PROJECT NO. RP-3

ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE
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PROJECT TITLE: Rice protection from invertebrate pests.

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OBJECTIVES AND EXPERIMENTS CONDUCTED BY LOCATION:

Objective 1: To determine the most effective control of rice invertebrate pests while maintaining environmental quality compatible with the needs of society.

1.1) Rice water weevil chemical control - Comparison of the efficacy of experimental materials versus registered standards for controlling rice water weevil in ring plots.

1.2) Evaluation of techniques to improve the utility of registered and experimental products for rice water weevil management in ring plots - evaluation of the efficacy of pyrethroid insecticides applied pre-flood for controlling rice water weevil in ring plots.

1.3) Rice water weevil chemical control - Evaluation of a biorational product versus registered standards for controlling rice water weevil in ring plots.

1.4) Evaluate the influence of treatments of registered and experiential insecticides on populations of non-target invertebrates in rice.

1.5) Tadpole shrimp control – Evaluation of control with registered and experimental insecticides.

1.6) Seed midge – Management of seed midge damaging pests with registered and experimental insecticides.

Objective 2: To evaluate the physical and biological factors that result in fluctuation and movement of populations of the rice water weevil so as to better time control options such as insecticide applications.

2.1) Evaluation of the movement of Rice Water Weevil (RWW) populations that result in economic injury to rice plants. Monitor seasonal trends (timing and magnitude) in the flight activity of the RWW.

2.2) Quantify the relative susceptibility of commonly grown rice varieties to RWW infestation and the yield response of these varieties to RWW infestation.

2.2.1) Studies with naturally-occurring populations of Rice Water Weevil

2.2.2) Studies with controlled populations of Rice Water Weevil

2.3) Evaluate the influence of rice seedling establishment methods of RWW and armyworm populations.

Objective 3: To investigate aspects of armyworm biology as a means of determining the reasons for an increase in armyworm populations in rice in recent years.

3.1) Investigate the biology of armyworms in rice as a means to understand recent population increase.

3.1.1). Study the role of weed populations on armyworm populations in rice.

3.1.2). Investigate the timing of armyworm moth flight in the rice production.

Objective 4: Conduct appropriate monitoring, exploratory research, and educational activities on emerging and new exotic rice invertebrate pests.

SUMMARY OF 2007 RESEARCH BY OBJECTIVE:

Objective 1:

1.1 – 1.3) Chemical Control of Rice Water Weevil - Ring Plots

1.1 – 1.3) Research for subobjectives 1.1 to 1.3 was conducted within one plot area and the results and discussion for this study will be considered together. The data will be reported in its entirety for ease of comparison across treatments and the conclusion from each sub-objective will be reported. Each treatment was replicated four times. Twenty treatments (a total of eight different active ingredients) were established in ring plots to accomplish this research. Plots were in a replicated field study at the Rice Experiment Station (RES) near Biggs, CA. Treatment details are listed in Table 1.

<u>Methods:</u>

Testing was conducted with >M-202= in 8 sq. ft aluminum rings. The plots were flooded on 18 May and seeded on 21 May. A seeding rate of 90 lbs./A was used. Prior to seeding, seed was soaked for 2 hours in a 5% Clorox Ultra solution (unless otherwise noted), followed by 22 hours soaking in water, drained, and 24 hrs. at rest. The Clorox was for Bakanae control. The application timings were as follows:

14 May, early pre-flood treatments

17 May, pre-flood (PF) applications

6 June, 3-leaf stage treatments

Granular treatments were applied with a Asalt-shaker@ granular applicator and liquid treatments were applied with a CO_2 pressurized sprayer at 15 GPA. The natural rice water weevil infestation was supplemented with 10 adults placed into each ring on 4 June and 6 adults into each ring on 11 June. The standard production practices were used. Copper sulfate was applied in mid June for algal management, herbicides on 4 June, and nitrogen was top-dressed in July. The following sample dates and methods were used for this study:

Sample Dates:

Emergence/ Seedling Vigor/Stand Rating: 5 June
Adult Leaf Scar Counts: 12 June
Larval Counts: 2 July and 16 July
Rice Yield: 8 October

Sample Method:

Emergence/ Seedling Vigor/Stand Rating:
stands rated on a 1-5 scale with
5=very good stand (>150 plants)
3=good stand (~100 plants)
1=very poor stand (<20 plants)
Adult Leaf Scar Counts: percentage of plants with adult feeding scars on either of the two newest leaves (50 plants per ring)
Larval Counts: 44 in^3 soil core containing at least one rice plant processed by washing/ flotation method (5 cores per ring per date)
Rice Yield: entire plots were hand-cut and grain recovered with a AVogel@ mini-thresher and yields were corrected to 14% moisture.
Data Analysis: ANOVA of transformed data and least significant differences test (? # 0.05). Raw data reported herein.

Results:

Rice Emergence

There were no significant differences among treatments in terms of seedling vigor and emergence (Table 2). Therefore, no phytotoxicity was seen from any of the treatments.

Adult Leaf Scar Counts

Adult leaf-scar damage normally is insignificant in terms of rice plant growth and development (except under extremely high pressure). Feeding scars are evaluated in our studies as a means to classify the infestation severity and to gain some insight on how the treatments are providing RWW control, i.e., through killing adults, killing larvae, etc. This is particularly important and interesting when dealing with seed and granular treatments. The amount of feeding varies yearly even though our methods used are identical every year because of differing conditions during this “feeding period”. The 12 June sample date was after all the infestations had been made. Counts were moderate with the untreated plots averaging 28% scarred seedlings; this value did not differ significantly from that of six other treatments including Dimilin, Trebon (both preflood treatments), and E2Y45 (all three seed treatments). The lowest value (numerically) was from the V10170 duel application (preflood and 3-leaf) (Table 2). The percentage damaged plants in this treatment was only slightly less than that in the single application (either preflood or 3-leaf) so this active ingredient clearly has activity via either method of application. Other active ingredients that provided some reduction in scarring compared with the untreated were Warrior, Mustang, Steward, Trebon (3-leaf), and Aza-Direct (Table 2). For the experimental materials, Etofenprox appears to have good activity on RWW adults with the 3-leaf application; V10170 was highly effective on adults; DPX-E2y45 was less effective; and Steward was very effective.

Larval Counts

RWW larval counts were made twice during the season. Populations were fairly consistent between the two sample dates with levels in the untreated averaging 1.9 and 2.25 per sample in the first and second dates, respectively (Table 3). The second date should provide some indication of the residual control provided by the treatments compared with the knock-down potential from the first evaluation.

<u>Results.</u> Four experimental insecticide active ingredients, etofenprox (Trebon), clothianidin (V10170), rynaxypyr (DPX-E2Y45), and Indoxacarb (Steward) were evaluated in 2007. In each case, this was a continuation of 2006 testing and allowed us to further evaluate the fit of the product under California rice conditions. The loss of Icon® in Southern rice and the developing environmental concerns regarding pyrethroid use in California have spurred a renewed interest from the agrichemical companies for rice water weevil active products. Compared with the untreated plots, ten of the treatments significantly reduced RWW populations on the first sample date. Similarly, none of the treatments significantly reduced populations compared with the untreated plots in the second sample. This resulted because of a statistical aberration (RWW populations were much higher in one of the treatments than the untreated) and did not result because of poor activity of the products. The results from each sample date as well as the seasonal average data will be detailed. In the first sampling, plots treated with Dimilin, Warrior (preflood and 3-leaf), Trebon (3-leaf), V10170 (preflood+3-leaf, preflood only, 3-leaf only, and seed treatment without Clorox), Mustang Max, and Steward (0.11 rate) reduced RWW levels and most reductions were in the 90% range. In the second sample date, results were similar as detailed above except that the V17170 seed treatment without Clorox seed soak appeared to lose activity, activity "increased" in the Steward (0.55 lb. rate) treatment, and some control was seen in the 0.1 mg rate of E2Y45. Averaged over the season, Dimilin, Warrior (preflood and 3-leaf), Trebon (3-leaf), V10170 (preflood+3-leaf, preflood only, and 3-leaf only), Mustang Max, and Steward (0.11 rate) significantly reduced the RWW populations compared with the untreated plots. The best control was a 95% reduction in larval populations.

<u>Experimental materials versus registered standards.</u> The Trebon 3G preflood applications were not effective. This application method was evaluated also in 2005 and 2006 with excellent results in 2006 and marginal control in 2005. It appears that the 3-leaf stage application is going to be the preferred application method for this product. The Clorox seed soak greatly affected the activity of V10170 seed treatment; the soaked treatment was largely ineffective whereas without the Clorox soak the activity was good (although not the best in the test). This seed treatment was applied by the company to the 'M-202'. The standard Clorox concentration and soak time was used and this reduced the insecticidal activity. This product is clearly effective

via a preflood and 3-leaf stage application. The seed treatment did show activity (without the Clorox soak) but it was less than with the other application methods. The E2Y45 seed treatment was largely ineffective, although these seeds were similarly soaked in Clorox. This likely affected the activity. Evaluation of this active ingredient without the seed soak is needed. The final experimental product, Steward, continues to perform well however, the 0.11 lb. AI/A rate is needed with the 3-leaf stage timing. This active ingredient has been submitted to IR-4 as a possibility to assist with registration in CA.

<u>Soil application of pyrethroid products.</u> Only Warrior was evaluated, among the pyrethroids, as a preflood application in 2007. In summary, the early preflood application of Warrior (1 week before flooding) provided only about 50% control, whereas the preflood application immediately before flooding was equally effective as the 3-leaf stage application. We have been working with Warrior for the last several years to determine if it can be used as a soil application. This application method would provide some flexibility to growers and may provide a greater buffer to nontarget effects. We have generally had excellent results with an application made up to 7 days before flooding, but there have been some inconsistencies in control with this application at the longer intervals before flooding. Environmental conditions between application and flooding undoubtedly influence the residual control results. It appears that those undefined conditions reduced efficacy in 2007. Warrior was registered for use with this application method in 2007.

