# Whitefly Management with Insect Growth Regulators and the Influence of *Lygus* Controls

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## *Abstract*

*The three keys to whitefly management are sampling, effective chemical use, and avoidance. This study examines factors relevant to the latter two keys in the context of Arizona's cotton pest spectrum. Insect growth regulators (IGRs) are central to Arizona's success in whitefly management. The basic usage guidelines developed for the IGRs—initial treatment timing, prescribed intervals between successive uses, and one use each seasonal limits—are all valuable in the development of a sustainable use pattern. Re-treatment timing guidelines for the second IGR has been the subject of investigation for the past two years. However, whitefly pressure in 1998 was strikingly different and lower than in any other post-introduction year. Re-treatment was unnecessary and thus could not be evaluated this year.* Lygus*, on the other hand, were at damaging levels early in plant development and for a protracted period. Future successes in whitefly management should consider the whole pest spectrum and depend on integrating chemical controls for all sprayed pests. While our primary focus is to optimize management of whiteflies in the context of other pests, this study examined the impact of* Lygus *controls on whitefly population dynamics and cotton production. Three sprays were required to control* Lygus *populations in this study. These sprays were atypically non-disruptive to whitefly population dynamics, and instead, helped to suppress low-level populations of whiteflies even further. This lack of disruption may have been due in part to the reduced abundance and role of natural enemies in this study.* Lygus *sprays did protect yields with a 3-fold advantage over untreated plots. Furthermore, there were a series of negative consequences of poor* Lygus *control. Plants tended to be more vegetative and more difficult to defoliate. Lower lint turnouts were documented for the* Lygus*-untreated areas. Sources of this additional loss were identified and included increased gin trash and larger seed size in* Lygus*-untreated areas. The lint also had significantly more sticking points as measured by manual thermodetector. While all cotton was determined to be non-sticky, this increased contamination may have been also related to the higher trash levels. Because of the differences in outcome in 1997 and 1998 in terms of* Lygus *spray effects on whiteflies, it is even more imperative that we further test whitefly management systems under near commercial conditions. A better understanding of the relationship between the control programs for these two major pests will help guide decisions on remedial inputs. This study also serves as an annual, replicated, and systematic accounting of whitefly population dynamics and control requirements useful for making historical comparisons across years. Inferences may be drawn about what are and are not the underlying causes of the unusual population dynamics observed in 1998.*

## Introduction

Whitefly management in Arizona depends on a matrix of factors which can be represented in the form of a pyramid, an inherently stable structure (Fig. 1). This pyramid consists of three basic levels or building blocks that can be defined for any pest (Ellsworth 1998, 1999a): 1) Sampling, 2) Effective chemical use, and 3) Avoidance. Confronted with a pest crisis, short term survival depends on the upper two levels of the pyramid. However, sustainable, long-term strategies ultimately must depend on the development of a solid foundation, “avoidance.” At the same time, a pyramid-strategy developed for one pest must be compatible with like strategies in place for all pests of a system.

This study has three major goals and is part of an on-going effort initiated in 1995 to refine whitefly management strategies in the context of whole systems that are representative of grower’s experience. We seek to optimize chemical use by determining the most efficient deployment patterns for insect growth regulators (IGRs). Our focus for the last three years has been on the development of IGR re-treatment thresholds. This represents a significant gap in our understanding and a considerable variable cost to growers due to the high per unit cost of IGRs. Second, we are attempting to exploit the detailed understanding of this pest’s biology and ecology in managed and unmanaged systems. Specifically, we seek to determine the respective roles of the IGRs and natural enemy conservation. This effort is reported elsewhere (Naranjo and Ellsworth, *this volume*). Finally, we want to fully understand the relationship between controls for whiteflies and other pests, specifically *Lygus* bugs, in order to design, develop and deliver a commercially-viable and grower-acceptable pest management solution.

*Lygus* is a major pest of low desert cotton for which we have no selective insecticidal technologies. This fact alone jeopardizes the advances made with IGR technology for whitefly control and Bt cotton for pink bollworm control. As these latter two technologies have become more widely used, sprays that were once made for each major pest have been replaced with broad-spectrum insecticides for *Lygus* . The net result is only a modest gain in the overall pest control budget of the average grower, in spite of dramatic improvements in control costs and losses associated with whiteflies. In 1998, the statewide average number and total cost of SWF sprays was 1.05 (of which ca. 0.5 were IGR sprays) and $36/A which constituted about 35% of a grower’s total foliar insecticide budget (Ellsworth 1999a). This represents dramatic reductions in the impact of SWF on cotton production and has proven, so far, to be sustainable since the introduction of the IGRs in 1996 under Section 18 emergency exemption. *Lygus*, on the other hand, has become Arizona’s number one pest in terms of control frequency (2.76 sprays), costs ($55.20/A) and statewide losses (over $16M) (Ellsworth, *this volume*; Ellsworth et al. *this volume*; Williams 1999).

The confidence that most growers have in their current whitefly management program overshadows our efforts to further advance understanding of this pest’s biology. This understanding is key to the continuing development of a solid foundation in avoidance practices which are by definition less reliant on chemical tactics. Reports of resistance to pyriproxyfen in whiteflies in Israel (Denholm et al. 1998), where limited use was mandated, have heightened the need to develop fully integrated management programs here. With consistent research on whitefly population dynamics and management like that reported here, we have gained an additional benefit from these studies, a scientifically-based historical perspective. From this perspective, we can characterize a “whitefly year” and begin to infer the many factors which may be operating to regulate populations. This sort of detailed perspective would not have been possible without the kind of studies reported here.

## Methods

A large-scale trial (about 9 A) was conducted using NuCOTN 33B and three different contrasted whitefly control regimes—Applaud® used first, Knack® used first, and conventional chemistry rotated according to recommendations developed prior to the introduction of the IGRs (‘95IRM’). Each regime whole-plot was split in half to accommodate two different *Lygus* control regimes—treated and untreated. Whole-plot sizes were square (120 X 120 ft) and 0.33 A in area. Each IGR regime whole plot was repeated for two different timings of IGR re-treatment for a total of 24 whole plots (6 X 4 replicates). The recommended threshold was used for re-treatment (t1): 1 large nymph / disk plus

3–5 adults / leaf (Ellsworth et al. 1995, 1996a–c). The higher re-treatment level targeted (t2), >1 large nymphs / disk and > 5 adults / leaf (Ellsworth et al. 1996b, c, 1997, Ellsworth et al. 1998), was never reached after the regulated waiting period, so the second IGR was never used. This, in effect, created a duplicate set of IGR regime plots, because each regime was treated only once for whiteflies. The 95IRM regime received one spray of endosulfan (0.75 lb ai/A) + Ovasyn® (0.25 lb ai/A). Whiteflies were treated in all regimes on 6–7 August after surpassing the threshold on 3 August. *Lygus* bugs were treated a total of three times, twice prior to the onset of threshold levels of whiteflies (7 July and 31 July) and once thereafter (17 August). Vydate C-LV® (1 lb ai/A) was applied first, followed by Orthene® (1 lb ai/A) and then Vydate C-LV (1 lb ai/A). All applications were made by ground using a John Deere 600A Hi-Cycle at 20 GPA for the *Lygus* sprays and 14 GPA for the whitefly sprays.

