Validity of the Pinhead Square Treatment Program for Pink Bollworm Suppression and Impact of Several Insecticides on Arthropod Fauna in Cotton

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Abstract

A limited chemical control tactic known as pinhead square treatment has gained recent favor as a component of pink bollworm population management. The strategy has economic and ecologic goals of using reduced insecticides early in the season (to include lower rates, half the acreage, and less potent chemistry) in order to reduce later season risk of pink bollworm infestations. This strategy also depends in part on the cultural tactic which results in "suicidal emergence" of overwintering pink bollworms through optimal planting date management. The combination of these tactics has been used in the past to overcome boll weevil populations area-wide. This study is focused on the evaluation of this system as a basis for pink bollworm suppression. Though only preliminary is presented here, it is clear that there are numerous insects impacted by this practice which interact in complex ways to influence pest populations of all kinds. Furthermore, the fate of such a practice in any production system is also influenced by the specific chemical agent used. This experiment details the use of four different classes of insecticide chemistry as well as one bioinsecticide. The experiment has been duplicated in 1993; however, only 1992 data are shown here.

Introduction

The pink bollworm, *Pectinophora gossypiella* (Saunders), is the key pest of cotton grown in Arizona. Management procedures for this pest have generally included both cultural and chemical components. The cultural component focuses upon the basic strategy of avoidance. This is accomplished through the manipulation of dates of key production events in order to minimize the chance of pink bollworm (PBW) reproduction and seasonal survival in cotton. Specifically, this can include observance of planting windows which result in cotton fruiting after the majority of pink bollworm moths have emerged from overwintering sites. This exploits the biological fact that PBW females require cotton fruit of a minimum age on which to lay eggs. This stage of fruiting generally occurs at about 900 heat units (HU; 86°/55°F) after planting and is referred to as susceptible square. Females which fail to find susceptible squares (or older fruiting structures) will eventually die, failing to effectively oviposit. This phenomenon is often called "suicidal emergence." Heat unit models predict the general occurrence of PBW overwintering emergence with about 50%, 75%, and 95% emergence occurring at about 1250 HU, 1500 HU, and 1850 HU, respectively. Through timely planting, growers can effectively avoid large portions of the overwintering emergence. The technique has added benefits, because PBWs are at their lowest levels in the spring of each year due to the cumulative mortality experienced all winter long.

Following the severe PBW outbreak year of 1990, many growers responded to this cultural program, especially in conjunction with a pinhead square treatment (PHST) program. The objective was to achieve about 75% suicidal emergence of the PBW through manipulation of planting dates alone and supplement this level of control with PHSTs. The PHST consisted of an appropriate chemical insecticide applied just prior to the occurrence of susceptible squares. This stage, the pinhead square, usually begins around 700 HU after planting (HUAP), while susceptible squares are generally seen around 900 HUAP. Therefore, the strategic placement of chemical insecticides on pinhead squares around 850 HUAP is thought to help deny females suitable oviposition sites either through adulticidal or residual ovicidal or larvicidal activity on PBWs (Fig. 1). Pinhead square treatments have been used in the past to help manage boll weevil populations (Moore & Watson, 1990) or other early season insects; however, the strategy has not been thoroughly evaluated for PBW management.

Another cultural technique involves the timely termination of irrigations and subsequent defoliation in order to prevent the production of small, green bolls by mid-September. PBWs overwinter as larvae in diapause, and this state is conditioned by photoperiod. At latitudes including Arizona, incidence of diapause sharply increases after mid-September and is usually concentrated in the upper parts of the plant where immature bolls are produced. Prevention of these fruiting forms during this time of the season reduces the number of potentially overwintering PBWs in any given field. The benefits of this practice include the reduction of pesticide use during the latter part of the season, and the subsequent overall reduction of PBWs carried through to the following season. With the advent of severe sweetpotato whitefly infestations during 1991 and 1992 in Arizona, more growers are considering this second cultural technique as their primary means for avoiding late season losses to whiteflies while still having an impact on PBWs.

A natural consequence of favoring the second cultural tactic for PBW and whitefly avoidance is an emphasis on earlier plantings in the spring. This places a greater premium on precise timing of planting and use of PHSTs, because fewer moths will suicidally emerge prior to the onset of susceptible squares. Thus, this study seeks to test the validity of PHST as an economically and ecologically viable compromise between planting date management for suicidal emergence (cultural control) and protection of early fruiting structures (chemical control). A second objective is to consider the relative impact of various insecticides used in this role (4 organophosphates, 2 carbamates, 1 formamadine, 1 synthetic pyrethroid combination, and 1 biological insecticide) and their season long impact on the insect fauna of a cotton field.

Materials and Methods

Design and Crop Development: Four blocks of cotton were arranged into 40 plots [38 ft X 12 rows (40")] with seven foot alleys between each plot. The test was buffered at either end by 144 ft of untreated cotton and on each side by at least 150 ft of untreated cotton. Each individual plot consisted of approximately 0.03 acres with the entire test equal to about 1.4 acres. DPL-90 was dry-planted on 4/16/92 (642 HU) and watered-up on 4/18/92 (675 HU). This places cotton in the low to moderate range of susceptibility to PBW infestation as predicted by College of Agriculture's Cotton Advisories (Brown et al. 1992 & 1993). This block of cotton was among the earliest fruiting cotton in the area and should have drawn a relatively large number of moths to the area. First pinhead square was found on 5/22/92 (1245 HU; 677 HUAP) and indicated a normal fruiting pattern. The first susceptible square was detected on 6/1/92 (1588 HU; 898 HUAP). Plant monitoring to include mapping, plant height, and nodes above the white bloom (NAWB) was conducted on 7/7/92. Irrigation termination was on 8/21/92 and harvest by machine on 11/10/92. Four of the 12 rows were harvested in two passes for individual plot yields.

Treatments and Applications: There were nine treatments and an untreated check per block of cotton. Each material was applied by ground on a band (≤ 20 in.) over the row with a John Deere Hi-Cycle modified with a compressed air system. Teejet TwinJet™ nozzles (TJ60-8003VS) delivered 20 gallons of water / acre, except in the Lock-on treatment which was put on at 10 gallons / acre. Applications were made on 6/2/92 (1612 HU; 922 HUAP) and eight days later on 6/10/92 (1804 HU; 113 HUAP). The first application was coincident with the beginning of susceptible squaring, and the PBW HU model predicted approximately 78% of the moths emerged up to this point. Pheromone traps in the area indicated the local abundance of PBW moths (≥ 15 moths / night per trap); however, trap catches fell just prior, during and after the applications. By the second application date, the PBW model predicted about 92% moth emergence. Thus, the residual activity of the second application should have extended efficacy through at least 96% moth emergence. All twelve rows of each plot were treated each time in two passes (6 rows / pass). The treatments represented four different classes of chemistry (organophosphate, carbamate, formamadine, and synthetic pyrethroid) and a *Bacillus thuringiensis*, biological-based insecticide:

Treatment Number	Compound	Rate (lb ai / acre)
1	Untreated Check	—
2	Biobit HPWP	
3	Guthion 3F	0.50
4	Larvin 3.2E	0.80
5	Lock-on 2.0S	0.50
6	Orthene 90S	1.00
7	Ovasyn 1.5EC	0.50
8	Ovasyn 1.5EC + Danitol 2.4 EC	0.25 + 0.20
9	Penncap M 2.0F	0.50
10	Vydate C-LV + Oil	0.50 + 0.50 pt.

