COTTON APHID MANAGEMENT - STATUS AND NEEDS

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Abstract

During the late 1980's and the 1990's, the cotton aphid became an important pest of cotton across the Belt and warrants annual consideration in cotton IPM programs. Numerous changes in insecticide use patterns, cotton varieties, crop mosaics, and other factors, including possible biotic changes in the aphid and/or natural enemies, account for the emergence of cotton aphid as a significant pest. In the more arid areas of Texas (High and Rolling Plains) and California, the cotton aphid continues to be a key pest. The lack of natural aphid control from *Neozygites fresenii* and the scarcity of rainfall in the late summer to remove any honeydew on lint have added to the pest potential of cotton aphid in these areas. Much research has been focused on cotton aphid biology and management in West Texas and California during the last 10 years. Following the major outbreak of cotton aphids in West Texas in 1991, a task force was formed to prepare a list of management suggestions based on what was already known and information gained through experiences managing the 1991 aphid outbreak. In California, early- and late-season aphid outbreaks occurred from 1991-93; thresholds and management options were of utmost, immediate importance. It was clear from the onset that considerable knowledge gaps existed in our knowledge of aphid ecology as it related to developing sound IPM strategies for this pest. The ensuing years of research provided a wealth of information that was subsequently incorporated into management guidelines in California and Texas. Research objectives included non-chemical (biological, cultural, and host plant resistance) means of management, chemical efficacy, insecticide resistance monitoring, treatment thresholds, sampling protocols, and indirect effects on cotton aphids of management actions against other insect pests. Current Texas studies are addressing issues such as factors responsible for late aphid outbreaks; the use of sprinkler irrigation to cleanse contaminated lint in the field; establishing the quantitative relationship between aphid numbers, insect sugars deposited and level of processing problems; elimination of plant sugar problems through harvest management or variety selection; and the determination of gene(s) responsible for sugar concentration which is optimal for aphid development with the goal of modifying this through plant breeding. In California, ongoing studies on cotton aphids include research on insecticide resistance status and factors influencing the magnitude of resistance in cotton aphids, cultural controls, expansion of the natural enemy complex, aphid overwintering strategies and seasonal life history, and the influence of lygus bug management approaches on the abundance of cotton aphids. FQPA has added an extra incentive to find non-chemical means of managing the aphid problem. New effective aphicides still need to be developed to be available for remedial control and to replace insecticides which may be lost to the FQPA or resistance.

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Status

The cotton aphid, *Aphis gossypii* Glover, has recently established itself as a key pest in the management of cotton insects in many areas across the Belt. The elevation of cotton aphids from secondary pest status in Texas and California is well documented by Leser (1994) and Rosenheim et al. (1995), respectively. Cotton aphids inflict several types of damage to a cotton crop. Pre-squaring infestations can reduce cotton growth and biomass accumulation. Lint yield losses result from mid to late season infestation damage. In addition, there have been years when late developing infestations threatened to produce a sticky cotton problem for the textile mills. For instance, in 1991, extremely high aphid infestation levels developed over much of the High and Rolling Plains cotton acreage of Texas. Because of the severity, extent and duration of these infestations, considerable insecticidal control was exercised which resulted in increased tolerance of the cotton aphid to several insecticides including oxydemetonmethyl, dimethoate, methomyl, methyl parathion, chlorpyrifos and dicrotophos. Since 1991, cotton aphid infestations have not been as severe in Texas but have remained an important consideration in growing cotton (Head 1992, 1993, Williams 1994, 1995, 1996, 1997, 1998, 1999). In California in 1992, high aphid densities developed during the mid-season period (July and August), and this trend has continued and reached a maximum in 1995. In 1995, the cotton aphid was recorded as one of the most economically important arthropod pest of SJV cotton with a 3.5% yield loss, paralleling the traditionally important pests of spider mites and lygus bugs (Williams 1996). This severe economic impact was repeated in 1997 (Williams 1998). In addition, late-season populations have the potential to lead to sticky cotton; a situation that has been minimal to date in California.

