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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, TO ACCOMPLISH OBJECTIVES:

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

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

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

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

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

SUMMARY OF 2006 RESEARCH BY OBJECTIVE:

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-four 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 26 May and seeded on 27 May. The application timings were as follows:

26 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 plan
26 May, pre-flood (PF) applications
8 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 6 June and 6 adults into each ring on 13 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:

Emergence/ Seedling Vigor: 2 June
Adult Leaf Scar Counts: 20 June
Larval Counts: 7 July and 25 July
Rice Yield: 17 October

Sample Method:

Emergence/ Seedling 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 (ρ # 0.05). Raw data reported herein.

Results:

Rice Emergence

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

Adult Leaf Scar Counts

Adult leaf-scar damage normally is insignificant in terms of rice plant growth and development (except under extremely high pressure). Feeding scars are evaluated in our studies as a means to classify the infestation severity and to gain some insight on how the treatments are providing RWW control, i.e., through killing adults, killing larvae, etc. The amount of feeding varies yearly even though our methods used are identical every year. The June 20 sample date was 1 week after all the infestations had been made. Counts were fairly high with the untreated plots averaging 34% scarred seedlings and highest being 55% in the Mustang Max pre-flood treatment (Table 2). Several treatments totally eliminated the leaf scarring including the Etofenprox 3-leaf application (25 lb. rate), Warrior 3-leaf, Mustang Max 3-leaf, and Proaxis 3-leaf treatments and several other treatments were statistically the same including the 15 and 20 lb. Etofenprox 3-leaf applications, the V10170 seed treatments and PF+3-leaf treatment, and Steward 3-leaf treatments (Table 2). For the experimental materials, Etofenprox appears to have good activity on RWW adults (reportedly kills larvae as well). V10170 was highly effective on adults and V10194 was moderately effective. Similarly, Steward was very effective and DPX-E2y45 was less effective.

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 sample plots twice, so that one sample will be during the peak population. The first sample gave the best evaluation of the treatments with the untreated plots averaging nearly 5.5 larvae per sample. In both samplings, the best treatments zeroed the population (Table 3).

Experimental materials versus registered standards. Testing continued from 2005 on three experimental insecticide active ingredients, Etofenprox, V10170, and Indoxacarb (Steward). Two other new active ingredients were evaluated for the initial time – V10194 and DPX-E2Y45. The loss of Icon® in Southern rice and the developing environmental concerns regarding pyrethroid use in California have spurred a renewed interest from the agrichemical companies for rice water weevil active products. In the first sampling, all plots treated with insecticides resulted in significantly lower RWW larval counts than the untreated plots; however, there was no separation among the 23 treated plots (Table 3). In the second sampling, there was some separation among the treatments, but the counts were overall low. The registered standards, Warrior, Mustang, Dimilin, and Proaxis all provided excellent RWW larval control. Etofenprox applied at the 3-leaf stage provided very good RWW control; there was really no separation among the three rates. Etofenprox applied preflood was also effective. This differs from the 2005 results where the preflood application of etofenprox was very poor. Additional work is needed to clarify this result. Steward, applied at the 3-leaf stage, was very effective for RWW control although the higher (0.11) rate was needed. The lower rate was fairly effective but probably under field conditions it would marginal in performance. V10170 (active ingredient clothianidan) was highly effective with all application methods – seed treatment, preflood, and preflood+3-leaf. Additional work needs to be done to determine the “limits” of this product’s effectiveness. V10194, tested as a seed treatment, was moderately effective. DPX-E2Y45 was also evaluated and provided good RWW control. The higher rate was consistently better than the lower rate and the granular formulation was better than the liquid formulation (both were applied into the water at 3 days post-flooding). Etofenprox is used for RWW control in Japan (marketed as Trebon®) and was available in Louisiana in 2006 under a Section 18 registration. Steward is registered in the U.S. for control of a related species, alfalfa weevil in alfalfa, as well as being available on several other crops. It has been submitted to IR-4 as a possibility to assist with registration in CA.

Soil application of pyrethroid products. Studies were conducted to evaluate possible changes to Warrior use patterns to improve efficacy and ease of use. Mustang Max was 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. The re-evaluation of pyrethroid registrations has at this point placed considerable caution on attempting to register this method. One important operational question for the use of preplant applications is how long in advance of the flood water can the treatment be made. We have generally had excellent results with an application made up to 1 week before flooding, but there have been some inconsistencies with this application. Therefore we wanted to continue to evaluate this technique. In 2006, the cool, wet spring greatly compressed the timing of the soil preparation, plot construction, and flooding. The treatments were applied preflood but less than 1 day before flooding. Both Warrior and

Mustang Max were highly effective with a preflood application timing (Table 3).

Rice Yield

Rice grain yields ranged from 5360 to ~8330 lbs./A. Grain yields were numerically highest in the DPX-E2Y45 0.2%G treatment (Table 4) and lowest in the Mustang Max preflood treatment. Yield values in the untreated plots were intermediate. Rice biomass at harvest ranged from slightly less than 6.9 to 11.0 t/A. Percentage moisture did not vary greatly among treatments.

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

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

Work on azadirachin was de-emphasized in 2006, based on the Board's recommendation. However, the late spring for rice planting allowed one greenhouse study to be conducted. Greenhouse results in 2005 were quite positive with this active ingredient, but field tests were poor. The greenhouse study in 2006 was intended to provide a second year of data as well as to perhaps provide some explanation of the poor field results. Azadirachtin is an insect active extract from the seeds of the neem tree. 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. Given the environmentally sensitive nature of the rice agroecosystem, a biological product of this type would be a benefit, if shown to be efficacious.

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 levees near rice fields in Butte Co. Adults were held in the laboratory in vials with rice leaf tissue before use (7 days at most). 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 number of feeding scars from RWW adults was recorded. The number of adults, period of time confined on the plants, and small size of plants resulted in considerable feeding. 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.

Comparison of formulations and rates for RWW control:

Methods:

Treatments shown in Table 5 were used. In this study, the effects of rate, application method, formulation, method of control (adult vs. larvae) 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 seeding, 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:

Feeding scar incidence ranged from 5 to 9.8 (Table 5). Overall plants treated with the highest rate had about 20% fewer scars than untreated plants. Numbers of RWW immatures are shown in Table 5. The following conclusions can be made: 1.) the foliar application was more effective than the preflood application, 2.) Aza-Direct (a liquid formulation) is more effective than Neemazal (a granular product), 3.) the lowest rate of Aza-Direct was moderately effective and the 0.01 rate was highly effective, and 4.) about 4 times more Neemazal was needed to reach comparable levels of control to that seen with Aza-Direct.

Potential of Azadirachtin formulations for sterilization of RWW:

Methods:

The objectives of this study 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 rice water weevil) 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 greatly reduced the number of RWW compared with the untreated plants keeping in mind that a "high" rate was used (Table 6). In terms of sterilizing the female RWW, the Aza-Direct showed a carryover effect for the 3-4 and 5-6 days after application with nearly complete control. NeemAzal was less effective with the sterilization of the weevils quickly dissipating as soon as the weevils were no longer exposed to the active ingredient. The Aza-Direct formulation also greatly reduced feeding scars in this study. It does seem clear that Azadirachtin sterilizes the RWW and that this effect can last at least for 6 days.