Sampling and Data Collection: A random sample of squares (25) and later bolls (10) were taken from the first or second fruiting positions of the cotton plants weekly (6/29-7/29). Each was examined for the presence of insect damage (e.g., PBW, *Lygus*, stinkbug) and counted. Nine weekly sweep samples were taken throughout the season (6/3-7/28) and consisted of 10, 25, or 50 (depending on insect density) standard sweeps from the middle of each plot. All means reported here have been standardized to the most common sample size, 25 sweeps, and all total counts are reported on a cumulative per 1000 sweeps basis. Sweep collections were placed in Zip-Loc™ bags and frozen for later sorting and identification of morphotypes.

Post Test Procedures: All insect fauna were tracked from the time of PHSTs through July. By mid-July, the plots were becoming infested with sweetpotato whiteflies and cotton aphids. Preliminary analyses suggested that there were no residual effects (direct or indirect) of the PHSTs on these population levels. Because it was unlikely that the crop could be taken to harvest without substantial losses directly attributable to these two pests, another series of insecticidal applications were made to form a second test in the same field (see Ellsworth & Meade, 1993). This second series of treatments was re-randomized over the design of the PHST trial and evaluated separately. The results of this second test will not be addressed in this report except under discussions of yields, which were impacted by the combined practices of both tests (i.e., PHSTs and whitefly/aphid applications).

Results and Discussion

The planting date was relatively late (642 HU) but still within the recommended planting window (450-700 HU). This placed the crop into the lower risk category for PBW infestation. By the time the crop reached susceptible square, approximately 78% of the PBWs had emerged from overwintering. For the two week period prior to susceptible square, moth captures were irregular but averaged 15.6 moths / trap / night. This level is consistent with the need for a PHST program under the current recommendations. One week prior to susceptible square, moth captures had reached nearly 0, but this is consistent with the relatively cool nighttime temperatures that Maricopa was experiencing (Fig. 2). Temperatures in the low 50°s or lower can depress trap counts, because moth activity is considerably lower on cold nights. A large degree of suicidal emergence may have already been realized before PHSTs. Nevertheless, two PHSTs were required to reach the recommended level of 95%+ PBW emergence. Moth captures after this point were quite low (Fig. 2) and remained low until 7/13 when a brief increase in moth activity (46 moths) was detected. Recent rains probably stimulated adult emergence from pupal chambers in the soil. The trap counts returned to their low levels (< 10 moths / night) almost immediately.

Fruit Survey: Surveys of total damaged fruit (i.e., by PBW, *Lygus*, or stinkbugs), showed some patterns according to treatment and date of sample (Fig. 3). PBWs stayed below threshold through July 13 for all treatments and close to or just above threshold through July 29. There were no significant differences among treatments for PBW damaged fruit; however, when all fruit damage was totalled, there was a significant effect of PHST (P=0.0226). Of this total damage, PBW damage was more or less consistent across treatments, and stinkbug damage was very low. Thus, the trends shown in figure 3 represent the activity of *Lygus* bugs more than anything else. No treatment was significantly different from the check; however, Danitol + Ovasyn had the most damaged fruit while the Vydate and Biobit plots had the least amount of fruit damage over the course of the season. Because PBWs were a relatively minor influence early to mid-season, more information can be gleaned from the sweep samples taken in this test.

Sweep Samples: Over 50 different species of arthropods were captured collectively in this test by sweep samples. Many have little direct impact on the cotton plant or crop production, but of these, some are natural enemies with potentially significant impact on pest populations. Because the number of insects were low on any given sample date, most data were summed across all dates and then analyzed. This summing eliminates the possibility of detecting trends through time, so the data are also presented as totals for each date by treatment. Whenever possible, comparisons were made against the untreated check plots by means of Dunnett's procedure. In many cases, the check fell in the middle of the range and thus no significant differences were found; however, differences between the highest and lowest treatments are sometimes reported due to significant ecological impact.

Numerous pests or plant feeding species were found among the sweep samples. Most, however, were at low or sub-economic levels for the duration of the sampling period (e.g., stink bugs, cotton fleahoppers, leafhoppers, flea beetles). There were three notable exceptions to this pattern, and each will be discussed separately below.

Lygus Bugs, Square Shed, and Sucking Plant Feeders

Lygus bugs were at low levels before and immediately after the PHSTs. They did, however, build steadily in numbers through the end of the sampling period when whitefly treatments were initiated. There was a significant effect of treatment season long (P=0.0075), but none of the treatments were significantly different from the check (Fig. 4a). *Lygus* bugs were highest in the pyrethroid combination treatment (Danitol + Ovasyn) and lowest in the Vydate treatment. The remaining treatments including the check were roughly similar. This trend was consistent on every date (i.e., more in the Danitol + Ovasyn and less in the Vydate treatments). Furthermore, the pyrethroid combination had more *Lygus* bugs sooner than any other treatment. Just 9 days after treatment (DAT) on 6/19, Danitol + Ovasyn were the only plots which exceeded the *Lygus* threshold (15 / 100 sweeps) with 19 bugs / 100 sweeps (Fig 4b). This is a period of early squaring. One week later, all treatments were below threshold again; however, on 7/2 Danitol + Ovasyn (18/100 sweeps) and the Lockon (17/100 sweeps) plots were above threshold. By the next sample date (7/10), all treatments were above threshold with the exception of Vydate (7.5 / 100 sweeps). Vydate continued to remain below threshold until 7/23 when all treatments were well above the *Lygus* threshold. Thus, there was over four weeks difference in the timing of severe *Lygus* bug infestations between the highest treatment (Danitol + Ovasyn) and the lowest treatment (Vydate).

The number of squares that shed into the sweep samples was counted for each treatment. The causes of square shed or abortion are many-fold, complicated, and often interrelated (e.g., physiological, biotic and abiotic stress-induced). Season long there were no differences among treatments (P=0.435) with average square shed of about 22 / 100 sweeps (Fig. 5a). Although square shed followed the same increasing trend as seen in the *Lygus* numbers, there were only weak correlations between the two variables (Fig 5b). Shed was highest on 7/16 and on that date there was a significant treatment effect with the Orthene, Biobit, and Vydate plots suffering the loss of twice as many squares as in the Larvin, Lockon, and Danitol + Ovasyn plots. This effect was weak, however, and the Danitol + Ovasyn plots had a tendency in other dates to have more aborted squares than any other treatment. Furthermore, significant and visible water stress occurred from 7/11-7/13 with the Vydate plots exhibiting severe signs of water stress.

Other sucking insects were present, but at low and variable levels. Say's stink bug and other stink bugs were at very low levels season long with no significant differences among treatments. Leafhoppers are not generally considered cotton pests, but were present in consistent numbers and indicative of insecticidal activity. There was a significant treatment effect of PHST on the seasonal means (P=0.0044); however, no treatments were different from the check (Fig. 6). Nevertheless, Orthene and Danitol + Ovasyn, both broad spectrum in activity, had among the lowest counts of leafhoppers. Vydate was consistently the lowest, and reasons for this are discussed later.

