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 exposure time on the efficacy of Warrior pre-flood application for controlling rice water weevil in ring plots.

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

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

**1.5)** 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 usefulness of an in-field floating barrier RWW trap for sampling RWW populations - evaluate factors which influence performance of floating barrier trap for sampling populations of RWW.

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

**Objective 3:** Refinement of rice plant response to rice water weevil infestation so as to better define the number of cost-effective applications needed for post-flood materials.

**3.1)** Study the relationship between timing, i.e., rice plant growth stage, and plant response to RWW-induced injury.

**Objective 4:** To investigate reasons for an increase in armyworm populations and biorational control measures for armyworms and possible involvement of insects in Apeck@ rice; conduct appropriate monitoring and exploratory research activities on emerging and new exotic rice invertebrate pests

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

**4.1.1).** Study the role of weed populations on armyworm populations in rice.
**4.1.2).** Investigate the timing of armyworm moth flight in the rice production region and relationship to armyworm larval populations in rice fields.
**4.1.3).** Investigate the factors that influence armyworm populations in grower rice fields.

<u>SUMMARY OF 2004 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 entirely 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 nine 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 13 May and seeded on 14 May. The application timings were as follows:

13 May, pre-flood (PPI) applications
28 May, 3-leaf stage

Applications of Warrior were also applied on 3, 7, 10, and 17 May to answer specific questions.

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 supplemente d with 10 adults placed into each ring on 26 May and 6 adults into each ring on 2 June. Copper sulfate was applied in early June for algal management, herbicides on 24 May, and nitrogen was top-dressed on 12 July. The following sample dates and methods were used for this study:

**Sample Dates:**

Emergence/ Seedling Vigor: 31 May
Adult Leaf Scar Counts: 2 June
Larval Counts: 21 June and 12 July
Rice Yield: 20 September

**Sample Method:**

Seedling Emergence and Vigor
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). Most stand rating values were 3.0, which represents a Agood@ stand of about 100 seedlings (before hand-thinning) and ratings ranged from 2.8 to 3.5. 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). We have infested rings at extremely high levels and this resulted in 100% of the plants with feeding scars and if the RWW larvae are controlled, there will be no yield losses. 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 untreated and the Dimilin treatment had the highest values at 14.5% scarred plants. These values differed significantly from all the other treatments (Table 2). The 14.5% scarred value was a much lower level than normally achieved. We only evaluate scarring on the two newest leaves. The growing conditions were so ideal in the spring 2004 that new leaves were being added rapidly and the feeding was being quickly "diluted". The 3-leaf stage treatments (pyrethroids) reduced adult feeding as anticipated. Of the Warrior PF treatments, the earliest one (3 May) had a numerically higher value than the other three PF timings (only significantly different from one other timing). The Proaxis and F 0570 preflood applications reduced scarring with the latter being more effective. Among the experimental materials, Platinum, Steward and Etofenprox were very effective and Dinotefuron was moderately effective.

**Larval Counts**

RWW larval counts were made twice during the season. Most individuals were first through third instars with relatively few pupae captured in the first sample and the more developed stages predominated in the second sample. In the 21 June samples (1$^{st}$ coring date), the average densities ranged from 0 to 6.0 RWW per core (Table 3). The average numbers for the 2$^{nd}$ coring date (12 July) ranged from 0 to 5.0 RWW per core.

<u>Experimental materials versus registered standards.</u> Three experimental insecticide active ingredients, Etofenprox, Dinotefuron, and Steward, were tested for the first time against RWW in California in 2004. There has been a renewed interest in this area from the agrichemical companies and regulatory agencies because of the cancellation of Icon registration in the southern rice. They are hesitant to rely on post-flood materials for RWW management. Etofenprox and Steward, both applied at the 3-leaf stage, were very effective for RWW control. The higher rate of Steward (0.11 lbs. AI/A) was slightly more effective than the lower rate and the double application of the lower rate was more effective than the single application. It was interesting that the efficacy with Steward was higher in the second sampling than in the first. Most materials perform better nearer the to the application than farther away. This may indicate that Steward is somewhat slow to act or to be "activated". 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 was not effective on RWW in 2004 testing. In fact, larval populations were higher than in the untreated. Apparently, there was a problem with the product/formulation that was sent for testing. This product is in the neonicotinoid class of chemistry (same as Thiamethoxam) and these materials are known as good soil insecticides. Dinotefuron was tested as a preflood and a post-flood application and both were unsuccessful. Research continued on Platinum[7] (Thiamethoxam), Proaxis[7] (gamma-cyhalothrin), and F0570 (similar active ingredient as Mustang; marketed as Mustang Max in the south and will apparently also be registered in CA) as soil-applied, post-flood and post-flood treatments, respectively. All three of these products provided very good RWW control. MANA lambda-cyhalothrin is a generic formulation of Warrior. It was tested at the 3-leaf stage with two rates and both were very effective and similar to the performance of Warrior. For the registered standards, treatment #2 (Dimilin) and treatment #5 (Warrior) were both effective; Dimilin showed some slippage in control in the second sampling date but the control was adequate.

Soil application of pyrethroid products. 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. In 2003, applications made at 5 days before flooding did not control RWW larvae; applications nearer to the time of flooding were successful. These results differed from 2002 in which an application at 6 days before flooding was successful. In 2004, a Warrior application made to the soil at 10, 6, 3, and 0 days before flooding universally controlled RWW larvae. The application of Warrior at 4 days after flooding was only marginally successful. Proaxis and F0570, applied preflood at 1 day before flooding, also provided excellent RWW control.

**Rice Yield**

Rice grain yields ranged from 6156 to 8007 lbs./A. These yields were fairly representative yields. Rice biomass at harvest ranged from slightly less than 11.1 to 14.9 tons/A. The relationship between RWW numbers and either grain yield or biomass yield was not particularly good. The three standard treatments, Warrior (Trt. 5), F0570 (Trt. 21), and Dimilin (Trt. 2) produced moderately high grain yields (Table 4). The highest yield was from the Warrior preflood treatment applied on the day of flooding. Yield from the experimental materials Etofenprox, Dinotefuron, Steward, Proaxis, and Platinum were generally intermediate. Even the Dinotefuron treatment, that did not provide RWW control, had a fairly high yield. It appears that the ideal growing conditions in 2004 (early seeding, warm spring, no extreme conditions in the summer, early harvest in the fall) allowed the plants to outgrow and compensate for the RWW feeding.

**1.3)** Rice water weevil control - comparison of registered and experiential products in large plots

Rice water weevil control was compared in 0.03-acre plots with 3 replications at RES. These plots were also used for the nontarget study (Objective 1.5). The RWW infestation and timing was natural compared to the ring tests so I believe that this style of testing has a purpose. The treatments listed in Table 5 were evaluated. The field was flooded on 20 May and seeded with ›M-202' on 21 May.

The standard sampling was done in these plots. Rice damage from RWW adults was evaluated on 8 June. RWW larval samples were collected on 16 July and 22 July. Yield was quantified by hand harvesting three 10.8 $ft^2$ areas per plot on 4 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 1% scarring in the untreated. RWW larval data showed very few RWW larvae in this plot area. Yield data showed the highest grain yields with the Warrior PF and Platinum treatments (Table 6), although there were not large differences in yield among the treatments. Yields overall were fairly low.

**1.4)** 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. A greenhouse test was done in 2004 to evaluate the activity of Neemazal™ 0.1%G against RWW. A key advantage of this product is the active ingredient is formulated into a slow release granule.

Rice (variety M-202) was grown in plastic cups (4.5 inch diameter x 6 inches 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 were placed in each pot. Pots were constantly flooded during the study. Rice water weevil adults were collected from untreated rice fields in Butte Co and held for 5-7 days in vials with rice leaf tissue in the laboratory until needed. Adults were placed on the potted rice plants (five per pot) when the rice was in the ~2 leaf stage. Adults were confined on to 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 7 days after which they were hand-removed. Eggs typically hatch about 5-7 days after oviposition. Pot contents were processed on 8 July 2004 using the standard washing-flotation technique.

Treatments (with 6 replications per treatment) were applied as follows:

1.) PAG0.1 (25 grams per pot) at the time of seeding (3 June)

2.) PAG0.1 (25 gram per pot) at the time of introduction of RWW adults (15 June)

3.) PAG0.1 (25 grams per pot) at the time of removal of RWW adults (22 June)

4.) Untreated control

**Results:**

Rice seeds germinated and established poorly in some pots; however, there was no effect of the treatments on plant establishment and growth. Results were 0 RWW (100% control) for treatments 1 (applied at the time of seeding) and treatment 3 (applied at the time of removal of RWW adults). Treatment 2 had an average of 4.3 RWW larvae per pot (81.5% control). Populations in the untreated pots averaged 23.2 RWW per pot. Additional testing of this product is needed but these results show considerable promise.

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

The plot design for this study was detailed in **1.3)**. Populations of non-target organisms were evaluated weekly from 27 May to 26 August. 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, quadrant samples (4 per plot) were used and these samples collected all organisms within a 0.55 $ft^2$ area.

A small portion of the results from 2004 are shown in Fig. 1 and 2. Most of the samples are not yet counted and/or data summarized. The total number of invertebrates following preflood applications and post-flood applications is shown in Fig. 1 and 2, respectively. Only the sample dates that have been completely processed are shown. Numbers of animals were much higher in 2004 than in 2003 early in the season; the field in 2004 had a high infestation of clam shrimp which were not present in the field in 2003. For the preflood treatments, it appears that the insecticide had minimal effects on the total number of invertebrates in 2004. Post-flood applications were more detrimental to numbers of invertebrates with all five treatments reducing numbers for the first 2 weeks after application. Numbers of organisms following Warrior applications were reduced through the 22 July sample date (7 weeks after treatment).