Overall, Azadirachtin seems to have some significant activity on rice water weevil. The liquid formulation was superior to the granular. 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.

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

The treatments listed in Table 7 were evaluated in this study in 2005 and 2006. 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. Data from 2005 will be discussed as the 2006 data are still being quantified and summarized. The procedures followed in 2006 will be described; 2005 methods were very similar.

Methods:

Each plot was ~0.04 A and each treatment was replicated three times. Key dates in 2006 were preflood treatments – 27 May, flooded – 28 May, seeded – 30 May and 3-leaf stage treatments – 14 June. The armyworm application timing was 13 July. Populations of non-target organisms were evaluated weekly from 8 June to 30 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, 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. Per square foot of surface area (and including the region extending to the soil surface as well as the top ~1 inch of soil), populations in untreated plots averaged 17.8 insects and 10.8 other invertebrates. The 2005 results are summarized and will be reported herein. Sorting and counting the 2006 samples is underway and will progress through the winter.

Preflood applications: Only one preflood application was evaluated in 2005. Warrior was used as a representative of a pyrethroid applied preflood. This treatment had no detrimental effects on populations of aquatic insects from one week after application until sampling ceased in September (Fig. 1). Results on non-target organisms following the preflood application also showed no definite trends in terms of populations reductions (Fig. 2). On weeks 1 and 2 after application, the treated and untreated plots had similar populations, following by a slight reduction in populations in weeks 3 and 4 and no effect the rest of the season. 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: Seven 3-leaf treatments were compared. For the first two weeks after application, there were some slight to moderate effects of the treatments on populations of aquatic insects. Reductions were most severe with dinotefuron and Mustang Max and intermediate with indoxacarb, etofenprox, and Warrior on aquatic insects for the first 2 weeks. Dimilin and azadirachtin had no effects in aquatic insect populations (Fig. 3). Levels of other aquatic invertebrates were even less severely affected by the treatments. Dinotefuron was the only product which reduced populations for more than one week; this treatment showed a 3 week reduction in invertebrate populations. Dimilin (week 1), indoxacarb and Mustang Max (week 2) and etofenprox (week 3) also caused some short-term reductions. Although some of the reductions were in the 70% range, the populations quickly recover and were 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 20 July). Results on aquatic insects and other aquatic organisms are shown in Fig. 5 and 6, respectively. Numbers of aquatic insects were reduced by ~70% by the Warrior application at 1 week after treatment but no effects were seen thereafter. Similarly, populations of other aquatic invertebrates were generally not affected reduced by the July Warrior application. These effects of Warrior were much less than seen 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. While we do not ever expect populations of this insect pest to disappear, the flight monitoring allows us to see the magnitude of flight and the peak flight periods. It is also interesting to compare RWW populations and flight trends over years and to draw some correlations with populations in the field. The insect overwinters in a diapause (period of suspended activity) and breaks this state in March and is apparently ready to fly. The weevil flights only occur in the evenings (6-11 pm) with warm (70-80^{0}F) and calm periods. During cool, wet springs, as in 2006 (and 2005), the flight was delayed. In 2006, the flight occurred fairly steadily from 25 April to 17 May. There were periods of high flight intensity from April 25-28, May 1-3, and May 11-17 (Fig. 7). These initial flights were before much rice was seeded, but the weevil adults can feed and survive on grassy weeds which were common. A total of ~2300 RWW adults were captured which was three times the number captured in 2005 (Fig. 8). The last 3 years the population has been on an upswing.

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

At present, there are no rice varieties that are resistant to RWW. Some incremental increases in rice plant tolerance to RWW have been made. These are based on plant vigor such that the plant can produce yield in spite of root pruning. This plant vigor is also important for facilitating increasing crop yields. The “bank” of rice genotypes world-wide is extremely large but true resistance to RWW (based on a chemical incompatibility or toxicity of the plant to the insect) has not been found. In studies conducted elsewhere, medium grain varieties have been shown to support higher RWW levels and to respond more severely, i.e., more yield loss, to infestation.

Therefore using the same management plans for medium grain varieties and a long-grain or specialty rice may be unwise. The goal of this study was to evaluate selected California varieties for susceptibility and response to RWW.

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

1. L-206
2. S-102
3. M-104
4. M-208
5. M-205
6. M-202
7. M-206
8. M-401
9. PI plant line
10. Calhikari-201
11. Calmati-202
12. Calmochi-101

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 26 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 26 May and seeded on 27 May. RWW adult feeding scars, seedling establishment rating, larval population numbers, and grain yields were determined as described previously. The amount of feeding scars was used to evaluate susceptibility to adult infestation, 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:

Are all varieties equally susceptible (preferred by) to RWW infestation by adults and establishment/survival by RWW immatures?

The naturally-occurring RWW population was low in this plot area. Percentage scarred plants, averaged across the varieties, was 1.6% for untreated plots and 1.3% for treated plots. Among the varieties, when untreated, percentage scarred plants ranged from 0% (M-205) to 3.5% (S-102) (Fig. 9). There were no significant differences. These data would be an indication of relative attractiveness of the varieties to RWW adult feeding. Compared with ‘M-202’, four varieties were more attractive to adult feeding and seven others were less conducive to adult feeding (Fig. 10). RWW populations were assessed on two dates with the first timing providing the highest population numbers and the second being slightly past the peak. RWW populations, averaged across the varieties, were 0.3 immatures per core sample for untreated plots and 0.1 for treated plots in the first sampling and overall 0.2 and 0.05 for the untreated and treated plots, respectively. These were both statistically significant differences, i.e., the insecticide treatment provided good control. There were significantly more larvae in L-206 than in M-205, M-206, M-104, the PI plant line, and S-102 (Fig. 9). These results are indicative to the relative susceptibility of the varieties to RWW infestation. Only L-206 supported more RWW immatures (almost twice as many) than the standard 'M-202'. These results are consistent with the concept behind the PI line. This line apparently exhibits tolerance to RWW, that is it vigorously regrows roots upon being damaged. Therefore, it may support "high" levels of RWW larvae but still produce acceptable yields. As shown below, the infestation levels were not high even to impact yields.

Are the yield losses equal among the varieties (do some varieties respond more negatively to root pruning than other varieties)?

Grain yields ranged from 4314 (M-104) to 8146 lbs./A (M-206) (Fig. 11). The RWW population was too low to substantially impact grain yields. In only three of the varieties did the treated plots outyield the untreated plots and these differences were minor in most cases.

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 through stale seedbed and dry seeding techniques. However, these techniques will also likely affect insect pest populations (and also perhaps mosquitoes). In 2006, plots were maintained with the following variations of rice stand establishment methods: 1.) Conventional water seeded, 2.) Conventional drill seeded, 3.) Delayed spring-tilled water seeded, 4.) Stale seedbed (no spring tillage) water seeded, and 5.) Stale seedbed (no spring tillage) drill seeded. Previous work has shown that drill-seeding reduces RWW populations. The effects of the stale seedbed are unknown. RWW adults are attracted to areas by water and foliage does not have to be present. Stale seedbed lengthens the period with water but some of this period is before seeding.