<u>Evaluation of a biorational product.</u> Aza-Direct, a neem-based product containing azadirachtin, was evaluated in 2007. This product has shown excellent results in greenhouse studies in 2005 and 2006; however, results in field studies have been modest. In 2007, the 32 oz. rate application provided RWW control in the 50% range.

Rice Yield

Grain moisture at harvest (percentage), grain yields (lbs. per A at 14% moisture standard), and biomass (straw + grain weight at harvest data) are shown in Table 4. Moisture values ranged from 13.5 to 15.7%. Rice grain yields ranged from 4305 to 7653 lbs./A which was a 43.7% difference. Grain yields were numerically highest in the preflood V10170 treatment (Table 4) and lowest in the E2Y45 (low rate) treatment. Seven treatments had yields that were significantly higher than in the untreated plots, including Dimilin, Warrior (3-leaf, early preflood, and preflood), V10170 (preflood+3-leaf, preflood only, 3-leaf only). Rice biomass at harvest ranged from 6.1 to 11.4 t/A. Treatments that protected yield also generally had more overall biomass.

In summary, etofenprox, indoxacarb, and clothianidan all appear to have significant potential for RWW management. All these products are a few years from any possible registration with their progress in this regard being approximately in the order listed above (from nearest to farthest from registration). Indoxacarb is active via a post-flood application whereas clothianidan has the most flexibility in terms of application timing. Given the re-evaluation of pyrethroid registrations due to possible off-site movement, it is important to continue to develop alternative active ingredients and classes of chemistry. These active ingredients have some very favorable properties in terms of toxicity to non-targets, persistence, etc. Rynaxypyr needs further evaluation.

1.4) Evaluate the influence of treatments of registered and experiential insecticides on populations of non-target invertebrates in rice.

The treatments listed in Table 5 were evaluated in this study in 2006 and 2007. I believe it is important to continue an effort in this area as long as West Nile Virus is prevalent and an issue in northern California. Mosquito management is of utmost importance and the aquatic nature of the rice agroecosystem puts the industry under the magnifying glass. Best Management Practices are in place and have been promoted but this should be a working document and subject to revision if supported by research results. The diverse fauna in rice fields helps to keep mosquitoes under control by feeding upon aquatic stages of mosquitoes. The use of insecticides for rice pest management can negatively impact populations of these nontarget organisms; however, there are likely differences among products in terms of these effects. Research conducted so far has allowed a fairly good understanding of the effects of registered insecticides on nontargets in rice fields. As new products are being developed, this type of research is important so as develop the underlying data necessary to allow a succinct evaluation of the product. Data from 2006 will be discussed as the 2007 data are still being quantified and summarized. The procedures followed in 2007 will be described; 2006 methods were very similar.

Methods:

Each plot was ~0.04 A and each treatment was replicated three times. In 2007, preflood treatments were applied on 22 May and the plots were seeded dry on 25 May immediately before the flooding. The 3-leaf stage treatments were applied on 14 June and the armyworm application timing was 13 July. Populations of non-target organisms were evaluated weekly from 7 June to 30 August. Floating barrier traps were used to collect swimming organisms for the first 4 weeks after seeding. Mosquito dip samples (25 dips in each of 5 locations per plot) were used to estimate populations of mosquito larvae and these data were collected in July and August. Finally, four quadrant samples per plot (0.55 ft^2 each) were collected weekly and these samples collected all organisms within these area.

Results:

The number and variety of insects and related invertebrates occurring in rice fields is impressive. The diversity (species that predominates) varies yearly but the high density is consistent. The 2006 results are summarized and will be reported herein. Only the numbers of aquatic insects will be reported; I would expect the most severe effects, if any, from the insecticides to be on the aquatic insects. Sorting and counting the 2007 samples is underway and will progress through the winter.

Preflood applications: Only one preflood application was evaluated in 2006. Warrior was used as a representative of a pyrethroid applied preflood. On the first sample date, this treatment reduced populations of aquatic insects compared with the untreated (Fig. 1). Following this date, there were no effects and over the first 6 weeks after flooding population averaged the same in the treated and untreated plots.

Post-flood applications: Seven 3-leaf treatments were compared, including the V10170 treatment which was applied preflood and at the 3-leaf stage to the same plots (and reported here). V10170 and Mustang reduced populations at 2 and 3 weeks after application, respectively (Fig. 2). The other dates and for the other products, populations of aquatic insects were equal or higher in the treated plots than in the untreated plots. Averaged over the 5-week period, all the treated plots had levels of aquatic insects equal to or greater than in the untreated.

July armyworm application: Warrior was evaluated as a representative material that could be applied against armyworms in July (on 14 July). This treatment was very damaging to populations of aquatic insects at 1 and 2 weeks after treatment (Fig. 3). Following this short-term reduction, populations responded in the Warrior-treated plots and bounced back to the levels in the untreated plots.

1.5) Tadpole shrimp control – Evaluation of control with registered and experimental insecticides.

Tadpole shrimp populations occur in many rice fields. Damage can range from minimal to severe but the infestations are generally spotty in distribution. Populations tend to build-up gradually from year-to-year unless control measures are used. Tadpole shrimp enter fields from irrigation ditches and lay eggs in soil. The eggs are very resistant and survive unfavorable conditions (uneven dry conditions) for up to 10 years. Once water is applied to the field, the eggs hatch in 1-2 days. Tadpole shrimp feed up seedling coleoptiles, roots, and leaves; the crop damage occurs from this feeding, uprooting of seedlings, and the reduction in light penetration. Copper sulfate has been a "standard" treatment to rice fields during establishment and this material in used, in part, for tadpole shrimp management. However, in recent years, it appears this product is not reducing shrimp numbers as well as previously. In addition, copper sulfate use has been questioned by some and reliance on one product for a given use is always undesirable. Recent results from Board funding showing the interaction of rice straw residue and reduced algal control with copper sulfate may also explain the lack of shrimp control in some cases.

Methods:

Ring plots, as described in subobjectives 1.1 to 1.3, were also used for this research. The same seeding date, establishment methods, and production practices were used as previously described. Treatments as listed in Table 6 were evaluated. Plots were flooded on 17 May and seeded on 18 May. Preflood treatments were applied on 17 May and the 3-leaf applications on 28 May. On 24 May, six tadpole shrimp were placed into each ring; shrimp were collected from a nearby infested untreated field. Treatments were evaluated using seedling counts per ring on 5 June and grain and biomass yield data were collected on 9 October.

Results:

Stand counts showed that numerically the lowest stand count was in the copper sulfate treatment and the highest value was in the Dimilin treatment (Table 6). The stand density in the untreated was intermediate and as such did not differ significantly from any of the other treatments. There were no significant yield differences among treatments with the grain yield ranging from 4041 (copper sulfate) to 5231 (Warrior at the 3-leaf stage) (Table 7).

1.6) Seed midge – Management of seed midge damaging pests with registered and experimental insecticides.

Seed midge populations were unexpectedly high in the spring of 2007. This pest is generally worse during cool springs when the rice struggles to germinate and to establish. Once the seeds have germinated and seedlings have pegged down, they are tolerant to this pest. These unfavorable conditions were not common in the spring of 2007; however, I had several calls on this pest in 2007. I have not examined control of this pest in recent years so some limited studies were done in 2007. Seed midge is ubiquitous in distribution; swarms are common in and around all rice fields. Once a field is flooded, the midge adults drop eggs into the water. The eggs hatch in a few days and the larvae drop to soil, form a mud tube and feed on germinating seeds. Larvae can hollow out seed and also feed on emerging shoot, leaves, and roots. Once the seedling spike is several inches long, it is tolerant of damage. The unpredictable nature of this pest makes it difficult on which to conduct research.

Methods:

Ring plots were also used for this research except they were larger (6 ft. diameter) than the ones used for the previously described work. Treatments as listed in Table 8 were evaluated. The goal was to evaluate timing with Mustang either preflood or immediately after seeding. The "fit" of an experimental seed treatment for management of this pest was also considered. Plots were flooded on 25 May and seeded on 4 June. The delay in seeding was used to try to enhance midge populations. The adults are attracted to the flooded conditions and it was hoped the eggs and resulting larvae would be present in the plots as the seeds and/or insecticides were introduced. Treatments were evaluated using 1.) seedling counts per sq. ft. on 20 June, and 2.) grain and biomass yield data collected on 12 October.

Results:

There were no significant differences in stand counts or yield among treatments in this study (Table 9). Stand counts ranged from 22.1 to 35 per sq. ft. Grain yields ranged from 4774 lbs. per A (Mustang applied at seeding) to 6016 lbs. per A (Mustang applied preflood).

Objective 2:

To evaluate the physical and biological factors that result in fluctuation and movement of populations of the rice water weevil so as to better time control options such as insecticide applications.

2.1) Evaluation of the movement of RWW populations that result in economic injury to rice plants. Monitor seasonal trends (timing and magnitude) in the flight activity of the RWW.

The timing of RWW adult flight in the spring has been monitored for 50+ years with a black light trap at RES. The flight monitoring allows us to see the severity of flight and the peak flight periods. It is also interesting to compare RWW populations and flight trends over years, to draw some correlations with populations in the field and to form some predictions about the future. The insect overwinters in a diapause condition within clumps of grass on levees, fencerows, etc. and other protected areas. In this reproductive diapause, the adults will not lay eggs until the diapause is broken by a specific set of conditions. Even in a diapause state, during warm days, the adults will feed on weedy grass leaves. The diapause is broken in about March and the adults are capable of flight at that time. However, flight only occurs during specific nights defined by evenings (6-11 pm) with warm temperatures (70-80^{0}F) and calm winds (<5 MPH). For instance in the spring of 2007, we recorded RWW flight only on 13 of the 76 nights we evaluated. Some of these “no flight” nights were rainy and obviously unsuitable for flight but many other nights had reasonable conditions for insect activity but still not the specific conditions required by this insect. In 2007, the RWW flight was concentrated from 26 April to 8 May. Two periods were noteworthy with 2/3 of the seasonal catch occurring on 7 May and another 30% on 26-27 April (Fig. 4). A total of ~2700 RWW adults were captured which was ~15% higher than in 2006 (Fig. 5). The last 3 years the population has been on an upswing.