Standard population measurements were made for whiteflies (eggs, small nymphs, large nymphs, and adults), *Lygus* bugs, and natural enemies (see Naranjo & Flint 1994, 1995, Ellsworth et al. 1997). Partial life tables were conducted over the course of six generations of whiteflies (see Naranjo & Ellsworth, *this volume*). Resistance bioassays were performed on four occasions. Each assay consisted of yellow sticky cards dosed with varying amounts of an indicator pyrethroid combination (Danitol®+Orthene). Cards were then passively loaded with adult whiteflies in the field. Adults were assayed from each whitefly regime plus the untreated control (see Castle et al. 1998; Ellsworth et al. 1998).

Seed cotton was machine-picked from two, 2-row subsamples and weighed. Grab samples were selected at random from each subsample and ginned in a one third, commercial-scale research gin. Lint and seed fractions were collected and weighed, and turnouts and gin trash calculated for each subsample. Individual turnouts were used to derive yield estimates for each plot and reported as no. of 480 lb bales / A. A 100-seed subsample of ginned seed was weighed from each subplot to give a seed index (g / 100 seed). A 20-g subsample of lint was taken from each ginned grab sample, and then 3 aliquots from each were subjected to the manual thermodetector for counts of sticking points. Statistics were performed on normalized data, where possible, including ANOVA for split-plot designs and appropriate orthogonal contrasts using JMP® Software (SAS, 1995).

## Results & Discussion

The 1998 season was unusual on several counts. Cotton was planted later than usual due to the cool and wet spring. Plant development was slow, and terminal abortion rates were very high (ca. 70%) due to sand-blasting caused by persistent winds on slow-growing meristem. Heat unit accumulations were lower than average and considerably behind the 1997 crop season. Production was therefore pushed into a less favorable window of extreme heat and high humidities in July with the onset of a heavier than average monsoon. While humidities remained high, free moisture or rain was uncommon at this site. *Lygus* bugs were locally abundant as a result of the lush spring weed growth and local alfalfa seed production less than 0.8 miles away. This caused the need to treat our *Lygus*-treated split plots three times, more than in previous implementations of this experimental design. The *Lygus*-untreated split received excessive square damage resulting in heavy fruit abortion rates and excessive vegetative growth. The late start and delayed fruiting pattern caused later than average production for this site. We terminated irrigations on 1 September and defoliated on 2 October.

### *The 1998 'Whitefly Year' in Perspective*

Specific accounting of the 1998 whitefly population is somewhat confounded by the atypical nature of the weather, plant development, and *Lygus* patterns this past year (see above). We sampled adults 16 times and immatures once per week for 14 weeks (7/6–10/5). Populations were delayed approximately 1–2 weeks behind 1997 and 1995 levels and 4 weeks behind 1996 (Fig. 2). Heat units were ca. 3 weeks behind 1997 and planting was delayed, and thus the infestation was earlier in relation to plant development in 1998.

The most striking feature of 1998 was the number of conventional sprays made for whitefly control (Fig. 2). In 1995, largely regarded as an outbreak year, we made six applications with conventional insecticides (95IRM). In 1996, the earliest whitefly year, and in 1997, we made five conventional applications each. However, in 1998, only a single application was made against whiteflies regardless of the regime prescribed (Fig. 3). Following this single application, both adults and nymphs declined and never recovered to economic levels season-long (Fig. 2 & 3). Our untreated checks can be compared for 1997 and 1998 (Fig. 4); checks could not be included in the 1995 and 1996 designs. In this comparison, it is evident that whitefly populations crashed even without treatment in 1998. Typically, we see continued build-up of populations with a natural decline at cut-out and then a rapid increase with cotton regrowth (Fig. 4, see 1997). The decline noted in 1998 was not associated with crop cut-out.

## *Comparative Performance of Whitefly Treatment Regimes*

Needless to say, performance of all whitefly treatments (IGR or conventional chemistry) was excellent, because only one spray was made in each regime (Fig. 3). In spite of the atypically low levels of whiteflies post-application, there were several unique features of each regime with respect to whitefly population dynamics. Adult levels were more rapidly reduced in the 95IRM regime, because the conventional chemistry had adult knockdown ability superior to the IGRs or the UTC (Fig. 3). As in the past, the Applaud treatment provided a more rapid, though minor, initial reduction in the adult levels relative to Knack (Fig. 3) (Ellsworth et al. 1997, 1998). The specific mechanism for this consistent, yet minor difference in adult reductions between the two immature-active IGRs is not known. Adult levels remained higher, yet below threshold, in the untreated check (UTC) relative to the other three whitefly regimes (Fig. 3). Egg levels were highest during August and showed a typical increase in the Knack regime due to the accumulation of inviable eggs on leaf surfaces (Fig. 5) (Ellsworth et al. 1997, 1998). During the same period, the conventional regime (95IRM) suppressed egg numbers more than the other treatments due to the direct effect of lowering adult numbers (Fig. 5). The small nymph levels were slightly elevated during August in the Applaud regime relative to Knack, because Applaud's lethal action does not take effect until the young nymphs molt (Fig. 6) (Ellsworth et al. 1997, 1998). Large nymphs cause the largest proportion of damage by whiteflies including honeydew production. All three regimes reduced large nymph numbers quickly during August (fig. 3 & 7); however, separation from the UTC was not as apparent in early September due to the extraordinarily low levels present in the UTC (Fig. 7). By late September, however, the UTC began to re-build more quickly with large nymphs, and the treated regimes continued to maintain levels below 'threshold' (fig. 7). After the whitefly sprays (early August), the adult levels progressively declined each month in the IGR and less so in the UTC treatments (Fig. 3 & 7). This type of population trend is inexplicable for the UTC in the absence of heavy or repeated rains or a significant regulating natural enemy. Interestingly, the monthly trend of adults in the conventional treatment (95IRM) was slightly increasing (Fig. 7). Though speculative, this might implicate the partial involvement of natural enemies in the slow decline observed in the non-conventional treatments, or in other words the partial disruption of natural enemies in the conventional regime.

## *Impact of* Lygus *Controls on Whitefly Population Dynamics*

In 1997, we documented a significant impact of *Lygus* controls on whitefly population dynamics (Ellsworth et al. 1998; Naranjo et al. 1998a, b). Just a single application for *Lygus* control resulted in short-term and long-term elevations in the whitefly populations. The mechanism for this may be inferred by the detailed life table analyses (Naranjo et al. 1998b) and the natural enemy abundance data (Naranjo et al. 1998a). That is, broad spectrum insecticides for *Lygus* (or other pest controls) have a negative impact on the natural enemy fauna that play a partial regulating role on whitefly populations. The relative importance of these mortality factors is subject of continued investigation and is reported elsewhere (Naranjo & Ellsworth, *this volume*).

In 1998, *Lygus* control was once again a production imperative. Attempting to resolve whitefly management strategies in the absence of controlling for other pests like *Lygus* and pink bollworm would be at this point an empty exercise. Growers need solutions that make sense for their production systems. This year we sprayed three times for *Lygus* with singular, high rates of an organophosphate or a carbamate. Two sprays occurred in July prior to the onset of economic levels of whiteflies, and one occurred in August after the initiation of whitefly controls. There are known non-target effects of the use of these insecticides.

