PROJECT NO. RP-3

ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE

January 1, 2005 - December 31, 2005

PROJECT TITLE: Rice protection from invertebrate pests.

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LEVEL OF FUNDING: $ 59,210

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 - Comparison of the efficacy of an experimental biological insecticide for controlling rice water weevil in ring plots.

1.4) Rice water weevil control - comparison of registered and experimental products in large plots

1.5) Rice water weevil chemical control - Evaluation of a biorational product in the greenhouse for Rice Water Weevil control

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

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.

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

2.3) 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 region and relationship to armyworm larval populations in rice fields.
3.1.3). Investigate the factors that influence armyworm populations in grower rice fields.

Objective 4: To determine the most effective control of armyworms in rice.

4.1) Armyworm chemical control - Comparison of the efficacy of experimental materials versus registered standards.

Objective 5: Conduct appropriate monitoring, exploratory research, and educational activities on emerging and new exotic rice invertebrate pests.

<u>SUMMARY OF 2005 RESEARCH BY OBJECTIVE:</u>

Objective 1:

1.1 & 1.2) Chemical Control of Rice Water Weevil - Ring Plots

1.1, 1.2) Research for subobjectives 1.1 and 1.2 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-two treatments (a total of ten 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.

Testing was conducted with >M-202= in 8 sq. ft aluminum rings. The plots were flooded on 27 May and seeded on 27 May. The application timings were as follows:

23 May, early pre-flood treatments (we had intended for these to be made 1 week before flooding but the difficult spring for planting confounded this
26 May, pre-flood (PF) applications

10 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 8 June and 6 adults into each ring on 15 June. The standard production practices were used. Copper sulfate was applied in mid June for algal management, herbicides on 7 June, and nitrogen was top-dressed in July. The following sample dates and methods were used for this study:

Sample Dates:

<u>Emergence/ Seedling Vigor</u>: 8 June
<u>Adult Leaf Scar Counts</u>: 17 and 23 June
<u>Larval Counts</u>: 13 July and 27 July
<u>Rice Yield</u>: 5 October

Sample Method:

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

<u>Results:</u>

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. The amount of feeding varies yearly even though our methods used are identical every year. The first sample date, 17 June, had low counts and generally were less than 10% scarred seedlings (only one treatment was greater than 10%). The June 23 sample date was about a week after all the infestations. Counts were again fairly low with the highest being 16.5%. Percentages in the Furadan, Neemazal (0.1 rate), and V10112 0.26 rate applied PF and 3-leaf were numerically the highest (Table 2). The percentage in the untreated was 7.5% scarred plants. The pyrethroid 3-leaf stage treatments, which control by killing the RWW adults, consistently had low feeding incidence. For the experimental materials, the percentage scarred plants was low for Etofenprox (higher rates at the 3-leaf timing), fairly high for Dinotefuron, low for V-10170, and low for the 3-leaf timing of Steward. Overall, leaf scarring was lower than expected.

Larval Counts

RWW larval counts were made twice during the season. Populations were much higher in the first sample than the second. The later sample was apparently after many larvae had pupated and emerged. This is why we generally sample twice; so that one sample will be during the peak population. I will discuss the results for the first sample in terms of treatment efficacy. In the 13 July samples (1st coring date), the average densities ranged from 0 to 1.4 RWW per core (Table 3). The average numbers for the 2nd coring date (27 July) ranged from 0 to 0.55 RWW per core.

<u>Experimental materials versus registered standards.</u> Testing continued on three experimental insecticide active ingredients, Etofenprox, Dinotefuron, and Indoxacarb which were tested for the first time in California rice in 2004. The loss of Icon in Southern rice and the developing environmental concerns regarding pyrethroid use have spurred a renewed interest from the agrichemical companies for rice water weevil active products. Excellent activity was shown from some treatments of all three of these active ingredients. Etofenprox applied at the 3-leaf stage provided very good RWW control; there was an indication that the higher rates may provide slightly better residual control but this needs to be examined further. Etofenprox applied preflood was ineffective. Steward, applied at the 3-leaf stage, was very effective for RWW control although the higher (0.11) rate was needed. The lower rate as well as a preflood application was ineffective. Dinotefuron was also effective although somewhat less than the other two products. The preflood application of the higher rate surpassed the split preflood-3 leaf application for RWW control. Neemazal at the two tested rates did not provide RWW control; this product will be discussed more under **1.3)**. V10112 applied as a split preflood and 3-leaf stage application was very effective. Etofenprox is used for RWW control in Japan and Steward is registered in the U.S. for control of a related species, alfalfa weevil in alfalfa. Dinotefuron is in a chemical class of insecticides that generally have good performance against soil insects and is registered on some U.S. crops. For the registered standards, the pyrethroid materials, Warrior, Proaxis, and Mustang, all with 3-leaf stage application, were very effective. In addition, a new formulation of Mustang (F0570), was equally effective to Mustang at ½ the rate. Dimilin was moderately effective in the first sample date but not effective in the second date.

<u>Soil application of pyrethroid products.</u> Studies were conducted to evaluate possible changes to Warrior use patterns to improve efficacy and ease of use. F0570 (similar active ingredient as Mustang) and Proaxis were also included in these studies. 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. One important operational question for the use of preplant applications is how long in advance of the water can the treatment be made. We have generally shown good results with application as far as 10 days before the flood, but in one study control was inexplicably poor with a treatment made 5 days before flooding. Our goal in 2005 was to apply the materials at 7

days before flooding but the wet soil conditions and delayed seeding hindered this and the application was made 4 days before flooding. All three products, Warrior, Proaxis and F0570, applied preflood provided excellent RWW control.

Rice Yield

Rice grain yields ranged from 3998 to 5481 lbs./A. These yields were quite low for M-202 in 2005; the production season in 2005 was not the best for rice in California. In addition, the cool, wet spring and compressed planting season resulted in our seed bed preparation being rather poor. This may have reduced yield. Grain yields were highest in the V10170 split application treatment (Table 4) and lowest in the Steward preflood treatment. These yield numbers correspond with the larval data. Overall the yield and larval data were in close agreement although many of the yield numbers were intermediate; the RWW larval population was not high enough to cause strong yield losses. Rice biomass at harvest ranged from slightly less than 10,475 to 14,750 lbs./A. There was good agreement between total biomass and grain yield. Percentage moisture did not vary significantly among treatments, another indication that the larval populations did not strongly impact the rice plants.

1.3) Rice water weevil chemical control - Comparison of the efficacy of an experimental biological insecticide for controlling rice water weevil in ring plots.

Rice water weevil control with a biological insecticide was studied in another set of ring plots. The procedures were identical to those detailed in **1.1.)** with these modifications. RWW adults were introduced at two different times so as to better assess the activity of the biological insecticide. In some treatment adults were introduced on 8 June and 15 June which corresponds to the 2 and 3 leaf stages. In other rings, adults were introduced on 3 June and 8 June (~1 and 2 leaf stages). The treatments evaluated are listed in Table 5.

RWW larval management was unacceptable with all treatments. The primary effort was made on the slow-release granular formulation (Neemazal 0.1%G) because this product showed potential in greenhouse studies in 2004, albeit with a very high application rate. In these 2005 ring studies, this product was less efficacious than the EC formulation Aza-Direct. For adult feeding, there were no trends or noticeable activity with any treatment (Table 6). However, it is possible that larval control is achieved but adult feeding is unaffected. Larval populations (looking primarily at the first sampling date), were reduced by about ½ with the Aza-Direct product and largely unaffected with the Neemazal formulation (Table 6). The Neemazal, 20 lbs./A preflood treatment also showed some activity however the 40 lbs. treatment of this product was surprisingly ineffective. Total biomass yield ranged from ~13,375 to 18,300 lbs./A with the untreated plots actually having the highest yield (Table 7). Grain yields ranged from 3170 to 4470 lbs./A with the more effective treatment (Aza-Direct) tending to have higher grain yields (Table 7).

1.4) Rice water weevil control - comparison of registered and experimental products in large plots.

Rice water weevil control was compared in unreplicated 0.06-acre plots at RES. The field was flooded on 25 May and seeded with >M-202' on 26 May. The following treatments were evaluated,

1.) Warrior preflood, 0.03 lbs. AI/A,
2.) Aza-Direct, preflood, 0.02 lbs. AI/A,
3.) Neemazal G, 3 leaf application, 0.02 lbs. AI/A,
4.) Neemazal G, preflood, 0.02 lbs. AI/A, and
5.) untreated.

The standard sampling was done in these plots. Rice damage from RWW adults was evaluated on 17 June and 23 June. RWW larval samples were collected on 21 July and 10 Aug. Yield was quantified by hand harvesting three 10.8 ft^2 areas per plot on 7 October and recovering the grain with a AVogel@ mini-thresher.

The RWW infestation in these plots was virtually non-existent. Data on scarred plants showed less than 10% scarring in the untreated. No RWW larvae were sampled in this plot area. Yield data showed the highest grain yields with the Warrior PF (5768 lbs/A) and Aza-Direct (5379 lbs./A) treatments and lowest in the untreated (4362 lbs./A). Yields were intermediate with the Neemazal treatments at 4511 lbs./A.

1.5) Rice water weevil chemical control - Evaluation of a biorational product in the greenhouse for Rice Water Weevil control

Azadirachtin is an insect active extract from the seeds of the neem tree. It consists of two primary limonoids and several other bioactive limonoids present at low levels. On insects, this material has exhibited repellency, antifeedant effects, direct effects on the digestive system, and insect growth regulatory effects, as well as some direct toxicity. The insect species involved, type of applications, etc. influence the exact activity of this product. Neem products are registered on several crops and are mainstays of organic crop productions in numerous systems. Given the environmentally sensitive nature of the rice agroecosystem, a product of this type would have a good fit. Greenhouse studies conducted in 2004 showed activity of a granular formulation of Azadirachtin on RWW. These studies confirmed only that a high rate of the product would reduce numbers of larvae resulting from an infestation of adults. Studies in 2005 were designed to examine the efficacy of two formulations of Azadirachtin each with several rates. In addition, studies were designed to investigate the mode of action of the active ingredient on RWW.