2.2) Quantify the relative susceptibility of commonly grown rice varieties to RWW infestation and the yield response of these varieties to RWW infestation.

At present, there are no rice varieties that are resistant to RWW. Host plant resistance is a common way to manage many common, severe insect pests. Rice as a crop is very amenable to improvement through plant breeding as evidenced by the large increases in yield that has been achieved, short stature rice, disease tolerance, and similar advances. Thousands of rice lines have been evaluated in the major rice producing states for resistance to RWW. At least two lines have been shown to have some capacity to withstand RWW; although neither of these cases would be classified as resistance. Work is proceeding on working some of this tolerance into commercial rice lines. Some incremental increases in rice plant tolerance to RWW have been made and work continues at the Rice Experiment Station. The “resistance’ factor is based on the plants’ ability to outgrow the damage. This type of plant vigor may also be present in commercial rice varieties to the point that they may withstand RWW feeding to some extent. Medium grain rice varieties have been shown to produce in spite for stressors, including RWW. Therefore using the same management plans for medium grain varieties and a long-grain or specialty rice may be unwise. The goal of this study was to evaluate selected California varieties for susceptibility and response to RWW.

Rice varieties were chosen to cover the range of rice types, maturities, and commonly grown varieties in California. In total, twelve different varieties were compared:

1. L-206
2. S-102
3. M-104
4. M-208
5. M-205
6. M-202
7. M-206
8. PI plant line
9. Calhikari-201

10. Calmati-202
11. Calmochi-101
12. Calamylow-201

Susceptibility can be divided and researched into two areas. First, will the insect (RWW in this case) infest the rice variety and secondly, if infested, will the variety suffer a yield loss and to what extent.

This objective was addressed in field plots (subobjective 2.2.1) and ring plots (subobjective 2.2.2). The field plot approach allows both the infestation question and the plant response question to be studied, but has the drawback of running the risk of low RWW infestation severity. The ring study approach insures an infestation (adults are placed in the rings) and thus the susceptibility to infestation by the pest cannot be studied.

Subobjective 2.2.1)

Methods:

Each variety was seeded into 8 plots (13 x 18 ft.); four plots were treated with an insecticide to control RWW on 18 May and four plots were left untreated. The study was set up as a randomized complete block design with four replicates. Plots were flooded on 18 May and seeded on 21 May. RWW adult feeding scars, seedling establishment rating, larval population numbers, and grain yields were determined as described previously. The amount of feeding scars was used to evaluate susceptibility to adult infestation, and the number of RWW larvae per plot in the untreated plots was indicative of the conduciveness of the variety to RWW infestation. The difference in yield between the treated and untreated plots of a given variety was used to show plant response to the feeding.

Results:

Plant scarring by adult RWW varied two-fold among varieties and RWW larval population data were generally in close agreement. M-104, M-206, M-202, and S-102 have the highest levels of RWW plant scarring, i.e., the highest adult infestations (Fig. 6). These same varieties, along with Calamylow-201, had the highest larval populations. This later variety is interesting in that the adult RWW apparently did not prefer to feed on it but the larvae established and survived well. Overall, the naturally-occurring RWW population in this plot area was moderate and as such higher than in recent years. Compared with M-202, no varieties were more attractive to adult feeding; seedling establishment was rather uneven in this plot and 'M-202' established very well. This could have resulted in more adults being attracted to these plots. In terms of larval populations, only Calamylow-201 exceeded that in M-202 and eight others were less conducive to larval populations (in some cases with ¼ as many larvae) (Fig. 6).

Grain yields, averaged over RWW treatment, ranged from 4974 (M-205) to 7750 lbs./A (M-202) (Fig. 7). The effect of RWW was studied by examining the linear relationship between RWW level and grain yield in each plot by variety (Table 10). S-102 was most responsive with a severe negative yield loss to RWW infestation, Calhikari-202 and Calamylow-201 were moderately responsive, and the PI line, M-206, and M-202 showed slight yield losses. The other six varieties showed no yield losses across the levels of RWW present in these plots.

Subobjective 2.2.2)

Methods:

Four varieties were selected for more detailed studies on susceptibility and responses to RWW - M-202, PI line, L-206, and Calmati-202. These varieties were grown in ring plots and infested with RWW using the procedures listed in Objective 1.1.

Results:

There were no significant differences among varieties in RWW adult feeding; the infested rings had more scarring than the uninfested rings (Table 11). For larval populations, the infested rings had significantly more larvae than the uninfested rings and within the infested ones there were about 1/3 as many larvae in Calmati-202 as the other three varieties (Table 12). For grain yield, comparing the uninfested rings, the yield was lower in Calmati-202 than the other three varieties. Yields were reduced in all the infested treatments (Table 13) and on a per larva basis the losses were highest in Calmati-202 (Table 14).

2.3) Evaluate the influence of rice seedling establishment methods of RWW and armyworm populations.

The "systems study" has been ongoing at the RES for the last 4 years. The primary goal is to investigate alternative seeding and establishment methods in order to open up new opportunities for weed management. The stale seedbed and dry (drill) seeding are two of these techniques. These changes in rice production need to be done without disrupting other aspects of rice agronomy and pest management. In terms of invertebrates, these techniques may affect insect pest populations (and also perhaps mosquitoes). In 2007, plots were maintained with the following variations of rice stand establishment methods: 1.) Conventional water seeded, 2.) Conventional drill seeded, 3.) Delayed spring-tilled water seeded, 4.) Stale seedbed (no spring tillage) water seeded, and 5.) Stale seedbed (no spring tillage) drill seeded. Previous work has shown that drill-seeding reduces RWW populations because the adults are not attracted to rice during "dry periods".

In 2007, we monitored RWW populations (adult scarring and larval numbers) as well as armyworm populations in this seedling establishment study. Data were collected on 20 June (adult scarring) and 30 June and 13 July (RWW immatures) using standards methods. RWW infestation in this plot was low with the highest average larval population in core samples being 0.8 per sample and most were in the 0.1 to 0.3 range (the threshold for yield loss is 1.0 RWW per sample). Adult scarring ranged from 5.5 (Water-Seeded, Conventional) to 15.0% (Drill-Seeded, Stale Seedbed, No-Till). I would classify this as a low to moderate population. Compared to the conventional water-seeded treatments, all the other treatments had more scarring from RWW adults (Fig. 8). This ranged from 2 to almost 3x the amount of scarring. Larval populations were much higher in the drill-seeded conventional than the water-seeded conventional treatments (Fig. 8). Both stale seedbed treatments (drill- and water-seeded) had slightly fewer larvae than the water-seeded standard.

The seeding method and production system may influence mosquito populations. Obviously by mid-season, all the plots were flooded. However, the amount of residue (such as burnt-down weeds), frequency of draining, water depth, etc. may all influence mosquito production. Mosquito populations were monitored in each plot on 12 Sept. 2007 by taking 150 dips with the standard mosquito dipper. Across all plots, populations averaged 4.2 mosquito larvae per 50 dips. Compared to the standard water-seeded treatment, there were about 20% more larvae in the drill-seeded, stale seedbed, no-till treatment and only ½ as many larvae in the water-seeded, stale seedbed, spring till treatment (Fig. 8).

Finally, armyworm damage was monitored in each plot on 2 Aug., 9 Aug., 16 Aug., 23 Aug., and 29 Aug. The percentage damage was estimated and the number of armyworms seen during a 15-minute search period was recorded; no damage or armyworms were found.

Objective 3: To investigate aspects of armyworm biology as a means of determining the reasons for an increase in armyworm populations in rice in recent years.

Two species of armyworms have been problematic in Sacramento Valley rice in recent year; the western yellow-striped armyworm (*Spodoptera praefica*) and the Atrue@ armyworm (*Pseudaletia unipuncta*) are the pests. Armyworms can damage rice 1.) by defoliation and 2.) by feeding on developing panicles and kernels. A rice plant has considerable “excess” leaf tissue so the plants can withstand a fairly high percentage of leaf damage. The panicle feeding/damage is much more important than is simple leaf removal. A mid-season application of a pyrethroid insecticide can provide armyworm control but is an added cost has the potential to upset the “balance” in rice fields and to promote populations of mosquitoes. Studies continued in 2007 to investigate armyworm biology and management; however, low populations greatly hindered these studies.

3.1) Investigate the biology of armyworms in rice as a means to understand recent population increase.

3.1.1). Study the role of weed populations on armyworm populations in rice.

Based on some observations we made about three years ago and due to the challenges in weed control common to many rice fields, it appears that higher armyworm populations are present in fields with a higher incidence of weeds, particularly broad-leaf weeds. We researched this in 2004 and 2005 and the data supported our observations but the results were not so strong that they could not be questioned. The two species of armyworms have several important differences. In particular the western yellow-striped armyworm is reported to have a wider host range and is actually a very general feeder. Numerous weed species hosts are also known to be suitable hosts and in many cases, western yellow-striped armyworm develops first on weed or rangeland plants, before moving on to crops. It is reported to only lay eggs on broad-leaf weeds and prefers to feed on these plants over rice. Therefore, weed populations may influence populations of armyworms. We continued investigations of this relationship in 2007 by setting up plots with 1.) very few weeds, 2.) predominantly grassy weeds, 3.) predominantly broadleaf weeds, and 4.) both grassy and broadleaf weeds. This was done by treating plots (20 by 50 ft.)

with Clincher, Shark, or both materials. Data were collected weekly (12 July, 19 July, 26 July, 2 Aug., 9 Aug., 16 Aug., 23 Aug., and 29 Aug.) on armyworm populations and on weed incidence.