In 2006, we monitored RWW populations (adult scarring and larval numbers) as well as armyworm populations in this seedling establishment study. Data were collected on 22 June (adult scarring) and 14 July and 2 Aug. (RWW immatures) using standards methods. RWW infestation in this plot was low to moderate (Fig. 12). Adult scarring did not differ significantly among the treatments and ranged from 2.5 (Drill-Seeded, Stale Seedbed, No-Till treatment) to 9.0% (Water-Seeded, Stale Seedbed, No-Till). All three water-seeded treatments had more scarring from RWW adults than the drill-seeded treatments. The stale seedbed water-seeded treatments had 1.4 to 2 times more scarring than the conventional water-seeded treatment (Fig. 12). Conversely, the larval populations were higher in the drill-seeded than the water-seeded treatments.

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*). There are years and periods within years where armyworm larvae are present in hordes (thus the name) and they seemingly feed on everything. These cycles have been studied by entomologists for years and the exact reasons are still unclear. However, the more routine build-up of armyworm populations is of more concern and this appears to be happening in many parts of the Sacramento Valley rice production region. This indicates that some factor has changed in the agroecosystem and that this is resulting in outbreaks. Changes in production practices that initially appear unrelated and distant to insect populations could play a role. Armyworms can damage rice 1.) by defoliation and 2.) by feeding on developing panicles and kernels. A rice plant has considerable "excess" leaf tissue so the plants can withstand a fairly high percentage of leaf damage. The panicle feeding/damage is much more important than is simple leaf removal. A mid-season application of a pyrethroid insecticide can provide armyworm control but is a added cost has the potential to upset the "balance" in rice fields and to promote populations of mosquitoes. Studies continued in 2006 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.

Based on some observations we made about three years ago and due to the challenges in weed control common to many rice fields, it appears that higher armyworm populations are present in fields with a higher incidence of weeds, particularly broad-leaf weeds. We researched this in 2004 and 2005 and the data supported our observations but the results were not so strong that they could not be questioned. The two species of armyworms have several important differences. In particular the western yellow-striped armyworm is reported to have a wider host range and is actually a very general feeder. Numerous weed species hosts are also known to be suitable hosts and in many cases, western yellow-striped armyworm develops first on weed or rangeland plants, before moving on to crops. It is reported to only lay eggs on broad-leaf weeds and prefers to feed on these plants over rice. Therefore, weed populations may influence populations of armyworms. We continued investigations of this relationship in 2006 by setting up plots with 1.) very few weeds, 2.) predominantly grassy weeds, 3.) predominantly broadleaf weeds, and 4.) both grassy and broadleaf weeds. This was done by treating plots (20 by 50 ft.) with Clincher, Shark, or both materials. Data were collected weekly on armyworm populations and on weed incidence.

Weed control was accomplished as planned and there were differences in weed species/populations. Armyworm populations were; however, nonexistent in this plot in 2006.

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.

Growers often report that the only way they know an armyworm infestation is occurring is to see birds staying and feeding within an area. This is useful, but the presence of birds means that the armyworms may have already done some damage and this could be important especially with panicle feeding. Also, there could be other reasons for birds to occupy an area. Pheromone traps are used in several crops to gain insights on the timing of movement of pest populations. These traps use the sex attractant naturally produced by female moths; this compound is synthesized, manufactured, and incorporated into a rubber lure. When placed in a trap, the lure attracts the male moths and they become stuck in the trap. Information from pheromone traps, coupled with knowledge of the influence of temperature of key events in the pest lifecycle, can be a useful predictive tool. The attractant is generally specific to one moth species, i.e., true armyworm and western yellow-striped armyworm in this case. Separate traps for western yellow-striped armyworm and Atrue@ armyworm were placed near rice fields in 4 locations in Colusa Co. and 3 locations in Butte Co. Moths were collected from traps weekly from early July to mid-August. In addition, larval populations were monitored in 11 rice fields in Colusa and Butte Co. every week. This involved searching for and counting all armyworm larvae within a five minute period (three individuals each for five minute per field = 15 minutes per field). Observations were recorded as to the pattern of armyworm infestation in the fields.

In 2006, the true armyworm exhibited a high flight peak in early-July and again a slight in increase in mid-Aug. (Fig. 13). Western yellow-striped armyworm flight was overall low in 2006. These results with western yellow-striped armyworm moth captures duplicate that seen in 2005. To put these data in some perspective, 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) and probably about 2 week to go from the egg stage to the larval stage. As shown in Fig. 14, the early-July moth peak corresponded to a mid-July peak of larvae found in the rice field searches. Populations peaked at ~12 worms found per 15-minute search at this time in Butte Co. Knowledge of the moth peak capture data and predicted population development would pinpoint when the larval population would develop. 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.

Armyworm larvae were collected in July and August and held in the laboratory on artificial diet. Two species of small parasitic wasps are common on these armyworms. On western yellow-striped armyworm larvae the common parasite is *Hyposoter exiguae* whereas *Apanteles militaris* is most common on true armyworm larvae. On the artificial diet, if parasitized the larva would die and the parasites will soon be obvious. A significant portion (up to 57%) of the armyworm larvae were parasitized in 2005. In 2006, parasitism was very uncommon. In total, only 14 of 136 larvae were parasitized and there were no trends with location and/or week.

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

Several nonvertebrate pests of rice occur in other countries and even in other U.S. states, but fortunately not in California. Some of these are extremely serious pests that would cause crop yields, increase costs of production, and have possible trade implications. 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. Given the world-wide nature of rice and the inter-state and inter-country transport of rice, pest movement is a concern. Through this project, we maintain a vigilant watch for exotic pests through our visits to numerous rice fields throughout the Sacramento Valley. Pests of particular concern include the rice stink bug, Mexican rice borer, sugarcane borer, South American rice leafminer, and apple snail; these pests are all present in the southern U.S. with the rice stink bug and stem borers causing significant damage. The South American rice leafminer was identified in Louisiana about 4 years ago and had spread its range into Texas. We have worked with CDFA personnel as they have surveyed for this pest in California in 2005 and 2006. The rice panicle mite is an extremely serious pest that is present in Asia and Central/South America. It is also present in Puerto Rico where winter rice nurseries are housed. The extremely small and cryptic nature of this pest make it difficult to exclude and to sample. We provide educational materials on these pests and remain aware for any other possibilities of exotic pests of rice.

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PUBLICATIONS OR REPORTS:

Godfrey, L. D. and R. R. Lewis. 2006. Alternatives to pyrethroid insecticides for management of key rice arthropod pests. Calif. Rice Experiment Station Field Day Report. pp 29-32.