As a result of the problems encountered during the 1991 production season in Texas and during the 1994 and 1995 seasons in California, industry groups have been formed to address the cotton aphid situation. The Cotton Aphid Task Force was created in Texas to develop management suggestions which would include both cultural and insecticidal controls. This has been provided to the cotton industry in the form of a bulletin, which has been revised each year, based on new research data. Since 1995, the Cotton Insect Review Conference, organized by the California Cotton Growers Association and Univ. of California Cooperative Extension, has been held annually to discuss cotton aphid management and to develop strategies for short-term and long-term research needs (Goodell et al. 1997). Resistance management guidelines have been developed and published every year with the most up-to-date information.

Many similarities exist between cotton aphid bionomics and management in Texas and California; however, there are also several notable differences. After the cotton aphid emerged as a primary pest, some of the initial studies in both states dealt with factors influencing aphid population build-up. Slosser et al. (1992, 1997, 1998) conducted several studies with this focus in Texas. They found that the abiotic factors of high temperatures and light intensity affected the time of aphid infestation increases. The rate of infestation decline following population increases was correlated to the biotic factors of predator numbers, plant nutritional status and aphid levels at peak density. Peak population density levels were determined by the interaction of plant nutrition status, light intensity, day length, and temperatures. High temperatures and light intensities suppressed aphid infestation development while high nitrogen levels in leaves later in the season promoted aphid infestation development. Nitrogen levels could be managed through planting date or fertility programs. Leser and Hickey (unpl.) found that high nitrogen levels would also increase aphid tolerance to dicrotophos. As a result of these findings, as well as insecticide screening trials conducted by Extension entomologists and IPM agents, further field work on fertility programs, and light intensity modification through crop residue ground covers and plant density manipulation, considerable improvements have been obtained in managing in-season aphid infestation development.

In California, the seasonal biology, and the variation in cotton aphid morphs, was one of the initial research thrusts. Dark morph aphids (dark green to black) were found to develop more rapidly, give birth to more offspring, and obtain a larger size than light morph (yellow to light green) cotton aphids (Wilhoit and Rosenheim 1993, Rosenheim et al. 1994). The differences in size and fecundity were 2.5 to 3x over the range of phenotypes (light yellow to black). With these life history parameters, the yellow morphs were found to have an intrinsic rate of increase of 0.2 compared ~0.5 for the dark morphs. Therefore, the dark aphids were implicated in the population explosions in the field. The factors associated with the production of dark morph aphids were identified in a laboratory study as cooler temperatures, shorter day lengths, and nutrient-rich host plants (Rosenheim et al. 1994).

The influence of management strategies used for other cotton arthropodpests was found to enhance cotton aphid populations. Kidd et al. (1996) substantiated anecdotal evidence from Texas that pyrethroid use for bollworm control was indeed responsible for flaring of infestations of aphids through predator population suppression, but also primarily through enhancement of the aphid's own reproductive rate. Multiple ULV malathion applications for boll weevil control also appear to affect the cotton aphid's reproductive rate (Leser unpl.). Other insecticides that significantly suppress predators and parasites can also have an impact on increasing aphid numbers, but to a lesser degree. This knowledge has led to a management system that avoids or at least delays the use of pyrethroids until late into the season. Alternative chemistry is encouraged for use against bollworms and budworms and pyrethroids are often reserved for those instances where both bollworms and boll weevils must be controlled with a single application. This last strategy has largely been responsible for the decrease in aphid problems statewide. The recent establishment of the boll weevil in the High Plains production area has greatly compromised the insecticide management component for aphid control (Leser, et al. 1997). In California, a similar situation exists with cotton aphid populations and lygus bug management. The pyrethroid insecticides generally provide the best lygus bug control and these products are needed to minimize damage from heavy lygus infestations. Anecdotal information and research data from Godfrey (1998) showed that pyrethroid applications were stimulating aphid populations probably by hastening reproduction.