Cotton fleahoppers were at low levels throughout the test period (<5/100 sweeps) with the exception of one date (Fig. 7b - 7/10). On that date, Vydate had again the lowest fleahopper numbers, which were significantly lower than the check (P<0.05). Season long, there were significant treatment effects (P=0.0002) with Guthion, Larvin, Orthene, and Vydate plots having significantly fewer cotton fleahoppers than the untreated check (Fig. 7a).

False Chinch Bugs

False chinch bugs are historically an early season problem in only an extremely minor acreage in relatively few years. Even then, they are generally a border problem usually restricted to areas adjacent to fallow or weedy fields. Also, the problem is usually caused by mass migrating immature forms or nymphs of the false chinch bugs, usually in response to the drying up of host vegetation in field borders. The spring of 1992 was exceptionally wet and warm bringing about extensive desert and weedy vegetation throughout our agricultural areas. This vegetation supported the development of huge numbers of false chinch bugs, and the warm weather allowed them to complete development outside of the cotton fields before their hosts dried down. Thus, adult false chinch bugs were generally distributed this past spring.

In the prior discussion, a pattern begins to emerge showing the Vydate plots to be consistently low in the incidence of a variety of arthropods. Indeed, this trend was consistent and clear in the majority of insect species studied. Furthermore, this phenomenon was occurring well beyond what would be considered the maximum duration or residual of the chemical itself (i.e., 4 weeks later). The Vydate plots were distinguished in one other significant and dramatic way; there were thousands of adult false chinch bugs present (Fig. 8a). Season long there were on average over 15,000 / 100 sweeps! It should be noted that the Vydate plots were randomly positioned throughout the field and that nearly 150 ft of cotton buffer existed on all sides of the test. This was not a border phenomenon and it was entirely selective of the Vydate plots. Shortly after the first PHST, an increase in the number of false chinch bugs were noted in the Vydate plots (Fig. 8b). Two days after the second PHST, over 20,000 / 100 sweeps were being captured in the Vydate plots <u>only</u>. All individuals captured were adults. During this period, dead false chinch bugs were observed in large piles on the ground, but equally apparent were the thousands of live individuals present on each plant. False chinch bug numbers continued to build to a high of about 50,000/100 sweeps on 7/10 (1 month after the last PHST). Then just three days later it was noted that almost all of the bugs had left! As noted earlier, a 2-3 day period of severe drought stress was observed especially in the Vydate plots starting on about 7/10. It may be inferred that the level of stress was such that the bugs dispersed to other areas where less stressed, turgid plants could be found.

Vydate, though initially lethal to false chinch bugs, was clearly behaving as an attractant for this species. The result was extreme densities all over the plant with greater concentrations in the upper third of the canopy as well as on developing squares and bracts. The density was so extreme that we believe that there was an actual physical exclusion of other species (e.g., note the low numbers of *Lygus* bugs in these plots). Numerous species were found at lower levels in the Vydate plots relative to the check or other treatments. At the same time, false chinch bugs represented "easy" prey items for predators. One in particular (Assassin bugs, *Zelus* spp.) was found to be closely associated with the presence of false chinch bugs (Pearson correlation = 0.84). Nearly six times as many assassin bugs were found in the Vydate plots when compared to the remaining treatments including the check (Fig. 9a). This association was reinforced by the simultaneous disappearance of both species after 7/10 (Fig. 9b). Furthermore, visual observation confirmed that *Zelus* spp. were feeding on false chinch bugs to the point of engorgement.

Sweetpotato Whitefly

It is common knowledge that sweetpotato whiteflies (SPWF) reached outbreak conditions during the summer of 1992. This experiment was no exception. In addition, there has been speculation by others that appropriate "early" chemical tactics could suppress SPWF during a time when they are at a low, sub-economic level, thus preempting future infestations. The definition of earliness is critical to evaluating the plausibility of such a strategy. In this case, whiteflies were not detectable at the time of PHSTs (Fig. 10). Though sweep samples are not commonly used for measuring SPWFs, it is a relatively simple and unbiased technique for detection of this species. SPWFs were first detected in our samples on 7/10 (ca. 2.25 / sweep). This level is approximately equivalent to no more than a pair per plant. On this date, orthene had the highest number of SPWFs (ca. 4/sweep) with a significant treatment effect (P=0.0090); however, only Vydate (no SPWFs) was significantly lower than the check (Fig. 11). False chinch bugs were still present at this time. Levels actually declined in the 7/16 samples with a test average of less than 1 SPWF / sweep (0.871), yet there was still a significant treatment effect (P=0.0137) and Vydate (0.03/sweep) still had significantly fewer than the check. One week later the population exploded almost instantaneously and throughout the entire field as a result of SPWFs dispersing from drying melons (Fig. 10). This large migration erased any prior treatment effects (P=0.5370) and resulted in a 20-fold increase in the number of SPWFs (17.6/sweep). The dispersal continued in the following week, doubling the number of whiteflies in the sweep samples. The counts (> 1000) per sample (25 sweeps) became to large to continue counting.

There are several conclusions that can be drawn from this experience: 1) PHSTs did in fact appear to lead to a minor delay in the onset of SPWFs in the Vydate plots; however, this was largely due to the extremely high density of false chinch bugs present (sampler error may also be responsible for the low numbers of SPWFs counted from the Vydate plots), 2) SPWFs, though present in the field as early as 7/10, largely originated from outside of the test site as a result of immigration, 3) SPWFs built-up to damaging levels in the test site in a relatively short period of time (< 1 week), and 4) PHSTs had no effect on the ultimate (economic) levels of SPWFs in this test.

Beneficials & Other Insects

Numerous beneficials and other incidental insects were monitored in this test; however, most were caught at low levels and thus summed over the entire season and then analyzed. In addition, various indices of species diversity were calculated and compared for each treatment (Shannon-Wiener; Pest to Beneficial Ratios). By and large there were no detectable treatment differences in the levels of the majority of arthropod species captured. Furthermore, there were even fewer instances where there was a significant difference between a PHST and the check. The following is a discussion of those species in which some significant differences were found either in terms of treatment effects or differences from the check. It should be noted here that for some species the strength of the "treatment effect" is probably due in part to the relatively depressed numbers of all species found in the Vydate plots.

White-marked fleahoppers are generally not considered pests of cotton, though their role as a predator is also not well established. There were significant treatment effects (P=0.0197) with Danitol + Ovasyn having the most and Vydate having the least number of fleahoppers (Fig. 12). There were no treatments significantly different from the check. Coccinellids (Lady-bird beetles) are important predators in cotton especially early in the season. They were present at only low levels with significant treatment effects over all (P=0.0053), but with no treatment significantly different from the check (Fig. 13). The check, Biobit, Ovasyn, and Penncap plots had the most beetles present. Season long numbers of spiders were not significantly different (P=0.15); however, the Danitol + Ovasyn plots did have the fewest number of spiders and were marginally significantly different from the check (Fig. 14). Green lacewing adults had a significant treatment effect (P=0.0038) with Larvin and Lockon plots with the most; however, none were significantly different from the check (Fig. 15). *Geocoris* (Big-eyed bugs) are important predators and were effected by PHSTs (P=0.0002); however, no treatment was significantly different from the check (Fig. 16).

