on high value, cultivated crops where human intervention masks many of the naturally occurring processes. However, in spite of several studies in this field (Gerling *et al.*, 1997; Hoelmer, 1997), the factors regulating whitefly populations remain unclear. Natural enemies, especially parasitoids, cause high whitefly mortality, but do not always control population development. Our understanding of the plant factors that would appear to have a decisive influence on determining whether the whitefly will become a pest or not, is, at present, insufficient. There are many other factors that affect whitefly population development such as weather, water stress, crop production methodology, and insecticide resistance that are also understood only in part.

Management of virus disease. Finally, silverleaf whitefly - caused cotton problems may also involve the coupling of insect feeding and excretion damage with the occurrence of viral diseases. This problem has materialized chiefly in Pakistan during the last 5-6 years. The history of the Pakistan problem suggests the involvement of a combination of factors, some of which have been implicated in the past with severe insect outbreaks in cotton (e.g. Reynolds *et al.*, 1982). These include: the increase of cotton acreage - expanding cotton culture into more marginal areas, and a considerable increase in the indiscriminate use of insecticides– in order to obtain higher yields (Anon., 1994). The latter has been practiced in both the newly developed agricultural areas and in the larger established cotton growing areas in which natural enemy activity was previously encouraged by the minimal use of insecticides. It is obvious that in addition to modification of management practices and incorporating more environmentally acceptable methods, the viral problem itself requires a solution. This has usually been accomplished by replacing susceptible cotton varieties with more resistant ones and breaking the disease cycles through proper crop sequencing and avoiding virus reservoirs.

Basic practices of whitefly control must be compatible and not disruptive with other pest control needs, and crop production management should avoid plant stress. Any technology implementation requires the grower's understanding of the need for action, the benefits of the system and the advantages for the growers. With such understanding, the growers are generally ready to co-operate and to accept changes. In Israel, continuous studies of whiteflies, their dynamics, and control, have been conducted concomitantly with other projects in cotton entomology (Gerling *et al.*, 1980; Gerling and Kravchenko, 1996; Horowitz and Ishaaya, 1996; Forer, 1990). These studies have led to two general practices: 1) Limiting the use of certain insecticides to defined parts of the cotton season and 2) using one or, at most, two seasonal treatments of IGR's (usually pyriproxifen) for whitefly control. These actions facilitate the development of populations of natural enemies that attack the whiteflies, while still providing compatible control when the populations rose beyond the determined action thresholds. The system also serves to preserve the effectiveness of insecticides by slowing-down the build-up of resistance and avoiding the build-up of secondary pests such as mites that are stimulated to high population levels by the use of pyrethroids. Such a program necessitates close co-operation between the on-site research addressed to the pertinent problems, the extension personnel who can plan the control strategy, and the growers who carry it out. Research has demonstrated the existence and relative importance of natural enemies (Gerling and Kravchenko, 1996; Gerling *et al*., 1997) and which chemicals can and should be used to delay resistance build-up, encourage natural enemy conservation and prevent the build-up of secondary pests (Horowitz and Ishaaya, 1996; Denholm *et al*., 1996). Research has also provided the theory and practice of the sampling methodology required to determine when the cotton should be treated (Naranjo *et al*., 1996), as well as details of pest biology and phenology (Byrne and Blackmer, 1996; Riley *et al*., 1996). This essential information, when utilized correctly by extension workers and growers, has led to successful cotton pest management.

Future Prospects

Looking towards the future, we need to address some of the main upcoming problems in whitefly management. These include the need for reduced insecticide use, the overcoming of insecticide resistance and the use of alternative methods in area-wide multicrop management systems. Experience has taught the entomological community that the probability of maintaining long-term insecticide-based pest management efficacy is remote. Thus, management systems that incorporate cultural, biological, and nonchemical methods into chemical control-IRM-based control methods are essential. Biological controls, including developing entomopathogenic fungi and varietal plant resistance, are expected to play an important role in long-term management of whitefly populations. The role of existing natural enemies requires further study, new ones should be introduced, and state-of-the-art augmentation and conservation should be developed. Whitefly sampling methods and action thresholds must be developed for area-wide multicropping systems as a basis upon which to establish decision-making processes. The extensive numbers of weed, ornamental, nursery stock and cultivated crop-host-plants provide nutritional and reproductive host continuity for the pest, which moves in and between crops. Therefore, breaking the pest cycle should be attempted. This can be done through crop sequencing, considering wind direction, the proximity of host crops when establishing new plantings, and strict adherence to early harvests of all host crops. Efficient water use to prevent stress in cotton provides less favourable conditions for whitefly. Definition of the underlying basis for such crop- whitefly interactions and further refinement may provide other methodologies that are economical and acceptable as long-term crop management systems to minimize whitefly impacts. whitefly plant resistance in cotton has been identified. Key factors may include the amount of vascular tissue per unit of leaf area and the proximity of vascular bundles to leaf surfaces. In addition, cotton leaf surface morphology has also been shown to play an important role in SPW nymph establishment. Studies on plant-insect interactions and mechanisms of resistance and modes of action for whitefly and disease resistance provide leads for identifying resistant germplasm for incorporation into agronomic cotton types. Extension and education activities have played and will continue to play essential roles in implementation of whitefly management. Integration of risk assessment information, spatial analysis, geographic information systems, communications networking, ecological modeling, and extension programs are continually contributing to our efforts to provide current and timely information to producers for implementation and to stimulate community-action control programs.

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