General Procedures:

Rice (‘M-202’) was grown in plastic cups (4.5 in. diameter x 6 in. high; ~1 liter) in the greenhouse. Soil collected from a rice field was sieved and placed in the pots. Pots were flooded and rice seeds (~25) were placed in each pot. Seedlings were thinned to 5 per cup after emergence. Pots were constantly flooded during the study. RWW adults were collected from untreated rice fields in Butte Co. Adults were held in the laboratory in vials with rice leaf tissue. Adults can be held for 7 days in this manner. Adults were placed on the potted rice plants (five per pot) when the rice was in the ~2 leaf stage. Adults were confined onto the plants using clear plastic cylinders placed over the rice plants. Cylinders had mesh-covered openings to allow air movement and to prevent over-heating of rice plants and weevil adults. Weevil adults were allowed to oviposit in the plants for 3 days after which they were hand-removed. Eggs typically hatch about 5-7 days after oviposition. The percentage of plants with feeding scars from RWW adults was recorded; these numbers were 100% for every pot in each study. The number of adults, period of time confined on the plants, and small size of plants resulted in considerable feeding. It is apparent, however, that the treatments did not kill adults or reduce adult feeding significantly (at least not to the point where plants were undamaged). At about 4 weeks after being infested with RWW adults, the pots were destructively sampled and the number of RWW immatures determined by a soil washing – flotation technique.

Study 1 - Comparison of formulations and rates for RWW control:

Methods:

Treatments shown in Table 8 were used. In this study, formulations and rates were compared for efficacy on RWW. The liquid treatments were applied with a hand sprayer and the granular treatments were applied by weighing the appropriate amount of material and placing it in each pot. The pre-flood applications were applied at the time of rice planting, i.e., right before the water was introduced, and the 1 day before infestation treatments were applied 1day before the adults were introduced (12 days after seeding). Each treatment was replicated four times.

Results:

Adult mortality was 0% and 100% of the plants had feeding scars. Numbers of RWW immatures are shown in Table 8. There was a definite rate response, especially with the AZA-Direct product. The 0.005 lbs./AI/A rate was ineffective but the higher rates (0.015 and greater) were effective. Results were generally slightly better with the post-flood than the preflood treatment – probably because of the shorter time before the RWW were present. This was clear with the lower rates such as 0.01 lbs. AI/A. The Neemazal product was less effective. There was not a rate response and actually the lower rates were numerically slightly more effective. Consistently, the post-flood was better than the preflood treatment.

Study 2 - Evaluation of RWW repellency potential:

Methods:

For the second study, we wanted to investigate possible repellency for Azadirachtin. The same treatments were used as in Study 1. The rice was grown in the pots and the treatments were applied as previously reported. At the time of RWW adult introduction, all 24 pots comprising one block of the study were placed in a large plastic basin and flooded such that the water covered the pots and about 1" of the rice above the pot. Pots were randomly placed around the perimeter of the basin. Fifty RWW adults were introduced into the center of the basin and given free access to any pot. This set-up was replicated four times.

Results:

All plants were scarred by RWW adults. Numbers of RWW immatures in each treatment are shown in Table 9. Results were not clear-cut and there were no trends in the data. The study design was probably flawed. The treated pots needed to be submerged in order to give the RWW an opportunity to swim to the pot of their choice, but this probably resulted in the weak concentration of Azadirachtin throughout the entire basin. This objective needs to be re-examined with a different approach.

Study 3 - Potential of Azadirachtin formulations for sterilization of RWW:

Methods:

The objectives of study 3 were to examine the sterility effects of Azadirachtin on RWW. All RWW adults are females (in California – this is not the case in the southern US with the same species) and they reproduce parthenogenetically. For this study, only one rate of AZA-Direct and Neemazal was used (52 oz./A and 40 lbs/A., respectively). The post-flood timing was used. Ten RWW adults were placed on the original plants for 2 days and allowed to feed and oviposit. They were then moved to another set of plants (all untreated) for 2 days to look for carry-over effects of the initial treatment and then to a third set of untreated plants for 2 more days. Four replications were used.

Results:

On the original plant, both formulations reduced the number of RWW compared with the untreated plants (Table 10). On the third plant, the numbers were also significantly reduced compared with the untreated (more so for AZA-Direct than Neemazal). On the second plant the numbers were "low" in all treatments so it was difficult to see any differences. We have seen this previously in untreated plants that the RWW initially lay several eggs, go through a lull period as they presumably mature more eggs followed by ovipositing a mass of eggs. It does seem clear that Azadirachtin sterilizes the RWW and that this effect lasts to some extent for at least 6 days.

Overall, Azadirachtin seems to have some significant activity on rice water weevil. The liquid formulation was superior to the granular. The promise shown by the slow-release granular formulation in 2004 studies was not supported by the 2005 work. The greenhouse studies did use a fairly high weevil population which "stresses" product performance, but environmental conditions are more moderate in the greenhouse compared with the field.

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

The treatments listed in Table 11 were evaluated in this study. The rationale for this study is that managing mosquito populations in rice fields is of utmost importance with the increased prevalence of West Nile Virus in northern California. 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. As part of a Best Management Practices program, the impacts of these various products on non-targets and the resulting effects on mosquito populations should be considered.

Methods:

Each plot was ~0.04 A and each treatment was replicated three times. To acquire this much space, the study was split between two fields with two replications being in one field and the final one being in another field about ¼ mile away. Unfortunately, the seeding dates and rice growth and development differed between these two sites as well as the timing of our treatments. Dates for Field 1 were preflood treatments – 31 May, flooded – 3 June, seeded – 3 June and 3-leaf stage treatments – 27 June. Dates for Field 2 were preflood treatments – 26

May, flooded – 1 June, seeded – 1 June and 3-leaf stage treatments – 15 June. The armyworm application timing was 20 July in both fields. Populations of non-target organisms were evaluated weekly from 10 June to 2 September. Floating barrier traps were used to collect swimming organisms. Mosquito dip samples (25 dips in each of 5 locations per plot) were used to estimate populations of mosquito larvae. Finally, four quadrant samples per plot (0.55 ft^2 each) were used and these samples collected all organisms within these area.

Results:

The animal life diversity in the rice agroecosystems is tremendous. Counting these samples and identifying the organisms is a large undertaking and generally takes 6 to 9 months after the field season to complete. Therefore, the 2004 results will be presented herein as these were not available at the time of the 2004 report. The 2005 results are still being counted and/or data summarized; one summary is shown.

Preflood applications: The number of aquatic insects and other aquatic invertebrates following preflood applications made on 19 May are shown in Fig. 1 and 2, respectively. The numbers of animals were much higher in 2004 than in 2003 early in the season; the field in 2004 had a high infestation of seed midges and clam shrimp which were not present in the field in 2003; these increased the tally for both graphs. For the preflood treatments, it appears that the insecticides had minimal effects on the number of aquatic insects and the number of invertebrates in 2004. In fact, the numbers were typically higher in the treated plots than the untreated plots. It is interesting that the Warrior preflood application did not impact numbers of non-targets as the post-flood application of this material has been shown to cause reductions.

Post-flood applications: Results on non-target organisms from the 3-leaf stage applications (on 3 June) are shown in Fig. 3 (aquatic insects) and 4 (other aquatic invertebrates). Populations in the untreated plots are highlighted for ease of comparison. It appears that some products (etofenprox, Mustang) have some short-term detrimental effects on populations of aquatic insects and that most if not all the insecticides reduced levels of other invertebrates for 2-3 weeks after application. Some of these reductions were in the 50% range, i.e., Warrior on invertebrates on 17 June. However, after this initial reduction, the populations recover and are not affected the rest of the season.

July armyworm application: Warrior was evaluated as a representative material that could be applied against armyworms in July (on 15 July). Results on aquatic insects and other aquatic organisms are shown in Fig. 5 and 6, respectively. Numbers of aquatic insects were very low on the first sample date but on the second date (29 July) the Warrior application was quite damaging to these populations. On three of the remaining four sample dates, this same trend was seen. Similarly, populations of other aquatic invertebrates were reduced by the July Warrior application for 3 weeks after treatment.

2005: As in 2004, application of Warrior preflood had minimal effects on populations of total aquatic invertebrates (Fig. 7).

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 45-50 years with a black light trap at RES. The trap has been at exactly the same place during my tenure during this work. Monitoring weevil flights is important to determine the levels and intervals of peak flight periods and to compare RWW trends over time (years). The switch to an adult control program, i.e., use of post-flood insecticides, has placed even greater importance on understanding RWW flight timing since the treatments are targeted at adults. RWW flight timing and intensity varies annually and responds to the weather patterns. The weevil adults fly in the evenings (6-11 pm) and need warm (70-80^{0}F) and calm periods to fly. In 2005, the flight occurred late (due to the unfavorable spring) and there were minor flights from 26 April to 2 May and from 11 May to 13 May (Fig. 8). The majority of the flight (over 75% of the total capture) occurred from 20 May to 26 May. A total of 978 RWW adults were captured compared with over 8000 in 2001, 655 in 2002, 1891 in 2003, and 703 in 2004.

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. Literally thousands of lines have been evaluated in the U.S. and a moderate level of resistance has been found in a few lines. Working this resistance/tolerance into commercial cultivars is ongoing. However, the different varieties and types of rice do have significantly different characteristics (growth, days to harvest, vigor, etc.) and these differences may also include their responses to insect pest infestations. In southern rice, medium grain varieties have been shown to have higher RWW levels and respond more severely to infestation. Other rice lines support high RWW infestations, but are extremely vigorous and regrow roots so fast that yield losses are minimal. The goal of this study was to evaluate selected California varieties for susceptibility and response to RWW. In previous years, this study was conducted at the RES. Naturally-occurring RWW populations have been low-moderate and this has hindered the progress for this study. In 2004 and 2005, this study was done at a grower field location that historically has had a high RWW infestation.