While most cotton aphid outbreaks have occurred during the boll-filling period, there have been limited instances of infestation development on cotton after boll opening. Based on field experiences, most aphid infestation development late in the season is curtailed once cotton bolls begin to open. An exception occurred in 1995 in the High and Rolling Plains area when aphid infestations developed on a limited amount of dryland acreage during the boll opening period. This was the result of regrowth following a late rain on cotton that had previously cutout following a prolonged dry period. The absence of an adequate boll load allowed plants to produce regrowth, which provided a substrate for aphid development. Poor yield potential discouraged producers from controlling these infestations and the absence of the usual rains in September allowed the honeydew-contaminated lint to remain through harvest. Complicating the stickiness issue was the presence of high plant sugar levels on lint from fields in other areas of the High Plains. This was caused by late maturing bolls in some varieties caught in a plant-killing freeze. The result was considerable processing problems at textile mills that purchased the honeydew contaminated bales and a widespread concern for the High Plains crop in general. Because of the high plant sugar levels in some cotton and the testing methods used by mills to detect potential sticky bales, estimates of the magnitude and extent of the honeydew-contaminated bales was greatly exaggerated. Nevertheless, there was considerable concern expressed by the cotton industry following the 1995 sticky cotton problem (Leser 1998). Since 1995, there have been no further instances of sticky cotton reported in Texas although there have been years when late developing infestations threatened a repeat occurrence. Parasitic wasps eliminated late infestations of aphids in 1998, but not prior to some honeydew contamination. Timely rains washed honeydew from contaminated bolls in the last three years.

The development of treatment thresholds was a primary emphasis of research on cotton aphid in California. Rosenheim et al. (1997) showed that cotton can fully compensate for aphid infestations during the pre-squaring stage. The compensatory nature of early-season cotton, and the generally short duration of these early-season aphid infestations (because of the actions of natural enemies), account for the classification of early season aphids as non-pests. In a limited region in the SJV, early-season aphid populations persist, but in most of the valley a conservative treatment approach is warranted on early-season aphids. During the squaring and boll-filling period, cotton aphids compete directly with these reproductive structures for energy. The phloem-feeding aphids act as a tap for the photosynthates along with the developing bolls. Research by Fuson et al. (1995), Godfrey et al. (1997), and Godfrey and Wood (1998) supported a working treatment threshold of 50-100 aphids per leaf (5th main stem node leaf) for 7-10 days. This mid-season threshold is similar to the ~50 per leaf used in Texas (Leser 1994). Following boll-opening, cotton aphids have the potential to deposit honeydew on the exposed lint, thereby contaminating the lint. A treatment threshold of 10-15 aphids per leaf is supported by research (Rosenheim et al. 1995).

Cotton aphid management in Texas and California has progressed significantly since the initial outbreaks of this pest ~10 years ago. Presently, good management strategies are in place, albeit at considerable cost to the grower, especially in California. The Texas Department of Agriculture ensured that producers in most regions of Texas during the last 5 years have had the use of Furadan 4F for cotton aphid control either through section 18's or a state label (24C) in 1997. Similarly, this product was available to California producers through the California Dept. of Pesticide Regulation during three of the last four years. Furadan 4F provides cost effective, residual control of cotton aphids over a wide range of conditions. Research, as outlined below, is underway to optimize management plans and to enhance the cost effectiveness of cotton aphid control. Management plans developed for cotton aphids are always tenuous because of the ability of the cotton aphid to develop resistance to insecticides and the potential for changes in insecticide availability because of regulatory actions, such as FQPA. Therefore, there continues to be a need for additional research efforts.

Current Studies

Several studies are in progress with the goal of improving integrated management of cotton aphid. Specifically, research is underway to

1.) better understand those factors responsible for causing late season aphid infestation development,
2.) establishing the relationship between aphid infestation levels, the amount of honeydew sugars deposited on the lint and the level of processing problems associated with that level of contamination,
3.) development of reliable sugar detection methods,
4.) development of management guidelines and tools for late aphid infestations and lint contaminated by plant and insect sugars
5.) new insecticide tools for aphid management
6.) influence of agronomic factors on cotton aphid susceptibility to insecticides and the incidence of insecticide resistance
7.) interaction of nitrogen application and cotton aphid population density
8.) cotton aphid seasonal history in California
9.) interaction of lygus and/or bollworm management approaches and cotton aphid populations
10.) expand the species diversity of natural enemies attacking cotton aphids in California.

Late Season Aphid Infestation Development

Studies initiated by Slosser (unpl.) at the Vernon Experiment Station are investigating factors which might be responsible for aphid outbreaks during the boll opening period. He is manipulating irrigation scheduling and pyrethroid applications (with and without the aphicide Fulfill applied). Measurements of aphid densities, leaf moisture and plant sugars from leaf disk samples, and level of honeydew contamination of lint are being made. Lint samples were collected both before and following rains in 1998.