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CONCISE GENERAL SUMMARY OF CURRENT YEAR'S (2006) RESULTS:

Larry D. Godfrey, Richard Lewis, and Karey Windbiel

Research was conducted in 2006 on the biology and management of rice water weevil (RWW) and armyworm (AW), two important rice arthropod pests of rice in CA. The goal was to refine IPM schemes for these pests and to maximize the management in light of the environmentally sensitive nature of the rice agroecosystem. The cost effectiveness of any management efforts in rice must also be carefully considered. Three overall themes provided direction for the 2006 research program.

1.) Best Management Practices have been developed and put forth for the industry to aid in mitigation of mosquito populations. This area has taken on added importance with the emphasis on West Nile Virus in California. A study was continued to evaluate the effects of registered and experimental rice insecticides on non-target invertebrates, which could play an important role in mosquito management in rice fields.

2.) CA-DPR is currently placing pyrethroid insecticides into reevaluation based on their propensity to accumulate and move off-site on organic sediment. Therefore, studies continued to develop alternative active ingredients and classes of chemistry for arthropod pest control.

3.) Armyworm populations at damaging levels have become more common in rice fields in recent years. Studies were conducted to investigate the biological reasons for this upswing in populations of this pest.

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.

Rice Water Weevil: Studies were continued in 2006 in ring plots to evaluate experimental materials versus registered standards for RWW control and to modify the use patterns of the existing products to facilitate management. Twenty-four 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, indoxacarb, and clothianidan all appear to have significant potential for RWW management. All these products are a few years from any possible registration with their progress in this regard being approximately in the order listed above (from nearest to farthest from registration). Indoxacarb is active via a post-flood application whereas clothianidan has the most flexibility in terms of application timing showing good RWW control with a seed treatment, soil, pre-flood application and 3-leaf stage application. Results with preflood application of etofenprox have been unclear but the 3-leaf stage application efficacy has been consistently excellent. Given the re-evaluation of pyrethroid registrations due to possible off-site movement, it is important to continue to develop alternative active ingredients and classes of chemistry. In 2006, these products applied with various rates and application methods provided 95%+ RWW larval control and excellent protection of grain yield. A high infestation was achieved in the ring plots to adequately assess these products (~5.5 RWW per sample in untreated plots). Two additional active ingredients, DPX-E2Y45 and V10194, were evaluated against RWW for the first time in my studies and both showed good performance albeit somewhat less than the previously mentioned products. Preflood applications of Warrior and Mustang Max were evaluated and found effective against RWW. Work on a biological insecticide, azadirachin, was de-emphasized in 2006 with only one greenhouse tested conducted. This greenhouse study was intended to provide a second year of data in this area as well as to perhaps provide some explanation of the poor field results obtained in 2005. In summary, the foliar application was more effective against RWW than the preflood application, a liquid formulation (Aza-Direct) was more effective than a granular product, and the 0.01 lb. AI rate of Aza-Direct was highly effective and about 4 times more of the granular formulation was needed to reach comparable levels of control to that seen with Aza-Direct. Finally, studies evaluated the effects of insecticide treatments in rice on populations of invertebrate non-targets. Results from 2005 field collections were finalized and the 2006 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 2005. For the post-flood applications, seven treatments were compared. For the first two weeks after application, there were some slight to moderate effects of the treatments on populations of aquatic insects. Reductions were most severe with dinotefuron and Mustang Max and intermediate with indoxacarb, etofenprox, and Warrior on aquatic insects for the first 2 weeks. Dimilin and azadirachtin had no effects in aquatic insect populations. Levels of other aquatic invertebrates were even less severely affected by the treatments. Dinotefuron was the only product which reduced populations for more than one week; this treatment showed a 3 week reduction in invertebrate populations. Although some of the reductions were in the 70% range, the populations quickly recover 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. In 2005, numbers of aquatic insects were reduced by ~70% by the Warrior application at 1 week after treatment but no effects were seen thereafter.

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. In 2006, the flight occurred fairly steadily from 25 April to 17 May. There were periods of high flight intensity from April 25-28, May 1-3, and May 11-17. These initial flights were before much rice was seeded, but the weevil adults can feed and survive on grassy weeds which were common. A total of ~2300 RWW adults were captured which was three times the number captured in 2005. Twelve rice varieties were compared for susceptibility to and yield loss from RWW. There were significantly more RWW larvae in L-206 than in M-205, M-206, M-104, the PI plant line, and S-102. Populations were not high enough to impact grain yield and to allow evaluation of the second aspect of this study. Refined rice seedling establishment techniques are being investigated at the RES primarily as a means to improve weed management through stale seedbed and dry seeding techniques. However, these techniques will also likely affect insect pest populations and also perhaps mosquitoes. In 2006, all three water-seeded treatments had more scarring from RWW adults than the drill-seeded treatments. The stale seedbed water-seeded treatments had 1.4 to 2 times more scarring than the conventional water-seeded treatment. Conversely, the larval populations were higher in the drill-seeded than the water-seeded treatments.

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. Based on some observations we made about three years ago and due to the challenges in weed control common to many rice fields, it appears that higher armyworm populations are present in fields with a higher incidence of weeds, particularly broad-leaf weeds. We continued investigations of this relationship in 2006 by setting up plots with 1.) very few weeds, 2.) predominantly grassy weeds, 3.) predominantly broadleaf weeds, and 4.) both grassy and broadleaf weeds. Unfortunately, no armyworm populations developed in this plot. Studies were conducted to develop an easy, accurate sampling method for armyworms in rice. Pheromone traps (these two species utilize different pheromones) were used to study the timing of armyworm moth flight. In 2006, the true armyworm exhibited a high flight peak in early-July and again a slight in increase in mid-Aug. Western yellow-striped armyworm flight was overall low in 2006 as it was in 2005. The early-July moth peak corresponded to a mid-July peak of larvae found in the rice field searches; populations peaked at ~12 worms found per 15-minute search at this time in the Butte Co. fields. 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. Parasitism of armyworm larvae collected in July and August was low (~10%) in 2006. In 2005, significant portions (up to 57%) of the armyworm larvae were parasitized.

Exotic Pests of Rice: Through this project, we maintain a vigilant watch for exotic pests through our visits to numerous rice fields throughout the Sacramento Valley. Pests of particular concern include the rice stink bug, Mexican rice borer, sugarcane borer, South American rice leafminer, and apple snail; these pests are all present in the southern U.S. with the rice stink bug and stem borers causing significant damage. We provide educational materials on these pests and remain aware for any other possibilities of exotic pests of rice.

Table 1. Treatment list for RWW management ring study, 2006.