Data from 2003 are completely summarized (they were in progress as the 2003 report was written). Data for the total number of invertebrates, for coleopteran (beetles), and for Annelids (segmented worms, i.e., earthworms) are shown (Fig. 3-8). In 2003, invertebrates were fairly rare for the first 2-3 weeks of sampling (in 2003 samples were collected twice per week through June) or until mid-June. Populations of total invertebrates were suppressed by the preflood treatments until early July and the Icon treatment appeared to suppress populations season-long. The post-flood treatments were generally detrimental to invertebrates until mid-August (Dimilin had less effects than the other treatments). The July Warrior application was particularly harmful to populations. On beetles, the effects of the preflood and post-flood treatments were significant and clearly reduced populations. This is not surprising since these materials are targeted for the control of a beetle and they also kill beneficial beetles. On Annelids, the results are also fairly clear in that none of the treatments had any consistent detrimental effect on populations. In summary, the effect of the materials on non-targets depends on the species/group in question and on the season. For instance, it appears that the effects in 2003 were more noticeable than in 2004.

**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. RWW flight timing and intensity varies annually; for instance flight was low in 2002 (655 captured), high in 2001 (over 8,000 captured) and intermediate in 2003 (1891 RWW adults). In 2004, RWW flight was also very low with only 703 adults trapped (Fig. 9). The flight in 2004 occurred very early and was completed by 3 May. There was a small peak in flight from 7 to 9 April and the rest of the flight occurred from 23 April to 3 May. The spring environmental conditions that were conducive to field preparation and seeding were also ideal for RWW flight. The adults fly in search of flooded fields, I believe. The amount of early-season flooded fields probably enticed many of the adults to not fly and they instead simply crawled to nearby, flooded fields. RWW requires flight conditions that include evening spring temperatures greater than $70F^0$, fairly high humidity, and calm winds.

**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, this study was done at a grower field location that historically has had a high RWW infestation.

Ten varieties were evaluated:

1. L-205
2. M-104
3. M-204
4. M-202
5. M-401
6. M-402
7. M-206
8. Calmati-201
9. Calhikari-201
10. Calmochi-101.

These varieties were chosen to cover the range of rice types, maturities, and commonly grown varieties in California.

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 (15 x 30 ft.); four plots were treated with an insecticide for RWW and four plots were left untreated. The study was set up as a randomized complete block design with four replicates.

Plots were flooded on 4 May and seeded on 7 May. RWW adult feeding scars, seedling establishment rating, larval population numbers, and grain yields (210 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.

The naturally-occurring RWW population was moderate in this plot area. Percentage scarred plants, averaged across the varieties were similar (23% for treated plots and 24% for the untreated pots). The insecticide treatment overall reduced larval populations by 72%. In the untreated plots, M-202, Calmati-201, and M-401 had the most leaf scarring from RWW adults although there was less than a 2x difference in scarring across all ten varieties. Larval populations in untreated plots varied to a greater degree. Larval levels were greatest in the M-202, Calhikari-201, and M-402 plots. There was a 5 times range in larval populations across the varieties. Fig. 10 summarizes the scarring and larval data by setting data from M-202 as the standard (to a value of 1.0) and comparing the other varieties to this value.

Grain yields ranged from 8932 (Calmati-201) to 10916 lbs./A (M-401) (Table 11). The RWW population, although moderate in scope, was too low to significantly influence grain yield. In fact, there was only a 0.2% difference in yield between the treated plots and the untreated plots. Only the M-402, Calmati-201, and Calhikari-201 varieties showed a yield advantage from the treatment and that was less than 1% and probably not statistically significant. As shown in Chemical Control of Rice Water Weevil - Ring Plots test, the weevil feeding did not impact rice yields much in 2004.

**2.3)** Evaluate the usefulness of an in-field floating barrier RWW trap for sampling RWW populations.
**2.3.1)** Evaluate factors which influence performance of floating barrier trap for sampling populations of RWW.

From 2001 to 2003, we conducted research on the applicability of a floating barrier trap for monitoring populations of RWW. This information should be useful for determining if a field needs to be treated with post-flood insecticides. A leaf scarring technique was developed for use with Furadan in the 1980's. However, when using postflood materials that are designed to prevent egg deposition, leaf scarring occurs after egg deposition has started. A floating barrier trap was developed at the Univ. of Arkansas as their rice growers were facing the same questions. Our work in 2001, 2002, and 2003 in 27 grower fields showed that if 1.5 or more RWW adults per trap per day are captured, this is indicative of the need to treat the field. This decision should be made during the first 5-7 days after flooding.

The results from the grower field studies with the floating barrier trap prompted some additional questions that could be best addressed in small plot studies. We worked on these issues in 2002 and 2003 and completed one study in 2004. We were interested in validating an observation from the grower field studies to determine the relationship between rice growth stage and trap efficacy.

Rice was seeded into 28 sq. ft. rings on 14 May and the plots were covered with the floating row cover material. Plots were infested with 2 RWW adults per sq. ft. at the 1, 2, 3, and 5 leaf stages. The corresponding dates for infestation were 20 May, 26 May, 31 May, and 7 June. One set of plots were not infested to act as a Acheck@. Upon infestation, one floating barrier trap was placed into each plot to see how effectively it captured adults. RWW captures were monitored for about 2 weeks after infestation.

The percentage RWW captured differed with plant growth stage (Table 7). When the infestations occurred at the 1 leaf stage, 8.0% of the adults were captured over the next the 2 to 3-week period. With larger plants, captures were 5.8, 4.9, and 0%, respectively, on 2, 3, and 5 leaf stage plants, respectively.

**2.4)** 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 2004, 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 2004, 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 19 July (RWW larvae) using standards methods. RWW infestation in this plot was extremely low. No adult scarring was recorded and larval populations were less than 0.2 per sample; there were no differences among the treatments.

**Objective 3:** Refinement of rice plant response to rice water weevil infestation so as to better define the number of cost-effective applications needed for post-flood materials.

**3.1)** Study the relationship between timing, i.e., rice plant growth stage, and plant response to RWW-induced injury.

My laboratory has been researching this area for several years. A number of studies have been specifically designed to investigate this area and in other cases we have been able to draw some conclusions from studies set up for other reasons. This is no longer a primary focus of our research on rice but some efforts are still made annually in this area. These studies require establishing plots with good stands free from other pests and being able to manipulate the populations of the pest as planned. We have been particularly interested in recent years in determining how large of a rice plant can withstand RWW feeding without suffering a yield loss. In 2000, any RWW infestations after the 3 leaf stage did not result in a loss of grain yield. However, in 2001, the yield loss was more severe than that seen in similar studies in 2000. With a moderate RWW infestation, grain yields were significantly reduced by 32.1% on 3-4 leaf plants (stage at which adults were introduced) and by 3.5% on 8-9 leaf plants. Results from 2003 were more similar to the 2000 results; rice grain yields were significantly reduced by severe, early RWW feeding. With infestations of adults at the 2-leaf stage, yields were reduced by about 50%. Yield losses averaged about 15% when the infestations were delayed by 1 week. The later infestation timings had no consistent effects on yield.

In 2004, yield data were collected from the study conducted for Objective 2.3.1. These plots were infested with 2 RWW adults per sq. ft. at either the 1, 2, 3, or 5 leaf stage (the fifth treatment was uninfested). RWW larval counts were made on 24 June 15 July and yield data were collected on 4 Oct. Results (Table 7) showed that the yield in the uninfested plots and that in plots infested with adults at the 3 and 5 leaf stages did not differ statistically (there was a trend for lower yields in infested plots). This was in spite of significant differences in larval populations. Grain yields in plots infested at the 1 and 2 leaf stages were significantly reduced compared with uninfested plots even though the larval populations in these plots were not as high as those infested later. Again this points to the fact that as the rice plants develop more they increase the ability to withstand and to compensate for the root damage.

In a second study, plots were seeded on 14 May with ›M-202' at the Rice Experiment Station. These plots were covered with a floating row cover material to retain controlled infestations of RWW adults that placed in the rings at specified times and numbers. The numbers used were 29 RWW adults per ring (a low-moderate infestation) and 58 RWW adults per ring (a severe infestation). RWW adults were collected from nearby fields and placed in the rings. Each of the three infestation severities (including a treatment which was uninfested) was initiated at six plant growth stages 1.) 1-leaf stage rice, 2. ) 2 leaf, 3.) 3 leaf, 4.) 4 leaf, and 5.) 5 leaf. A variation of this study has been done in previous years, but in 2004 a 1-leaf stage infestation timing was added. Our research with the floating barrier trap has shown that RWW adults actually move into rice fields at this early timing. Data were collected on plant scarring by adult RWW, larval numbers, plant growth, development data (including panicle emergence), and rice yield.(including numbers of panicles). Only the grain yield data will be discussed herein.

Scarring from adult RWW was substantial in these studies. Plots infested with 58 RWW adults had plants that were 100% scarred; scar incidence in the 29 RWW infestation treatment was generally 80-90%. In fact, adult feeding alone completely killed plants in several of the 1-leaf stage timings and in the high infestation treatment of the 2-leaf stage timing. Larval populations peaked at 10.8 per core sample; this occurred with infestations of adults at the 4-leaf stage (Fig. 11). Infestation at earlier plant growth stages had fewer larvae because the severe damage to the plants hindered larval survival. Reductions in grain yield were severe (77%) with the 1-leaf stage infestations (Fig. 11). This early and high of an infestation, that was sustained (due to the row covering in our case), was probably much more severe than in a natural situation. However, infestations of adult RWW at the 2, 3, 4, and 5 leaf stages resulted in an average of 25.8, 20.4, 8.7, and 0% grain yield loss, respectively.

**Objective 4:** To investigate reasons for an increase in armyworm populations and biorational control measures for armyworms and possible involvement of insects in Apeck@ rice; conduct appropriate monitoring and exploratory research activities on emerging and new exotic rice invertebrate pests.