Season long *Orius* numbers also showed some treatment effects (P=0.0075) with the Ovasyn and Biobit plots having the most pirate bugs and Vydate having none (Fig. 17a). Only on one sample date, however, was there any treatment significantly different from the check (P≤0.05) (Fig. 17b). Ovasyn had significantly more pirate bugs than the check, Vydate, Orthene, or Larvin on 7/10. Assassin bugs (*Zelus* spp.) were impacted by PHSTs as well (P=0.0000); however, as noted before the Vydate plots had almost a 6-fold increase in the number of these insect when compared with the check or other treatments (Fig. 9). Clearly, these insects were feeding on false chinch bugs. Damsel bugs (Nabidae) were also affected by PHSTs (P=0.0003). Furthermore, Danitol + Ovasyn and Orthene plots had significantly fewer of these predators when compared to the check (Fig. 18a). Higher numbers were found in the Guthion, Penncap, and Vydate plots. On their most abundant date (6/19), Penncap had significantly more damsel bugs than the Danitol + Ovasyn, Orthene, Lockon, and Biobit plots (Fig. 18b).

Diversity Indices: It is quite clear from the above discussion that there are many and varied ways in which PHSTs influenced arthropod numbers in this test. Some indications point towards a positive effect in favor of a few treatments while others attribute negative effects to the same sets of treatments. Each of these factors has a potentially yield "stimulating" or yield limiting effect dependent on the net effect on the pests in the treatment. Furthermore, in the absence of significant numbers of PBWs, determining the advantages of PHSTs becomes much more complex. Diversity indices measure in some sense the "health" of the system. They are based on the numbers of species present and their relative abundance. In short, the higher the number the more "diverse" the system is and more stable it is considered to be. The lower the number is the more disturbed (or sometimes polluted) the system may be. In crop production, the objective is to minimize the number of potential pest numbers while maximizing the presence and numbers of natural enemies. Therefore, the actual relationship between diversity indices and a successful crop production system is not clear at all. Nevertheless, these indices do provide comparative information and possibly indicate the "harshness" of various compounds relative to the check.

In addition to the classical Shannon-Weiner index, a pest to beneficial ratio was calculated for every plot. This classification placed all insects captured into either a pest category or a beneficial category. Those insects which were clearly incidental or with no presumed role were excluded from the analysis. In both approaches, it was necessary to exclude false chinch bugs from the analyses, because nearly 200,000 individuals were captured from the Vydate plots. Also, these false chinch bugs did occasionally "spill out" and impact adjacent plots. Whiteflies were also excluded from the analyses because counts had to be discontinued due to time constraints once they reached outbreak levels.

Shannon-Weiner Diversity Index

Graphically the differences appear minor (Fig. 19a); however, there was a significant PHST treatment effect (P=0.0035). Furthermore, Guthion, Biobit, and the Check were significantly higher than the lowest treatment, Danitol + Ovasyn. This suggests that the pyrethroid treatment was the least diverse of the test. This can be due to either a fewer number of species present or numbers skewed towards a smaller number of species. It should be emphasized here that these numbers represent the arthropod community over a nine week period including a full eight weeks after the last PHST. In other words, this suggests that the effects of PHSTs are much longer term than simply the residual of their respective chemistries. It also points to the fact that pyrethroid use early season may have negative consequences for a longer period of time relative to less disruptive chemical classes. All of the treatments had indices greater than 2.44 with the exception of Orthene (2.39), Vydate (2.39), and Danitol + Ovasyn (2.26). The Vydate result was probably due to 1) fewer species being found, and 2) higher numbers being skewed towards certain key species (e.g., Assassin bugs). The Orthene result was probably due to a heavier skew towards lower numbers of sucking insects (e.g., cotton fleahoppers, leafhoppers, *Orius*, *Geocoris*, and Damsel bugs).

Pests to Beneficial Ratio

The relationship of this measure and ultimate crop performance is more clear cut. Obviously the more pests there are relative to the number of beneficials, the more likely a pest will reach outbreak status. The pyrethroid treatment clearly had a significantly higher ratio than any other treatment including the check (Fig. 19b). This suggests that this treatment combination was selectively detrimental to beneficials relative to pests over the long term. The actual mechanism for this could be short term by killing more beneficials or more long term by killing needed prey items early leading to slower recolonization by beneficials. In either case, it would seem that this had some impact on the higher and earlier *Lygus* numbers noted in the Danitol + Ovasyn plots. It should be noted here that Ovasyn applied alone did not result in the same pattern as the pyrethroid combination for this or other variables. It is also interesting to note that nearly all of the treatments had a lower Pest:Beneficial ratio than the check with the exceptions of Danitol + Ovasyn and Orthene. Also, even though Vydate had thousands of false chinch bugs present, it also had a low ratio or high numbers of beneficials. This could be due to the selective nature of the compound or more likely due to the large numbers of beneficials that were drawn to the plots by the availability of false chinch bugs.

Yields: Unfortunately the data are confounded with the laying over of a second test in the same field. The field could have been lost if nothing was done to control the aphids and whiteflies which caused a generalized stickiness by 8/1, less than 10 days after their initial arrival (Fig. 10). Furthermore, the "residual" effects of PHSTs made two months earlier were thought to be minimal (especially in light of the low PBW counts and generalized distribution of whiteflies). Analyzing the yield data according to the pinhead square treatments, the Ovasyn + Danitol treatment was significantly lower than the check and the Vydate treatment was significantly higher than the check (Fig. 20a). The remaining treatments were similar. Interestingly, the Vydate and Ovasyn + Danitol treatments had the highest amount of season long square shed (Fig. 5a). In retrospect, we can see now that the pest:beneficial ratio was highest for Danitol + Ovasyn and lowest for the Vydate plots (Fig. 19b). It is still astonishing that the Vydate plots yielded so well in the face of such large numbers of false chinch bugs — these bugs were excluded from the pest:beneficial ratio. These yields are most certainly also influenced by the subsequent whitefly/aphid treatments they received. Therefore, yields were analyzed in terms of their later treatments as well. In this second look, the Orthene + Danitol and the

Endosulfan + Ovasyn treatments did well relative to the check (Fig. 20b), but no treatment was significantly different from the check. Unfortunately, each PHST compound was not always followed by the same whitefly treatment, so a third look at the data was necessary. In this view (Fig. 21), a "super treatment" is formed by the combined usage of insecticide at pinhead square and later for whiteflies and aphids. In essence, this "super" treatment represents the season long insecticide input for each plot. In this scenario, it is difficult to reconcile the yield numbers statistically. Only a small subset of the "super treatments" listed were actually replicated, which happened only by chance. Of those combinations which were replicated, the Vydate treatments at pinhead square followed by either Endosulfan + Ovasyn or Capture yielded the best. Other good whitefly materials did well too: Orthene + Danitol following Ovasyn PHSTs and Capture + Ovasyn following Larvin PHSTs. The only replicated Danitol + Ovasyn plots were followed by Asana applications, a synthetic pyrethroid which did not control aphids and whiteflies well. Thus this super treatment represents season long usage of pyrethroids and resulted in a 250 lb. yield disadvantage relative to the check. Further analyses will be necessary in order to identify the relative contribution of the PHSTs and whitefly treatments on yield preservation.