We found that contrary to findings in 1997, there were no decidedly positive (i.e., increasing), consistent, effects of *Lygus* controls on whiteflies. Significant effects of *Lygus* control or its interaction with whitefly regime were noted throughout the post-spray season, in fact in 9 out of 9 weeks. However, in all but one case (1/19) the effects showed significant ***reductions*** in whitefly numbers as a result of *Lygus* controls. The effects were sometimes extremely small, yet significant. On only one date (8/24), we found a week association of increased whitefly egg densities in association with the *Lygus* treatments (P=0.078). This may have signalled the negative, yet temporary, impact of the *Lygus* sprays on a key egg predator or perhaps indirectly on a key adult predator, though adult levels were not significantly lower in the *Lygus*-treated split-plots during this period. In all other cases that included effects on egg, small and large nymph, and adult densities, *Lygus* treatments significantly reduced whitefly populations. The effects were often very small and of little management consequence given the already small populations observed in 1998; however, on at least one occasion, there was as much as a ten-fold reduction in whitefly densities in the *Lygus*-treated split versus the untreated split-plot.

Why, then, are there ostensibly different results of *Lygus* treatments in 1998 versus 1997? One major inference may be drawn along with several mitigating or confounding factors. First, natural enemy densities were considerably lower in 1998 than in 1997 in this test (Naranjo & Ellsworth, unpubl. data). Thus, in spite of the negative impact that *Lygus* insecticides generally have on predator fauna, there were not enough predators present to play as much of a major regulating role on whitefly populations (Naranjo & Ellsworth, *this volume*). Also, whitefly densities were at a considerably lower level in 1998 as in 1997, and this fact alone may have a feedback effect on predator fauna, i.e., there were far fewer hosts to support predation even in the untreated plots.

There is also the direct effect of *Lygus* control on plant development (e.g., Ellsworth, *this volume*). *Lygus* attack the fruiting forms of the cotton plant directly and thus have drastic impact on the physiology of the cotton plant as well as its productivity. We observed significantly taller plants in *Lygus*-untreated split-plots than in *Lygus*-treated split-plots, as a result of the reduced reproductive sink caused by lost squares (e.g., see Ellsworth, *this volume*). This large change in plant physiology actually alters the ratio of leaf biomass to overall plant biomass (Flint, unpubl. data), and leaves are what support whitefly populations. Also, the biochemistry of the comparative treatments was likely significantly altered.

## *Yield Response to Whitefly Regime and* Lygus *Controls*

Yield potential was good, considering a relatively late planting and slow start, provided *Lygus* were controlled. The impact of *Lygus* control was visibly apparent by the excessive rank growth noted in the *Lygus*-untreated split-plots. These plants were proportionately more refractory to a clean defoliation. Lint turnouts were not significantly different among whitefly regimes; however, *Lygus*-untreated split-plots had a significantly lower turnout (30.0 ± 0.16%) than the *Lygus*-treated split-plots (32.8 ± 0.16%) (Fig. 9). The 2.8% average difference was due in part to the increased levels of trash (1.6% more) found in the *Lygus*-untreated split-plots (Fig. 10). The remaining difference between *Lygus*-treated and untreated split-plots (ca. 1.2%) is due to sources other than trash. One such source is seed size as indicated by the seed index (fig. 11). Seeds were significantly lighter in the *Lygus*-treated (10.76 ± 0.09 g / 100 seeds) than in the untreated split-plots (11.20 ± 0.09 g / 100 seeds) (P=0.04). With far fewer bolls to mature, the *Lygus*-untreated plots directed more carbohydrates to the seeds than in the treated plots where yields were 3-fold higher (see below). This helps to explain the lower turnouts in the untreated plots. There may be additional factors affecting turnouts such as those related to fiber maturity in *Lygus*-protected versus *Lygus*-damaged areas.

Lint yields were not significantly different among whitefly regimes including the untreated check (Fig. 12). This outcome is not unexpected because of the relatively light season-long whitefly pressure. It also confirms that our currently recommended threshold levels for IGRs and conventional chemistry (Ellsworth et al. 1996a, b) are conservatively protective. That is, based on the outcome of the UTC and the costs of the whitefly sprays in the other regimes, treatments for whiteflies were not economically-warranted. This suggests that sprays timed according to these thresholds, while unlikely to result in damaging whitefly populations, may not always provide the maximum economic savings. There was, however, a large difference between the *Lygus*-treated and -untreated split-plots. Three sprays for *Lygus* provided for a 3-fold larger yield (ca. 2.60 ± 0.06 bales / A) than in the *Lygus*-untreated areas (0.90 ± 0.06 bales / A). Yields were numerically higher in the conventionally-treated regime suggesting that the endosulfan+Ovasyn application provided some additional *Lygus* control; however, the effect was not significant (P=0.23). This contrast was not possible in 1997, because the *Lygus* split-plot was not instituted in the 95IRM regime (Ellsworth et al. 1998).

Ultimately, growers in Arizona must protect lint quality from insect contamination (i.e., honeydew). Not surprisingly with such low season-long levels of whiteflies, lint contamination as measured by manual thermodetector (TD) was well below levels believed to be associated with cotton “stickiness” in all regimes tested including the UTC (fig. 13). As with other yield parameters, there was, however, a significant effect of *Lygus* treatments on TD scores (P=0.03). We found that areas that were not protected against *Lygus* resulted in ca. a 71% increase in TD scores. Because there were only minor differences in whitefly population dynamics between the two *Lygus* split-plots, it is likely that the differences in TD scores were more related to the trashiness of the harvested and ginned lint. Where *Lygus* was not controlled, the plant was considerably more vegetative and less responsive to the defoliation measures. This resulted in more trash in the lint during ginning (fig. 10) and possibly this minor (< 2 TD points), yet significant, increase in TD scores in the *Lygus*-untreated split-plots. Alternatively, we cannot dismiss the possibility that the persistent green foliage of the *Lygus*-untreated split-plots may have supported more whiteflies later in the season which in turn increased the contamination levels on open bolls.

This study has sought to integrate whitefly management strategies with the control of Arizona's other major cotton insect pests. Pink bollworms were effectively controlled through the use of Bt cotton and were not further studied. *Lygus* dominated the production season in 1998, requiring 3 sprays for its control. Whiteflies, on the other hand, were controlled with just a single spray regardless of type. The population dynamics of whiteflies were highly unusual with an atypical late-season decline. IGR re-treatment timing could not be explicitly tested this past year, because of the lack of need to re-spray whiteflies later in the season. Contrary to past findings, the disrupting influence of *Lygus* chemical controls on natural enemies was not apparent via whitefly population dynamics. These studies are beginning to uncover the myriad of factors responsible for the regulation of whitefly populations in quasi-commercial, managed systems, and should lead to optimal use recommendations for our most valuable whitefly insecticides, the IGRs. Furthermore, we have begun to reveal the intricacies of the relationship between pest control practices for two major insect pests. We have demonstrated, for the first time, a cascading series of negative consequences — reduced yields, vegetative plants, difficult defoliation, lower turnouts, more gin trash, heavier seed mass, more lint contamination — in failing to control *Lygus* in an optimum manner while still managing whiteflies.