Armyworms have developed into significant pests of rice during the last 5+ years. An insecticide application to control these larval 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. Armyworm larvae damage rice plants by chewing off sections of leaves. Rice plants are fairly tolerant of this damage and significant yield reduction can occur if defoliation is greater than 25% at 2 to 3 weeks before heading. Larvae also feed on the developing panicles and this damage may cause kernels to Ablank@. Treatment thresholds for this damage are 10% or more of panicles with damage within a sq. ft. area and worms are still present. However, the problem does seem to be escalating. Two species of armyworms are present in Sacramento Valley rice fields; the western yellow-striped armyworm (*Spodoptera praefica*) and the Atrue@ armyworm (*Pseudaletia unipuncta*). Studies continued in 2004 to investigate why this pest appears to be increasing in importance and to develop management schemes for armyworms.

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

Armyworms have many host plants and, in fact, the western yellow-striped armyworm 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 investigated this relationship in 2004 by setting up plots with 1.) very few weeds, 2.) predominantly grassy weeds, 3.) predominantly broad -leaf weeds, and 4.) both grassy and broad-leaf weeds. This was done by treating plots (20 by 30 ft.) with Clincher, Shark, or both materials on 24 June. Data were collected weekly on armyworm populations and on weed incidence.

No armyworms were sampled until late July and populations peaked in mid-August (Fig. 12). Results showed a trend for fewer armyworms in plots with weeds controlled vs. plots with high levels of weeds. Weeds populations were low to moderate even in untreated plots.

**4.1.2).** Investigate the timing of armyworm moth flight in the rice production region and relationship to armyworm larval populations in rice fields.
**4.1.3).** 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 2004. 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. 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 peaked in early-mid Aug. (Fig. 13). Western yellow-striped armyworm moth captures peaked in early Aug. and true armyworms were trapped about 2 weeks later. Slightly higher populations of western yellow-striped armyworm were present in Colusa Co. than Butte Co. whereas the opposite was true for the other species. During a typical August day, about 22-25 degree-days will accumulate for armyworm development. Given that following peak moth capture, about a week is needed for mating and egg development, ~4 days for egg hatch, and 5-7 days for the larvae to develop to a size which can be easily found, peak larval populations in fields should occur about 2 weeks later. As shown in Fig. 14, this corresponds to what we found in the fields where peak larval populations occurred on 24 Aug. Armyworm populations were nil on 10 Aug. and increased to 7.6 and 9.8 worms per 5-minute search in Butte and Colusa Co., respectively. In 2004, most of the rice matured past the susceptible stage at this time. Armyworm larvae were collected during this peak period and held in the laboratory on artificial diet. A significant portion of the armyworms were parasitized with a small wasp (probably *Apanteles militaris*). This is an area that warrants additional research. 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.

**Acknowledgments:**

There are several people that we would like to acknowledge that contributed to the operations and success of the 2004 rice invertebrate pest management project. We thank Crompton/Uniroyal Chemical Co., Syngenta, FMC, Dow Agroscience, Valent, 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.

**PUBLICATIONS OR REPORTS:**

Godfrey, L. D., K. C. Windbiel, and R. R. Lewis. 2004. Influence of insecticide applications on non-target-fauna in rice systems. Calif. Rice Experiment Station Field Day Report. pp 11-12.

Godfrey, L. D. and R. R. Lewis. 2004. Update on improved management strategies for important insect pests of rice. Calif. Rice Experiment Station Field Day Report. pp 33-35.

Godfrey, L. D. and R. R. Lewis. 2003. Annual report comprehensive research on rice, RP-3. pp. 107-136.

Godfrey, L. D. 2003. 35th Annual report to the California rice growers. Protection of rice from invertebrate pests. pp 22-24.

**PROJECT NO. RP-3**

## CONCISE GENERAL SUMMARY OF CURRENT YEAR=S (2004) RESULTS:

Larry D. Godfrey, Richard Lewis, and Karey Windbiel

Research was conducted in 2004 on various aspects of rice water weevil (RWW) and armyworm (AW) biology; results from these studies will complement investigations on insecticidal management to build cost-effective, environmentally compatible management schemes for these pests. A study was continued to evaluate the effects of commonly used and experimental rice insecticides on non-target invertebrates in rice fields. These organisms could play an important role in mosquito management; this area has taken on added importance with the emphasis on West Nile Virus in California. Significant progress was made on all objectives especially on the AW research which was an added thrust in 2004. The rice water weevil is the most important invertebrate pest of California rice, although armyworms are becoming more important. Dimilin[7] 2L, Warrior[7] and Mustang[7] are the insecticides used to control both of these pests. The efficacy of new insecticides and alternative application methods were stressed.

**Rice Water Weevil:** Studies were continued in 2004 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. Three experimental insecticide active ingredients, Etofenprox, Dinotefuron, and Steward, were tested for the first time against RWW in California in 2004. There has been a renewed interest in this area from the agrichemical companies and regulatory agencies because of the cancellation of Icon registration in the southern rice and the additional scrutiny placed on rice insecticides due to West Nile Virus. Etofenprox and Steward, both applied at the 3-leaf stage, were very effective for RWW control. 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 was not effective on RWW in 2004 testing. Apparently, there was a problem with the product/formulation that was sent for testing. This product is in the neonicotinoid class of chemistry (same as Thiamethoxam) and these materials are known as good soil insecticides. Research continued on Platinum[7] (Thiamethoxam), Proaxis[7] (gamma-cyhalothrin), and F0570 (similar active ingredient as Mustang) as soil-applied, post-flood and post-flood treatments, respectively. All three of these products provided very good RWW control. MANA lambda-cyhalothrin is a generic formulation of Warrior and performed comparable to Warrior. Studies were conducted to evaluate possible changes to Warrior use patterns to improve efficacy and ease of use. Warrior applied as a soil treatment, a method which would provide added flexibility to growers, was studied. One important operational question is how long in advance of the water can the treatment be made. In 2004, a Warrior application made to the soil at 10, 6, 3, and 0 days before flooding universally controlled RWW larvae. Proaxis and F0570 were also included in these studies and applied preflood at 1 day before flooding, also provided excellent RWW control. Finally, the efficacy of an azadirachtin product (an insect active extract from the seeds of the neem tree) was evaluated. 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. A greenhouse test was done in 2004 to evaluate the activity of Neemazal™ 0.1%G against RWW. Results were 100% RWW control when the material was applied at the time of seeding or 19 days after seeding (approximate time of RWW egg hatch). Slightly less control (81.5%) was seen from an application made 12 days after seeding (introduction of adults to the pots). Additional testing of this product is needed but these results show considerable promise.

The registered products, along with Etofenprox, Dinotefuron, Platinum, and Warrior pre-flood were evaluated in large field plots for their effects on non-target invertebrates. Data from the 2004 season are still being summarized. Based on the data in-hand, for the preflood treatments, the insecticide appears to have had minimal effects on the total number of invertebrates in 2004. Post-flood applications were more detrimental to numbers of invertebrates with all five treatments reducing numbers for the first 2 weeks after application. Data from 2003 are completely summarized. Populations of total invertebrates were suppressed by the preflood treatments until early July. The post-flood treatments were generally detrimental to invertebrates until mid-August (Dimilin had less effects than the other treatments). The Warrior application made in July (armyworm timing) was particularly harmful to invertebrate populations. The effects of the insecticides on beetles were significant; however, on segmented worms, none of the treatments had any consistent detrimental effect on populations. In summary, the effect of the materials on non-targets depends on the species/group in question and on the season.

In 2004, RWW flight was also very low with only 703 adults trapped. The flight occurred very early and was completed by 3 May. Research has been done in grower fields for the last 3 years to evaluate the applicability of a floating barrier trap for assessing adult RWW populations in order to better make a treatment decision. Small plots studies were done in 2004 to validate an observation from the grower field studies and to determine the relationship between rice growth stage and trap efficacy. When the RWW infestations occurred at the 1 leaf stage, 8.0% of the adults were captured over the next the 2 to 3-week period. With larger plants, captures were 5.8, 4.9, and 0%, respectively, on 2, 3, and 5 leaf stage plants, respectively. Ten rice varieties were compared for their susceptibility to RWW infestation and yield loss to a standardized RWW infestation. M-202, Calmati-201, and M-401 had the most leaf scarring from RWW adults and larval levels were greatest in the M-202, Calhikari-201, and M-402 plots. There was a 5 times range in larval populations across the varieties. Yield losses, at the larval numbers recorded, were minimal in this study. Refined rice seedling establishment techniques are being investigated, primarily as a means to improve weed management, but these may also have influences on insect pests. We monitored RWW populations (adult scarring and larval numbers) as well as armyworm populations in this seedling establishment study, but infestations were very low.

**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. Studies and observations on armyworms were started in 2003. Armyworms have many host plants and, in fact, the western yellow-striped armyworm 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 investigated this relationship in 2004; no armyworms were sampled until late July and populations peaked in mid-August. Results showed a trend for fewer armyworms in plots with weeds controlled vs. plots with high levels of weeds. Pheromone traps were used to gain insights on the timing of armyworm moth flights. In addition, larval populations were monitored in 6 and 7 rice fields in Colusa and Butte Co., respectively every week. Armyworm moth captures peaked in early-mid

Aug. Western yellow-striped armyworm moth captures peaked in early Aug. and true armyworms were trapped about 2 weeks later. Peak larval populations occurred on 24 Aug; populations were nearly 0 on 10 Aug. and increased to 7.6 and 9.8 worms per 5-minute search in Butte and Colusa Co., respectively. Significant numbers of the armyworm larvae were parasitized with a small wasp (probably *Apanteles militaris*). This is an area that warrants additional research. 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.