Product	**Rate (lbs. AI/A)**	**Formulation per A**	**Timing**
1. Furadan 5G	0.5	10 lbs.	PF
2. Dimilin 2L	0.125	8 oz.	3-leaf
3. Proaxis	0.015	3.84 oz.	3-leaf
4. Untreated	---	---	---
5. Warrior	0.03	3.84 oz.	3-leaf
6. Warrior	0.03	3.84 oz.	PF
7. Etofenprox 0.9%G	0.135	15 lbs.	3-leaf
8. Etofenprox 0.9%G	0.18	20 lbs.	3-leaf
9. Etofenprox 0.9%G	0.225	25 lbs.	3-leaf
10. V10170 50WD (2 appl.)	0.19 x 2	6 + 6 oz.	PF & 3 leaf
11. V10170	0.22		Seed trt.
12. V10170	0.44		Seed trt.
13. V10194	0.22		Seed trt.
14. V10194	0.44		Seed trt.
15. Mustang Max 0.8EC	0.02	3.2 fl. oz	PF
16. Mustang Max 0.8EC	0.02	3.2 fl. oz	3 leaf
17. Steward EC	0.065	6.7 oz.	3 leaf
18. Steward EC	0.11	13.3 oz.	3 leaf
19. DPX-E2Y45 0.2%G	0.067	33.5 lbs.	3 days postflood
20. DPX-E2Y45 0.2%G	0.134	67 lbs.	3 days postflood
21. Etofenprox 0.9%G	0.225	25 lbs.	PF
22. DPX-E2Y45 SC	0.067	5.3 oz.	3 days postflood
23. DPX-E2Y45 SC	0.134	10.6 oz.	3 days postflood
24. V10170 50WD	0.19	6 oz.	PF

Table 2. Rice plant stand and adult feeding damage in chemical ring study, 2006.

Product	**Rate (lbs. AI/A) & Timing**	**Stand Rating (1-5)**	**% Scarred Plants**	
1. Furadan 5G	0.5 - PF	3.5	18.7	cde
2. Dimilin 2L	0.125 - 3-leaf	3.0	43.5	ab
3. Proaxis	0.015 - 3-leaf	2.7	0.0	e
4. Untreated	---	3.3	34.0	bc
5. Warrior	0.03 - 3-leaf	3.3	0.0	e
6. Warrior	0.03 - PF	3.1	32.0	bc
7. Etofenprox 0.9%G	0.135 - 3-leaf	3.0	5.5	e
8. Etofenprox 0.9%G	0.18 - 3-leaf	3.1	2.5	e
9. Etofenprox 0.9%G	0.225 - 3-leaf	2.9	0.0	e
10. V10170 50WD (2 appl.)	0.19 x 2 – PF&3-leaf	3.1	1.3	e
11. V10170	0.22 – seed trt.	2.7	2.0	e
12. V10170	0.44 – seed trt.	2.5	1.0	e
13. V10194	0.22 – seed trt.	3.1	10.0	de
14. V10194	0.44 – seed trt.	2.7	8.0	de
15. Mustang Max 0.8EC	0.02 - PF	3.1	55.0	a
16. Mustang Max 0.8EC	0.02 - 3-leaf	2.6	0.0	e
17. Steward EC	0.065 - 3-leaf	2.8	5.0	e
18. Steward EC	0.11 - 3-leaf	3.0	1.0	e
19. DPX-E2Y45 0.2%G	0.067 – 3-d post	3.4	25.0	bcd
20. DPX-E2Y45 0.2%G	0.134 - 3-d post	3.3	26.5	bcd
21. Etofenprox 0.9%G	0.225 - PF	3.2	43.5	ab
22. DPX-E2Y45 SC	0.067 - 3-d post	3.0	18.7	cde
23. DPX-E2Y45 SC	0.134 - 3-d post	3.1	13.0	de
24. V10170 50WD	0.19 - PF	3.1	9.0	de

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, 2006.

		RWW per Core Sample				
Product	**Rate (lbs. AI/A) & Timing**	**7 July**		**25 July**		**Average**
1. Furadan 5G	0.5 - PF	0.15	b	0.00	d	0.08
2. Dimilin 2L	0.125 - 3-leaf	0.00	b	0.15	bcd	0.08
3. Proaxis	0.015 - 3-leaf	0.10	b	0.00	d	0.05
4. Untreated	---	5.45	a	0.80	a	3.13
5. Warrior	0.03 - 3-leaf	0.05	b	0.00	d	0.03
6. Warrior	0.03 - PF	0.05	b	0.00	d	0.03
7. Etofenprox 0.9%G	0.135 - 3-leaf	0.10	b	0.00	d	0.05
8. Etofenprox 0.9%G	0.18 - 3-leaf	0.25	b	0.00	d	0.13
9. Etofenprox 0.9%G	0.225 - 3-leaf	0.05	b	0.05	cd	0.05
10. V10170 50WD (2 appl.)	0.19 x 2 – PF&3-leaf	0.05	b	0.00	d	0.03
11. V10170	0.22 – seed trt.	0.15	b	0.00	d	0.08
12. V10170	0.44 – seed trt.	0.00	b	0.00	d	0.00
13. V10194	0.22 – seed trt.	0.95	b	0.00	d	0.48
14. V10194	0.44 – seed trt.	0.75	b	0.35	bc	0.55
15. Mustang Max 0.8EC	0.02 - PF	0.00	b	0.00	d	0.00
16. Mustang Max 0.8EC	0.02 - 3-leaf	0.00	b	0.00	d	0.00
17. Steward EC	0.065 - 3-leaf	0.45	b	0.10	cd	0.28
18. Steward EC	0.11 - 3-leaf	0.00	b	0.00	d	0.00
19. DPX-E2Y45 0.2%G	0.067 – 3-d post	0.30	b	0.00	d	0.15
20. DPX-E2Y45 0.2%G	0.134 - 3-d post	0.15	b	0.00	d	0.08
21. Etofenprox 0.9%G	0.225 - PF	0.15	b	0.00	d	0.08
22. DPX-E2Y45 SC	0.067 - 3-d post	0.95	b	0.45	b	0.70
23. DPX-E2Y45 SC	0.134 - 3-d post	0.05	b	0.00	d	0.03
24. V10170 50WD	0.19 - PF	0.10	b	0.00	d	0.05

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, 2006.

Product	**Rate (lbs. AI/A) & Timing**	**% Moisture**		**Grain Yield (lbs./A)**		**Biomass - Straw + Grain (t/A)**	
1. Furadan 5G	0.5 - PF	18.0	a-d	7381.3	abc	9.7	a-d
2. Dimilin 2L	0.125 - 3-leaf	19.2	ab	7533.3	abc	9.8	a-d
3. Proaxis	0.015 - 3-leaf	18.8	abc	7527.7	abc	9.6	a-d
4. Untreated	---	17.9	a-d	6356.5	abc	6.5	f
5. Warrior	0.03 - 3-leaf	18.5	abc	6506.5	abc	7.6	def
6. Warrior	0.03 - PF	18.5	a-d	6878.7	abc	9.5	a-e
7. Etofenprox 0.9%G	0.135 - 3-leaf	17.8	bcd	5965.9	bc	6.9	f
8. Etofenprox 0.9%G	0.18 - 3-leaf	16.8	d	5753.8	bc	8.3	b-f
9. Etofenprox 0.9%G	0.225 - 3-leaf	17.9	bcd	7025.0	abc	7.7	c-f
10. V10170 50WD (2 appl.)	0.19 x 2 – PF&3-leaf	18.6	abc	6410.7	abc	8.5	b-f
11. V10170	0.22 – seed trt.	18.8	abc	7819.1	ab	8.5	b-f
12. V10170	0.44 – seed trt.	19.6	a	6955.6	abc	10.0	abc
13. V10194	0.22 – seed trt.	18.4	a-d	6984.4	abc	10.1	ab
14. V10194	0.44 – seed trt.	18.4	a-d	6329.6	abc	8.3	b-f
15. Mustang Max 0.8EC	0.02 - PF	18.0	a-d	5360.7	c	7.5	def
16. Mustang Max 0.8EC	0.02 - 3-leaf	17.9	bcd	5818.3	bc	6.8	f
17. Steward EC	0.065 - 3-leaf	18.1	a-d	5943.4	bc	7.9	b-f
18. Steward EC	0.11 - 3-leaf	18.9	abc	5798.5	bc	8.1	b-f
19. DPX-E2Y45 0.2%G	0.067 – 3-d post	19.1	ab	6487.2	abc	8.2	b-f
20. DPX-E2Y45 0.2%G	0.134 - 3-d post	19.4	ab	8328.1	a	11.0	a
21. Etofenprox 0.9%G	0.225 - PF	17.4	cd	6506.1	abc	8.1	b-f
22. DPX-E2Y45 SC	0.067 - 3-d post	18.3	a-d	6257.1	abc	7.3	ef
23. DPX-E2Y45 SC	0.134 - 3-d post	17.9	bcd	6899.1	d	8.1	b-f
24. V10170 50WD	0.19 - PF	19.2	ab	7076.3	d	8.4	b-f