Summary

Pink bollworm populations were low this past year, and "suicidal emergence" was near maximal for this cotton planting. Thus, the question of PHSTs for PBW management cannot be answered here. Nevertheless, both negative and positive impacts of this management practice have been outlined. Furthermore, though many indices of performance showed negligible differences among insecticides, chemical classes, and modes of action, there were some striking differences in the levels of some pest, some beneficial, and some incidental insect populations. Some results seemed counterintuitive (e.g., Vydate yield response in the face of tremendous false chinch bug pressures), but when examined within the context of the entire faunal system may be better understood (e.g., *Lygus* levels; Pest:Beneficial ratios). The use of synthetic pyrethroids at pinhead square caused long-lasting changes (> 4 weeks) to the arthropod fauna which under these conditions resulted in pest resurgence and yield reductions. Yield results were intriguing, but at this time the data are still confounded with subsequent action taken for whitefly and aphid infestations and are therefore inconclusive.

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Figure 1: Generalized cotton and PBW phenology in relation to heat units for four different planting dates in 1992 at Maricopa. This test was planted on 4/18 and required two PHSTs to reach 95+% PBW emergence.

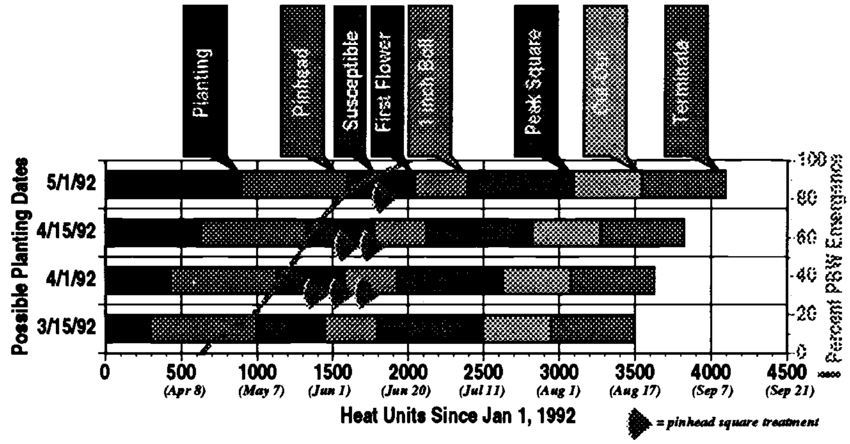


Figure 2: Mean trap catches of PBW moths in the test area (4 pheromone traps) and the low nighttime temperatures over the course of the season. Applications were made on 6/2 & 6/10.

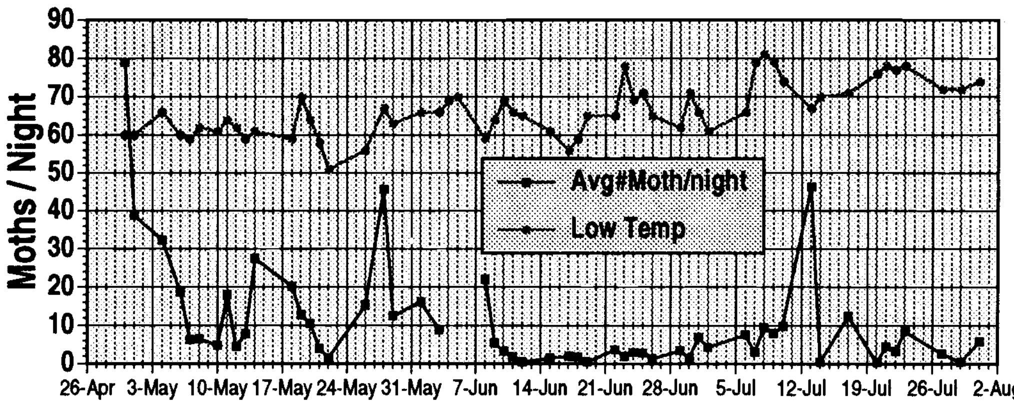


Figure 3: Damaged fruit included injury by PBWs, *Lygus* bugs, or other sucking pests. No PHST was significantly different from the check, though there was a significant treatment effect season long (P=0.0226). The majority of damage was caused by *Lygus* bugs.

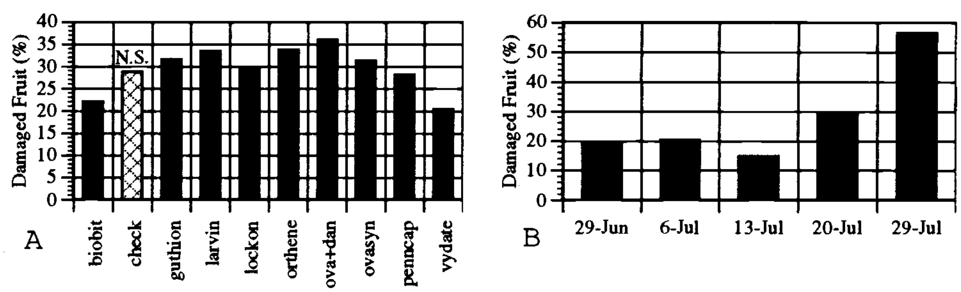


Figure 4: Cumulative counts of Lygus bugs (per 1000 sweeps. a) No PHST was significantly different from the check, though there was a significant treatment effect (P= 0.0075). b) Danitol + Ovasyn reached threshold on 6/19, at least 2 weeks before any other material.

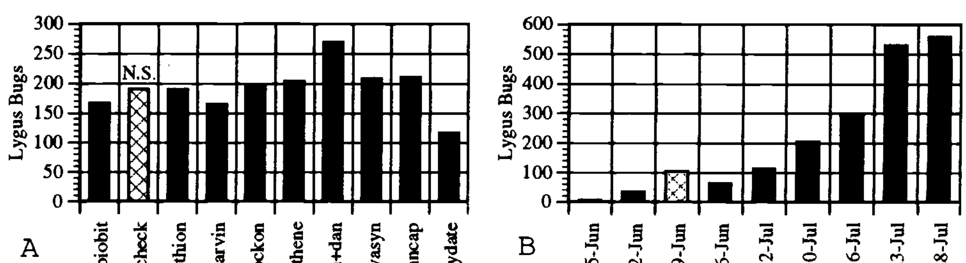
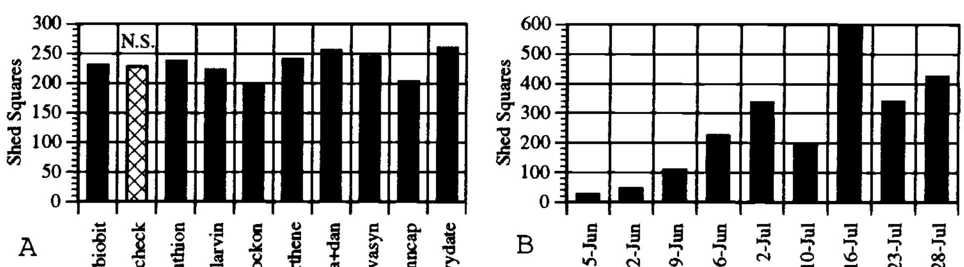


Figure 5: Cumulative counts of shed squares (per 1000 sweeps) by a) compound and by b) date. There was no significant impact of PHSTs on the number of shed squares (P=0.435).