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## Disclaimer

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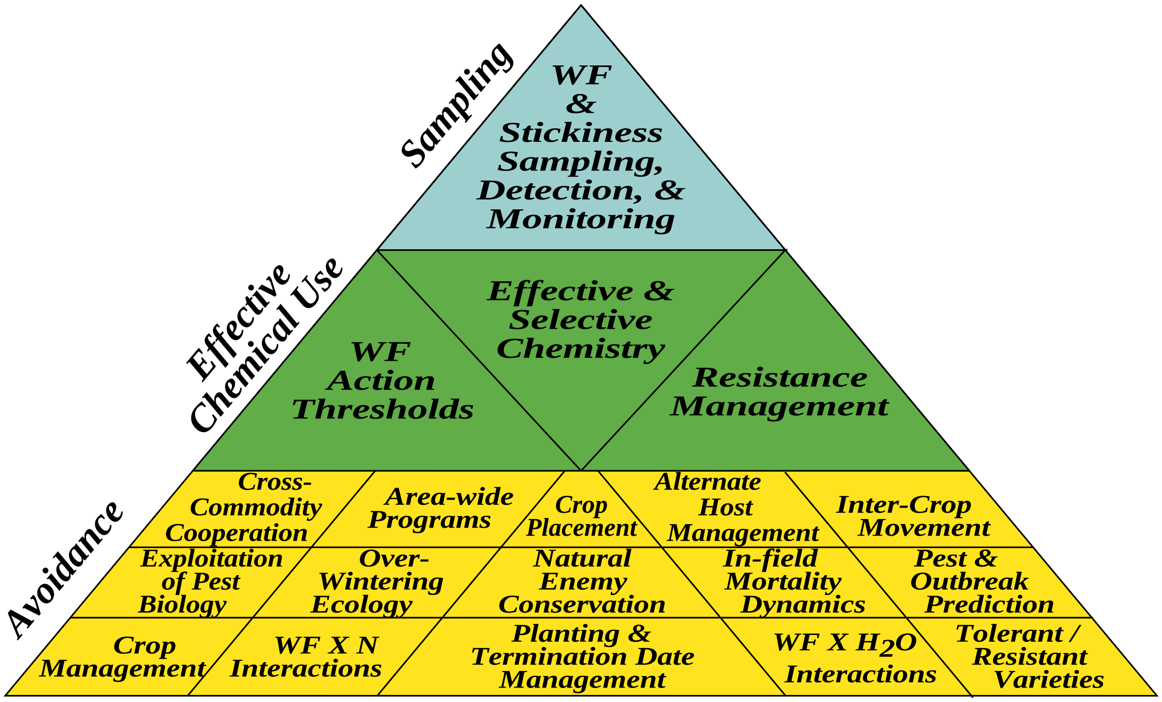

Figure 1. Conceptual diagram of integrated whitefly management in cotton. The pyramid structure is inherently stable and contains three levels or keys to whitefly management: Sampling, Effective Chemical Use, and Avoidance. The studies reported here reflect efforts to optimize deployment of insect growth regulators and other whitefly chemistry, while building upon the foundation of avoidance through improved understanding of this pest's biology and ecology. These studies also serve to integrate management of this pest with the other primary pests of the system, specifically *Lygus* and pink bollworm.

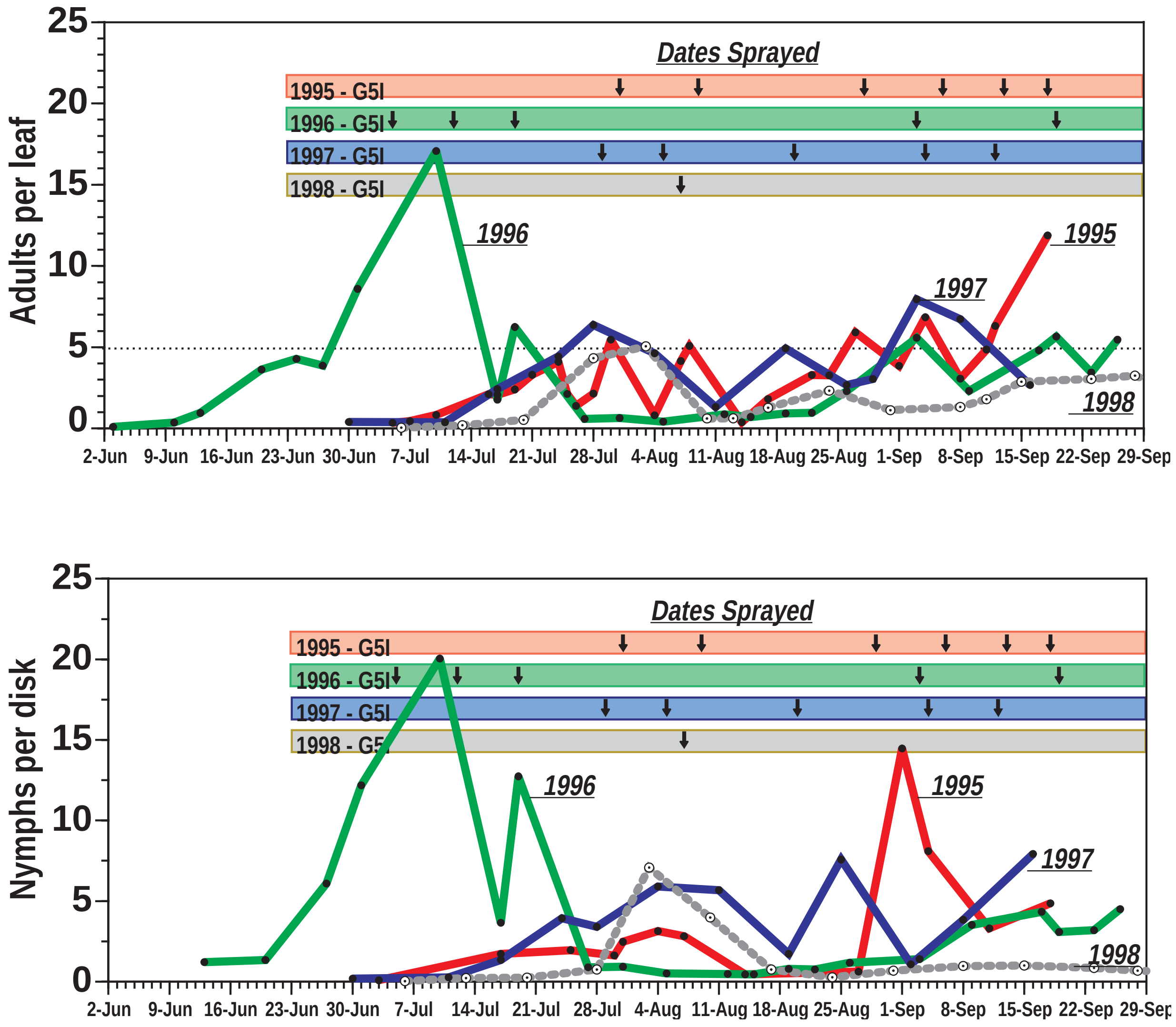

Figure 2. Seasonal dynamics of SWF, 1995–1998: Adults per leaf (above) and total nymphs per disk (3.88 $cm^2$) (below) for the conventional insecticide regime (‘95IRM’). SWF sprays for each year are denoted by arrows. Timing of the 1998 population was about 1–2 weeks later than 1997 or 1995; however, 1998 heat units (and plant development) were considerably behind normal and the previous three years. Heat Units (86/55°F) since 1 January 1995, 1996, 1997, and 1998 on July 15 were 2505, 2858, 2808, and 2286, respectively.