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-205
2. M-104
3. M-204
4. Calmati-201
5. Calhikari-201
6. PI506230
7. M-205
8. M-202

9. M-206
10. S-102
11. Calmochi-101
12. M-401

This objective was divided into two important questions.
1.) are all varieties equally susceptible (preferred by) to RWW infestation by adults and establishment/survival by RWW immatures and
2.) given an equal infestation level by RWW larvae, are the yield losses equal among the varieties (do some varieties respond more negatively to root pruning than other varieties). Each variety was seeded into 8 plots (10 x 20 ft.); four plots were treated with an insecticide for RWW on 25 May and four plots were left untreated. The study was set up as a randomized complete block design with four replicates.

Methods:

Plots were flooded on 27 May and seeded on 28 May. RWW adult feeding scars, seedling establishment rating, larval population numbers, and grain yields (144 sq. ft area taken with the small plot harvester) were determined as described previously. The amount of feeding scars was used to evaluate susceptibility to adult infestation, the number of RWW larvae per plot in the untreated plots was indicative of the conduciveness of the variety to RWW infestation and the difference in yield between the treated and untreated plots of a given variety was used to show plant response to the feeding.

Results:

The naturally-occurring RWW population was moderate in this plot area. Percentage scarred plants, averaged across the varieties were similar (3% for both treated and for untreated plots). Among the varieties, when untreated, percentage scarred plants ranged from 1.5 (M-206) to 5% (S-102) (Table 12). There were no significant differences. This would be an indication of relative attractiveness of the varieties to RWW adult feeding. We also rated the plots for "bleaching" from a Cerano® herbicide application in early June. There was an indication that the varieties were responding to this material to different degrees. A 1 to 5 visual rating system was used with 1 being normal green and 5 being totally white. Indeed there were significant differences in the phytotoxicity with L-205 and M-104 showing the least damage and M-204 numerically showing the most damage (Table 12). RWW populations were assessed on two dates with the second being too late to sample the population well. Looking at the data from the first sample date, there were significant differences in the population level. There were significantly more larvae in M-206 and M-205 than in Calhikiri-201 (Table 12). These results are indicative to the relative susceptibility of the varieties to infestation. The insecticide treatment overall reduced larval populations by about 60%.

Grain yields ranged from 1816 (M-401) to 7682 lbs./A (M-205) (Fig. 9) [M-401 yield was severely impacted by bird damage due to its early maturity and the need to wait for some other entries to mature]. The RWW population was too low to substantially impact grain yields. In six of the varieties, there was a yield advantage for the plots where RWW was controlled and this averaged 8.0%.

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

Refined rice seedling establishment techniques are being investigated at the RES primarily as a means to improve weed management. However, these techniques will also likely affect insect pest populations (and also perhaps mosquitoes). In 2005, plots with the following variations of rice stand establishment were set-up: 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 nearly eliminates RWW populations. The stale seedbed technique may also reduce RWW numbers if the weevil adults are attracted to the field when it is initially flooded and they would subsequently be eliminated during the drydown.

In 2005, we monitored RWW populations (adult scarring and larval numbers) as well as armyworm populations in this seedling establishment study. Data were collected on 11 June (adult scarring) and 21 July and 11 Aug. (RWW larvae) using standards methods. RWW infestation in this plot was low. Adult scarring did not differ significantly among the treatments (Table 13) but did range up to 18.8% scarred plants in the stale seedbed no till water-seeded treatment. This was about 3x more damage than inn the drill-seeded plots. Larval populations were significantly higher (a 5X difference) in the delayed spring till water-seeded treatment than in the stale seedbed no till drill-seeded treatment (Table 13).

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 are present in Sacramento Valley rice fields; the western yellow-striped armyworm (*Spodoptera praefica*) and the Atrue@ armyworm (*Pseudaletia unipuncta*) and seem to be adapting to the rice agroecosystem and becoming a more significant pest. Armyworms can damage rice 1.) by defoliation and 2.) by feeding on developing panicles and kernels. The latter damage is much more important than is simple leaf removal. An insecticide application to control these armyworm pests is now common in some rice production areas. Besides hindering the profitability, mid-season applications of broad-spectrum insecticide have the potential to upset the “balance” in rice fields and to promote populations of mosquitoes. Studies continued in 2005 to investigate armyworm biology and management.

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.

The two species of armyworms have similarities and differences. Both have many host plants with the true armyworms strongly preferring grasses and cereals, although they will infest various vegetables (including bean, beet, cabbage, carrot, cauliflower, corn, cucumber, lettuce, onion, pea, pepper, radish, and sweet potato), fruits, legumes, and weeds, especially when they are on the march. The western yellow-striped armyworm is described as a very general feeder, reportedly damaging vegetable crops (including asparagus, bean, beet, cabbage, cantaloupe, carrot, corn, cucumber, lettuce, onion, pea, potato, rhubarb, sweet potato, tomato, and turnip), fruit crops (blackberry, grape, peach), and field crops such as alfalfa, cotton, clover, sorghum, soybean, sugarbeet, sunflower, tobacco, and wheat. 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 2005 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 (on 27 June), Shark (on 17 June), or both materials. Data were collected weekly on armyworm populations and on weed incidence.

Armyworm populations were fairly low but peaked on 5 Aug. and were highest in the plots with no weed control (Fig. 10). These plots also had the most weeds and were primarily infested with ricefield bulrush, bearded sprangletop and some arrowhead (in broadleaf plots).

3.1.2). Investigate the timing of armyworm moth flight in the rice production region and relationship to armyworm larval populations in rice fields.
3.1.3). Investigate the factors that influence armyworm populations in grower rice fields.

Pheromone traps are used in several crops to gain insights on the timing of movement of pest populations. Pheromone technology is especially well-developed for moth pests. 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. We started work in 2003 to study the timing of armyworm adult flight with pheromone traps. This work was continued in 2005. Separate traps for western yellow-striped armyworm and Atrue@ armyworm were placed near rice fields in 4 locations in Colusa Co. and 3 locations in Butte Co; these two species utilize different pheromones. Moths were collected from traps weekly. In addition, larval populations were monitored in 6 and 7 rice fields in Colusa and Butte Co., respectively every week. Observations were recorded as to the pattern of armyworm infestation in the fields.

Armyworm moth captures in 2003 and 2004 exhibited distinct peaks, i.e., periods of very few moths captured followed by periods of high activity. These peaks are representative of the various life cycle generations for this pest. In 2005, from July to September the true armyworm exhibited a high flight peak in mid-July and again in late Aug. (Fig. 11). The late Aug. peak was only seen in Butte Co. Western yellow-striped armyworm moth captures really showed no peaks in 2005; more of a constant but low flight during July and August. Given typical mid-summer temperatures, about 22-25 degree-days will accumulate for armyworm development per day and therefore about 35-40 days are needed for a complete generation (eggs through the cycle back to eggs). As shown in Fig. 12, the mid-July peak corresponds to a mid-July peak found in the rice field searches for armyworm larvae. Populations peaked at 6 worms found per 15-minute search at this time. Armyworm larvae were collected in July and August and held in the laboratory on artificial diet. After a few days, if the larva was parasitized, it was obvious. A significant portion of the armyworms were parasitized as shown in Fig. 13. Percentages of parasitism ranged up to 57% on 9 Aug. Two species of parasites are common; these are both small wasps. On western yellow-striped armyworm larvae the common parasite is *Hyposoter exiguae* whereas

Apanteles militaris is most common on true armyworm larvae. Have these parasitic wasps become less common or delayed or impeded in terms of their period of activity? This is an area that warrants additional research but could play a role in armyworm larval populations build-up to treatable levels in rice field. In summary, it does appear that the use of pheromone traps could provide a forewarning of the time sampling needs to be intensified for armyworms in rice fields.

Objective 4: To determine the most effective control of armyworms in rice.

4.1) Armyworm chemical control - Comparison of the efficacy of experimental materials versus registered standards.

Several biorational products are available that could control armyworms well in rice. These would be innocuous to most non-targets. We conducted an insecticide efficacy test against armyworm in 2005 at the RES. The following treatments were applied, 1.) Dimilin 2L at 8 oz./A, 2.) Dipel at 2 qt./A, 3.) Warrior at 3.84 oz./A, 4.) Steward at 11.3 oz./A, and 5.) Untreated. The treatments were applied on 18 July with a backpack sprayer. At 3 days following application, the worm population had ceased in all plots so no useable data was obtained.

Objective 5: Conduct appropriate monitoring, exploratory research, and educational activities on emerging and new exotic rice invertebrate pests.

Numerous rice insect pests (and related organisms) occur in other state and countries but not in California. Those that are present in the southern U.S. potentially pose the most threat to California rice since the environmental conditions are not drastically different. Through this project, we maintain a vigilant watch for exotic pests through our visits to numerous rice fields throughout the Sacramento Valley. The rice stink bug is a significant rice pest in the southern US but it fortunately is not in California. Stem borers are becoming a bigger issue for rice production in the South. In particular, the Mexican rice borer and sugarcane borer are problematic. These do not occur in California, but could likely flourish here. Finally, a new insect pest has occurred in the South during the last few years. It is related to our rice leafminer (same scientific genus) and is called the rice whorl maggot. The larval stage feeds in the whorl and kills the seedlings (a different damage pattern than our rice leafminer). We provide educational materials on these pests and remain aware for any other possibilities of exotic pests of rice.

Acknowledgments:

There are several people that we would like to acknowledge that contributed to the operations and success of the 2005 rice invertebrate pest management project. We thank Crompton/Uniroyal Chemical Co., Syngenta, FMC, Dow Agroscience, Valent, Landis International and Dupont for products; UC Cooperative Extension Sacramento Valley Farm Advisors for grower contacts and assistance; UC Davis Rice Project student assistants for their diligent work; and numerous growers for use of their land and resources. Lastly, we are grateful to the staff at the Rice Experiment Station for the study site and light trap collections and the California Rice Research Board for providing the funding necessary to achieve our objectives.