Rainfall and Honeydew Contaminated Lint

California data indicates that rainfall of at least a ¼ inch may be sufficient to cleanse honeydew contaminated open bolls (Rosenheim et al. 1995). Their work with sprinkler systems was inconclusive in determining if overhead irrigation could be used to wash plants of honeydew. Much of Texas frequently receives rainfall in sufficient amounts during the open boll period to eliminate the honeydew contaminated lint problem. Another Texas study is underway by Rummel at the Lubbock Experiment Station to determine if center pivot irrigation systems can be used to wash honeydew from contaminated bolls on plants in the field. A LEPA (Low Energy Precision Application) system is being used to simulate the effects of rainfall on contaminated lint. Various treatments are being evaluated including overhead or in-canopy placement of irrigation nozzles, 1 to 3 irrigations, and either ¼ or ½ inch of water applied. Plots are harvested the day after watering.

Impacts of Aphid Versus Plant Sugars on Stickiness

Studies have been initiated by Ethridge from the Lubbock International Textile Center of Texas Tech University to investigate the relative impacts of aphid versus plant sugars on stickiness in textile processing. The objectives of this 3-year study are to quantify the relationships between fiber immaturity and the types and quantities of plant sugars in the fibers, quantify the relationships among late aphid infestation levels, plant architecture, and the amount of honeydew on the lint; and quantify the impacts of each source of sugar on the sticky cotton performance in textile processing. Plant sugar levels are being manipulated with varieties, planting dates, irrigation and fertility management. Aphid infestation levels are being manipulated with pyrethroids and aphicides. Sugars will be identified and quantified with High Performance Liquid Chromatography (HPLC). Stickiness is being measured using a manual thermodetector (SCT), Fiber Contamination Tester (FCT), and a modified High Speed Thermodetector (H2SD).

Plant Sugars

Studies have been underway for 4 years by Gannaway at the Lubbock Experiment Station with the goal of eliminating the plant sugar problem. Plant sugars on lint fibers are stratified vertically on the plant with the highest concentration in bolls in the upper 3rd of the plant (Gannaway unpl.). The creation of immature fiber through the early application of either Prep or paraquat did not result in increased plant sugars on the lint even though these early applications did result in increases in immature fiber. Only a plant killing freeze significantly increased plant sugars on fibers resulting in sticky cotton. Gannaway also found that there were tremendous differences between both commercial varieties and experimental genotypes in the expression of plant sugars on cotton fiber. Other studies investigated 8 genotypes, 7 tetraploids and 1 diploid, for cotton aphid preference and reproductive performance. The diploid genotype had very high leaf plant sugars compared to the tetraploids and was avoided by cotton aphids when given a choice. Aphids forced to feed on the diploid genotype had a significant reduction in the rate of infestation development. This increased leaf sugar content was not manifested in bolls. Applications of synthetic pyrethroids reduced the sugar content of the leaf as well. These data have led to the conclusion that high sugar levels in leaves are a detriment to aphid infestation development and it may be possible to manipulate this factor in a plant breeding program.

New Insecticide Tools

Insecticide screening has continued to evaluate newer chemistry. Imidacloprid (Provado®) was the last aphicide registered in cotton (~5 years ago). No currently labeled product has demonstrated the efficacy of Furadan 4F. While imidacloprid and pymetrozine (Fulfill®) have shown promise in a more preventative use mode, they have not exhibited efficacy levels needed as a remedial control tool. Imidacloprid more closely approaches this level of remedial control in California than in Texas; imidacloprid has not proved to be a material that provides remedial control of aphid infestations approaching or exceeding the current treatment threshold of 50 aphids per leaf in situations where cotton plants are under heat or moisture stress. The performance of the chloronicotinyls acetamiprid (Rhone-Poulenc) and thiomethoxam (Novartis) have been much more promising.

Interaction of Other Insect Management Approaches with Cotton Aphid

Screening of materials that target pests other than aphids but might flare aphid infestations has yielded interesting results. While both thiodicarb (Larvin®) and indoxacarb (Steward®) are relatively "soft" on natural enemies, these products have a significant negative impact on lady beetles (Leser et al. unpl.). Fipronil has shown promise in California as a lygus bug management tool without flaring cotton aphid populations and this product has even shown some aphid activity in studies in west Texas. Imidacloprid has shown promise as an aphid-flaring preventative when mixed at lower use rates with a pyrethroid targeting bollworms. Brazzle and Goodell are conducting studies in California to examine the interaction between an aggressive lygus bug management approach versus a more moderate approach on cotton aphid levels, applications for other pests, lint yields, and economic return. The aggressive approach utilizes a high level of lygus control with repeated applications of pyrethroids and a high target square retention goal whereas the moderate approach uses a lower target lygus efficacy with applications of organophosphates and carbamates and a more moderate square retention value.