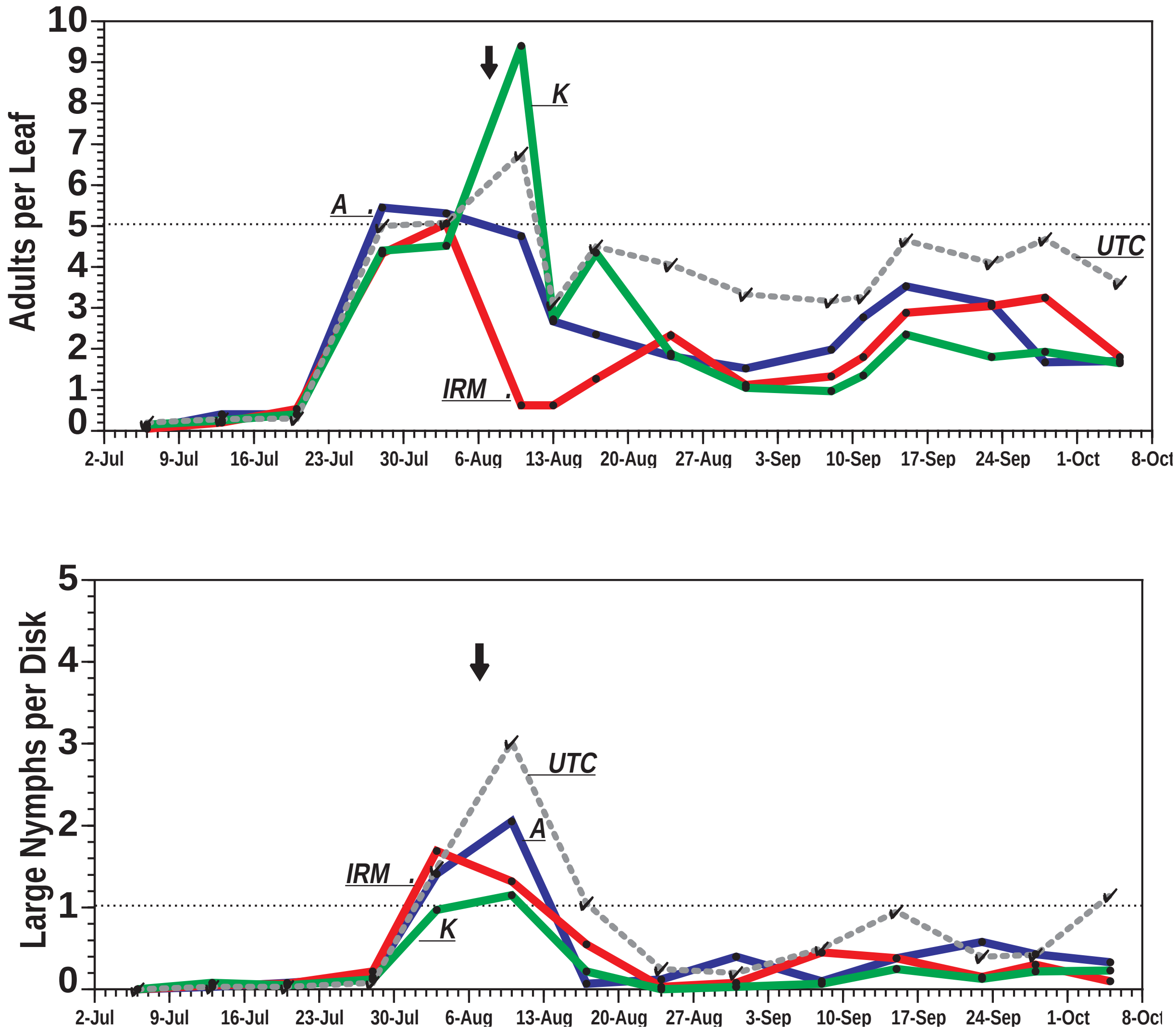

Figure 3. Seasonal dynamics of SWF, 1998: adults per leaf (above) and large nymphs (instars 3 & 4 per 3.88 cm$^2$ disk) (below) in response to SWF spray regime. One spray against SWF was made on 7 August in each regime, except for the UTC (see arrow). 'IRM' was sprayed with endosulfan (0.75 lb ai/A) + Ovasyn (0.25 lb ai/A). The threshold for taking action with IGRs is 3–5 adults per leaf with 1 large nymph per disk (horizontal lines). 'A' = Applaud regime; 'K' = Knack regime.

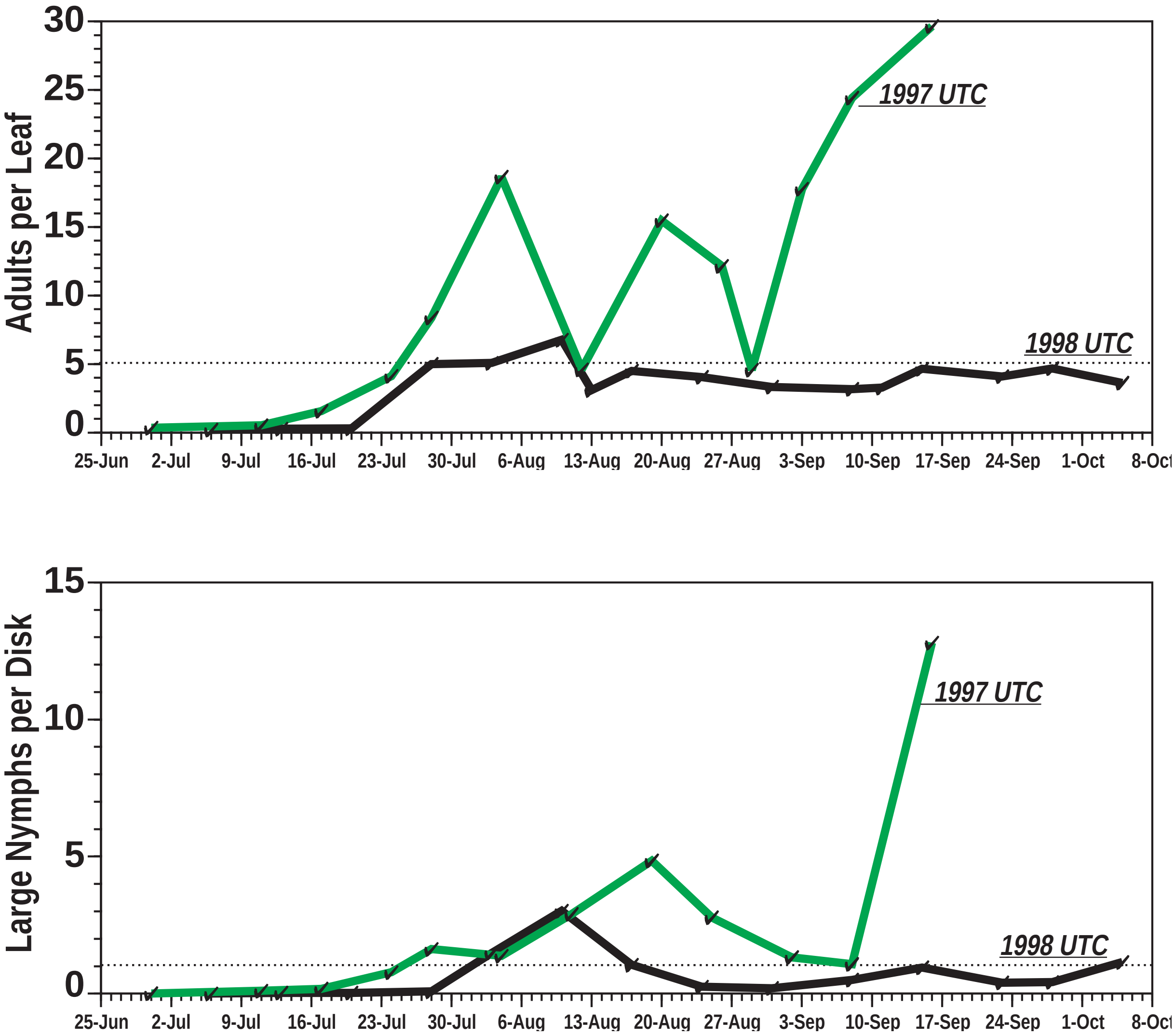

Figure 4. SWF adults per leaf (above) and large nymphs (instars 3 & 4 per 3.88 $cm^2$ disk) (below) in the untreated check (UTC) for 1997 versus 1998. The threshold for taking action with IGRs is 3–5 adults per leaf with 1 large nymph per disk (horizontal lines). Populations during 1997 exceeded the threshold on 28 July and never returned below threshold for the remainder of the season. Levels during 1998 were unusual in that after exceeding threshold on 3 August, the population abated and never returned to economic levels in spite of the lack of sprays for SWF.