Table 1. Treatment list for RWW management ring study, 2004.

| Product | Rate (lbs. AI/A) | Formulation per A | Timing | Application Date |
|---|---|---|---|---|
| 1. Furadan 5G | 0.5 | 10 lbs. | PF | 13 May |
| 2. Dimilin 2L | 0.125 | 8 oz | 3-leaf | 28 May |
| 3. F 0570 0.8 EC (zeta-cypermethrin) | 0.025 | 4 oz | PF | 13 May |
| 4. Untreated | --- | --- | --- | --- |
| 5. Warrior | 0.03 | 3.84 oz. | 3-leaf | 28 May |
| 6. Warrior | 0.03 | 3.84 oz. | PF | 3 May |
| 7. Warrior | 0.03 | 3.84 oz. | PF | 7 May |
| 8. Warrior | 0.03 | 3.84 oz. | PF | 10 May |
| 9. Warrior | 0.03 | 3.84 oz. | PF | 13 May |
| 10. Proaxis | 0.015 | 3.84 oz. | PF | 13 May |
| 11. Dinotefuron 1%G | 0.26 | 26 lbs. | 3-leaf | 28 May |
| 12. Platinum | 0.125 | 8 oz | PF | 13 May |
| 13. MANA lambda-cyhalothrin 1EC | 0.03 | 3.84 oz. | 3-leaf | 28 May |
| 14. MANA lambda-cyhalothrin 1EC | 0.04 | 5.12 oz. | 3-leaf | 28 May |
| 15. Warrior | 0.03 | 3.84 oz. | after flood | 17 May |
| 16. Steward | 0.065 | 6.7 oz. | 3-leaf | 28 May |
| 17. Steward | 0.11 | 11.3 oz. | 3-leaf | 28 May |
| 18. Proaxis | 0.015 | 3.84 oz. | 3-leaf | 28 May |
| 19. Steward | 0.065 X 2 | 6.7 oz. X 2 | post-flood | 17 & 28 May |
| 20. Etofenprox 1.5%G | 0.27 | 17.9 lbs. | 3-leaf | 28 May |
| 21. F 0570 0.8 EC (zeta-cypermethrin) | 0.025 | 4 oz. | 3-leaf | 28 May |
| 22. Dinotefuron 1%G | 0.26 | 26 lbs. | PF | 13 May |

Table 2. Rice plant stand and adult feeding damage in chemical ring study, 2004.

| Product | Rate (lbs. AI/A) & Timing | Stand Rating (1-5) | % Scarred Plants - 2 June |
|---|---|---|---|
| 1. Furadan 5G | 0.5 - PF | 3.4 | 5.0 bcde |
| 2. Dimilin 2L | 0.125 - 3 leaf | 3.0 | 14.5 a |
| 3. F 0570 0.8 EC (zeta-cypermethrin) | 0.025 - PF | 3.1 | 8.0 b |
| 4. Untreated | --- | 3.3 | 14.5 a |
| 5. Warrior | 0.03 - 3 leaf | 3.3 | 0.5 de |
| 6. Warrior | 0.03 - PF (5/3) | 3.5 | 5.5 bcd |
| 7. Warrior | 0.03 - PF (5/7) | 3.1 | 0.5 de |
| 8. Warrior | 0.03 - PF (5/10) | 3.3 | 0.0 e |
| 9. Warrior | 0.03 - PF (5/13) | 3.1 | 0.5 de |
| 10. Proaxis | 0.015 - PF | 3.1 | 0.0 e |
| 11. Dinotefuron 1%G | 0.26 – 3 leaf | 3.0 | 4.5 bcde |
| 12. Platinum | 0.125 - PF | 3.1 | 1.0 de |
| 13. MANA lambda-cyhalothrin 1EC | 0.03 - 3 leaf | 3.0 | 0.5 de |
| 14. MANA lambda-cyhalothrin 1EC | 0.04 – 3 leaf | 2.9 | 0.5 de |
| 15. Warrior | 0.03 - post flood (5/17) | 3.3 | 1.5 cde |
| 16. Steward | 0.065 – 3 leaf | 3.4 | 0.0 e |
| 17. Steward | 0.11 – 3 leaf | 2.8 | 0.5 de |
| 18. Proaxis | 0.015 - 3 leaf | 3.3 | 0.5 de |
| 19. Steward | 0.065 X 2 – post-flood | 3.4 | 1.0 de |
| 20. Etofenprox 1.5%G | 0.27 – 3 leaf | 3.1 | 1.5 cde |
| 21. F 0570 0.8 EC (zeta-cypermethrin) | 0.025 – 3 leaf | 3.0 | 0.5 de |
| 22. Dinotefuron 1%G | 0.26 - PF | 3.0 | 6.5 bc |

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, 2004.

| Product | Rate (lbs. AI/A) & Timing | RWW per Core (21 June) | RWW per Core (12 July) | Average |
|---|---|---|---|---|
| 1. Furadan 5G | 0.5 - PF | 0.12 e | 0.10 d | 0.11 |
| 2. Dimilin 2L | 0.125 - 3 leaf | 0.30 de | 0.95 cd | 0.63 |
| 3. F 0570 0.8 EC (zeta-cypermethrin) | 0.025 - PF | 0.10 e | 0.20 d | 0.15 |
| 4. Untreated | --- | 4.90 b | 3.30 b | 4.10 |
| 5. Warrior | 0.03 - 3 leaf | 0.00 e | 0.05 d | 0.03 |
| 6. Warrior | 0.03 - PF (5/3) | 0.10 e | 0.10 d | 0.10 |
| 7. Warrior | 0.03 - PF (5/7) | 0.00 e | 0.00 d | 0.00 |
| 8. Warrior | 0.03 - PF (5/10) | 0.00 e | 0.05 d | 0.03 |
| 9. Warrior | 0.03 - PF (5/13) | 0.05 e | 0.05 d | 0.05 |
| 10. Proaxis | 0.015 - PF | 0.05 e | 0.15 d | 0.10 |
| 11. Dinotefuron 1%G | 0.26 – 3 leaf | 6.00 a | 5.00 a | 5.50 |
| 12. Platinum | 0.125 - PF | 0.15 e | 0.10 d | 0.13 |
| 13. MANA lambda-cyhalothrin 1EC | 0.03 - 3 leaf | 0.00 e | 0.05 d | 0.03 |
| 14. MANA lambda-cyhalothrin 1EC | 0.04 – 3 leaf | 0.00 e | 0.10 d | 0.05 |
| 15. Warrior | 0.03 - post flood (5/17) | 1.30 d | 1.42 c | 1.36 |
| 16. Steward | 0.065 – 3 leaf | 1.05 de | 0.10 d | 0.58 |
| 17. Steward | 0.11 – 3 leaf | 0.30 de | 0.05 d | 0.18 |
| 18. Proaxis | 0.015 - 3 leaf | 0.05 e | 0.05 d | 0.05 |
| 19. Steward | 0.065 X 2 – post-flood | 0.30 de | 0.40 d | 0.35 |
| 20. Etofenprox 1.5%G | 0.27 – 3 leaf | 0.20 e | 0.00 d | 0.10 |
| 21. F 0570 0.8 EC (zeta-cypermethrin) | 0.025 – 3 leaf | 0.00 e | 0.00 d | 0.00 |
| 22. Dinotefuron 1%G | 0.26 - PF | 2.60 c | 2.84 b | 2.72 |

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, 2004.

| Product | Rate (lbs. AI/A) & Timing | Biomass - Straw + Grain (t/A) | Percentage Moisture | Estimated Grain Yield (lbs./A) |
|---|---|---|---|---|
| 1. Furadan 5G | 0.5 - PF | 11.5 de | 20.3 bc | 6747 abc |
| 2. Dimilin 2L | 0.125 - 3 leaf | 12.3 abcde | 19.8 c | 6889 abc |
| 3. F 0570 0.8 EC (zeta-cypermethrin) | 0.025 - PF | 12.9 abcde | 23.1 ab | 7050 abc |
| 4. Untreated | --- | 14.8 ab | 24.3 a | 7352 abc |
| 5. Warrior | 0.03 - 3 leaf | 13.6 abcde | 22.3 abc | 7860 a |
| 6. Warrior | 0.03 - PF (5/3) | 12.1 cde | 21.7 abc | 6561 abc |
| 7. Warrior | 0.03 - PF (5/7) | 14.4 abc | 23.8 a | 7920 a |
| 8. Warrior | 0.03 - PF (5/10) | 12.6 abcde | 23.5 a | 7139 abc |
| 9. Warrior | 0.03 - PF (5/13) | 14.9 a | 23.4 a | 8007 a |
| 10. Proaxis | 0.015 - PF | 11.9 cde | 21.3 abc | 6844 abc |
| 11. Dinotefuron 1%G | 0.26 – 3 leaf | 12.2 bcde | 22.3 abc | 6892 abc |
| 12. Platinum | 0.125 - PF | 14.1 abcd | 23.1 ab | 7693 ab |
| 13. MANA lambda-cyhalothrin 1EC | 0.03 - 3 leaf | 13.3 abcde | 23.5 a | 7360 abc |
| 14. MANA lambda-cyhalothrin 1EC | 0.04 – 3 leaf | 11.1 e | 22.8 abc | 6156 c |
| 15. Warrior | 0.03 - post flood (5/17) | 13.8 abcd | 22.9 ab | 7653 ab |
| 16. Steward | 0.065 – 3 leaf | 12.9 abcde | 21.8 abc | 7214 abc |
| 17. Steward | 0.11 – 3 leaf | 11.8 cde | 21.8 abc | 6365 bc |
| 18. Proaxis | 0.015 - 3 leaf | 12.5 abcde | 23.5 a | 6788 abc |
| 19. Steward | 0.065 X 2 – post-flood | 13.7 abcde | 23.2 ab | 7764 ab |
| 20. Etofenprox 1.5%G | 0.27 – 3 leaf | 13.5 abcde | 22.0 abc | 7282 abc |
| 21. F 0570 0.8 EC (zeta-cypermethrin) | 0.025 – 3 leaf | 12.2 bcde | 22.7 abc | 7128 abc |
| 22. Dinotefuron 1%G | 0.26 - PF | 14.0 abcd | 23.1 ab | 7688 ab |

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

Table 5. Treatment list for large plot RWW control/nontargets study, 2004.