Weed control was accomplished as planned and there were differences in weed species/populations. Armyworm populations were; however, nonexistent in this plot in 2007.

3.1.2). Investigate the timing of armyworm moth flight in the rice production region.

Pheromone traps are used in several crops to gain insights on the timing of movement of pest populations. These traps use the sex attractant naturally produced by female moths; this compound is synthesized, manufactured, and incorporated into a rubber lure. When placed in a trap, the lure attracts the male moths and they become stuck in the trap. Information from pheromone traps, coupled with knowledge of the influence of temperature of key events in the pest lifecycle, can be a useful predictive tool. The attractant is generally specific to one moth species, i.e., true armyworm and western yellow-striped armyworm in this case. Separate traps for western yellow-striped armyworm and Atrue@ armyworm were placed near rice fields in 2 areas of the RES in Butte Co. Moths were collected from traps weekly from early July to mid-August.

In 2007, the true armyworm exhibited a high flight peak in early Aug. and the western yellow-striped armyworm flight was overall low with no real peaks (Fig. 9).

Objective 4: Conduct appropriate monitoring, exploratory research, and educational activities on emerging and new exotic rice invertebrate pests.

Several nonvertebrate pests of rice occur in other countries and even in other U.S. states, but fortunately not in California. Some of these are extremely serious pests that would cause crop yields, increase costs of production, and have possible trade implications. The rice panicle mite is an extremely serious pest that is present in Asia and Central/South America. In 2007, it was found in TX in July and later in the season in LA, AR, Puerto Rico, and NY. These finds were in greenhouses and breeders plots. Some 20-30 suspect samples from CA rice fields were examined for the panicle mite from Aug. to Oct. and no mites were found. The standard sample processing technique from APHIS was used.

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PUBLICATIONS OR REPORTS:

Godfrey, L. D. and W. Pinkston. 2007. Studies on refining management of sporadic invertebrate pests of rice. Calif. Rice Experiment Station Field Day Report. p. 24.

Godfrey, L. D. 2007. New insecticides under development for managing rice water weevil in rice. Calif. Rice Experiment Station Field Day Report. pp. 36-38.

Godfrey, L. D. and R. R. Lewis. 2006. Annual report comprehensive research on rice, RP-3. 29 pp.

Godfrey, L. D. 2006. 38th Annual report to the California rice growers. Protection of rice from invertebrate pests. pp 25-27.

Godfrey, Larry D., Richard R. Lewis, Karey Windbiel-Rojas, and Wade Pinkston. 2007. Impact of Management Strategies for Rice Water Weevil on Populations of Non-Target Invertebrates in California Rice. Proc. 4th International Temperate Rice Conference 2007.

CONCISE GENERAL SUMMARY OF CURRENT YEAR=S (2007) RESULTS:
Larry D. Godfrey

Research was conducted in 2007 on the biology and management of key invertebrate pests of California rice. Concentrated efforts continued on rice water weevil (RWW) and limited studies were continued on armyworm (AW), two important rice arthropod pests of rice in CA. In addition, research was done on two early-season pests of seedling rice, seed midge and tadpole shrimp. The goal was to refine IPM schemes for these pests and to maximize the management in light of the environmentally sensitive nature of the rice agroecosystem. The cost effectiveness of any management efforts in rice must also be carefully considered. Four overall themes provided direction for the 2007 research program.
1.) CA-DPR is currently placing pyrethroid insecticides into reevaluation based on their propensity to accumulate and move off-site on organic sediment. Therefore, studies continued to develop alternative active ingredients and classes of chemistry for arthropod pest control.
2.) Best Management Practices have been developed and put forth for the industry to aid in mitigation of mosquito populations. This area has taken on added importance with the emphasis on West Nile Virus in California. A study was continued to evaluate the effects of registered and experimental rice insecticides on non-target invertebrates, which could play an important role in mosquito management in rice fields. As part of this, possible changes in rice seeding methods were studied and the role of these changes in mosquito populations monitored.
3.) Early-season invertebrate pests were more common in 2007 than in recent years. To respond to grower questions about control of these pests, studies were done on seed midge and tadpole shrimp control.
4.) Exotic pests moving into California are unfortunately being a more common occurrence. Thus far, the rice system has avoided being infested by several potentially serious invertebrate pests that occur in other parts of the U.S and in other countries. The rice panicle mite was found in the southern U.S. rice belt in 2007. Samples from California were processed for this pest and so far there has been no occurrence of the panicle mite in California. Communication and education on this pest was hastened in 2007.

Significant progress was made on all objectives. AW populations were overall low and this hindered research on this pest but this was not a key objective in 2007.

Rice Water Weevil: Studies were continued in 2007 in ring plots to evaluate experimental materials versus registered standards for RWW control and to modify the use patterns of the existing products to facilitate management. Twenty treatments (a total of eight different active ingredients) were established in ring plots to accomplish this research. Research continued on four experimental insecticide active ingredients; etofenprox (Trebon®), indoxacarb (Steward®), rynaxypyr, and clothianidan. In summary, etofenprox, indoxacarb, and clothianidan all appear to have significant potential for RWW management. All these products are a few years from any possible registration with their progress in this regard being approximately in the order listed above (from nearest to farthest from registration). Indoxacarb is active via a post-flood application whereas clothianidan has the most flexibility in terms of application timing. Given the re-evaluation of pyrethroid registrations due to possible off-site movement, it is important to continue to develop alternative active ingredients and classes of chemistry. These active ingredients have some very favorable properties in terms of toxicity to non-targets, persistence, etc. In these studies, Dimilin, Warrior (preflood and 3-leaf), Trebon (3-leaf), V10170 (preflood+3-leaf, preflood only, and 3-leaf only), Mustang Max, and Steward (0.11 rate) significantly reduced the RWW populations compared with the untreated plots. The best control was a 95% reduction in larval populations. The Trebon 3G preflood applications were not effective; it had shown some promise in testing in 2005 and 2006, but it appears that the 3-leaf stage application is going to be the preferred application method for this product. The Clorox seed soak (used for Bakanae control) greatly affected the activity of V10170 seed treatment; the soaked treatment was largely ineffective whereas without the Clorox soak the activity was good. This was not observed in studies in 2006. The E2Y45 (rynaxypyr) seed treatment was largely ineffective, although these seeds were similarly soaked in Clorox. This likely affected the activity. Only Warrior was evaluated, among the pyrethroids, as a preflood application in 2007. In summary, the early preflood application of Warrior (1 week before flooding) provided only about 50% control, whereas the preflood application immediately before flooding was equally effective as the 3-leaf stage application. We have generally had excellent results with an application made up to 7 days before flooding, but there have been some inconsistencies in control with this application at the longer intervals before flooding. Environmental conditions between application and flooding undoubtedly influence the residual control results. It appears that those undefined conditions reduced efficacy in 2007. Warrior was registered for use with this application method in 2007. Aza-Direct, a neem-based product containing azadirachtin, was evaluated and provided RWW control in the 50% range.

The effects of insecticide treatments in rice on populations of non-target invertebrates and mosquitoes were studied. I believe it is important to continue an effort in this area as long as West Nile Virus is prevalent and an issue in northern California. The study was conducted in 2007 but results are not yet available. From 2006, a preflood Warrior application reduced populations of aquatic insects compared with the untreated for the first week after application but not thereafter. Seven treatments applied at the 3-leaf stage were compared and V10170 and Mustang reduced aquatic insect populations at 2 and 3 weeks after application; averaged over the 5-week period following application, all the treated plots had levels of aquatic insects equal to or greater than in the untreated. Warrior was evaluated as a representative material that could be applied against armyworms in July and this treatment was very damaging to populations of aquatic insects at 1 and 2 weeks after treatment.

RWW biology was studied in terms of adult flight, relative susceptibility of commonly grown rice varieties to RWW infestation and to yield losses, and the influence of rice seedling establishment methods of RWW population severity. For instance in the spring of 2007, we recorded RWW flight only on 13 of the 76 nights we evaluated. The RWW flight was concentrated from 26 April to 8 May. Two periods were noteworthy with 2/3 of the seasonal catch occurring on 7 May and another 30% on 26-27 April A total of ~2700 RWW adults were captured which was ~15% higher than in 2006. Twelve rice varieties were compared for susceptibility to and yield loss from RWW in field plots with a moderate natural infestation. M-104, M-206, M-202, and S-102 had the highest levels of RWW leaf scarring and these same varieties, along with Calamylow-201, had the highest larval populations. S-102 was most responsive with a severe negative yield loss to RWW infestation, Calhikari-202 and Calamylow-

201 were moderately responsive, and the PI line, M-206, and M-202 showed slight yield losses. The other six varieties showed no yield losses across the levels of RWW present in these plots. in ring plots infested with RWW, ~1/3 as many larvae survived on Calmati-202 compared with the other three varieties but grain yield losses were highest in Calmati-202 on a loss per larva basis. Refined rice seedling establishment techniques are being investigated at the RES primarily as a means to improve weed management through stale seedbed and dry seeding techniques. However, these techniques will also likely affect insect pest populations and mosquitoes. Leaf scarring from RWW adults was higher in all the other treatments compared with the standard water-seeded method and larval populations were much higher in the drill-seeded conventional than the water-seeded conventional treatments. Both stale seedbed treatments (drill- and water-seeded) had slightly fewer larvae than the water-seeded standard. Compared to the standard water-seeded treatment, there were about 20% more mosquito larvae in the drill-seeded, stale seedbed, no-till treatment and only ½ as many larvae in the water-seeded, stale seedbed, spring till treatment.

Armyworm Biology and Infestations in Rice: Armyworm larval populations and damage were monitored in two studies at the RES and were too low to draw meaningful conclusions. Moth flights were monitored using pheromone traps and the true armyworm exhibited a high flight peak in early Aug. and the western yellow-striped armyworm flight was overall low with no real peaks.