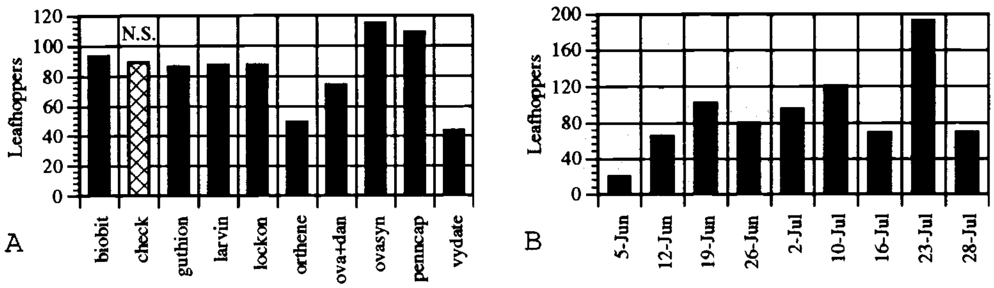


Figure 6: Cumulative counts of leafhoppers (per 1000 sweeps) by a) compound and by b) date. No PHST was significantly different from the check, though there was a significant treatment effect (P=0.0044).

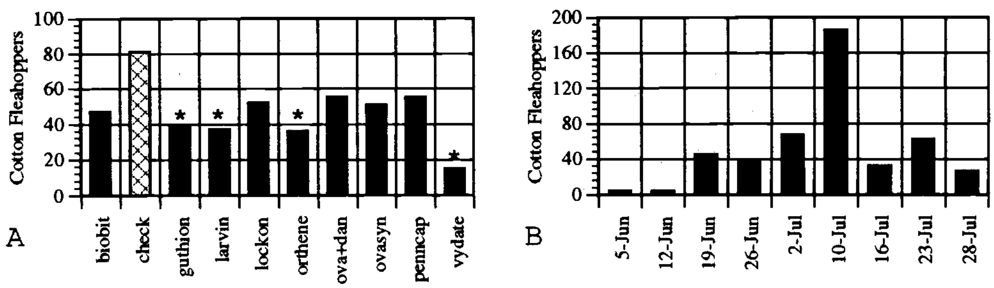


Figure 7: Cumulative counts of cotton fleahopper adults (per 1000 sweeps). a) vydate, orthene, larvin & guthion had significantly fewer fleahoppers than the check. Fleahopper levels were low season long (b).

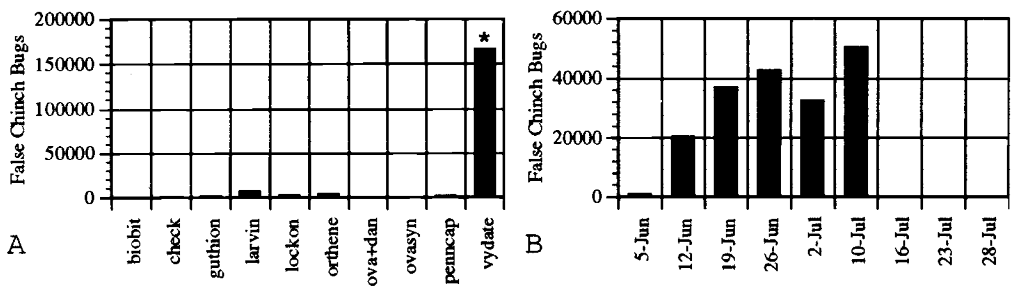


Figure 8: Cumulative counts of false chinch bugs (per 1000 sweeps). a) Vydate plots were selectively attractive to these insects. b) Once the plots became water-stressed (>7/10), all of the false chinch bugs dispersed.

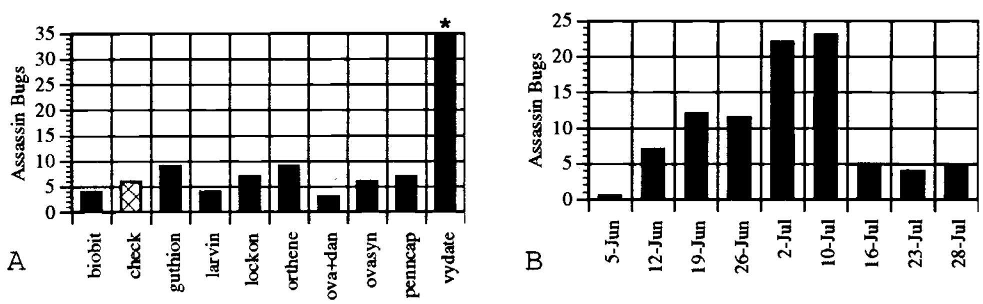


Figure 9: Cumulative counts of assassin bugs (per 1000 sweeps). a) Vydate had significantly more assassin bugs than the check. b) Assassin bugs were closely correlated with false chinch bugs — both declined after 7/10.

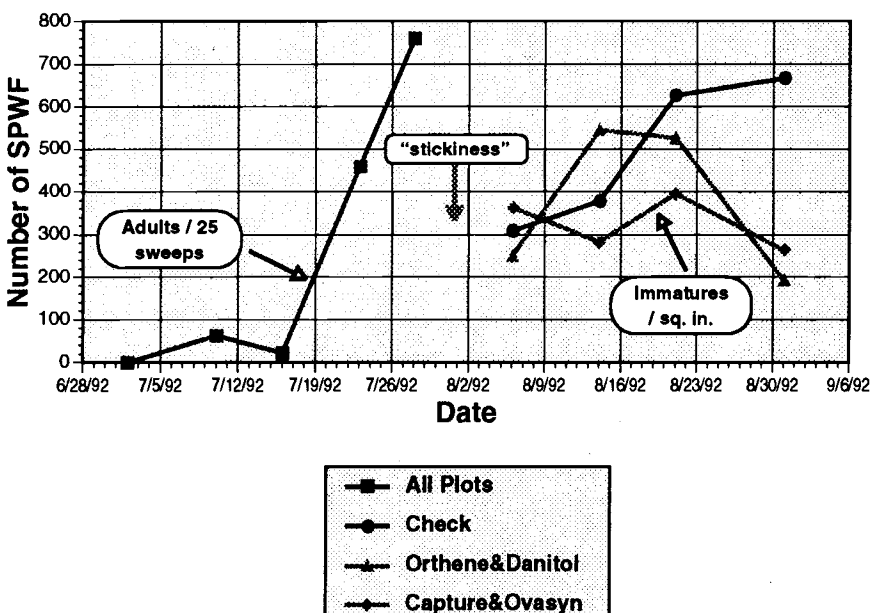


Figure 10: Build-up of whiteflies was dramatically sudden, followed by visible stickiness on 8/1 and chemical controls starting on 8/11. Prior to 7/10, whiteflies were not found in the cotton field. Mass movement of whiteflies in late July resulted in a near instantaneous infestation of the entire field without bias towards any PHST or position within the field. Drying melons were thought to have provided the abundant supply of moving adults.