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CONCISE GENERAL SUMMARY OF CURRENT YEAR=S (2005) RESULTS:

Larry D. Godfrey, Richard Lewis, and Karey Windbiel

Research was conducted in 2005 on various aspects of rice water weevil (RWW) and armyworm (AW); studies were generally divided into those on the biology and management of each of these two major rice arthropod pests. Results will aid in refining the IPM schemes for these pests as well as to continue to build upon the existing cost-effective and environmentally compatible management programs in rice. 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 in rice fields. These organisms could play an important role in mosquito management. Significant progress was made on all objectives. Inconsistent RWW and AW populations hindered data collection on a couple of studies but overall success was achieved. The rice water weevil is the most important invertebrate pest of California rice, although armyworms are becoming more important. Dimilin[7] 2L, Warrior[7], Proaxis[7], and Mustang[7] are the insecticides used to control both of these pests. The efficacy of new insecticides and management approaches were stressed.

Rice Water Weevil: Studies were continued in 2005 in ring plots and in large field plots to evaluate experimental materials versus registered standards for RWW control and to modify the use patterns of the existing product to facilitate management. Twenty-two treatments (a total of ten different active ingredients) were established in ring plots to accomplish this research. Research continued on three experimental insecticide active ingredients, Etofenprox, Dinotefuron, and Steward, and began with another, V10170. Efforts in this research area have increased recently due to the cancellation of Icon registration in the southern rice, the additional scrutiny placed on rice insecticides due to West Nile Virus, and some emerging environmental issues with pyrethroid insecticides. Etofenprox applied at the 3-leaf stage provided very good RWW control; Etofenprox applied preflood was ineffective. Indoxacrb, applied at the 3-leaf stage, was very effective for RWW control although the higher (0.11 oz.) rate was needed. The lower rate as well as a preflood application was ineffective. Dinotefuron was also effective although somewhat less than the other two products. Finally V10170 provided nearly 100% RWW control at the rates and application methods tested. A biological matieral was also evaluated in this ring test and in another field test in 2005. A granular formulation of Azadirachtin (Neemazal[7]) at the two tested rates did not provide RWW control. In the second field test, Neemazal also was ineffective with six tested rates/application methods; however, a liquid formulation of this material (Aza-Direct[7]) showed moderate activity. Greenhouse studies were used to investigate this biological material further and there was a definite rate response, especially with the AZA-Direct product. Rates higher than 0.015 lbs. AI/A were effective with the post-flood timing being slightly better than the preflood treatment. The Neemazal product was also less effective in greenhouse studies. The mode of action of Azadirachtin on RWW was investigated; the product affects different species of insects in different ways. RWW were sterilized by feeding on treated foliage; however, studies on repellency were inconclusive. Additional studies in small field plots were hindered due to low RWW populations. In ring tests, the efficacy of preflood applications of pyrethroid insecticides against RWW was studied. Warrior, Proaxis and Mustang (applied 4 days before flooding) provided good RWW larval control. Finally, studies evaluated the effects of insecticide treatments in rice on populations of invertebrate non-targets. Results from 2004 field collections were finalized and the 2005 samples are still being sorted, counted, and summarized. Preflood applications of Warrior had minimal effects on the number of aquatic insects and the number of invertebrates in 2004. For the post-flood applications (five different products were tested), it appears that some products (etofenprox, Mustang) have some short-term detrimental effects on populations of aquatic insects and that most, if not all, the insecticides reduced levels of other invertebrates for 2-3 weeks after application. Some of these reductions were in the 50% range, i.e., Warrior on invertebrates on 17 June. However, after this initial reduction, the populations recovered and were not affected the rest of the season. Warrior was evaluated as a representative material that could be applied against armyworms in mid-July. The Warrior application was quite damaging to these populations.

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. The timing of RWW adult flight was delayed in 2005, as was the rice seeding, because of the cool, wet spring. In 2005, there were minor flights from 26 April to 2 May and from 11 May to 13 May with the majority of the flight (over 75% of the total capture) occurring from 20 May to 26 May. A total of 978 RWW adults were captured, slightly more than in 2004 but about ½ the total in 2003 and 1/8 that in 2001. Twelve rice varieties were compared for susceptibility to and yield loss from RWW. There were significantly more larvae in M-206 and M-205 than in Calhikiri-201; populations were similar in the other varieties from within the randomized plot area. An eleven-fold difference in larval populations was noted between the most and least susceptible variety. The RWW population was too low to substantially impact grain yields. In six of the varieties, there was a yield advantage for the plots where RWW was controlled and this averaged 8.0%. RWW populations (adult scarring and larval numbers) as well as armyworm populations were evaluated in the rice systems/seedling establishment study. RWW infestation in this plot was low. Adult scarring did not differ significantly among the treatments but did range up to 18.8% scarred plants in the stale seedbed no till water-seeded treatment. This was about 3x more damage than in the drill-seeded plots. Larval populations were significantly higher (a 5X difference) in the delayed spring till water-seeded treatment than in the stale seedbed no till drill-seeded treatment.

Armyworm Biology and Infestations in Rice: Armyworms have developed into significant pests of rice during the last ~5 years and in some areas a mid-season insecticide treatment for this pest is common. Two species of armyworms are present in Sacramento Valley rice fields; the western yellow-striped armyworm (*Spodoptera praefica*) and the Atrue@ armyworm (*Pseudaletia unipuncta*) and seem to be adapting to the rice agroecosystem and becoming a more significant pest. Armyworms can damage rice 1.) by defoliation and 2.) by feeding on developing panicles and kernels. The latter damage is much more important than is simple leaf removal. The two species of armyworms have similarities and differences. Numerous weed species hosts are 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 2005 by setting up plots with 1.) very few weeds, 2.) predominantly grassy weeds, 3.) predominantly broadleaf weeds, and 4.) both grassy and broadleaf weeds. Armyworm populations were fairly low in this test but peaked on 5 Aug. and were highest in the plots with no weed control. These plots also had the most weeds and were primarily infested with ricefield bulrush, bearded sprangletop and some arrowhead (in broadleaf plots). Pheromone traps (these two species utilize different pheromones) were used to study the timing of armyworm adult flight. Separate traps for western yellow-striped armyworm and Atrue@ armyworm were placed near rice fields in 4 locations in Colusa Co. and 3 locations in Butte Co; with moths collected from traps weekly. In addition, larval populations were monitored in 6 and 7 rice fields in Colusa and Butte Co., respectively, every week. Armyworm moth captures in 2003 and 2004 exhibited distinct peaks, i.e., periods of very few moths captured followed by periods of high activity. These peaks are representative of the various life cycle generations for this pest. In 2005, from July to September the true armyworm exhibited a high flight peak in mid-July and again in late Aug. (the late Aug. peak was only seen in Butte Co.). Western yellow-striped armyworm moth captures showed no peaks in 2005; more of a constant but low flight during July and August. The mid-July flight peak corresponded to a mid-July larval population peak in the rice field searches. Populations peaked at 6 worms found per 15-minute search at this time. Armyworm larvae were collected in July and August and held in the laboratory on artificial diet to evaluate parasitism. Parasitized larvae die within a few days. Percentages of parasitism ranged up to 57% on 9 Aug. Two species of parasites are common; these are both small wasps. On western yellow-striped armyworm larvae the common parasite is *Hyposoter exiguae* whereas *Apanteles militaris* is most common on true armyworm larvae. Have these parasitic wasps become less common or delayed or impeded in terms of their period of activity? This is an area that warrants additional research but could play a role in armyworm larval populations build-up to treatable levels in rice field. In summary, it does appear that the use of pheromone traps could provide a forewarning of armyworm infestations. An insecticide efficacy test against armyworm was conducted in 2005 with five treatments but populations were not high enough for meaningful data.

Table 1. Treatment list for RWW management ring study, 2005.

Product	Rate (lbs. AI/A)	Formulation per A	Timing	Application Date
1. Furadan 5G	0.5	10 lbs.	PF	26 May
2. Dimilin 2L	0.125	8 oz	3-leaf	10 June
3. Mustang 1.5 EW	0.04	3.4 fl. oz.	3-leaf	10 June
4. Untreated	---	---	---	---
5. Warrior	0.03	3.84 oz.	3-leaf	10 June
6. Warrior	0.03	3.84 oz.	PF - ~week before flooding	23 May
7. MTI-500 (etofenprox) 1.5%G	0.13	8.9 lbs.	3-leaf	10 June
8. MTI-500 (etofenprox) 1.5%G	0.18	11.9 lbs.	3-leaf	10 June
9. MTI-500 (etofenprox) 1.5%G	0.22	14.9 lbs.	3-leaf	10 June
10. XDE 225 (Proaxis)	0.015	3.84 oz.	3-leaf	10 June
11. V10112 1G + V10112 1G (dinotefuron)	0.26 + 0.26	26.4 + 26.4 lbs.	PF & 3 leaf	25 May & 10 June
12. V10170 0.5G + V10170 50WD	0.22 + 0.044	44.1 + 0.09 lbs.	PF & 3 leaf	25 May & 10 June
13. V10112 1G (dinotefuron)	0.53	52.8 lbs.	PF	26 May
14. F0570 0.8 EC (Mustang Max)	0.02	3.2 fl. oz	PF - ~week before flooding	23 May
15. Neemazal G	0.05	50 lbs	PF	26 May
16. Steward (indoxacarb)	0.065	6.7 fl. oz.	3 leaf	10 June
17. Steward (indoxacarb)	0.11	11.3 fl. oz.	3 leaf	10 June
18. XDE 225 (Proaxis)	0.015	3.84 oz.	PF - ~week before flooding	23 May
19. Steward	0.11	11.3 fl. oz.	PF	26 May
20. MTI-500 (etofenprox) 1.5%G	0.18	11.9 lbs.	PF	26 May
21. F0570 0.8 EC (Mustang Max)	0.02	3.2 fl. oz	3 leaf	10 June
22. Neemazal G	0.1	100 lbs.	PF	26 May

Table 2. Rice plant stand and adult feeding damage in chemical ring study, 2005.