Agronomic Factors and Cotton Aphid Insecticide Susceptibility

Leser and Hickey (unpl.) found that high levels of nitrogen could increase aphid tolerance to organophosphate insecticides. Studies conducted in California in 1997 have shown that cotton aphid tolerance to insecticides can be increased by high levels of nitrogen and by late planted cotton (Cisneros and Godfrey 1998), and in 1998 studies, these factors and previous aphid host plant were shown to cause this effect (Cisneros and Godfrey unpl.). This occurred not only with an organophosphate insecticide but also with a pyrethroid, carbamate, organochlorine, and chloronicotinyl insecticide.

Nitrogen Rate and Cotton Aphid Populations

Research in Texas by Slosser and others has shown the importance of nitrogen management in minimizing cotton aphid population densities. Similar research is ongoing in California's irrigated cotton production system. Results from 1997 and 1998 have shown a correlation between high levels of nitrogen fertilization and high cotton aphid populations. The goal of this research is to design a nitrogen program that will optimize cotton yield without promoting populations of cotton aphids. Other factors are also important in building cotton aphid levels, since regardless of the nitrogen level, 1997 was characterized by higher aphid levels than in 1998.

Cotton Aphid Seasonal History

O'Brien et al. (1993) characterized the host plants infested by cotton aphids during the year in Mississippi and Louisiana. Similar information from California is lacking and there are a high number of annual crop plants, perennial plants, and winter annual weeds available for aphid overwintering and spring build-up. Studies are just beginning which will investigate the seasonal biology of cotton aphid in California. Knowledge of the host sequence used during the year and plants on which early-spring populations build is critically needed. The concept of managing cotton aphids before they infest cotton, possibly with natural enemies or cultural techniques, will be facilitated with these research results.

Expanding the Natural Enemy Diversity

Research is underway to expand the diversity of natural enemies attacking cotton aphids in California. *Lysiphlebus testaceipes* is the primary parasitoid of cotton aphid in the state and its effectiveness wanes during the hot summer months at a time when control is most critical for cotton production. A cooperative project among CDFA-BioControl Program, USDA-ARS, and Univ. of California was initiated in 1996 to construct an introduced natural enemy complex to compliment the existing complex. To date, 4 species have been or are currently being tested.

Needs

The Cotton Aphid Task Force revised the Texas management suggestion bulletin in 1998 by incorporating a greatly expanded sticky cotton avoidance section as well as modifying many of the recommendations based on Slosser's work. While still recommending the use of the California threshold of 10-15 aphids per leaf (Rosenheim et al. 1995) once boll opening is occurring, Texas could probably use a higher threshold since unlike California, honeydew-cleansing rains usually occur during the open boll period. There is a need to develop more selective chemistry for control of pests other than cotton aphids. There are several new unregistered products under development that will substitute for synthetic pyrethroids for bollworm, budworm, beet armyworm, Lygus and boll weevil control in Texas and for lygus bugs in California. Particular attention must be directed toward insecticide impact studies on natural enemies of aphids. Boll weevil eradication in Texas will aid with aphid management. Producers use synthetic pyrethroids late in the season to control mixed infestations of bollworms and boll weevils; these late applications can flare aphid numbers and result in a sticky cotton problem. During eradication, the use of ULV malathion can also exacerbate the late season aphid situation. There is a need for the development and timely registration of new remedial control aphicides. Both Novartis and Rhone-Poulenc have such products under development and Furadan 4F needs to receive full registration in cotton for aphid control. There is considerable concern for the impact that the Food Quality Protection Act (FQPA) may have on the future availability of effective insecticides. Without boll weevil eradication and the registration of new chemistry for aphid control, the removal of all carbamates and organophosphates would leave imidacloprid as the only registered aphicide and would lead to a overall pest management system almost wholly dependent upon aphid-flaring synthetic pyrethroids. Maximizing aphid management through the use of effective cultural techniques will help to take the pressure off the available aphicides. Finally, especially in California, reducing cotton aphid populations through biocontrol or other techniques before the aphid infest cotton will be useful.

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