Early-Season Invertebrate Pests: Tadpole shrimp populations occur in many rice fields and damage can range from minimal to severe. In recent years, there have been reports that copper sulfate is not reducing shrimp numbers as well as previously. Recent results from Board funding showed the interaction of rice straw residue and reduced algal control with copper sulfate; this may also explain the lack of shrimp control in some cases. Seven registered and experimental insecticide treatments were evaluated in ring plots infested with tadpole shrimp. Stand counts showed that numerically the lowest stand count was in the copper sulfate treatment and the highest value was in the Dimilin treatment. Seed midge populations were unexpectedly high in the spring of 2007. This pest is generally worse during cool springs when the rice struggles to germinate and to establish; conditions which generally were not present in 2007. The unpredictable nature of this pest makes it difficult on which to conduct research, but we flooded a field and delayed seeding to try to facilitate populations. There were no significant differences in stand counts or yield among treatments in this study and no clear sign that the pest was present.

Exotic Pests of Rice: Through this project, we maintain a vigilant watch for exotic pests through our visits to numerous rice fields throughout the Sacramento Valley. The rice panicle mite is a potentially extremely serious pest that is present in Asia and Central/South America and was found in TX in July and later in the season in LA, AR, Puerto Rico, and NY. Some 20-30 suspect samples from CA rice fields were examined for the panicle mite from Aug. to Oct. and no mites were found.

Table 1. Treatment list for RWW management ring study, 2007.

Product	Rate (lbs. AI/A)	Formulation per A	Timing
1. Dimilin 2L	0.125	8 fl. oz	3-leaf
2. Untreated	---	---	---
3. Warrior	0.03	3.84 fl. oz.	3-leaf
4. Warrior	0.03	3.84 fl. oz.	preflood - ~week before flooding
5. Trebon 3G	0.18	6 lbs.	3-leaf
6. V10170 50WD + V10170 50WD	0.01875 x 2	6 oz. + 6 oz.	preflood & 3 leaf
7. V10170 5SC	0.1 per 100 lbs. seed		seed treatment
8. V10170 50WD	0.01875	6 oz.	preflood
9. V10170 50WD	0.01875	6 oz.	3 leaf
10. V10170 5SC*	0.1 per 100 lbs. seed		seed treatment
11. Warrior	0.03	3.84 fl. oz	preflood
12. Mustang Max 0.8 EC	0.02	3.2 fl. oz	3 leaf
13. Aza-Direct		32 fl. oz.	3 leaf
14. Steward EC	0.11	11.3 fl. oz.	3 leaf
15. Steward EC	0.055	5.65 fl. oz.	3 leaf
16. Trebon 3G	0.18	6 lbs.	preflood
17. E2Y45	0.025 mg per seed		seed treatment
18. E2Y45	0.05 mg per seed		seed treatment
19. E2Y45	0.1 mg per seed		seed treatment
20. Trebon 3G	0.24	8 lbs.	Preflood

* no Clorox seed soak; all other treatments had Clorox seed soak

Table 2. Rice plant stand and adult feeding damage in chemical ring study, 2007.

Product	Rate (lbs. AI/A) & Timing	Stand Rating (1-5)	% Scarred Plants	
1. Dimilin 2L	0.125 - 3-leaf	2.5	31.0	a
2. Untreated	---	3.0	27.5	a
3. Warrior	0.03 - 3-leaf	3.0	6.0	bc
4. Warrior	0.03 – early preflood	3.0	13.5	b
5. Trebon 3G	0.18 - 3-leaf	3.0	5.5	bc
6. V10170 50WD + V10170 50WD	0.1875 x 2	2.5	0.5	c
7. V10170 5SC	0.1 per 100 lbs. seed	3.3	11.0	bc
8. V10170 50WD	0.1875 - preflood	3.3	4.0	bc
9. V10170 50WD	0.1875 - 3-leaf	3.3	3.5	bc
10. V10170 5SC*	0.1 per 100 lbs. seed	2.5	11.5	bc
11. Warrior	0.03 – preflood	3.3	4.5	bc
12. Mustang Max 0.8 EC	0.02 – 3-leaf	3.8	1.5	bc
13. Aza-Direct	32 fl. oz. – 3-leaf	3.3	9.0	bc
14. Steward EC	0.11 – 3-leaf	3.8	5.5	bc
15. Steward EC	0.055 – 3-leaf	3.3	5.0	bc
16. Trebon 3G	0.18 - preflood	3.0	30.0	a
17. E2Y45	0.025 mg per seed	2.5	32.5	a
18. E2Y45	0.05 mg per seed	2.5	35.5	a
19. E2Y45	0.1 mg per seed	2.8	32.5	a
20. Trebon 3G	0.24 - preflood	3.5	27.5	a

* no Clorox seed soak; all other treatments had Clorox seed soak

Means within columns followed by same letter are not significantly different; least significant differences test (? #0.05).

Table 3. RWW immature density (first and second sample dates and average) in chemical ring study, 2007.

Product	Rate (lbs. AI/A) & Timing	RWW per Core Sample 7 July		25 July		Average	
1. Dimilin 2L	0.125 - 3-leaf	0.13	De	0.05	c	0.10	e
2. Untreated	---	1.90	Abc	2.25	abc	2.08	abcd
3. Warrior	0.03 - 3-leaf	0.00	E	0.10	c	0.05	e
4. Warrior	0.03 – early preflood	0.87	Cde	0.90	bc	0.78	cde
5. Trebon 3G	0.18 - 3-leaf	0.25	De	0.00	c	0.13	e
6. V10170 50WD + V10170 50WD	0.1875 x 2	0.10	De	0.00	c	0.05	e
7. V10170 5SC	0.1 per 100 lbs. seed	2.60	A	2.13	abc	2.28	abc
8. V10170 50WD	0.1875 - preflood	0.10	De	0.00	c	0.05	e
9. V10170 50WD	0.1875 - 3-leaf	0.10	De	0.13	c	0.10	e
10. V10170 5SC*	0.1 per 100 lbs. seed	0.36	De	1.20	bc	0.88	cde
11. Warrior	0.03 – preflood	0.15	De	0.00	c	0.08	e
12. Mustang Max 0.8 EC	0.02 – 3-leaf	0.05	E	0.00	c	0.03	e
13. Aza-Direct	32 fl. oz. – 3-leaf	1.18	abcde	1.05	bc	1.08	cde
14. Steward EC	0.11 – 3-leaf	0.25	De	0.00	c	0.13	e
15. Steward EC	0.055 – 3-leaf	1.05	bcde	0.25	c	0.65	de
16. Trebon 3G	0.18 - preflood	2.05	Abc	2.25	abc	2.15	abcd
17. E2Y45	0.025 mg per seed	2.45	Ab	4.75	a	3.60	a
18. E2Y45	0.05 mg per seed	2.34	Ab	0.83	bc	1.48	bcde
19. E2Y45	0.1 mg per seed	2.50	Ab	3.35	ab	2.88	ab
20. Trebon 3G	0.24 - preflood	1.65	abcd	1.30	bc	1.48	bcde

* no Clorox seed soak; all other treatments had Clorox seed soak

Means within columns followed by same letter are not significantly different; least significant differences test (? #0.05).

Table 4. Effect of RWW populations on rice biomass and grain yields in chemical ring study, 2007.

Product	Rate (lbs. AI/A) & Timing	% Moisture		Grain Yield (lbs./A)		Biomass - Straw + Grain (t/A)	
1. Dimilin 2L	0.125 - 3-leaf	15.4	Abc	6865.9	abcd	10.2	abcd
2. Untreated	---	14.6	Bcd	5402.7	efg	7.7	efg
3. Warrior	0.03 - 3-leaf	13.5	E	7527.0	ab	11.4	a
4. Warrior	0.03 – early preflood	15.1	Abc d	7014.0	abcd	10.3	abcd
5. Trebon 3G	0.18 - 3-leaf	14.9	Abc d	6367.0	b-f	9.3	b-f
6. V10170 50WD + V10170 50WD	0.1875 x 2	15.2	Abc	6860.1	abcd	10.3	abcd
7. V10170 5SC	0.1 per 100 lbs. seed	15.0	Abc d	6024.6	cdef	8.8	defg
8. V10170 50WD	0.1875 - preflood	15.7	A	7652.5	a	10.8	abc
9. V10170 50WD	0.1875 - 3-leaf	15.2	abcd	7262.1	abc	10.6	abc
10. V10170 5SC*	0.1 per 100 lbs. seed	15.1	abcd	5943.8	def	8.5	def
11. Warrior	0.03 – preflood	15.5	ab	7202.2	abc	10.6	abc
12. Mustang Max 0.8 EC	0.02 – 3-leaf	15.3	abc	6145.2	c-f	9.1	b-f
13. Aza-Direct	32 fl. oz. – 3-leaf	14.5	cde	6266.2	c-f	8.9	cdef
14. Steward EC	0.11 – 3-leaf	15.5	ab	6468.1	a-e	9.1	b-f
15. Steward EC	0.055 – 3-leaf	15.2	abcd	6363.2	a-e	9.3	bcde
16. Trebon 3G	0.18 - preflood	14.9	abcd	5166.6	fg	7.4	fg
17. E2Y45	0.025 mg per seed	15.3	abc	4304.9	g	6.1	g
18. E2Y45	0.05 mg per seed	14.8	abcd	5386.4	efg	8.0	efg
19. E2Y45	0.1 mg per seed	14.2	de	5307.8	efg	7.5	efg
20. Trebon 3G	0.24 - preflood	14.9	abcd	6232.8	c-f	9.0	b-f

* no Clorox seed soak; all other treatments had Clorox seed soak

Means within columns followed by same letter are not significantly different; least significant differences test (? #0.05).

Table 5. Treatments evaluated in non-target study, 2006 and 2007.