| Product | Rate (lbs. AI/A) | Product/A | Application Timing | Date of Application |
|---|---|---|---|---|
| 1. Platinum | 0.125 | 8 oz. | preflood | 19 May |
| 2. Warrior | 0.03 | 3.84 oz. | 3-leaf | 3 June |
| 3. Warrior | 0.03 | 3.84 oz. | preflood | 19 May |
| 4. Warrior | 0.03 | 3.84 oz. | mid-season | 19 July |
| 5. Mustang (F0570) | 0.025 | 4 oz. | 3-leaf | 3 June |
| 6. Dimilin 2L | 0.125 | 8 oz. | 3-leaf | 3 June |
| 7. Untreated | --- | --- | --- | --- |
| 8. Dinotefuron 1%G | 0.26 | 26 lbs. | 3-leaf | 3 June |
| 9. Etofenprox 1.5%G | 0.27 | 17.9 lbs. | 3-leaf | 3 June |

Table 6. Yield parameters for RWW level in large plot RWW control/nontargets study, 2004.

| Product | Rate (lbs. AI/A) | Biomass - Straw + Grain (t/A) | Percentage Moisture | Estimated Grain Yield (lbs./A) |
|---|---|---|---|---|
| 1. Platinum | 0.125 | 9.9 | 17.8 | 6115 |
| 2. Warrior | 0.03 | 8.3 | 16.6 | 5189 |
| 3. Warrior | 0.03-PF | 9.9 | 17.4 | 6484 |
| 4. Warrior | 0.03-July | 10.2 | 17.1 | 6050 |
| 5. Mustang (F0570) | 0.025 | 9.4 | 17.1 | 5686 |
| 6. Dimilin 2L | 0.125 | 7.7 | 16.1 | 4353 |
| 7. Untreated | --- | 9.2 | 16.7 | 5446 |
| 8. Dinotefuron 1%G | 0.26 | 7.3 | 16.3 | 5170 |
| 9. Etofenprox 1.5%G | 0.27 | 8.9 | 17.0 | 5435 |

Table 7. RWW adults captured, larval populations, and estimated grain yields from small plot floating barrier trap study, 2004.

| Plant growth stage at Time of Infestation | % of RWW Adults Captured | RWW Larval Population per Core Sample | Rice Grain Yield (lbs./A) |
|---|---|---|---|
| Uninfested | 0.0 | 0.8 c | 7450.3 a |
| 1 leaf stage | 8.0 | 3.6 bc | 5565.4 b |
| 2 leaf stage | 5.8 | 5.8 ab | 5782.6 b |
| 3 leaf stage | 4.9 | 9.2 a | 6783.1 ab |
| 5 leaf stage | 0.0 | 7.4 ab | 6387.1 ab |

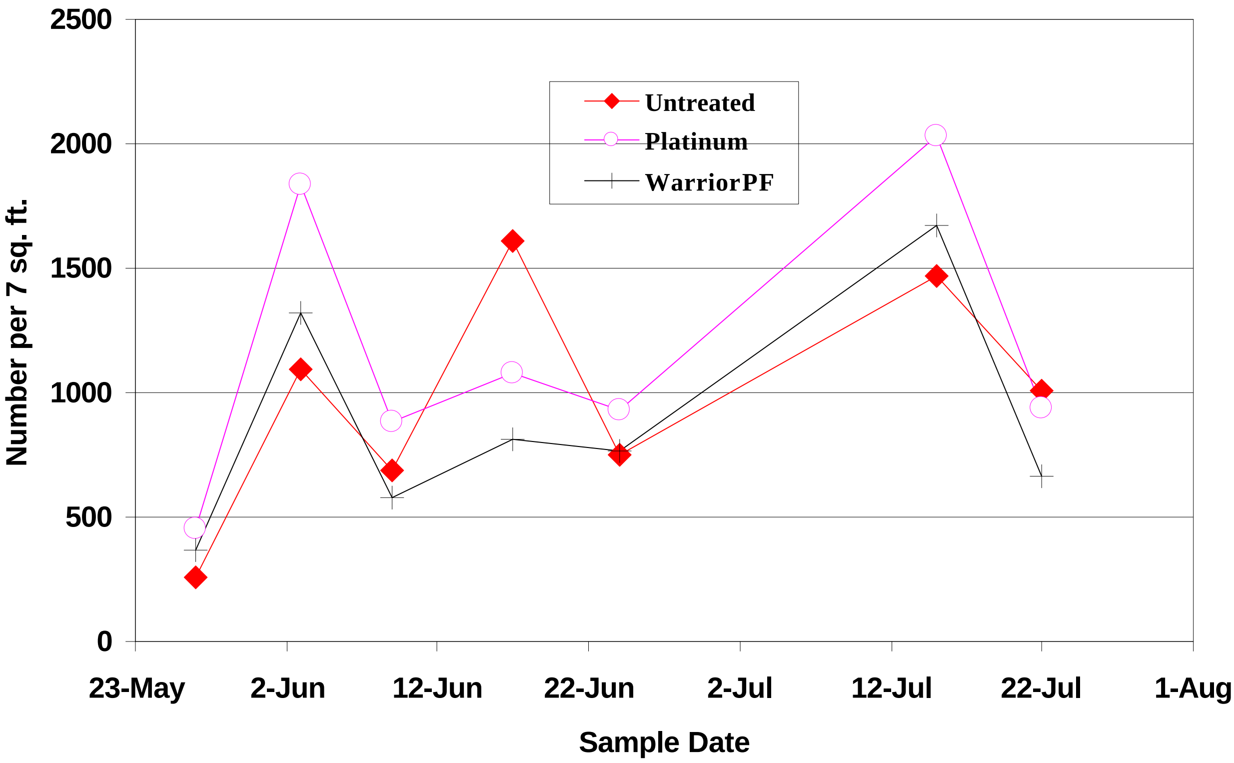


Figure 1. Populations of invertebrates following preflood insecticide application to rice, 2004.

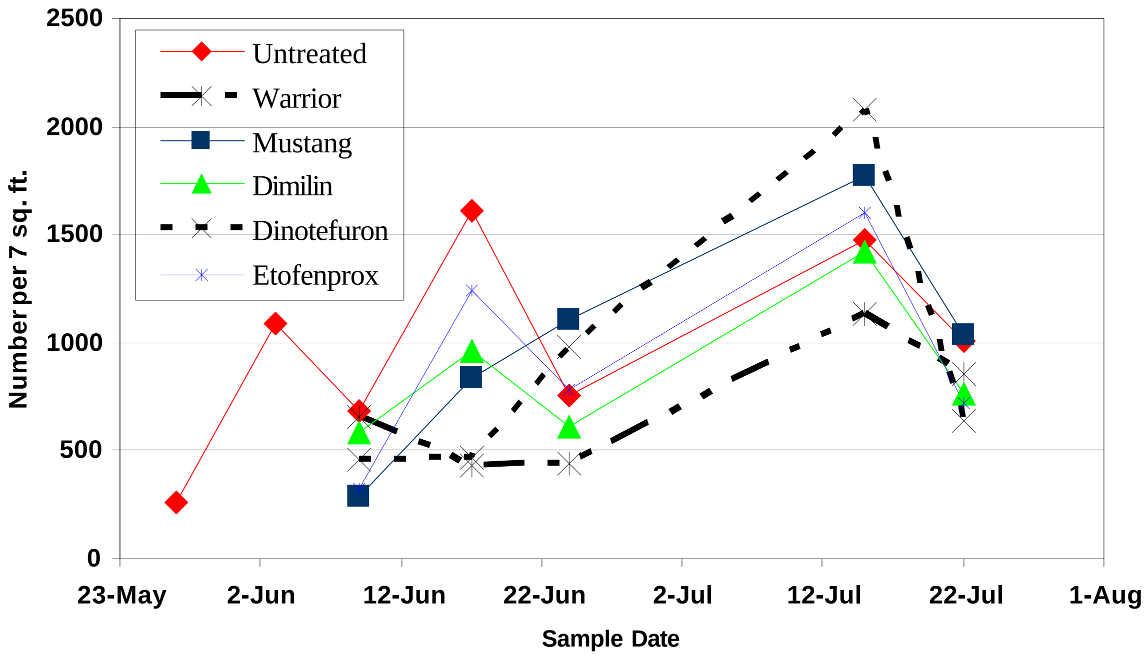


Figure 2. Populations of invertebrates following postflood insecticide application to rice, 2004

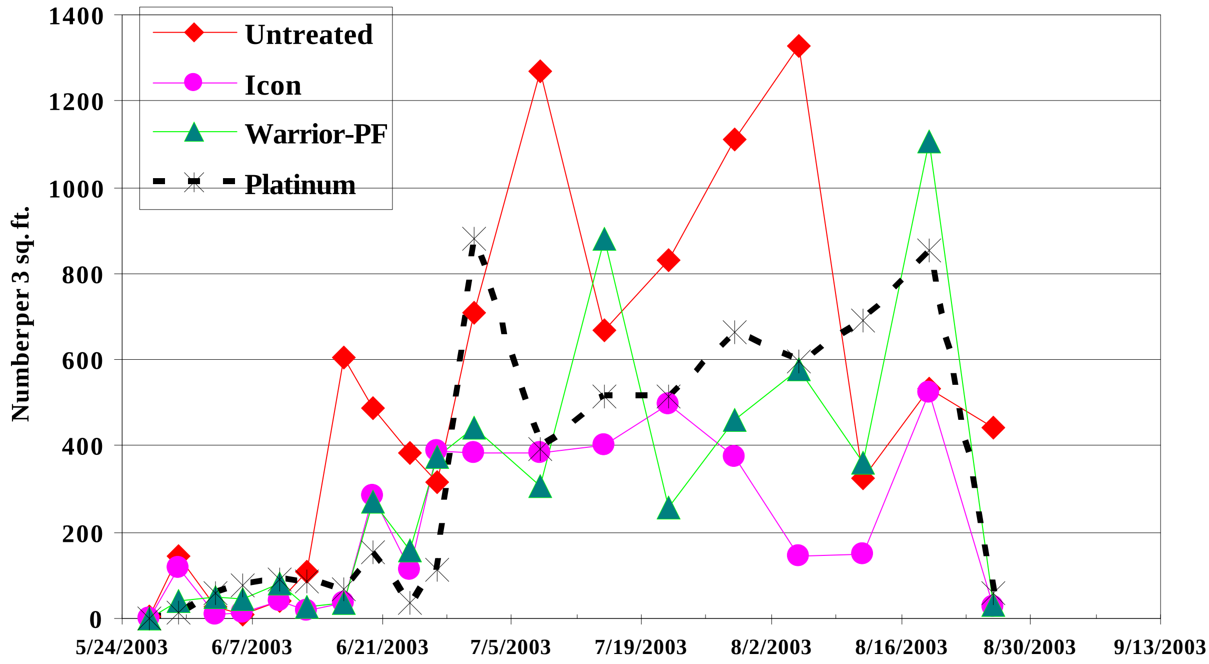


Figure 3. Populations of invertebrates following preflood insecticide application to rice, 2003.