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

Table 5. Greenhouse comparison of formulations and rates of Azadirachin for RWW control 2006.

Treatment	Timing	Rate - oz. or lbs./A (lbs. AI/A)	RWW per Pot		Feeding Scars	
1. AZA-Direct	pre-flood	6.5 (0.005)	13.0	cde	6.8	ab
2. AZA-Direct	foliar - 1-d before infesting	6.5 (0.005)	11.3	def	6.8	ab
3. Neemazal G	pre-flood	5 (0.005)	30.3	a	8.3	ab
4. Neemazal G	foliar - 1-d before infesting	5 (0.005)	11.0	def	7.8	ab
5. AZA-Direct	pre-flood	13 (0.01)	3.3	fghi	5.0	b
6. AZA-Direct	foliar - 1-d before infesting	13 (0.01)	1.0	hi	9.0	ab
7. Neemazal G	pre-flood	10 (0.01)	9.8	defgh	6.3	ab
8. Neemazal G	foliar - 1-d before infesting	10 (0.01)	10.3	defg	9.8	a
9. AZA-Direct	pre-flood	19.5 (0.015)	0.8	i	7.5	ab
10. AZA-Direct	foliar - 1-d before infesting	19.5 (0.015)	0.0	i	6.0	ab
11. Neemazal G	pre-flood	15 (0.015)	17.8	bcd	8.3	ab
12. Neemazal G	foliar - 1-d before infesting	15 (0.015)	12.5	cde	9.8	a
13. AZA-Direct	pre-flood	26 (0.02)	2.8	fghi	7.0	ab
14. AZA-Direct	foliar - 1-d before infesting	26 (0.02)	0.0	i	9.0	ab
15. Neemazal G	pre-flood	20 (0.02)	7.5	efghi	9.0	ab
16. Neemazal G	foliar - 1-d before infesting	20 (0.02)	6.3	efghi	8.0	ab
17. AZA-Direct	pre-flood	52 (0.04)	0.0	i	8.5	ab
18. AZA-Direct	foliar - 1-d before infesting	52 (0.04)	0.3	i	7.8	ab
19. Neemazal G	pre-flood	40 (0.04)	1.5	ghi	5.0	b
20. Neemazal G	foliar - 1-d before infesting	40 (0.04)	1.5	ghi	6.5	ab
21. AZA-Direct	pre-flood	0	24.3	ab	8.3	ab
22. AZA-Direct	foliar - 1-d before infesting	0	13.8	cde	8.5	ab
23. Neemazal G	pre-flood	0	12.8	cde	8.3	ab
24. Neemazal G	foliar - 1-d before infesting	0	20.3	bc	9.3	a

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

Table 6. Evaluation of potential for Azadirachtin to sterilize RWW, greenhouse studies, 2006.

Treatment	Timing	RWW per Pot		Feeding Scars	
Aza-Direct	Treated plant- days 0 to 2	0.3	e	3.0	cd
Aza-Direct	Days 2 to 4	0.0	e	0.0	d
Aza-Direct	Days 4 to 6	0.0	e	0.0	d
Neemazal	Treated plant- days 0 to 2	1.3	de	7.3	ab
Neemazal	Days 2 to 4	10.3	bcd	6.3	bc
Neemazal	Days 4 to 6	16.0	b	9.8	a
Untreated	Days 0 to 2	33.8	a	6.0	bc
Untreated	Days 2 to 4	5.0	cde	6.3	bc
Untreated	Days 4 to 6	12.0	bc	10.3	a

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

Table 7. Treatments evaluated in non-target study, 2005 and 2006.

Product	**Rate**	**Timing**	**2005**	**2006**
1. Azadirachtin*	0.02 lbs. AI/A	3-leaf	X	X
2. Warrior	0.03 lbs. AI/A	3-leaf	X	X
3. Warrior	0.03 lbs. AI/A	Preflood	X	X
4. Warrior	0.03 lbs. AI/A	July armyworm timing	X	X
5. Mustang Max	0.025 lbs. AI/A	3-leaf	X	X
6. Dimilin 2L	0.125 lbs. AI/A	3-leaf	X	X
7. Untreated	---	---	X	X
8. dinotefuron 1%G (2005) V10170 50WD (2006)	0.26 lbs. AI/A (2005) 0.19 lbs. AI/A (2006)	3-leaf (2005) preflood and 3-leaf (2006)	X	X
9. etofenprox**	0.44 lbs. AI/A	3-leaf	X	X
10. indoxacarb	0.11 lbs. AI/A	3-leaf	X	X

* tested as NeemAzal at 0.02 lbs. AI/A in 2005 and Aza-Direct at 0.04 lbs. AI/A in 2006