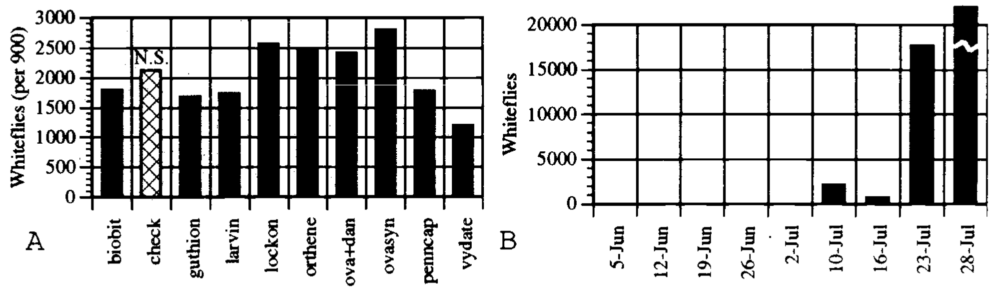


Figure 11: Cumulative counts of whiteflies (per 900 sweeps). No PHST was significantly different from the check overall (a) or on the date prior to applications for SPWF control; however, Vydate had significantly fewer SPWF than the check on 7/10 and 7/16 (b).

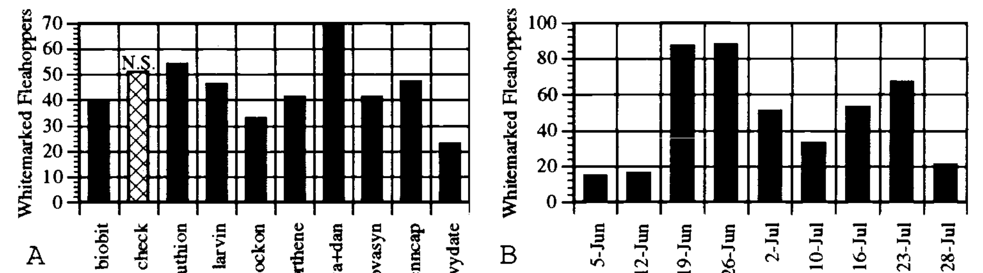


Figure 12: Cumulative counts of whitemarked fleahoppers (per 1000 sweeps) by a) compound and by b) date. No PHST was significantly different from the check, though there was a significant treatment effect season long (P=0.0197).

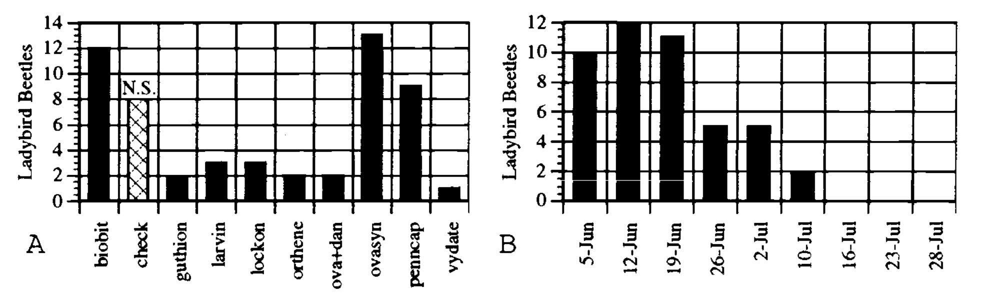


Figure 13: Cumulative counts of ladybird beetles (per 1000 sweeps) by a) compound and by b) date. No PHST was significantly different from the check, though there was a significant treatment effect season long (P=0.0053).

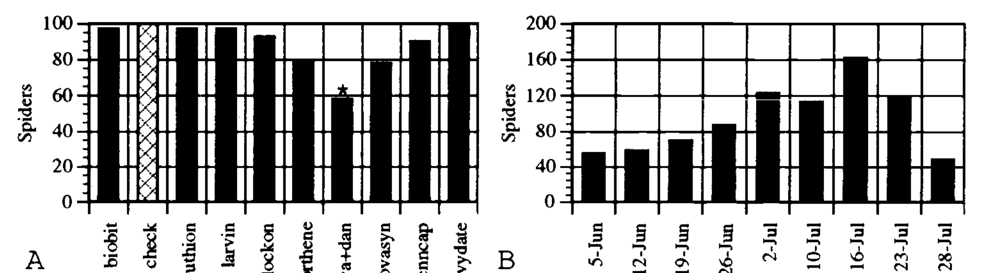


Figure 14: Cumulative counts of spiders (per 1000 sweeps). a) Danitol + Ovasyn had significantly fewer spiders than the check season long, though the effect was slight and not apparent on any single date (b).

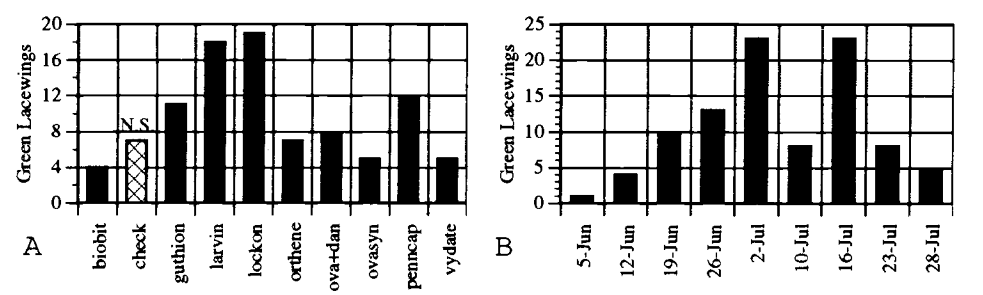


Figure 15: Cumulative counts of lacewing adults (per 1000 sweeps) by a) compound and by b) date. No PHST was significantly different from the check, though there was a significant treatment effect season long (P=0.0038).

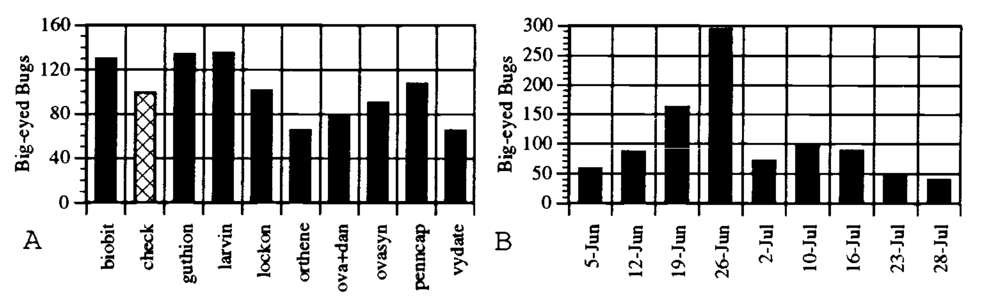


Figure 16: Cumulative counts of *Geocoris* (per 1000 sweeps) by a) compound and by b) date. No PHST was significantly different from the check, though there was a significant treatment effect season long (P=0.0002).