Product	Rate (lbs. AI/A) & Timing	Stand Rating (1-5)	% Scarred Plants - 17 June		% Scarred Plants - 23 June	
1. Furadan 5G	0.5 - PF	3.0	6.0	bcd	16.5	a
2. Dimilin 2L	0.125 - 3-leaf	3.0	7.0	bc	11.0	bcd
3. Mustang 1.5 EW	0.04 - 3-leaf	2.8	1.5	cde	2.5	fgh
4. Untreated	---	3.3	3.5	bcde	7.5	cdef
5. Warrior	0.03 - 3-leaf	3.3	2.5	bcde	0.5	h
6. Warrior	0.03 – early PF	3.5	1.0	de	2.0	gh
7. MTI-500 (etofenprox) 1.5%G	0.13 - 3-leaf	3.0	2.5	bcde	11.0	bcd
8. MTI-500 (etofenprox) 1.5%G	0.18 - 3-leaf	3.3	1.0	de	1.5	gh
9. MTI-500 (etofenprox) 1.5%G	0.22 - 3-leaf	3.2	2.5	bcde	3.5	efgh
10. XDE 225 (Proaxis)	0.015 - 3-leaf	3.1	1.5	cde	0.5	h
11. V10112 1G + V10112 1G (dinotefuron)	0.26 + 0.26 - PF+3-leaf	2.7	3.0	bcde	11.5	abc
12. V10170 0.5G + V10170 50WD	0.22 + 0.044 – PF+3-leaf	3.1	0.0	e	0.0	h
13. V10112 1G (dinotefuron)	0.53 - PF	3.1	2.0	bcde	6.0	defg
14. F0570 0.8 EC (Mustang Max)	0.02 – early PF	3.0	1.5	cde	8.0	cde
15. Neemazal G	0.05 - PF	3.1	7.5	ab	7.5	cdef
16. Steward (indoxacarb)	0.065 - 3-leaf	2.9	3.5	bcde	8.0	cde
17. Steward (indoxacarb)	0.11 - 3-leaf	2.8	2.0	bcde	1.0	gh
18. XDE 225 (Proaxis)	0.015 – early PF	3.0	1.0	de	1.5	gh
19. Steward	0.11 - PF	3.4	3.5	bcde	10.5	bcd
20. MTI-500 (etofenprox) 1.5%G	0.18 - PF	3.0	7.5	ab	11.0	bcd
21. F0570 0.8 EC (Mustang Max)	0.02 - 3-leaf	3.0	0.5	de	3.5	efgh
22. Neemazal G	0.1 - PF	3.0	13.0	a	14.5	ab

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

Table 3. RWW immature density (first and second sample dates and average) in chemical ring study, 2005.

Product	Rate (lbs. AI/A) & Timing	RWW per Core (13 July)		RWW per Core (27 July)		Average
1. Furadan 5G	0.5 - PF	0.15	cde	0.30	abc	0.23
2. Dimilin 2L	0.125 - 3-leaf	0.50	bcde	0.55	a	0.53
3. Mustang 1.5 EW	0.04 - 3-leaf	0.35	bcde	0.10	c	0.23
4. Untreated	---	0.80	abc	0.25	abc	0.53
5. Warrior	0.03 - 3-leaf	0.10	de	0.05	c	0.08
6. Warrior	0.03 – early PF	0.00	e	0.00	c	0.00
7. MTI-500 (etofenprox) 1.5%G	0.13 - 3-leaf	0.15	cde	0.25	abc	0.20
8. MTI-500 (etofenprox) 1.5%G	0.18 - 3-leaf	0.16	cde	0.05	c	0.11
9. MTI-500 (etofenprox) 1.5%G	0.22 - 3-leaf	0.10	de	0.15	bc	0.13
10. XDE 225 (Proaxis)	0.015 - 3-leaf	0.05	e	0.00	c	0.03
11. V10112 1G + V10112 1G (dinotefuron)	0.26 + 0.26 - PF+3-leaf	0.75	abcd	0.25	abc	0.50
12. V10170 0.5G + V10170 50WD	0.22 + 0.044 – PF+3-leaf	0.00	e	0.05	c	0.03
13. V10112 1G (dinotefuron)	0.53 - PF	0.30	bcde	0.15	bc	0.23
14. F0570 0.8 EC (Mustang Max)	0.02 – early PF	0.20	cde	0.05	c	0.13
15. Neemazal G	0.05 - PF	1.30	a	0.50	ab	0.90
16. Steward (indoxacarb)	0.065 - 3-leaf	0.95	ab	0.25	abc	0.60
17. Steward (indoxacarb)	0.11 - 3-leaf	0.05	e	0.05	c	0.05
18. XDE 225 (Proaxis)	0.015 – early PF	0.00	e	0.00	c	0.00
19. Steward	0.11 - PF	0.95	ab	0.25	abc	0.60
20. MTI-500 (etofenprox) 1.5%G	0.18 - PF	0.80	abc	0.05	c	0.43
21. F0570 0.8 EC (Mustang Max)	0.02 - 3-leaf	0.10	de	0.20	abc	0.15
22. Neemazal G	0.1 - PF	1.40	a	0.50	ab	0.90

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

Table 4. Effect of RWW populations on rice biomass and grain yields in chemical ring study, 2005.

Product	Rate (lbs. AI/A) & Timing	Biomass - Straw + Grain (lbs./A)		% Moisture		Estimated Grain Yield (lbs./A)	
1. Furadan 5G	0.5 - PF	13,164.5	abc	13.0	a	5058.6	ab
2. Dimilin 2L	0.125 - 3-leaf	12,199.6	bcdef	13.0	a	4416.0	bc
3. Mustang 1.5 EW	0.04 - 3-leaf	12,682.0	abcdef	13.3	a	4993.7	ab
4. Untreated	---	10,752.2	ef	13.2	a	4416.9	bc
5. Warrior	0.03 - 3-leaf	11,234.6	cdef	12.6	a	4250.7	bc
6. Warrior	0.03 – early PF	12,888.8	abcde	13.3	a	4910.1	abc
7. MTI-500 (etofenprox) 1.5%G	0.13 - 3-leaf	12,337.4	bcdef	12.9	a	4775.4	abc
8. MTI-500 (etofenprox) 1.5%G	0.18 - 3-leaf	11,923.9	bcdef	12.7	a	4842.1	abc
9. MTI-500 (etofenprox) 1.5%G	0.22 - 3-leaf	12,061.7	bcdef	13.1	a	4838.0	abc
10. XDE 225 (Proaxis)	0.015 - 3-leaf	11,510.3	cdef	13.1	a	4503.3	abc
11. V10112 1G + V10112 1G (dinotefuron)	0.26 + 0.26 - PF+3-leaf	12,199.6	bcdef	13.2	a	4602.9	abc
12. V10170 0.5G + V10170 50WD	0.22 + 0.044 – PF+3-leaf	14,060.5	ab	13.3	a	5481.2	a
13. V10112 1G (dinotefuron)	0.53 - PF	12,268.5	bcdef	12.4	a	4683.9	abc
14. F0570 0.8 EC (Mustang Max)	0.02 – early PF	11,923.9	bcdef	12.9	a	4679.2	abc
15. Neemazal G	0.05 - PF	11,441.4	cdef	13.1	a	4179.0	bc
16. Steward (indoxacarb)	0.065 - 3-leaf	11,717.1	bcdef	12.9	a	4264.3	bc
17. Steward (indoxacarb)	0.11 - 3-leaf	11,717.1	bcdef	13.0	a	4615.1	abc
18. XDE 225 (Proaxis)	0.015 – early PF	14,749.7	a	12.9	a	5450.3	a
19. Steward	0.11 - PF	10,545.4	ef	13.1	a	3998.0	c
20. MTI-500 (etofenprox) 1.5%G	0.18 - PF	13,026.6	abcd	12.7	a	4333.3	bc
21. F0570 0.8 EC (Mustang Max)	0.02 - 3-leaf	11,923.9	bcdef	12.4	a	4604.8	abc
22. Neemazal G	0.1 - PF	10,476.5	f	13.2	a	4172.2	bc

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

Table 5. Treatment list for ring plot test of biological insecticides for RWW control, 2005.

Product	Rate (lbs. AI/A)	Product/A	Appl. Timing	Appl. Date	RWW Introduction
1. Neemazal G	0.02	20 lbs.	PF	25 May	2 & 3 leaf
2. Neemazal G	0.04	40 lbs.	PF	25 May	2 & 3 leaf
3. Neemazal G	0.02	20 lbs.	3-leaf	10 June	2 & 3 leaf
4. Neemazal G	0.04	40 lbs.	3-leaf	10 June	2 & 3 leaf
5. Neemazal G	0.02	20 lbs.	PF	25 May	1 & 2 leaf
6. Neemazal G	0.04	40 lbs.	PF	25 May	1 & 2 leaf
7. Aza-Direct	0.02	26 oz.	PF	25 May	2 & 3 leaf
8. Aza-Direct	0.02	26 oz.	3-leaf	10 June	2 & 3 leaf
9. Untreated	---	---	---	---	2 & 3 leaf

Table 6. Efficacy of biological insecticides for RWW control, 2005.

Product	% Scarred Plants - 17 June		% Scarred Plants - 23 June		RWW per Core (13 July)		RWW per Core (27 July)		Average
1. Neemazal-20 lbs, PF	9.5	a	38.0	a	2.10	ab	0.20	a	1.2
2. Neemazal-40 lbs, PF	18.0	a	17.0	b	2.25	ab	0.25	a	1.3
3. Neemazal-20 lbs, 3-leaf	18.5	a	27.0	ab	2.80	a	0.35	a	1.6
4. Neemazal-40 lbs, 3-leaf	21.5	a	21.0	ab	2.70	ab	0.15	a	1.5
5. Neemazal-20 lbs, PF	14.0	a	24.5	ab	1.40	ab	0.10	a	0.8
6. Neemazal-40 lbs, PF	21.0	a	33.0	ab	2.15	ab	0.25	a	1.2
7. Aza-Direct-PF	21.5	a	22.5	ab	1.33	b	0.2	a	0.8
8. Aza-Direct-3-leaf	9.0	a	26.0	ab	1.25	b	0.15	a	0.7
9. Untreated	17.5	a	29.5	ab	2.35	ab	0.25	a	1.3

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

Table 7. Yield parameters from biological insecticides for RWW control test, 2005.