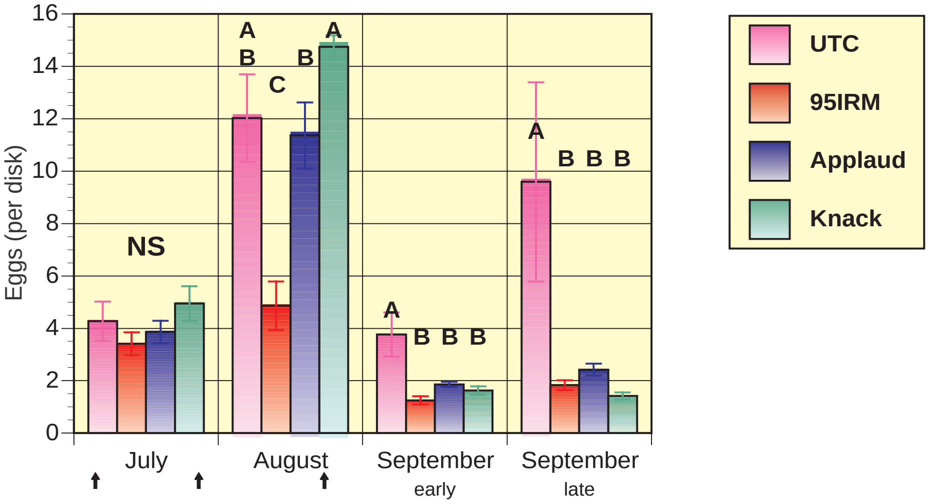

Figure 5. SWF eggs (per 3.88 $cm^2$ disk ± SE) in response to SWF spray regime. One spray against SWF was made prior to the August evaluation. '95IRM' was sprayed with endosulfan (0.75 lb ai/A) + Ovasyn (0.25 lb ai/A). Arrows denote 2 sprays against *Lygus* in July and 1 in August. Bars not sharing a letter within a month are significantly different by orthogonal contrasts ($P \leq 0.05$). 95IRM lowered egg counts more quickly than either IGR regime due to superior adult knockdown. Egg counts were elevated in the Knack regime during August because of the accumulation of inviable eggs. All three regimes effectively reduced egg numbers relative to the untreated check (UTC) one generation after application.

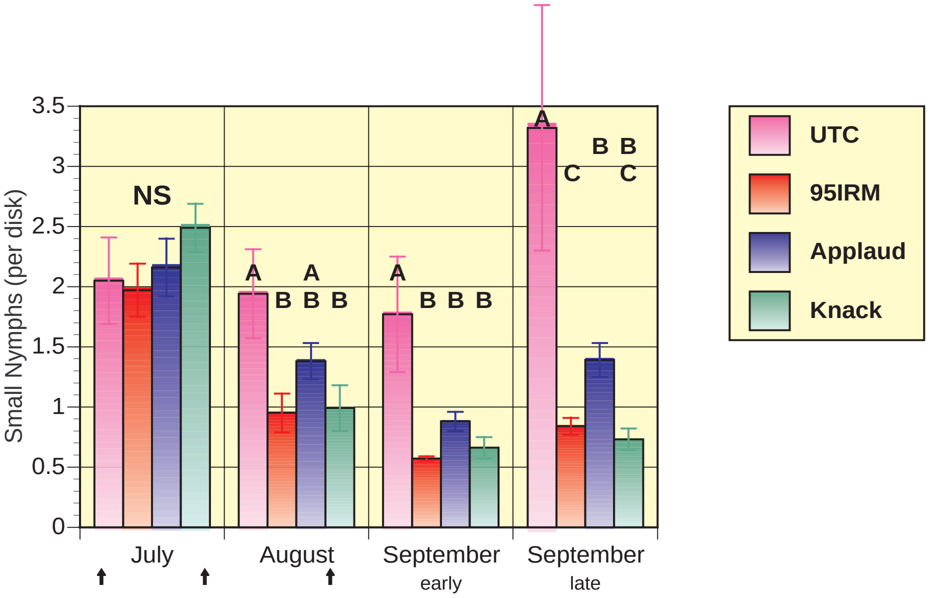

Figure 6. SWF small nymphs (instars 1 & 2 per 3.88 $cm^2$ disk ± SE) in response to SWF spray regime. One spray against SWF was made prior to the August evaluation. '95IRM' was sprayed with endosulfan (0.75 lb ai/A) + Ovasyn (0.25 lb ai/A). Arrows denote 2 sprays against *Lygus* in July and 1 in August. Bars not sharing a letter within a month are significantly different by orthogonal contrasts ($P \leq 0.05$). Small nymph numbers tend to be higher in the Applaud regime, because nymphs are not killed by Applaud until they molt. All three regimes effectively reduced small nymph numbers relative to the untreated check (UTC) one generation after application.

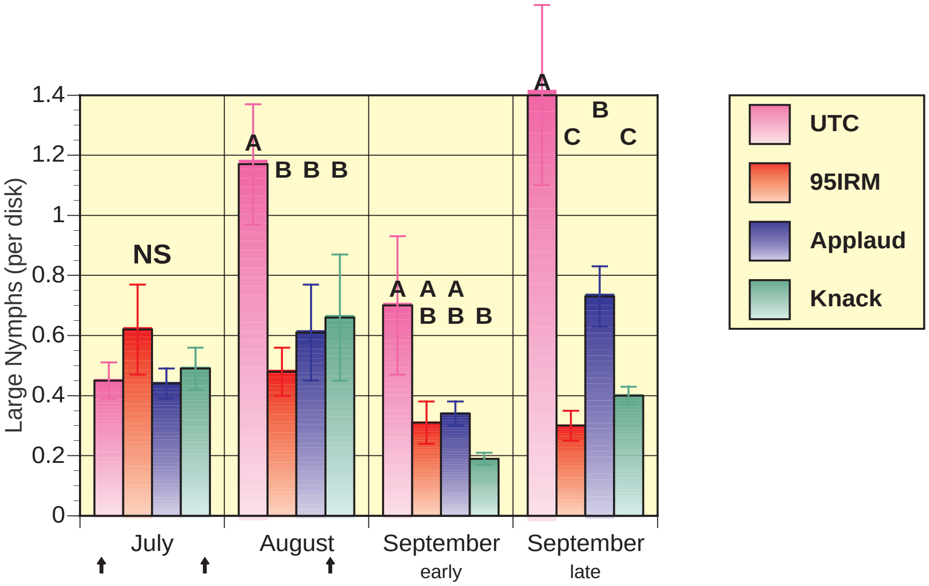

Figure 7. SWF large nymphs (instars 3 & 4 per 3.88 $cm^2$ disk ± SE) in response to SWF spray regime. One spray against SWF was made prior to the August evaluation. '95IRM' was sprayed with endosulfan (0.75 lb ai/A) + Ovasyn (0.25 lb ai/A). Arrows denote 2 sprays against *Lygus* in July and 1 in August. Bars not sharing a letter within a month are significantly different by orthogonal contrasts ($P \leq 0.05$). Large nymph numbers declined in all regimes following application. Even the untreated check (UTC) declined in early September before increasing later in the month.