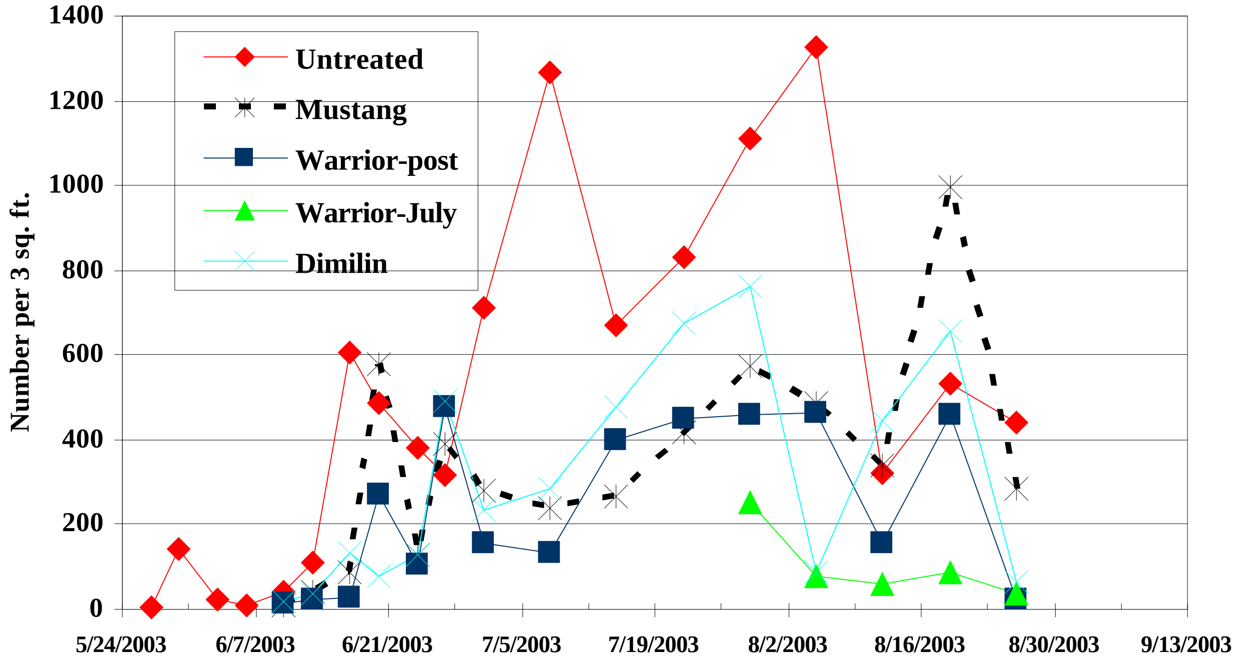


Figure 4. Populations of invertebrates following postflood insecticide application to rice, 2003.

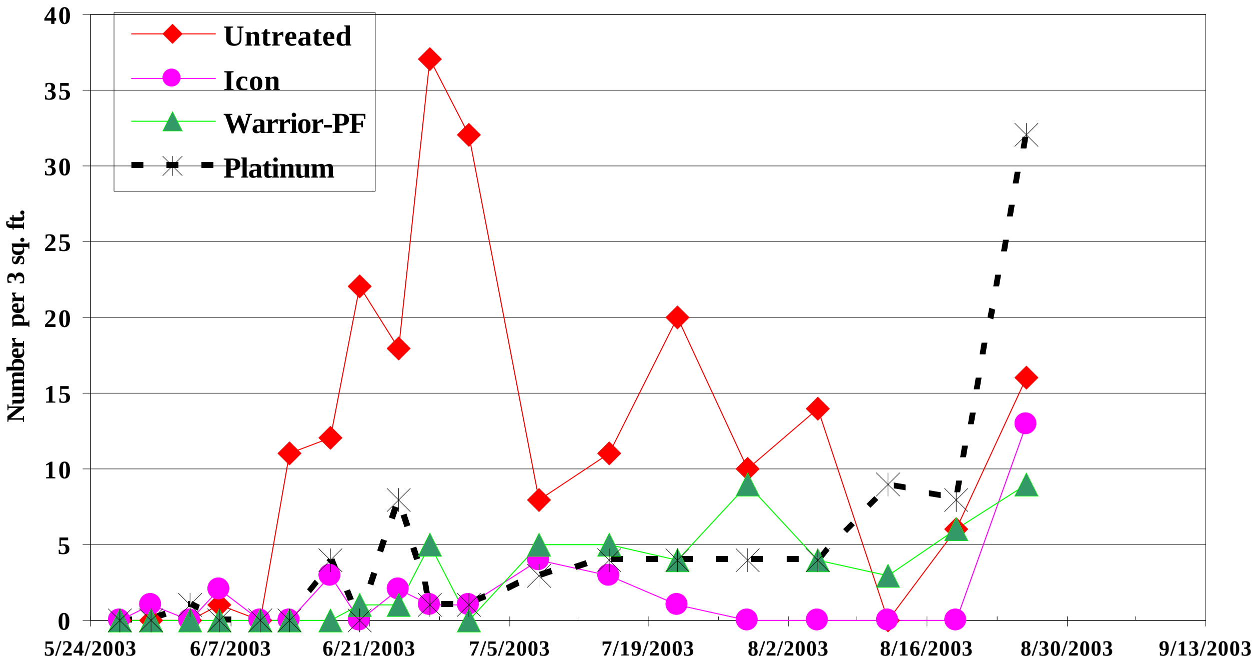


Figure 5. Populations of Coleoptera (beetles) following preflood insecticide application to rice, 2003.

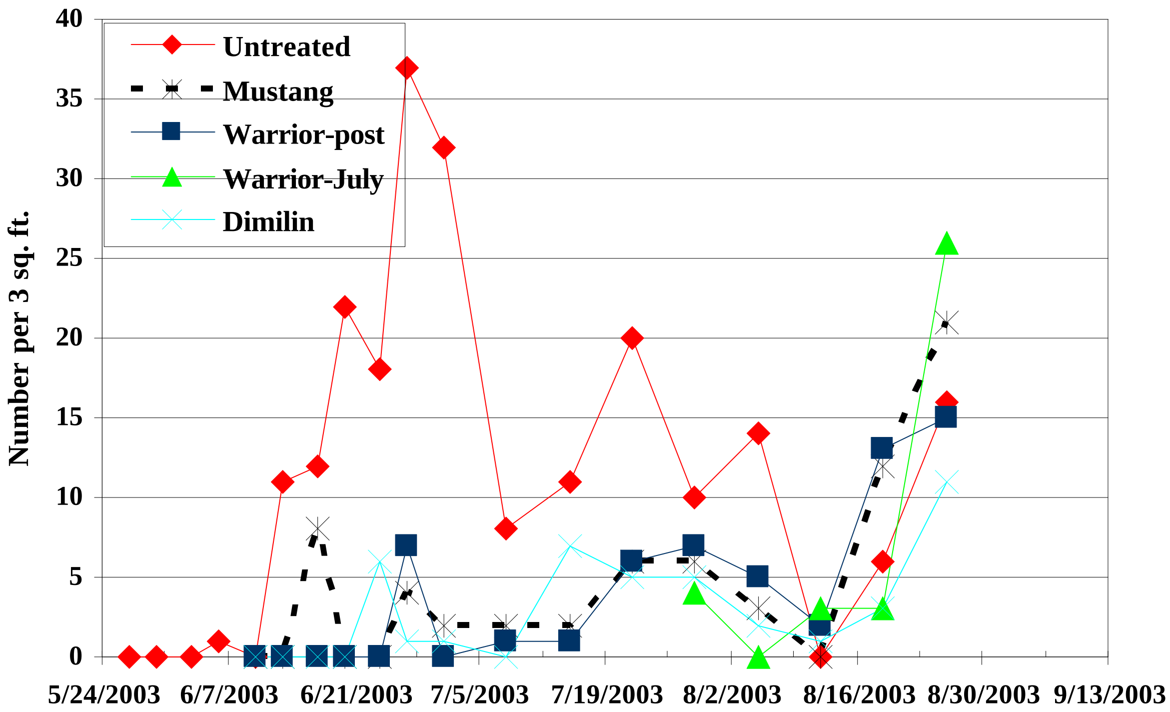


Figure 6. Populations of Coleoptera (beetles) following post-flood insecticide application to rice, 2003.