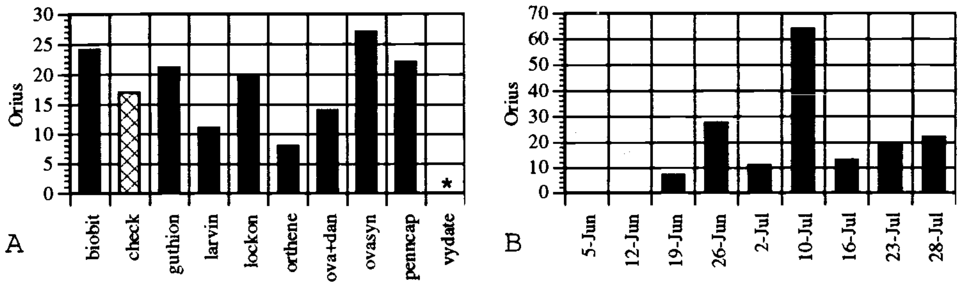


Figure 17: Cumulative counts of *Orius* (per 1000 sweeps). a) Vydate had fewer pirate bugs than the check. b) On 7/10, Ovasyn had significantly more pirate bugs than the check (vydate, orthene, or larvin).

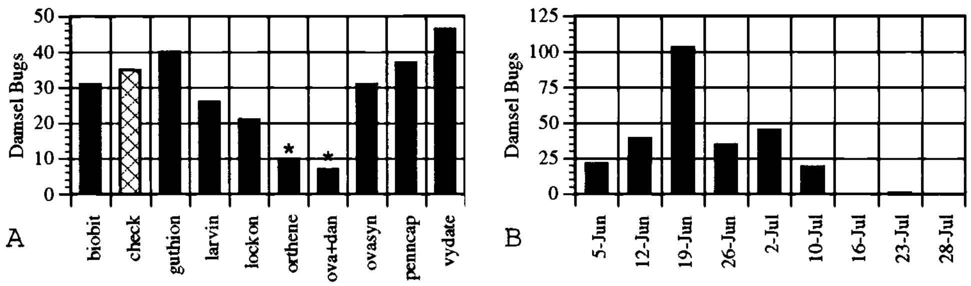


Figure 18: Cumulative counts of damsel bugs (per 1000 sweeps). a) Danitol + Ovasyn and Orthene had significantly fewer nabids than the check. b) Very few nabids were found later in the season.

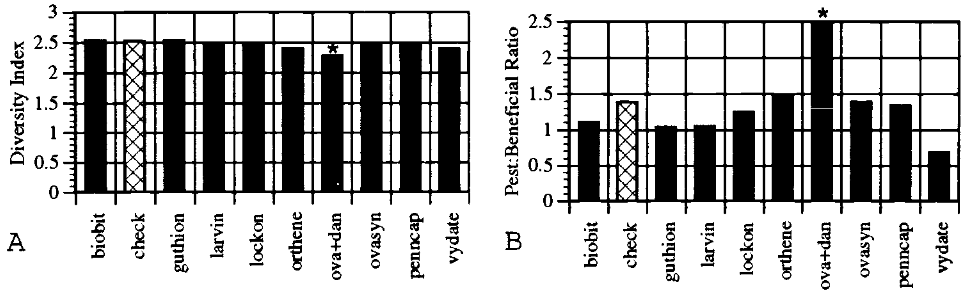


Figure 19: a) Danitol + Ovasyn had a significantly lower diversity index and (b) higher pest:beneficial ratio than the check. A higher index indicates greater diversity and a more stable system, while a high ratio indicates the selective loss of predators and/or release of pests.

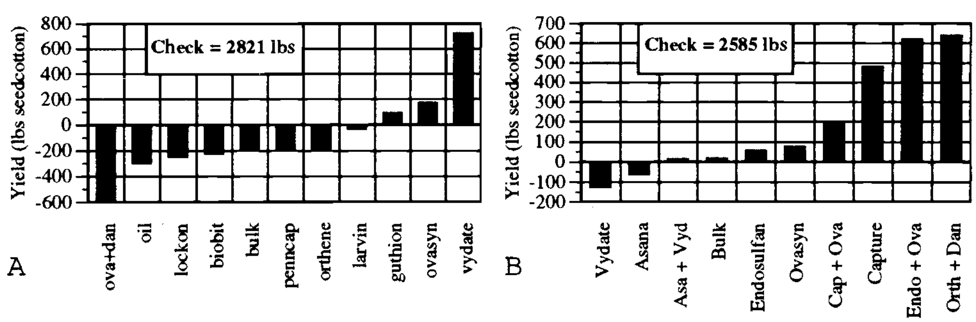


Figure 20: a) Seedcotton yields for the test according to PHSTs. The PHST check served as the baseline (i.e., the baseline did receive SPWF treatments—see fig. 21). b) Yield for the same area according to their respective SPWF treatments relative to the untreated check. "Bulk" and "oil" plots were not formally within the test design and received no insecticide season long.

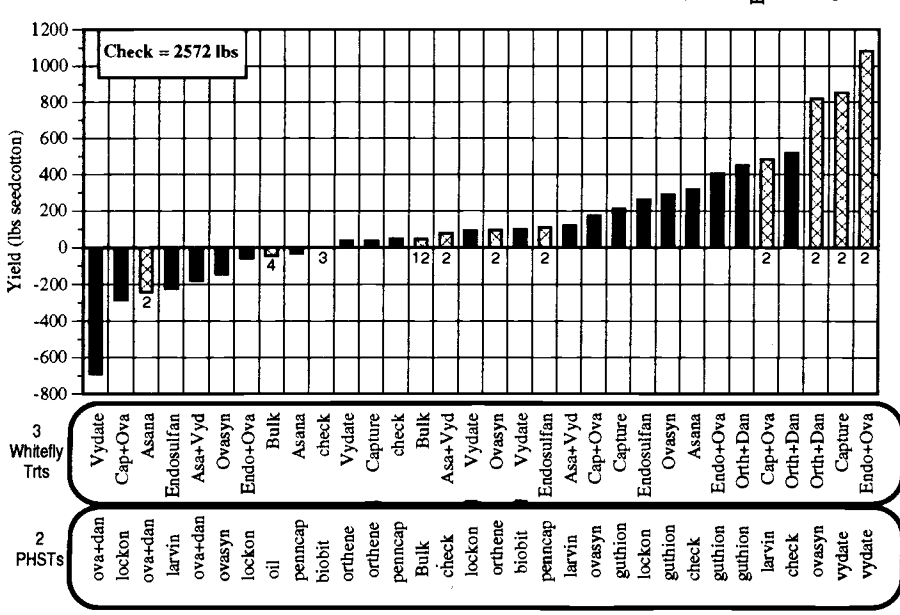


Figure 21: Seedcotton yields according to the season long pesticide load for each plot. Hatched bars are replicated "super" treatments as indicated by their adjacent number. Other bars represent unreplicated combinations. Biobit plots which remained untreated at the time of SPWF applications serves as the combined baseline check.