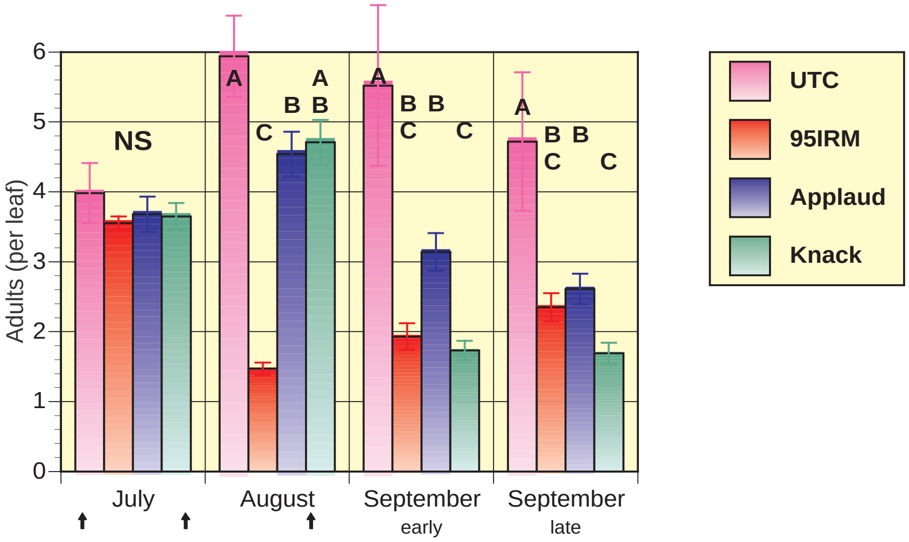

Figure 8. SWF adults (per leaf ± SE) in response to SWF spray regime. One spray against SWF was made prior to the August evaluation. '95IRM' was sprayed with endosulfan (0.75 lb ai/A) + Ovasyn (0.25 lb ai/A). Arrows denote 2 sprays against *Lygus* in July and 1 in August. Bars not sharing a letter within a month are significantly different by orthogonal contrasts ($P \leq 0.05$). Adult numbers declined immediately after treatment in the 95IRM regime (August); however due to their mode of action, the IGR regimes required one generation before resulting in lower adult numbers (early September). Note the declining monthly trend for the 2 IGR regimes, less so for the UTC, and the increasing trend in the '95IRM' regime.

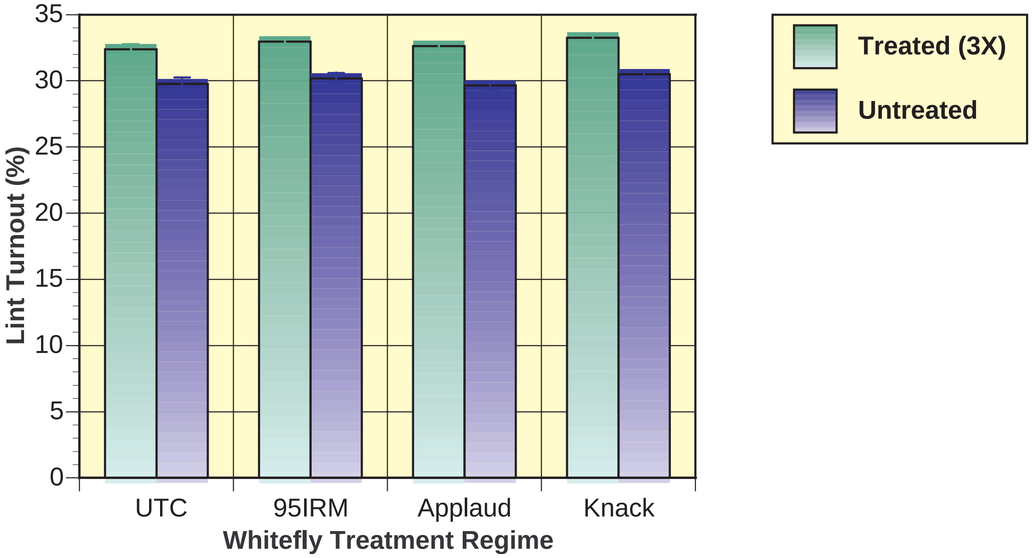

Figure 9. Lint turnout (% ± SE) response to SWF treatment regime and *Lygus* control. Only one spray against SWF was made season long. '95IRM' was sprayed with endosulfan (0.75 lb ai/A) + Ovasyn (0.25 lb ai/A). *Lygus* bugs were sprayed 3 times (Vydate C-LV, Orthene, Vydate C-LV; each at 1 lb ai/A) or not at all. Turnouts were not significantly different among SWF regimes (P>0.10); however, turnouts were significantly higher in *Lygus*-treated versus untreated regimes (P<0.01). The average difference was 2.8%.

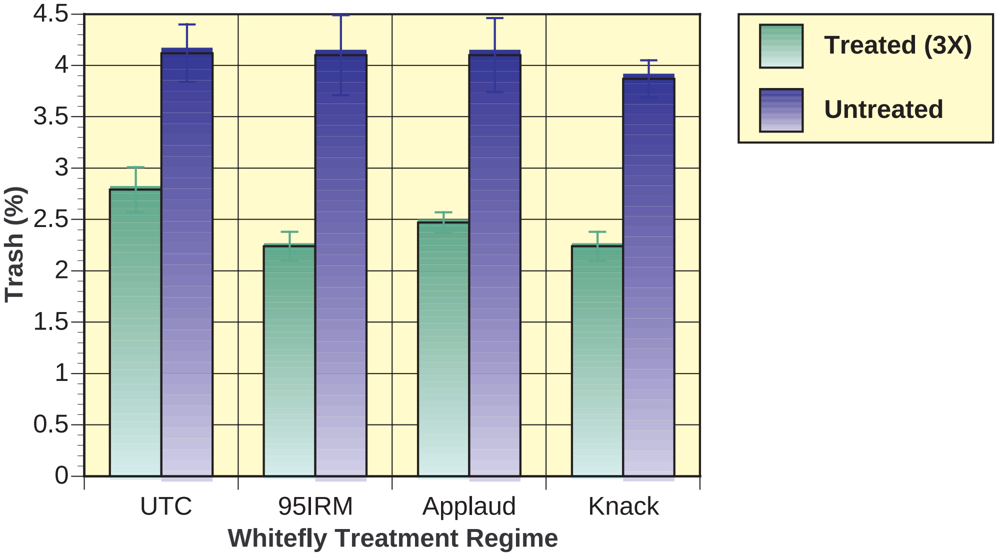

Figure 10. Gin trash (% ± SE) in response to SWF treatment regime and *Lygus* control. Only one spray against SWF was made season long. '95IRM' was sprayed with endosulfan (0.75 lb ai/A) + Ovasyn (0.25 lb ai/A). *Lygus* bugs were sprayed 3 times (Vydate C-LV, Orthene, Vydate C-LV; each at 1 lb ai/A) or not at all. Gin trash levels were not significantly different among SWF regimes (P>0.10); however, gin trash levels were significantly lower in *Lygus*-treated versus untreated regimes (P<0.01). The average difference was 1.6% and due in part to the relatively rank growth and subsequent poor defoliation in areas left unmanaged for *Lygus*.