Product	Biomass - Straw + Grain (lbs./A)		% Moisture		Estimated Grain Yield (lbs./A)	
1. Neemazal-20 lbs, PF	14611.9	ab	16.5	a	3501.8	ab
2. Neemazal-40 lbs, PF	15783.6	ab	16.4	a	3959.6	ab
3. Neemazal-20 lbs, 3-leaf	14474.1	ab	16.4	a	3468.5	ab
4. Neemazal-40 lbs, 3-leaf	13095.6	b	16.2	a	3169.6	b
5. Neemazal-20 lbs, PF	15714.7	ab	16.1	a	3787.7	ab
6. Neemazal-40 lbs, PF	13371.3	b	16.4	a	3349.6	ab
7. Aza-Direct-PF	15921.5	ab	16.6	a	3955.9	ab
8. Aza-Direct-3-leaf	17713.5	a	16.0	a	4469.8	a
9. Untreated	18195.9	a	16.6	a	4325.5	ab

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

Table 8. Treatments compared and RWW populations in Study 1 for Azadirachtin greenhouse study; 2005.

Treatment	Timing	Rate	RWW per Pot	
1. AZA-Direct	pre-flood	6.5 oz./A (0.005 lbs. AI/A)	19.25	a
2. AZA-Direct	foliar - 1 day before infesting	6.5 oz./A (0.005 lbs. AI/A)	18.25	ab
3. Neemazal G	pre-flood	5 lbs./A (0.005 lbs. AI/A)	13.75	ab
4. Neemazal G	foliar - 1 day before infesting	5 lbs./A (0.005 lbs. AI/A)	10.50	abcd
5. AZA-Direct	pre-flood	13 oz./A (0.01 lbs. AI/A)	15.75	ab
6. AZA-Direct	foliar - 1 day before infesting	13 oz./A (0.01 lbs. AI/A)	6.50	bcd
7. Neemazal G	pre-flood	10 lbs./A (0.01 lbs. AI/A)	22.00	a
8. Neemazal G	foliar - 1 day before infesting	10 lbs./A (0.01 lbs. AI/A)	13.00	abc
9. AZA-Direct	pre-flood	19.5 oz./A (0.015 lbs. AI/A)	1.00	d
10. AZA-Direct	foliar - 1 day before infesting	19.5 oz./A (0.015 lbs. AI/A)	1.00	d
11. Neemazal G	pre-flood	15 lbs./A (0.015 lbs. AI/A)	20.50	a
12. Neemazal G	foliar - 1 day before infesting	15 lbs./A (0.015 lbs. AI/A)	14.25	ab
13. AZA-Direct	pre-flood	26 oz./A (0.02 lbs. AI/A)	2.00	cd
14. AZA-Direct	foliar - 1 day before infesting	26 oz./A (0.02 lbs. AI/A)	0.75	d
15. Neemazal G	pre-flood	20 lbs./A (0.02 lbs. AI/A)	14.75	ab
16. Neemazal G	foliar - 1 day before infesting	20 lbs./A (0.02 lbs. AI/A)	12.00	abcd
17. AZA-Direct	pre-flood	52 oz./A (0.04 lbs. AI/A)	0.50	d
18. AZA-Direct	foliar - 1 day before infesting	52 oz./A (0.04 lbs. AI/A)	0.75	d
19. Neemazal G	pre-flood	40 lbs./A (0.04 lbs. AI/A)	18.50	a
20. Neemazal G	foliar - 1 day before infesting	40 lbs./A (0.04 lbs. AI/A)	13.25	ab
21. AZA-Direct	pre-flood	0	18.00	ab
22. AZA-Direct	foliar - 1 day before infesting	0	11.00	abcd
23. Neemazal G	pre-flood	0	14.00	ab
24. Neemazal G	foliar - 1 day before infesting	0	16.25	ab

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

Table 9. Evaluation of potential of Azadirachtin to repel RWW; greenhouse study,2005.

Treatment	Timing	Rate	RWW per Pot	
1. AZA-Direct	pre-flood	6.5 oz./A (0.005 lbs. AI/A)	16.00	abc
2. AZA-Direct	foliar - 1 day before infesting	6.5 oz./A (0.005 lbs. AI/A)	16.67	abc
3. Neemazal G	pre-flood	5 lbs./A (0.005 lbs. AI/A)	19.50	abc
4. Neemazal G	foliar - 1 day before infesting	5 lbs./A (0.005 lbs. AI/A)	23.50	ab
5. AZA-Direct	pre-flood	13 oz./A (0.01 lbs. AI/A)	11.00	bc
6. AZA-Direct	foliar - 1 day before infesting	13 oz./A (0.01 lbs. AI/A)	12.75	bc
7. Neemazal G	pre-flood	10 lbs./A (0.01 lbs. AI/A)	14.00	bc
8. Neemazal G	foliar - 1 day before infesting	10 lbs./A (0.01 lbs. AI/A)	20.25	abc
9. AZA-Direct	pre-flood	19.5 oz./A (0.015 lbs. AI/A)	8.00	c
10. AZA-Direct	foliar - 1 day before infesting	19.5 oz./A (0.015 lbs. AI/A)	9.25	c
11. Neemazal G	pre-flood	15 lbs./A (0.015 lbs. AI/A)	18.75	abc
12. Neemazal G	foliar - 1 day before infesting	15 lbs./A (0.015 lbs. AI/A)	14.50	bc
13. AZA-Direct	pre-flood	26 oz./A (0.02 lbs. AI/A)	13.75	bc
14. AZA-Direct	foliar - 1 day before infesting	26 oz./A (0.02 lbs. AI/A)	11.50	bc
15. Neemazal G	pre-flood	20 lbs./A (0.02 lbs. AI/A)	17.50	abc
16. Neemazal G	foliar - 1 day before infesting	20 lbs./A (0.02 lbs. AI/A)	15.50	bc
17. AZA-Direct	pre-flood	52 oz./A (0.04 lbs. AI/A)	15.25	bc
18. AZA-Direct	foliar - 1 day before infesting	52 oz./A (0.04 lbs. AI/A)	16.00	abc
19. Neemazal G	pre-flood	40 lbs./A (0.04 lbs. AI/A)	17.50	abc
20. Neemazal G	foliar - 1 day before infesting	40 lbs./A (0.04 lbs. AI/A)	23.25	ab
21. AZA-Direct	pre-flood	0	19.75	abc
22. AZA-Direct	foliar - 1 day before infesting	0	15.00	bc
23. Neemazal G	pre-flood	0	28.25	a
24. Neemazal G	foliar - 1 day before infesting	0	18.50	abc

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

Table 10. Evaluation of potential for Azadirachtin to sterilize RWW, greenhouse studies, 2005.

Treatment	Timing	RWW per Pot	
Aza-Direct	original plant	0.5	d
Aza-Direct	second plant	4.8	cd
Aza-Direct	third plant	11.3	c
Neemazal	original plant	1.5	d
Neemazal	second plant	5.5	cd
Neemazal	third plant	27.0	b
UTC	original plant	12.3	c
UTC	second plant	6.5	cd
UTC	third plant	35.0	a

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

Table 11. Treatments evaluated in non-target study, 2005.

Product	Rate	Timing
1. Neemazal	0.02 lbs. AI/A	3-leaf
2. Warrior	0.03 lbs. AI/A	3-leaf
3. Warrior	0.03 lbs. AI/A	Preflood
4. Warrior	0.03 lbs. AI/A	July armyworm timing
5. Mustang Max	0.025 lbs. AI/A	3-leaf
6. Dimilin 2L	0.125 lbs. AI/A	3-leaf
7. Untreated	---	---
8. dinotefuron 1%G	0.26 lbs. AI/A	3-leaf
9. etofenprox	0.44 lbs. AI/A	3-leaf
10. indoxacarb	0.11 lbs. AI/A	3-leaf

Table 12. RWW infestation severity in untreated plots of representative California rice varieties; phytotoxicity response to Cerano® herbicide is also shown.

Variety	% Scarred Plants [A]		Phytotoxicty Rating (1-5) [B]		RWW per Core (12 July) [A]		RWW per Core (4 Aug.) [A]		Avg.
1. L-205	4.5	a	1.4	d	0.6	ab	0.1	a	0.4
2. M-104	3.5	a	1.1	d	0.7	ab	0.0	a	0.4
3. M-204	2.0	a	4.0	a	0.7	ab	0.1	a	0.4
4. Calmati-201	2.5	a	2.0	cd	0.8	ab	0.1	a	0.5
5. Calhikari-201	2.5	a	3.6	ab	0.1	b	0.1	a	0.1
6. PI506230	2.0	a	2.8	abc	0.9	ab	0.2	a	0.6
7. M-205	4.0	a	3.0	abc	1.1	a	0.1	a	0.6
8. M-202	3.0	a	3.3	abc	0.7	ab	0.0	a	0.4
9. M-206	1.5	a	3.1	abc	1.0	a	0.0	a	0.5
10. S-102	5.0	a	3.5	ab	0.5	ab	0.1	a	0.3
11. Calmochi-101	2.0	a	2.4	bcd	0.3	ab	0.1	a	0.2
12. M-401	4.0	a	3.9	abc	0.4	ab	0.1	a	0.3

[A] Untreated (for RWW) plots.
[B] 1=normal, 5=totally white.

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

Table 13. RWW population in rice systems study, 2005.