** 0.9%G applied at 0.18 lbs. AI/A in 2006

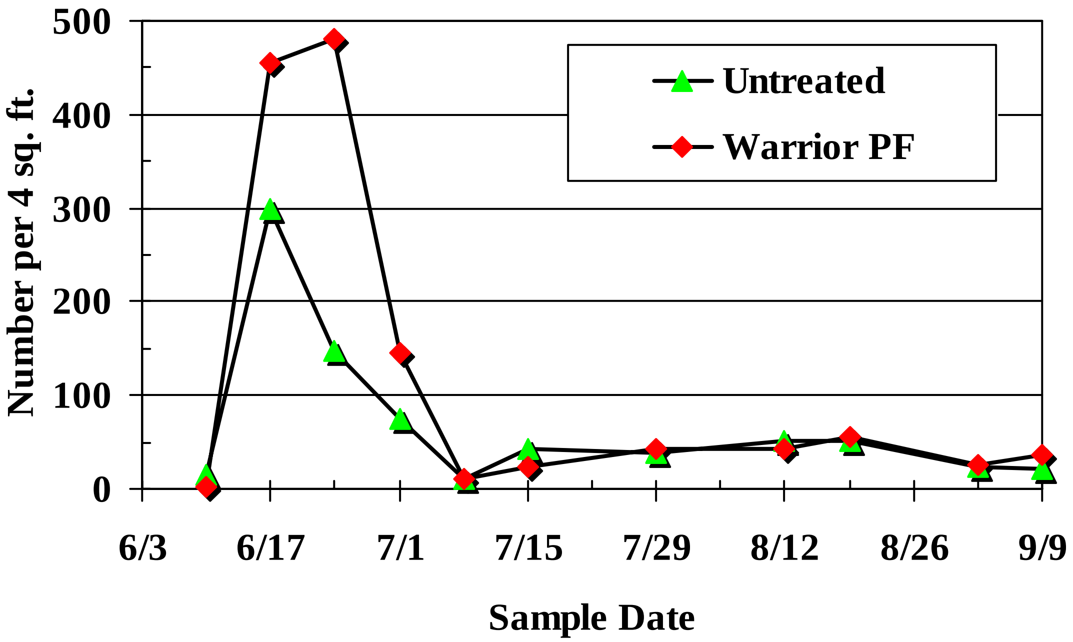

Figure 1. Populations of aquatic insects following application of pre-flood insecticides, 2005.

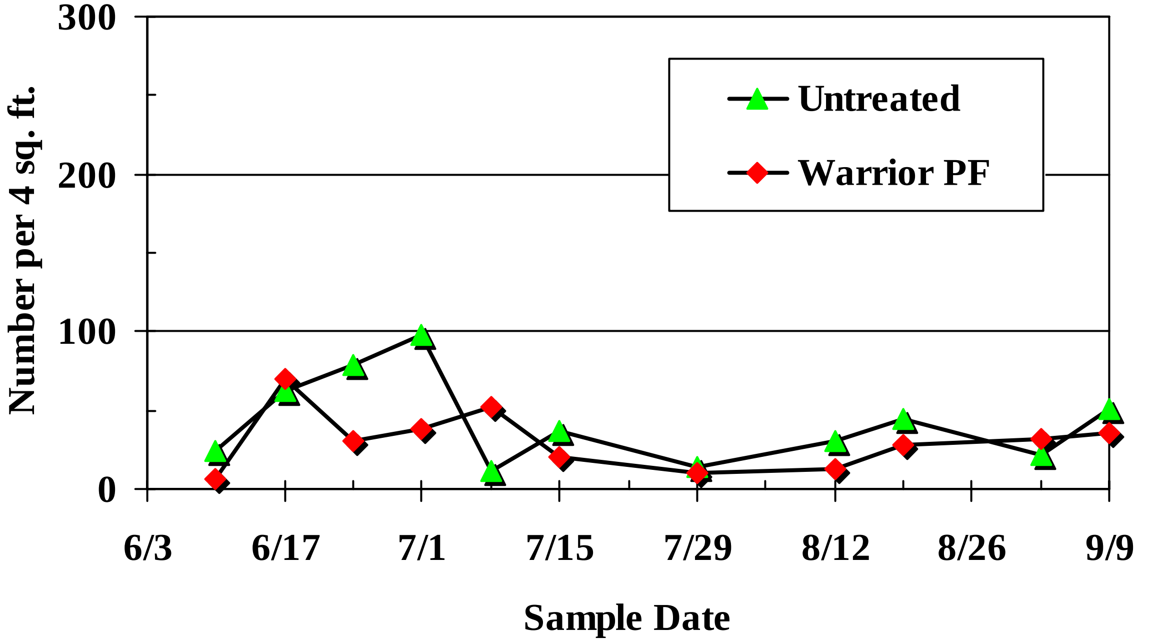

Figure 2. Populations of aquatic invertebrates (excluding insects) following application of pre-flood insecticides, 2005.

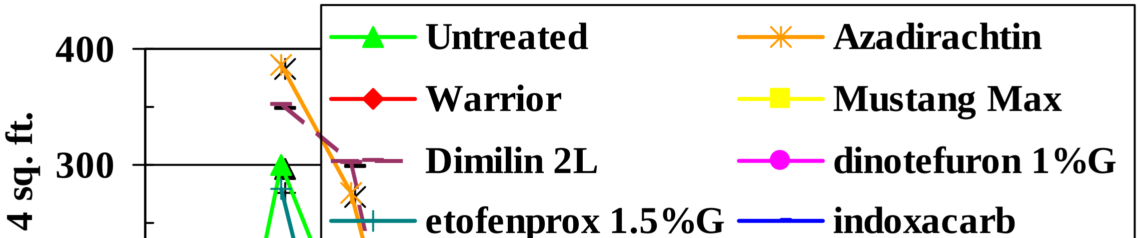

Figure 3. Populations of aquatic insects following application of post-flood (3-leaf stage) insecticides, 2005.

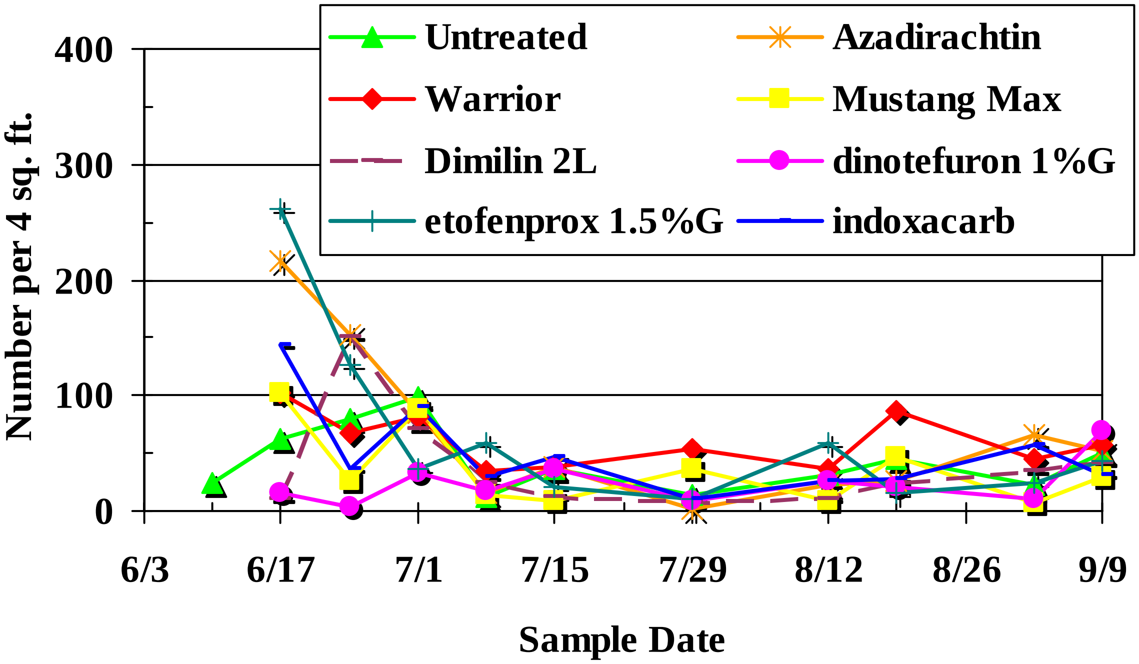

Figure 4. Populations of aquatic invertebrates (excluding insects) following application of post-flood (3-leaf stage) insecticides, 2005.