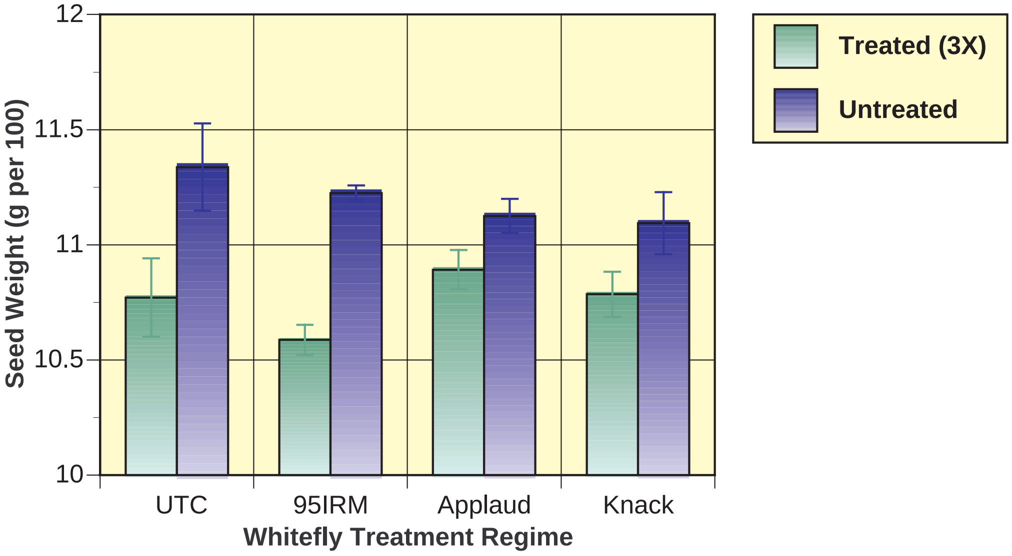

Figure 11. Seed index (g per 100 ginned seed ± SE) in response to SWF treatment regime and *Lygus* control. Only one spray against SWF was made season long. '95IRM' was sprayed with endosulfan (0.75 lb ai/A) + Ovasyn (0.25 lb ai/A). *Lygus* bugs were sprayed 3 times (Vydate C-LV, Orthene, Vydate C-LV; each at 1 lb ai/A) or not at all. Seed size was not significantly different among SWF regimes (P>0.10); however, seeds were ca. 4.1% heavier in *Lygus*-untreated versus treated regimes (P=0.04). The average difference was 0.44 g / 100 seed. With fewer boll sinks to fill in the untreated plots, carbohydrates went towards seed development.

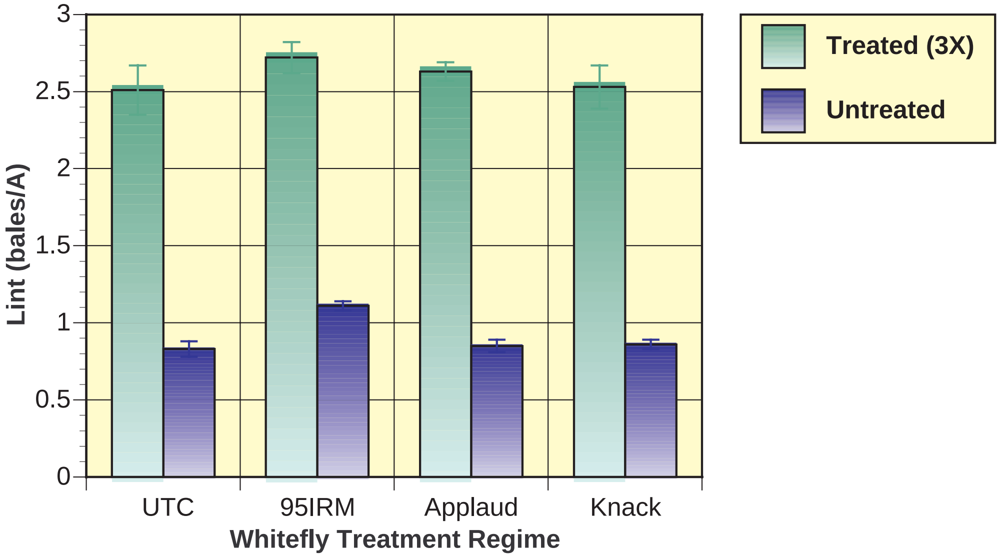

Figure 12. Lint yield (bales/A ± SE) response to SWF treatment regime and *Lygus* control. Only one spray against SWF was made season long. '95IRM' was sprayed with endosulfan (0.75 lb ai/A) + Ovasyn (0.25 lb ai/A). *Lygus* bugs were sprayed 3 times (Vydate C-LV, Orthene, Vydate C-LV; each at 1 lb ai/A) or not at all. Lint yield was not significantly different among SWF regimes (P>0.10); however, yields were nearly 3-fold higher in *Lygus*-treated versus untreated regimes (P<0.001). The average difference was 1.7 bales/A.

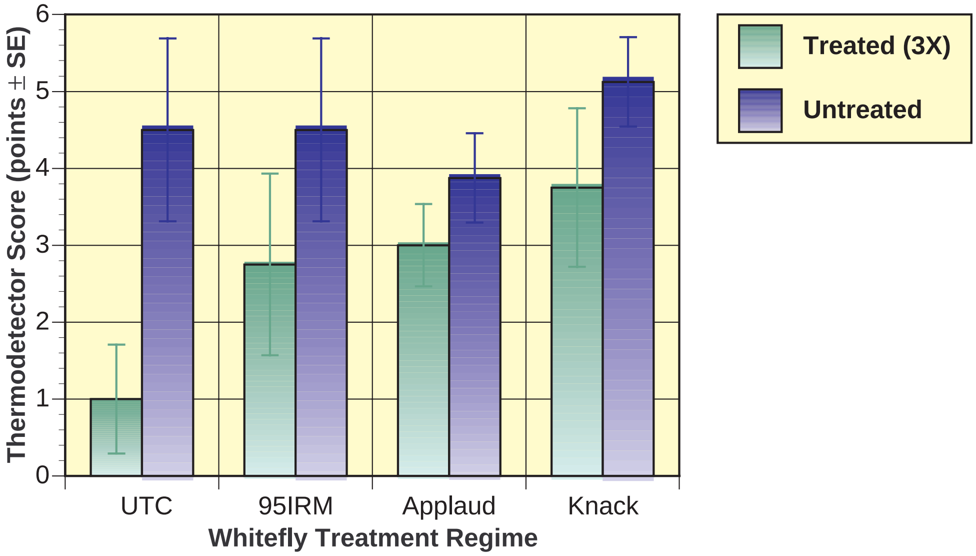

Figure 13. Manual thermodetector (TD) scores (no. of sticking points ± SE) in response to SWF treatment regime and *Lygus* control. Only one spray against SWF was made season long. '95IRM' was sprayed with endosulfan (0.75 lb ai/A) + Ovasyn (0.25 lb ai/A). *Lygus* bugs were sprayed 3 times (Vydate C-LV, Orthene, Vydate C-LV; each at 1 lb ai/A) or not at all. TD scores were not significantly different among SWF regimes (P>0.10) and all cotton was not sticky. However, TD scores were ca. 71% higher in *Lygus*-untreated versus treated regimes (P=0.03). The average difference was < 2 points and could have been related to the increased trash in the *Lygus*-untreated regimes.