Treatment	% Scarred Plants		RWW per Core Sample	
Conventional water seeded	10.6	a	0.1	ab
Conventional drill seeded	2.1	a	0.1	ab
Delayed spring-tilled water seeded	17.6	a	0.28	a
Stale seedbed no till water seeded	18.8	a	0.13	ab
Stale seedbed no till drill seeded	5.1	a	0.05	b

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

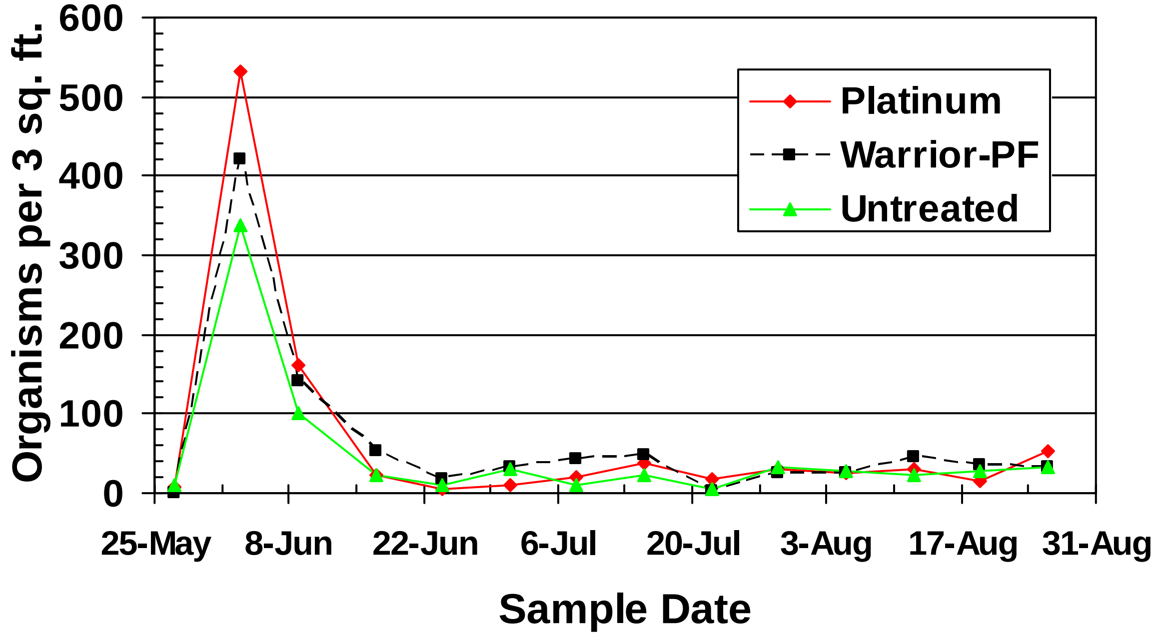


Figure 1. Populations of aquatic insects following preflood insecticide application in rice, 2004.

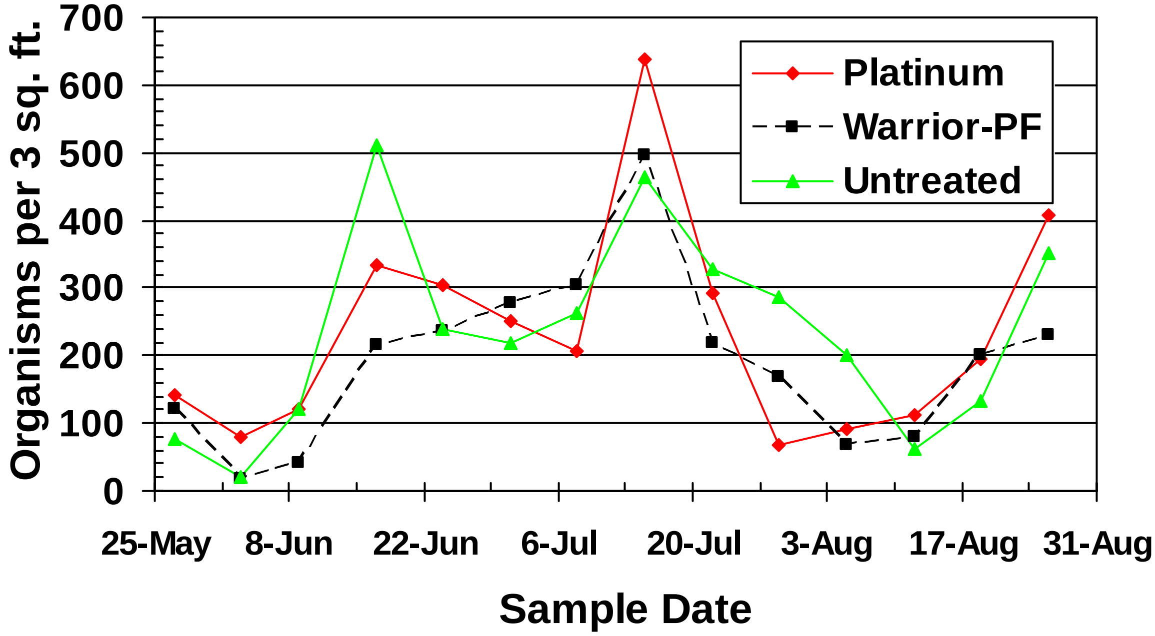


Figure 2. Populations of aquatic invertebrates following preflood insecticide application in rice, 2004.

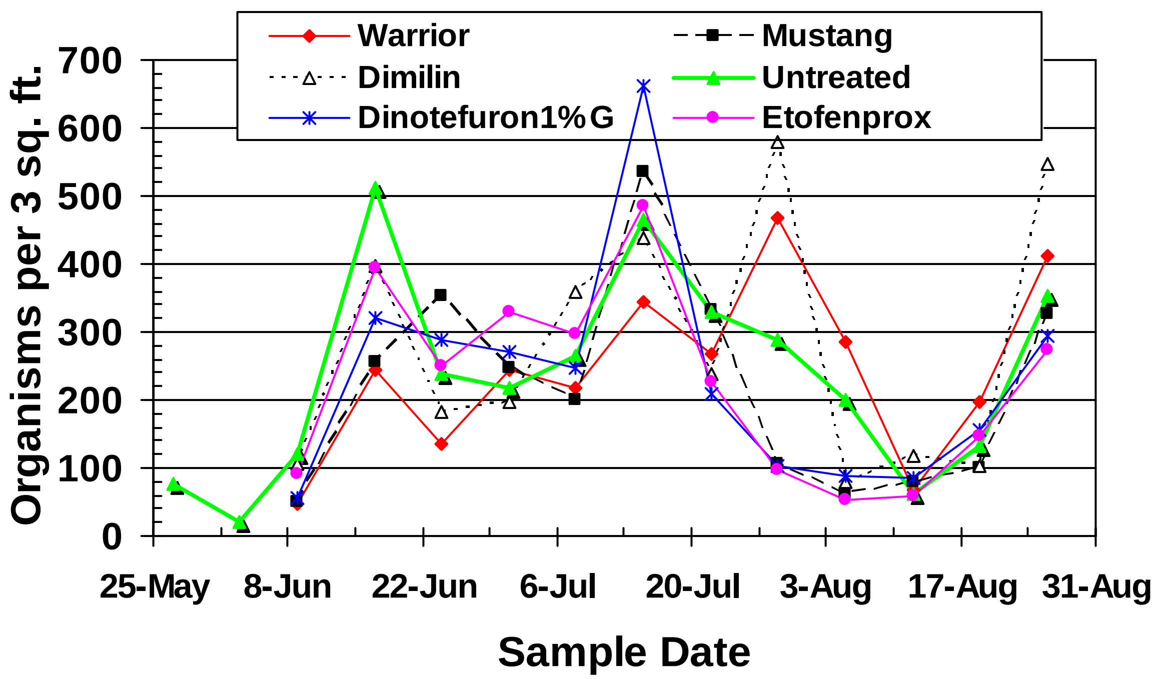


Figure 4. Populations of aquatic invertebrates following application of insecticides at the rice 3-leaf stage, 2004.

Figure 5. Populations of aquatic insects following application of insecticide in mid-July for armyworms in rice, 2004.

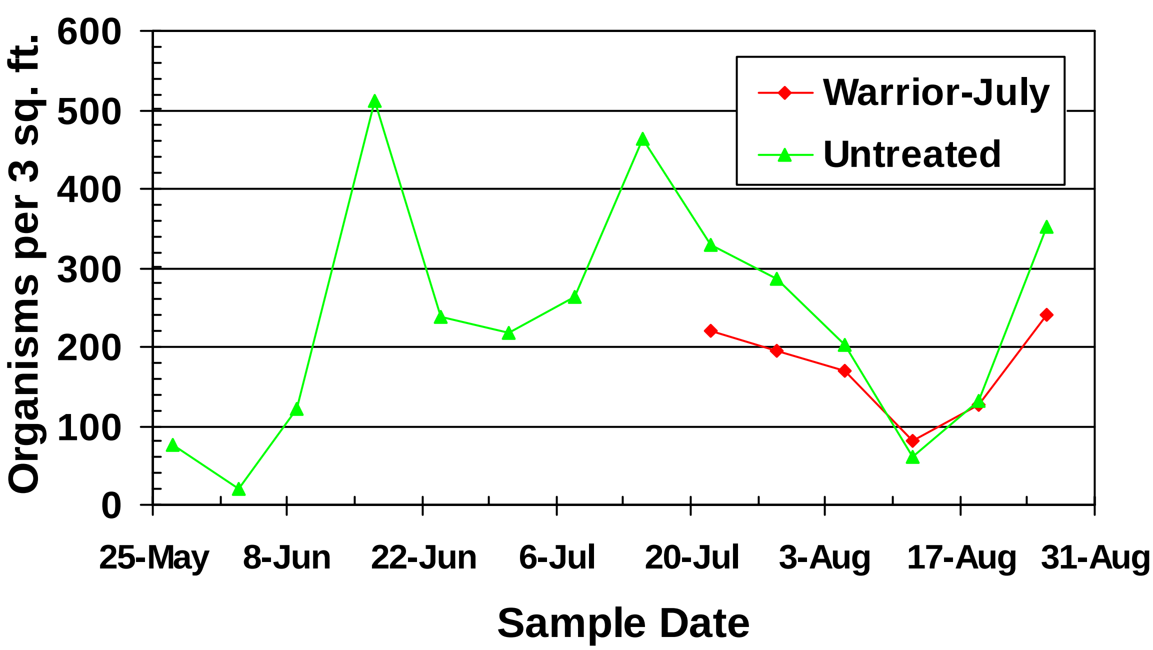
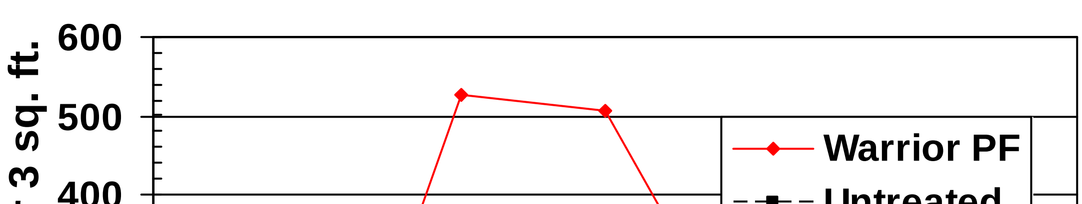


Figure 6. Populations of aquatic invertebrates following application of insecticide in mid-July for armyworms in rice, 2004.