Product	Rate (lbs. AI/A)	Timing	2006	2007
1. Untreated	---	---	X	X
2. Warrior	0.03	3-leaf	X	X
3. Warrior	0.03	preflood	X	X
4. Warrior	0.03	July armyworm timing	X	X
5. Mustang Max	0.025	3-leaf	X	X
6. Dimilin 2L	0.125	3-leaf	X	X
7. V10170 50WD	0.19	preflood and 3-leaf	X	X
8. V10170 5SC	0.1 per 100 lbs. seed	seed treatment		X
9. Trebon 3G	0.18	3-leaf	X	X
10. Steward EC	0.11	3-leaf	X	X
11. Aza-Direct	0.04	3-leaf	X	

Table 6. Treatments evaluated for tadpole shrimp control and resulting stand counts, 2007.

Product	Rate (lbs. AI/A)	Formulation per A	Timing	Seedlings per Ring	
1. Warrior	0.03	3.84 oz.	preflood	67.0	bc
2. Steward EC	0.11	11.3 oz.	3 leaf	75.8	abc
3. V10170 5SC	0.1 per 100 lbs. seed		seed treatment	77.5	abc
4. Trebon 3G	0.18	6 lbs.	3 leaf	83.8	ab
5. Copper sulfate	---	10 lbs.	3 leaf	62.0	c
6. Dimilin 2L	0.125	8 fl. oz	3 leaf	93.8	a
7. Untreated	---	---	---	75.3	abc
8. Warrior	0.03	3.84 oz.	3 leaf	89.0	a

Means within columns followed by same letter are not significantly different; least significant differences test (? #0.05).

Table 7. Yield results for tadpole shrimp control study, 2007.

Product	Rate (lbs. AI/A) & Timing	% Moisture	Grain Yield (lbs./A)	Biomass - Straw + Grain (t/A)
1. Warrior	0.03 - preflood	13.5	6426	8.6
2. Steward EC	0.11 – 3-leaf	14.2	6536	8.8
3. V10170 5SC	0.1 per 100 lbs. seed	14.7	6448	9.1
4. Trebon 3G	0.18 - 3-leaf	13.5	6790	9.3
5. Copper sulfate	10 lbs. - 3-leaf	14.4	5504	7.4
6. Dimilin 2L	0.125 - 3-leaf	14.2	6418	8.3
7. Untreated	---	14.0	5924	8.1
8. Warrior	0.03 - 3-leaf	14.2	7125	10.1

No significant differences among means within columns; least significant differences test (? #0.05).

Table 8. Treatments evaluated for seed midge control and resulting stand counts, 2007.

Product	Rate (lbs. AI/A)	Formulation per A	Timing	Seedlings per sq.ft.
1. Mustang 1.5EW	0.05	4.3 oz.	at seeding	35.0
2. Mustang 1.5EW	0.05	4.3 oz.	preflood	22.5
3. V10170 5SC	0.1 per 100 lbs. seed		seed treatment	22.1
4. Untreated	---	---	---	26.3

No significant differences among means within column; least significant differences test (? #0.05).

Table 9. Yield results for midge control study, 2007.

Product	Rate (lbs. AI/A)	% Moisture	Grain Yield (lbs./A)	Biomass - Straw + Grain (t/A)
1. Mustang 1.5EW	0.05 - at seeding	20.9	4774	16.1
2. Mustang 1.5EW	0.05 - preflood	21.0	6016	16.8
3. V10170 5SC	0.1 per 100 lbs. seed	21.3	4829	16.6
4. Untreated	---	20.0	5272	13.2

No significant differences among means within columns; least significant differences test (? #0.05).

Table 10. Effect of RWW populations on rice grain yields in variety comparison conducted in small plots, 2007.

Variety	RWW Range	Yield Loss Indicated by Linear Relationship	% Yield Loss
L-206	0 – 0.3	none	---
M-104	0 – 1.3	none	---
M-208	0 – 0.73	none	---
Calmati-202	0 – 0.5	Loss of 690 lbs./A per 1 RWW larva	12.6
Calhikari-201	0 – 1.3	none	---
PI plant line	0 – 1.1	Loss of 523 lbs./A per 1 RWW larva	8.3
M-205	0 – 0.7	none	---
M-202	0 – 1.4	185	2.4
M-206	0 – 0.9	Loss of 450 lbs./A per 1 RWW larva	6.5
S-102	0 – 0.8	Loss of 2590 lbs./A per 1 RWW larva	41.1
Calmochi-101	0 – 0.27	none	---
Calamylow-201	0 – 1.9	Loss of 650 lbs./A per 1 RWW larva	11.1

Table 11. Rice plant stand and adult feeding damage in variety comparison to RWW study, 2007.

Variety	RWW Infestation	% Scarred Plants	
M-202	Natural	1.5	b
PI	Natural	1.5	b
L-206	Natural	0.5	b
Calmati-202	Natural	1.5	b
M-202	Introduced	23.5	a
PI	Introduced	22.5	a
L-206	Introduced	15.5	a
Calmati-202	Introduced	23.0	a

Means within columns followed by same letter are not significantly different; least significant differences test (? #0.05).

Table 12. RWW immature density (first and second sample dates and average) in variety comparison to RWW study, 2007.

		RWW per Core Sample					
Variety	RWW Infestation	7 July		25 July		Averag e	
M-202	Natural	0	b	0.05	b	0.03	b
PI	Natural	0	b	0.1	b	0.05	b
L-206	Natural	0	b	0.1	b	0.05	b
Calmati-202	Natural	0	b	0.05	b	0.03	b
M-202	Introduced	1.2	ab	2.0	a	1.8	a
PI	Introduced	1.95	a	1.6	ab	1.78	a
L-206	Introduced	1.6	a	2.2	a	1.9	a
Calmati-202	Introduced	0.6	ab	0.35	b	0.48	b

Means within columns followed by same letter are not significantly different; least significant differences test (? #0.05).

Table 13. Effect of RWW populations on rice biomass and grain yields in variety comparison to RWW study, 2007.

Variety	RWW Infestation	% Moisture		Grain Yield (lbs./A)		Biomass - Straw + Grain (t/A)	
M-202	Natural	13.8	b	6150	a	8.3	a
PI	Natural	12.4	b	6276	a	8.2	a
L-206	Natural	13.0	b	6827	a	8.2	a
Calmati-202	Natural	12.8	b	4243	b	7.1	ab
M-202	Introduced	15.3	b	4026	b	5.4	bc
PI	Introduced	13.3	b	3801	b	5.9	bc
L-206	Introduced	13.8	b	3988	b	5.6	c
Calmati-202	Introduced	21.0	a	1628	c	3.8	d

Means within columns followed by same letter are not significantly different; least significant differences test (? #0.05).

Table 14. Effect of RWW populations on rice biomass and grain yields in variety comparison to RWW study, 2007.

Variety	Yield Loss from RWW (lbs./A)	Yield Loss per 1.0 RWW (lbs./A)
M-202	2124	1180
PI	2475	1390
L-206	2839	1494
Calmati-202	2615	5448

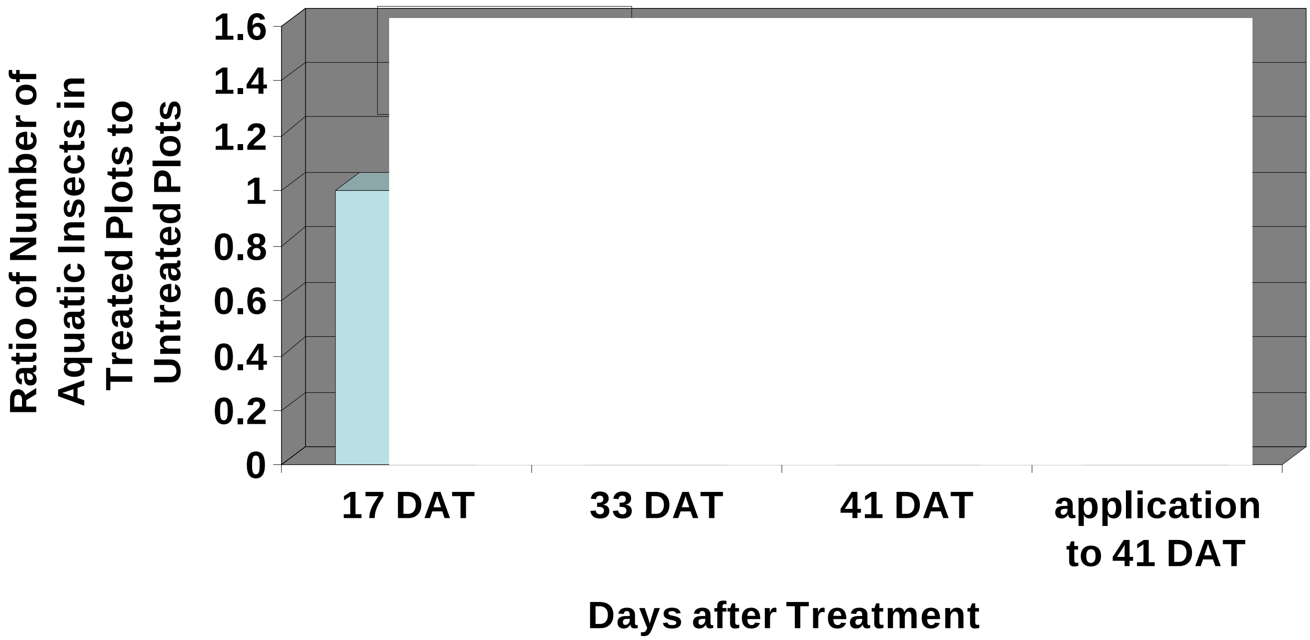


Figure 1. Influence of pre-plant insecticide applications on populations of aquatic insects in rice, 2006.