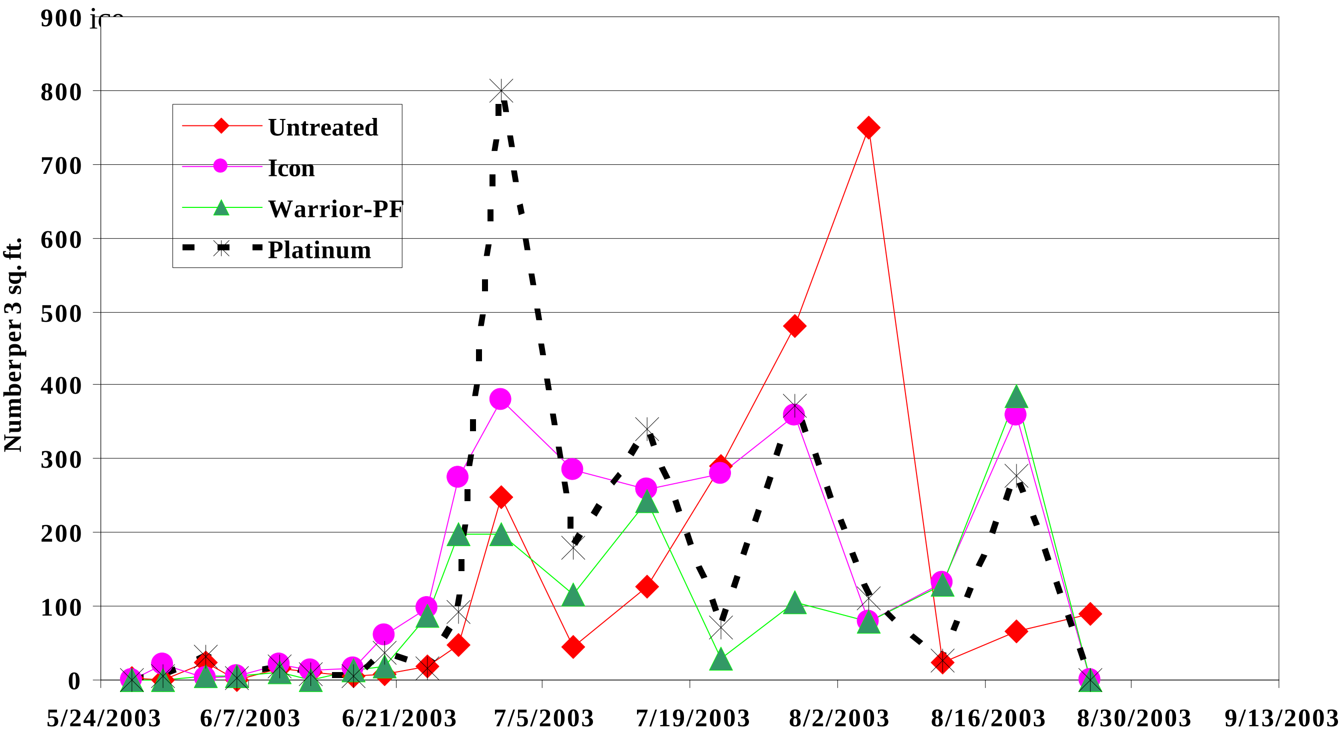


Figure 7. Populations of Annelids (segmented worms) following preflood insecticide application to rice, 2003.

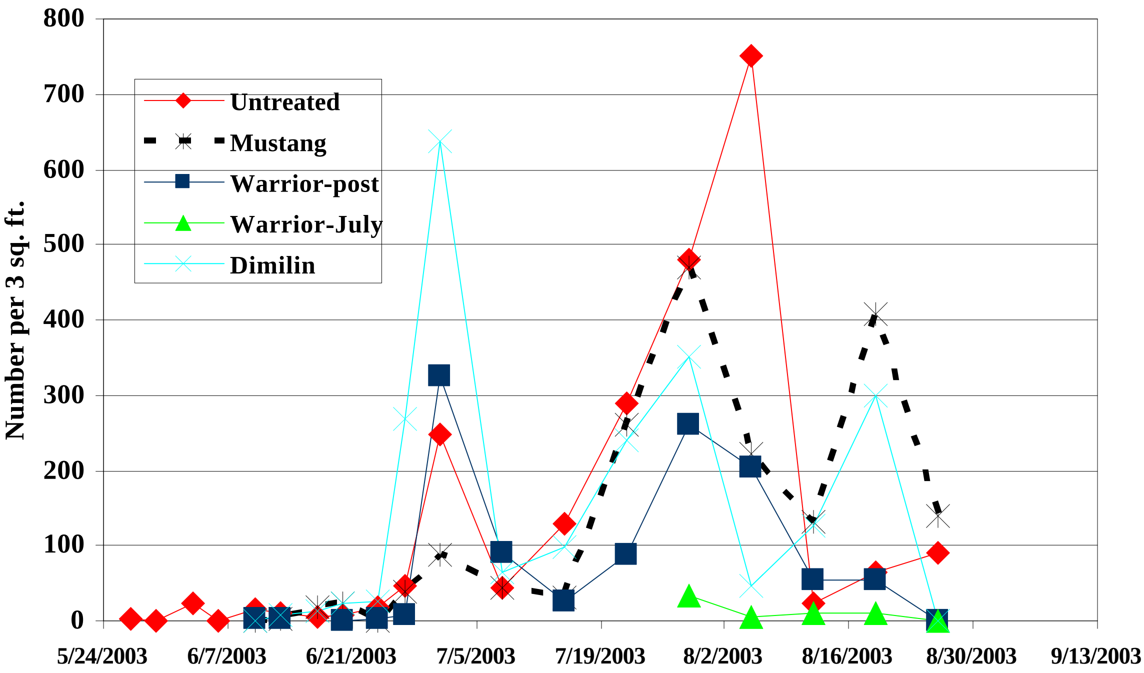


Figure 8. Populations of Annelids (segmented worms) following post-flood insecticide application to rice, 2003.

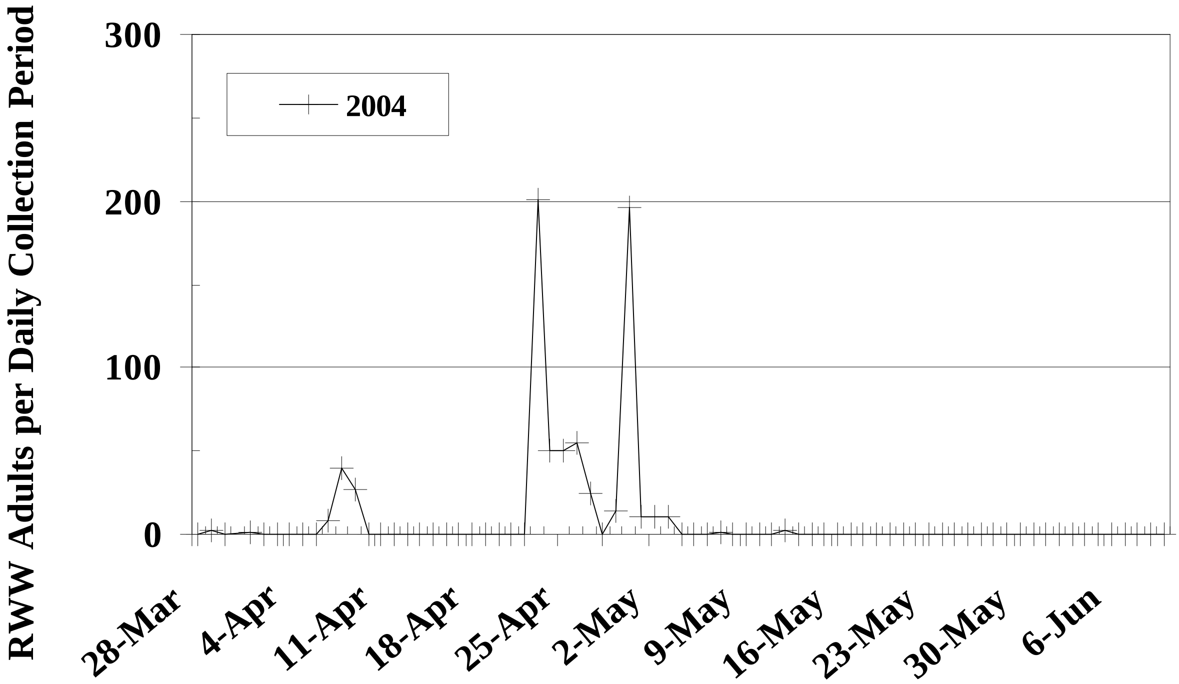


Figure 9. Rice water weevil adult flight in light trap located at the Rice Experiment Station, 2004.

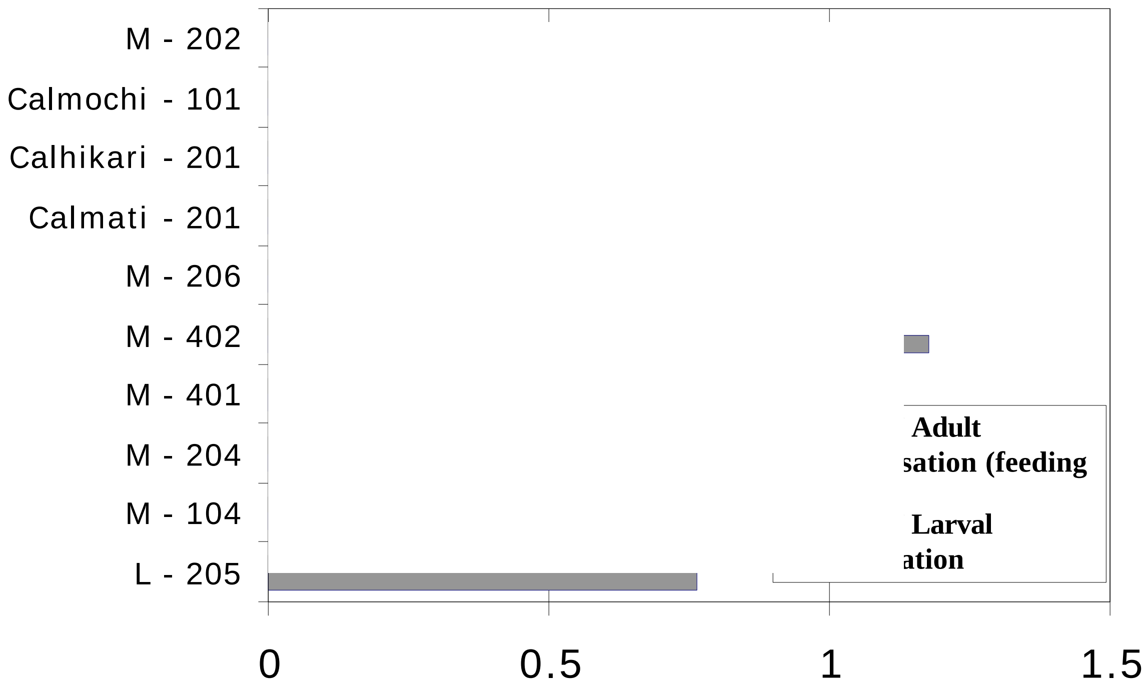


Figure 10. Relative susceptibility of rice varieties to rice water adult feeding and larval infestation, 2004. Varieties are compared relative to M-202.