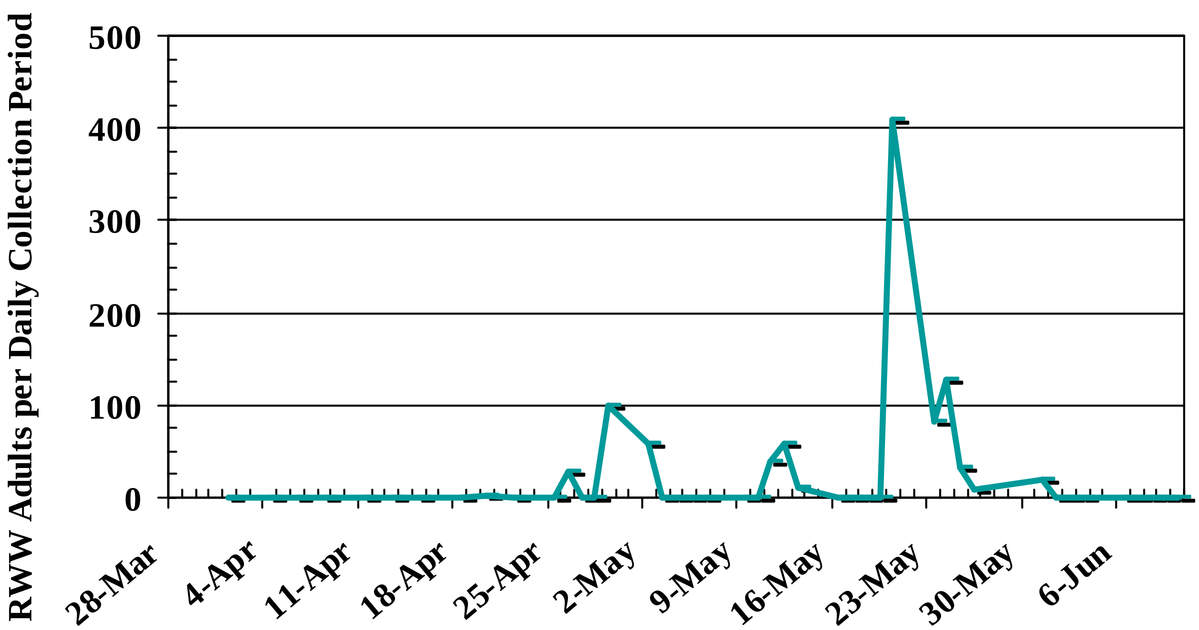
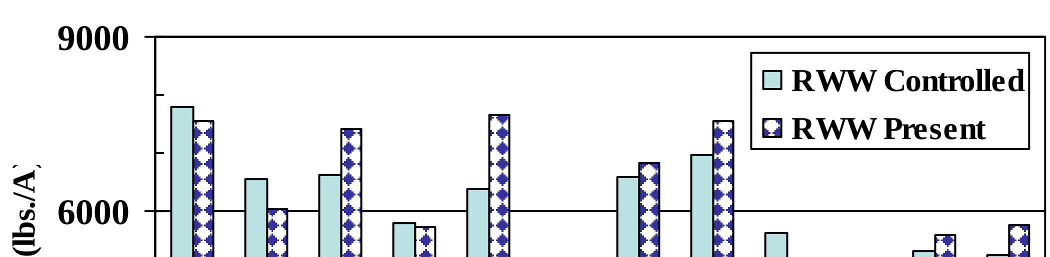


Figure 8. Rice Water Weevil flight as monitored with a light trap at the RES, 2005.



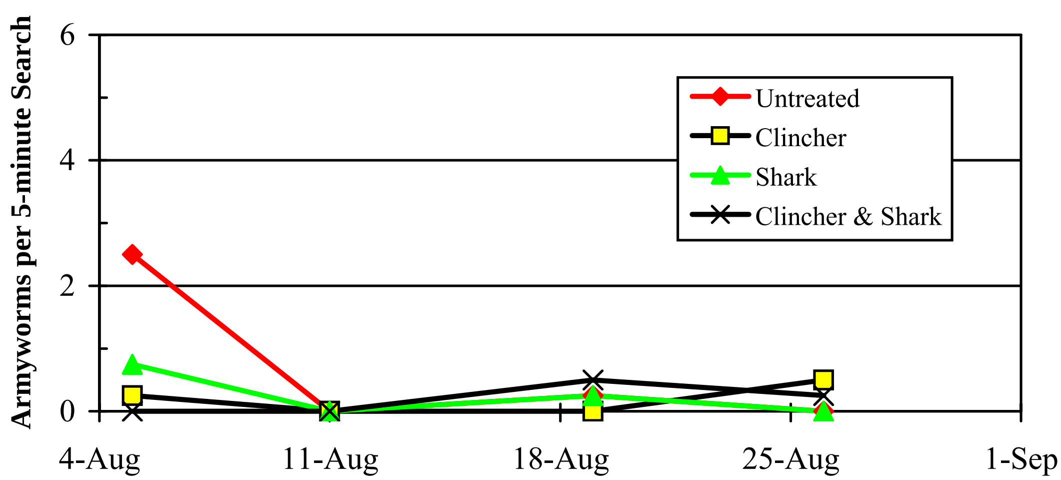


Figure 10. Interaction of weed populations in rice and armyworm levels in rice, 2005.

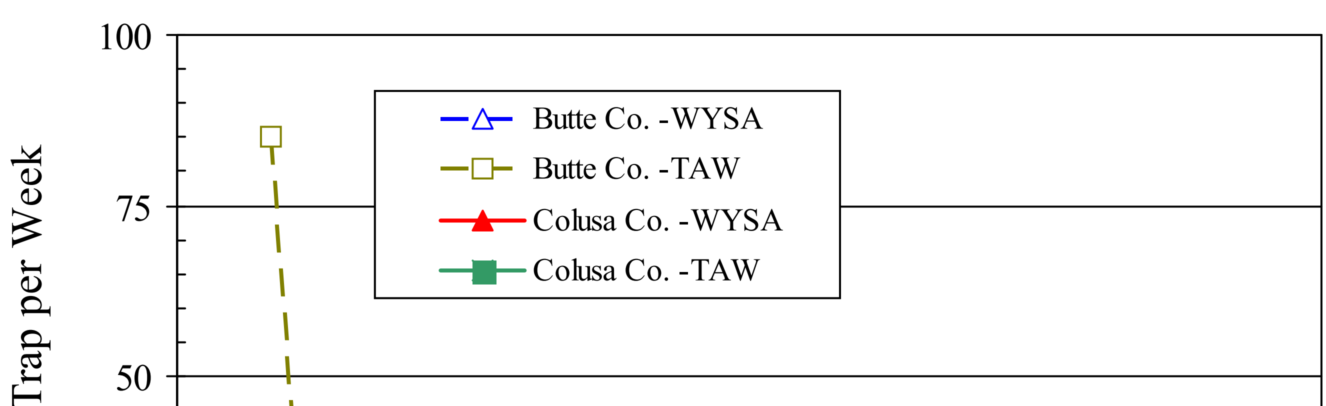


Figure 11. Armyworm moth flight timing (WYSA=western yellow-striped armyworm and TAW-true armyworm) from pheromone traps located near rice fields in Colusa Co. and Butte Co., 2005.

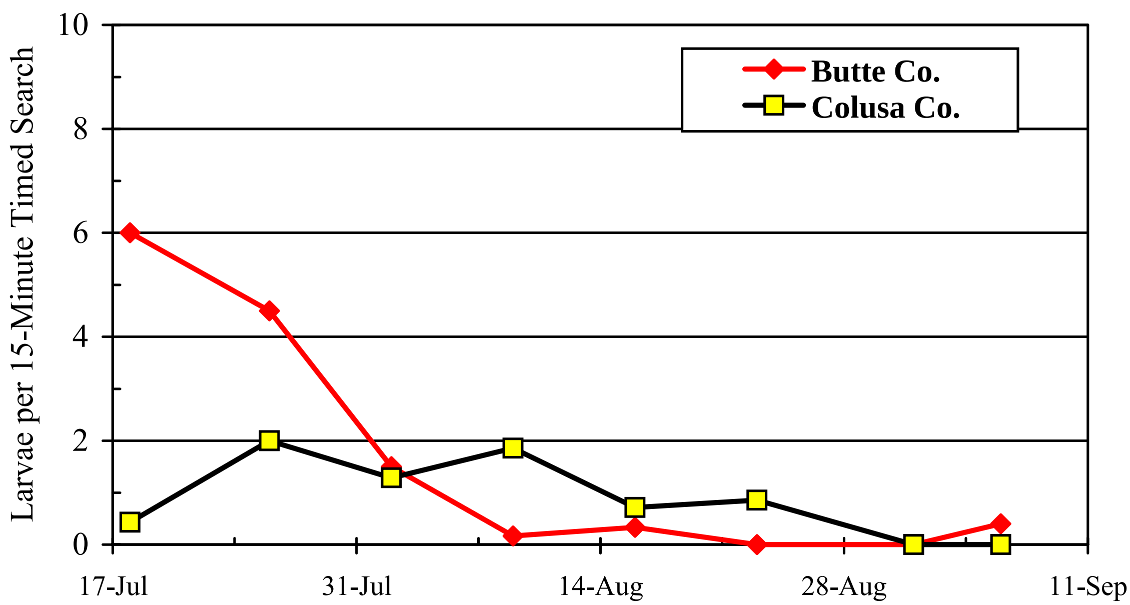


Figure 12. Armyworm larval population in rice fields in Colusa Co. and Butte Co., 2005.