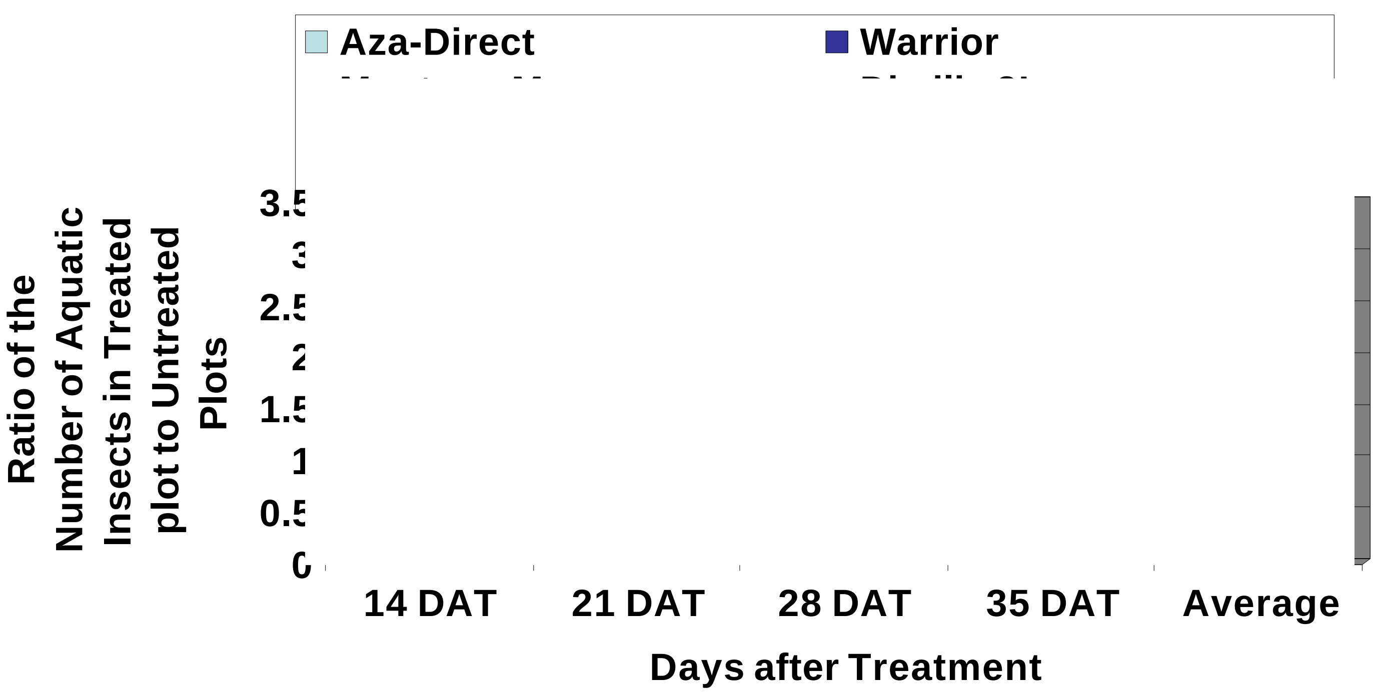


Figure 2. Influence of insecticides applied at the 3-leaf stage on populations of aquatic insects, 2006.

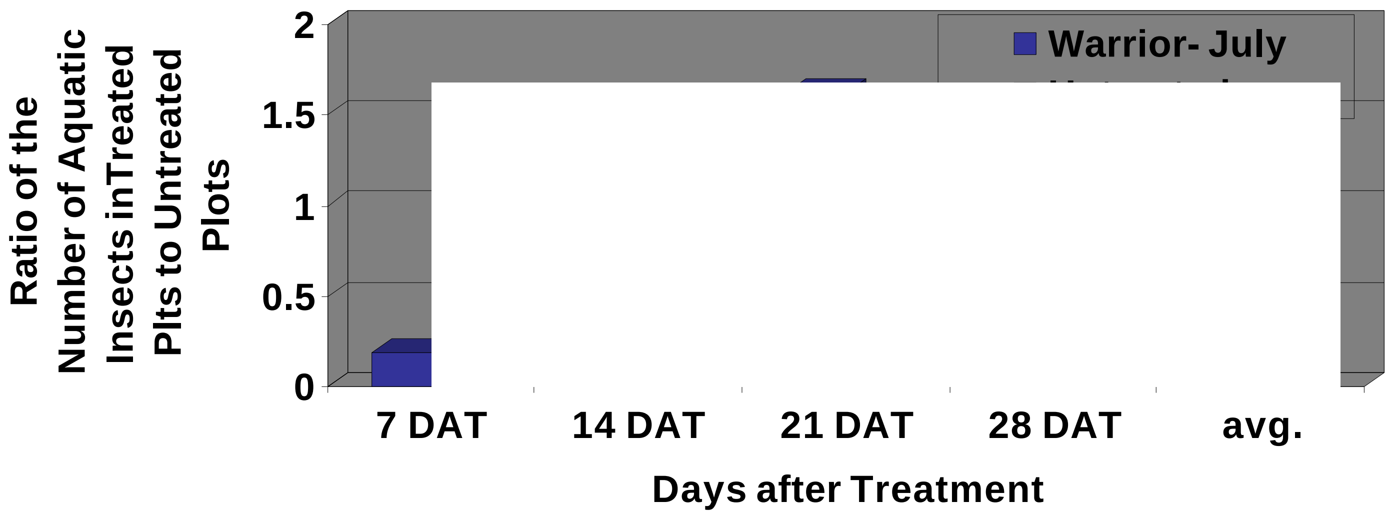


Figure 3. Influence of insecticide applied at the July armyworm timing on populations of aquatic insects, 2006.

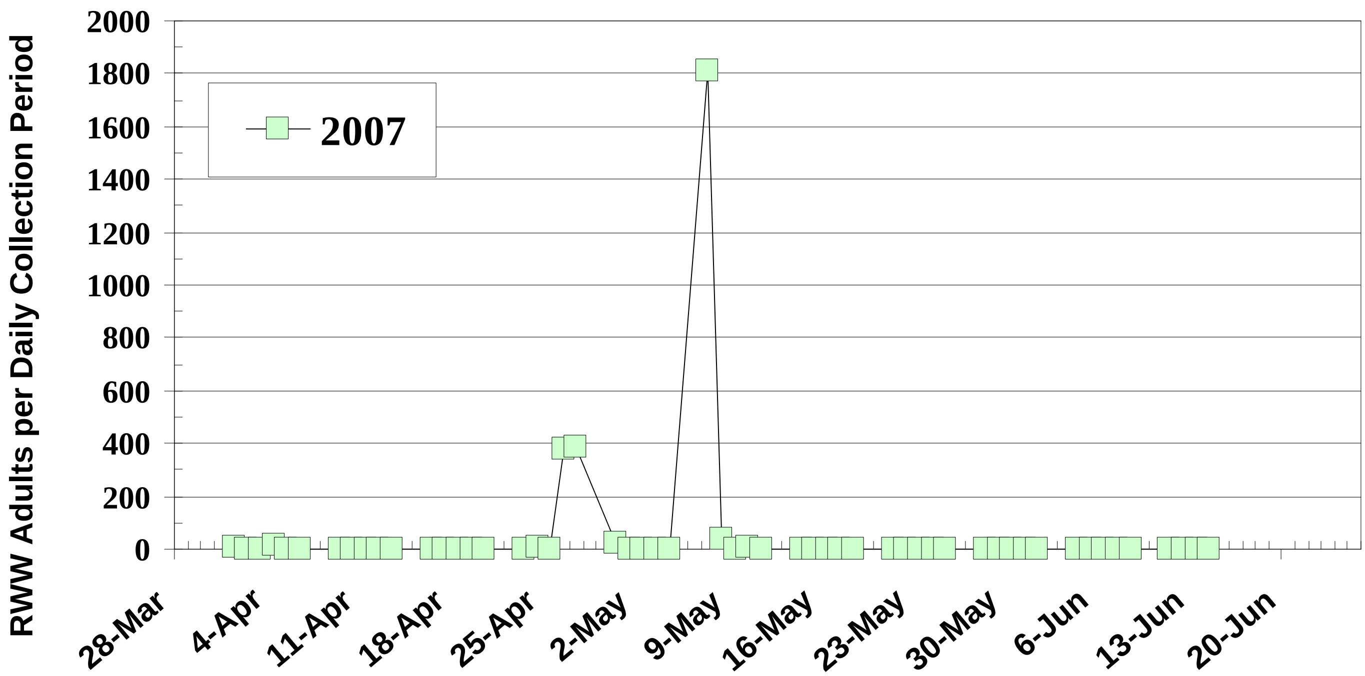


Figure 4. RWW adult flight as monitored with a light trap, RES, 2007.

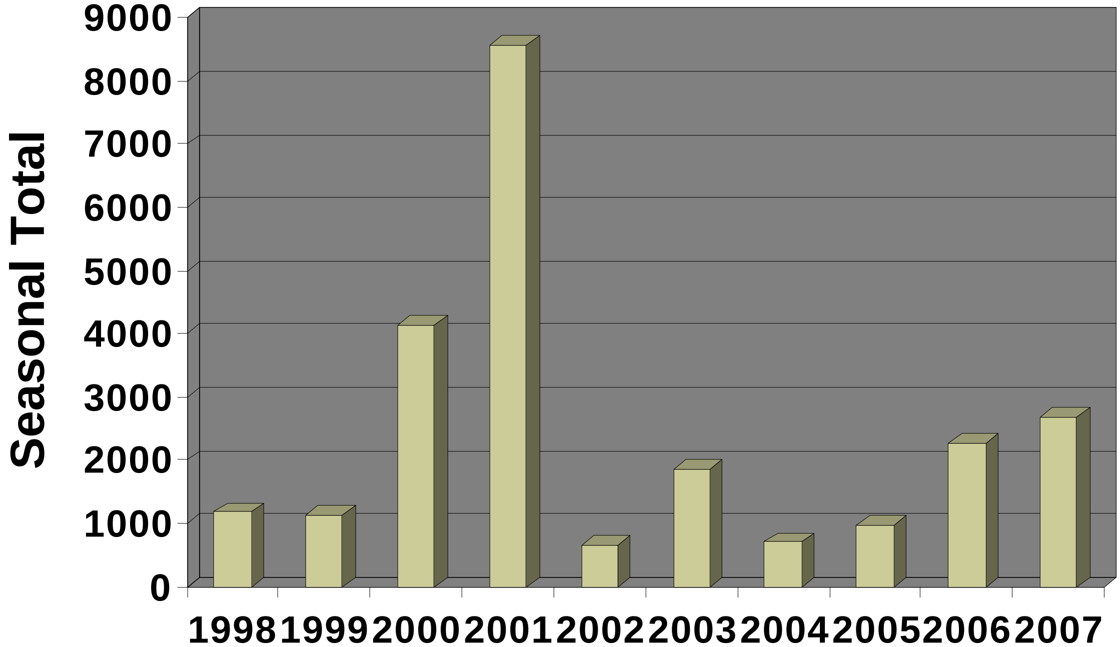


Figure 5. Comparison of RWW flight magnitude from light trap monitoring, RES, 1998 to 2007.