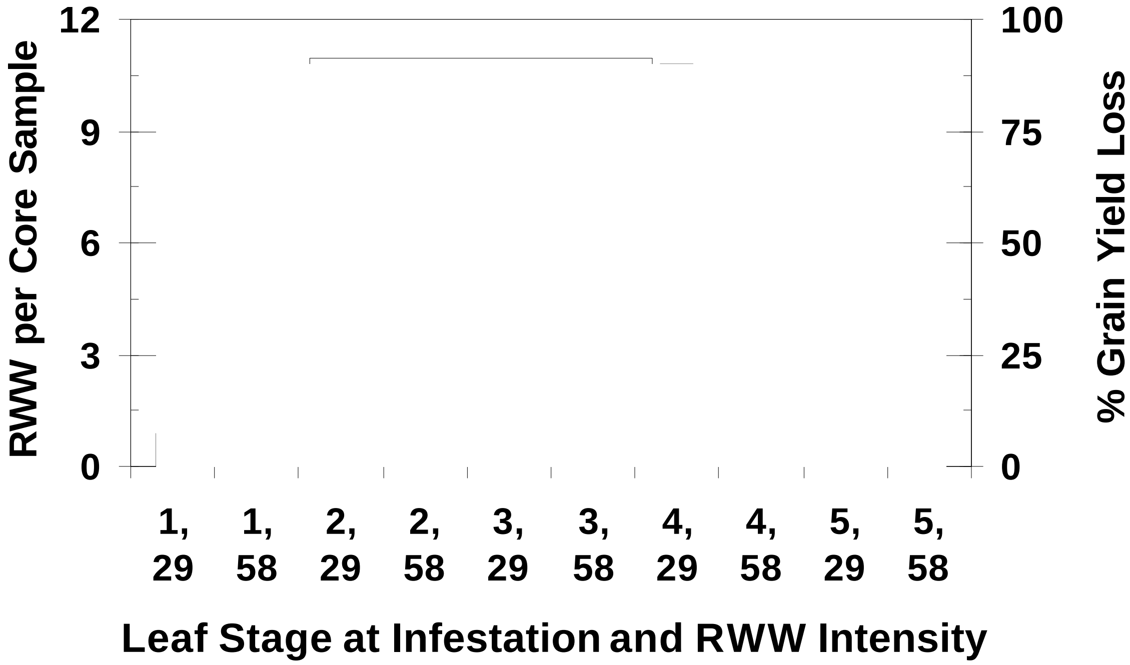


Figure 11. Influence of RWW feeding (by adults and larvae), with infestation occurring at various plant growth stages and intensities, on larval numbers and % yield loss (compared with uninfested plots).

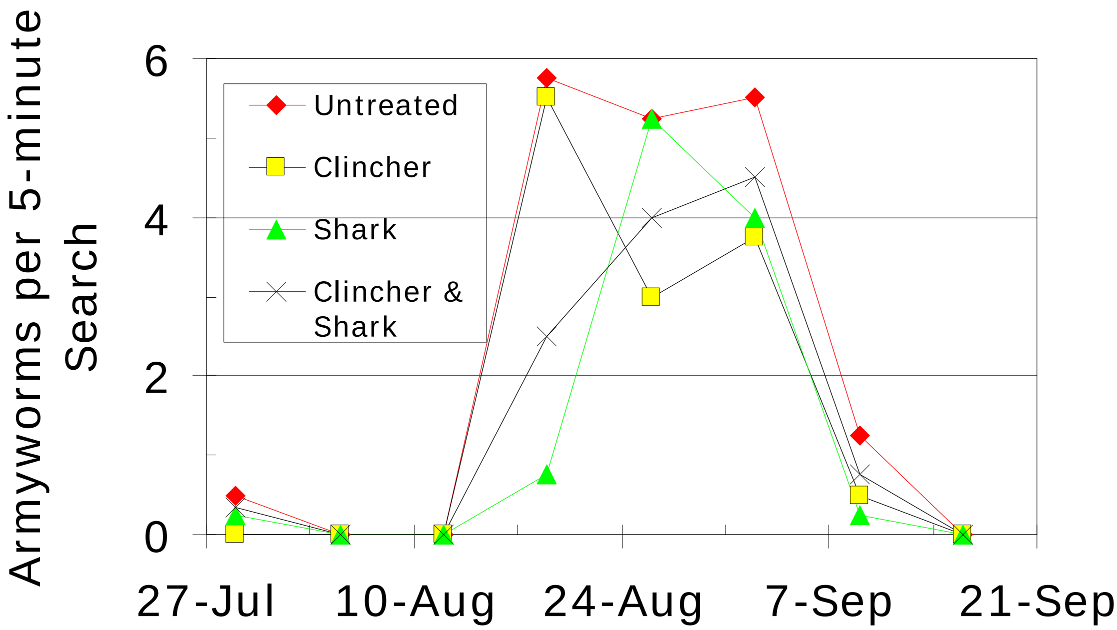


Figure 12. Armyworm population in rice as influenced by weed levels, 2004.

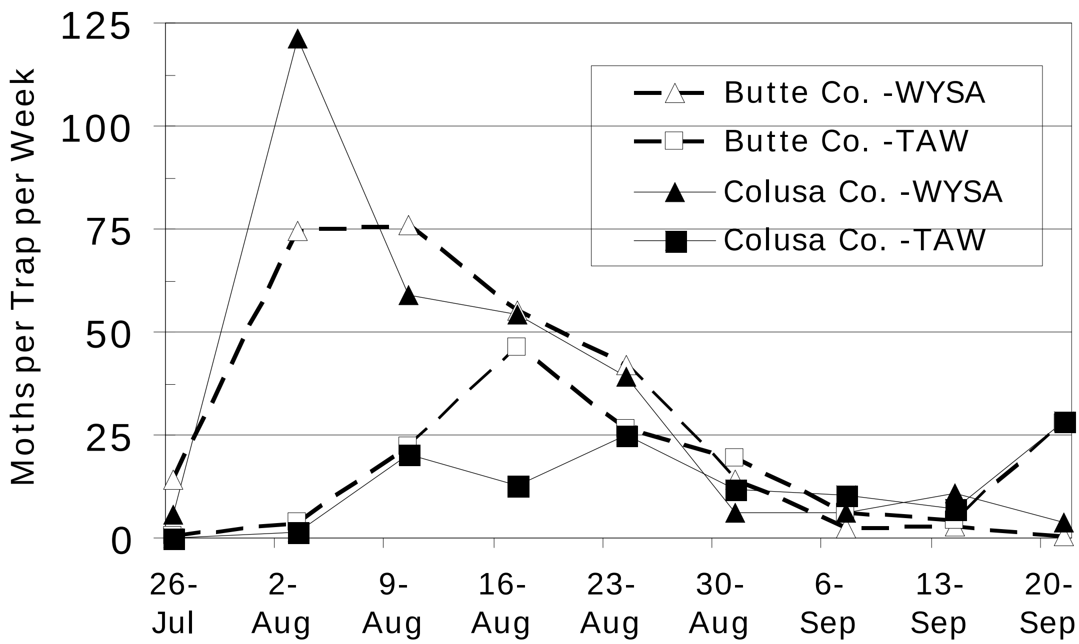


Figure 13. Western yellow-striped and true armyworm moth flights near rice fields, 2004.

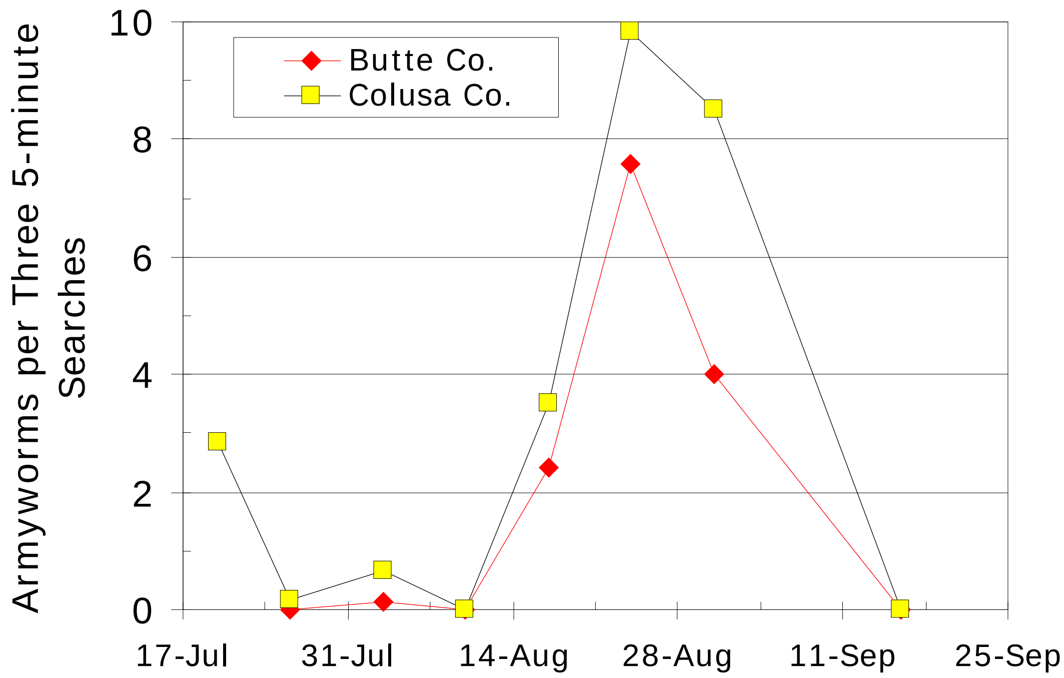


Figure 14. Armyworm populations in rice fields in Colusa and Butte Co., 2004.