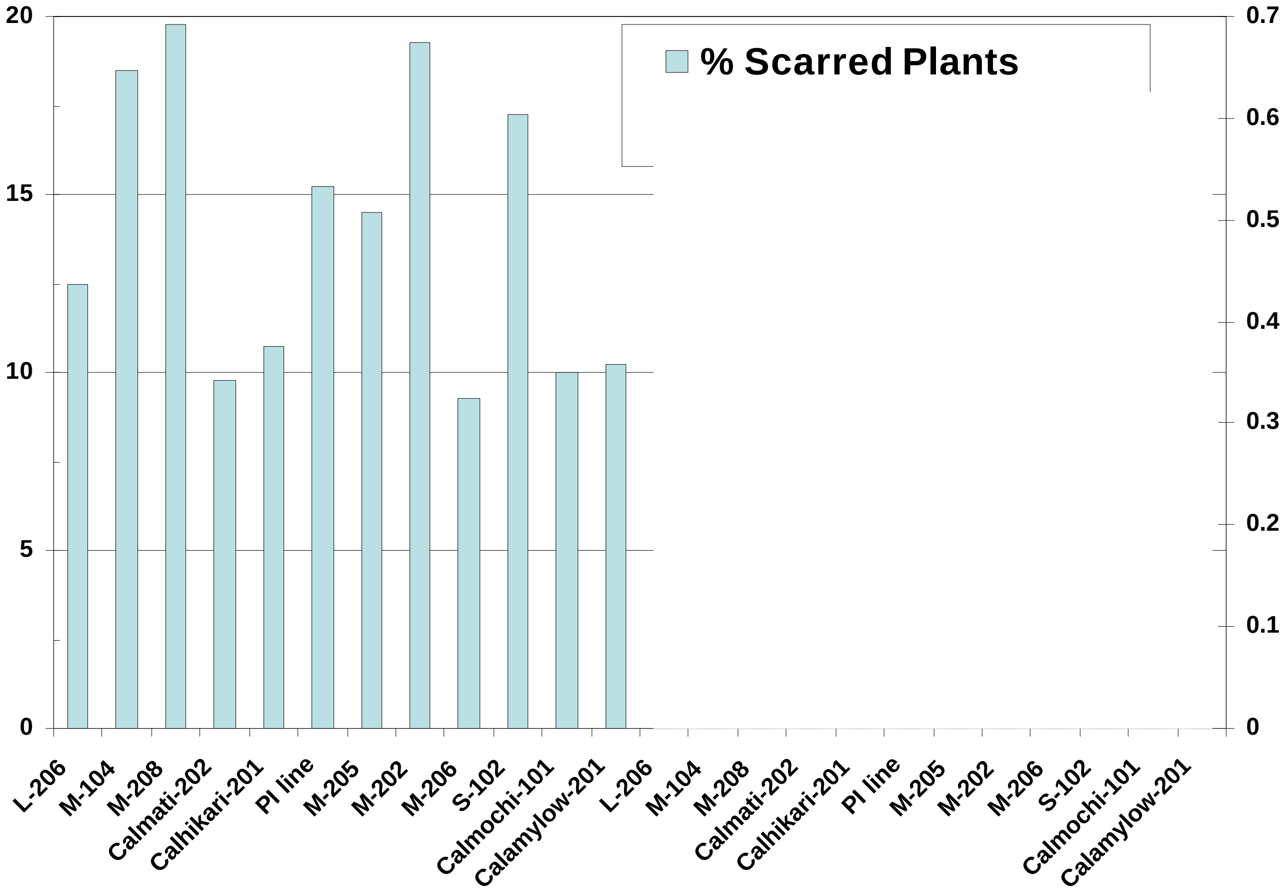
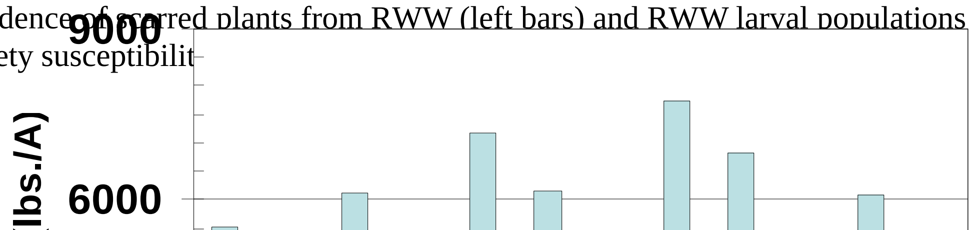


Figure 6. Incidence of scarred plants from RWW (left bars) and RWW larval populations (right bars) in variety susceptibilit



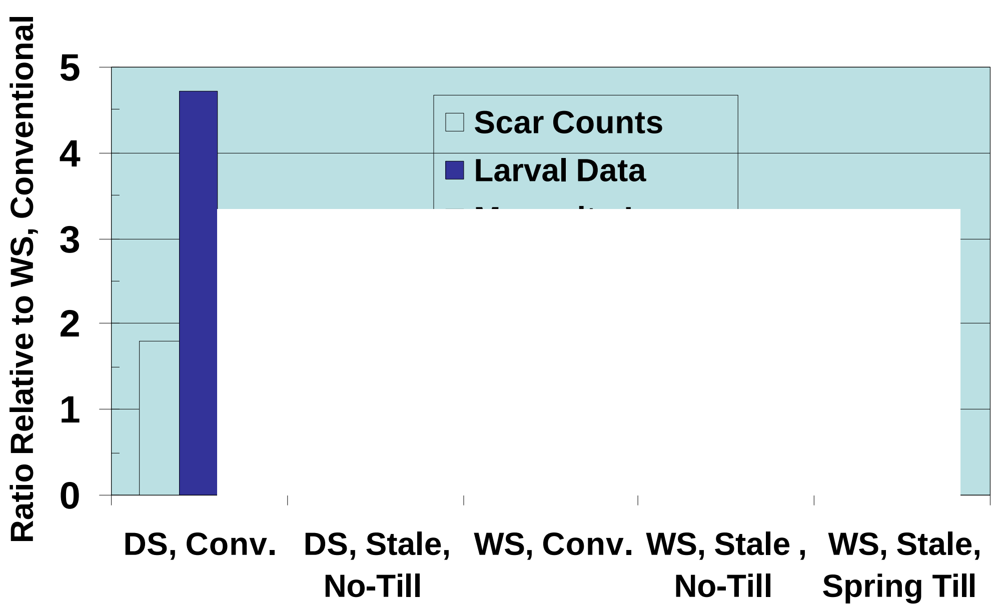


Figure 8. Incidence of plant scarring from RWW, larval RWW populations, and mosquito populations in the Systems study, 2007.

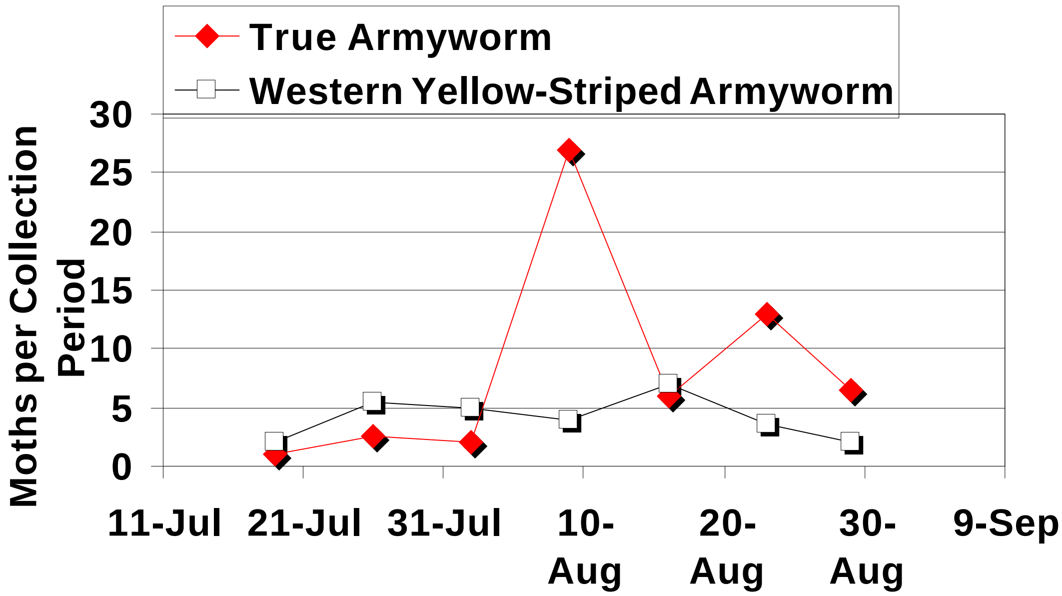


Figure 9. Armyworm moth flight from pheromone traps, RES, 2007.