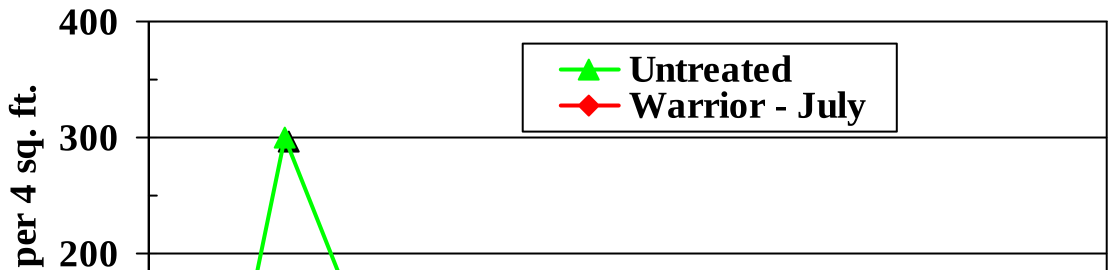

Figure 5. Populations of aquatic insects following application of post-flood (July timing) insecticides, 2005.

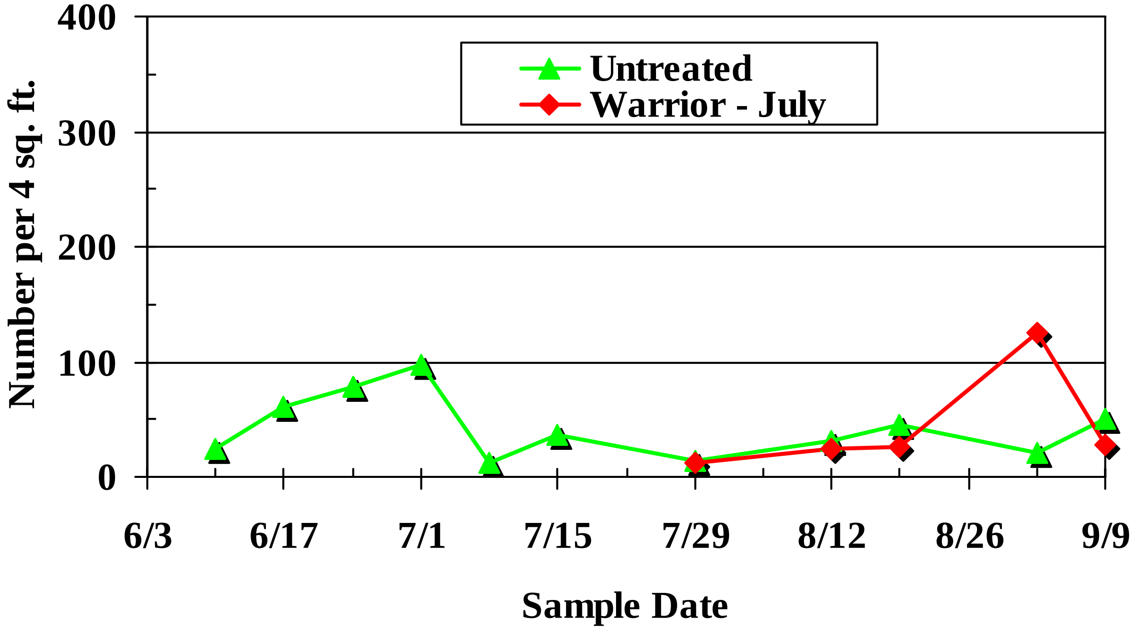

Figure 6. Populations of aquatic invertebrates (excluding insects) following application of post-flood (July timing) insecticides, 2005.

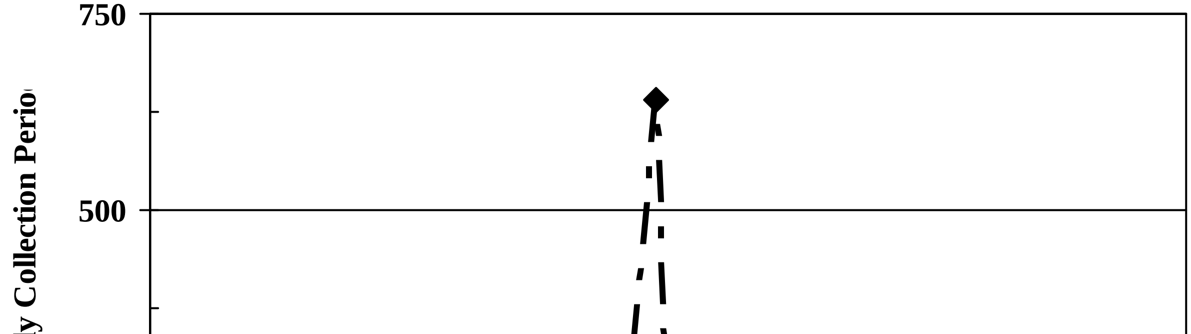

Figure 7. Rice water weevil adult flight as monitored with a light trap at the Rice Experiment Station, 2006.

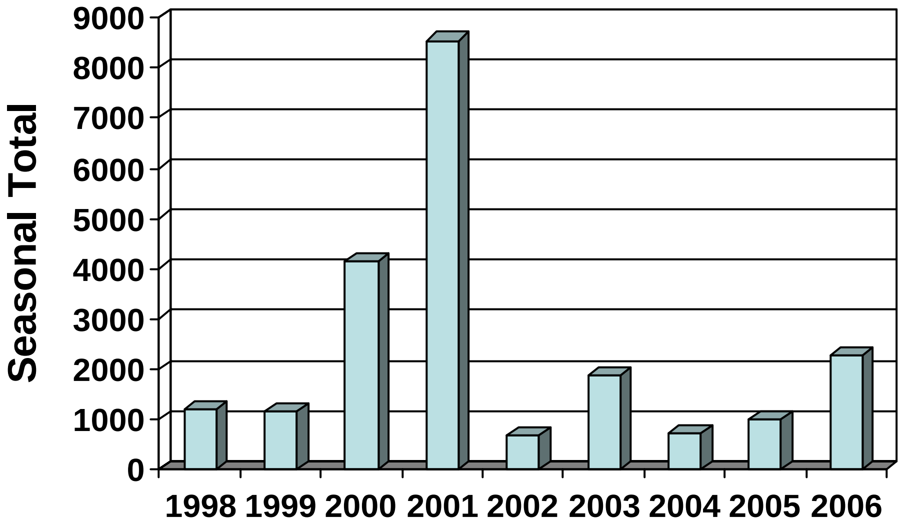

Figure 8. Seasonal total rice water weevil adult capture with light trap sampling, 1998-2006.

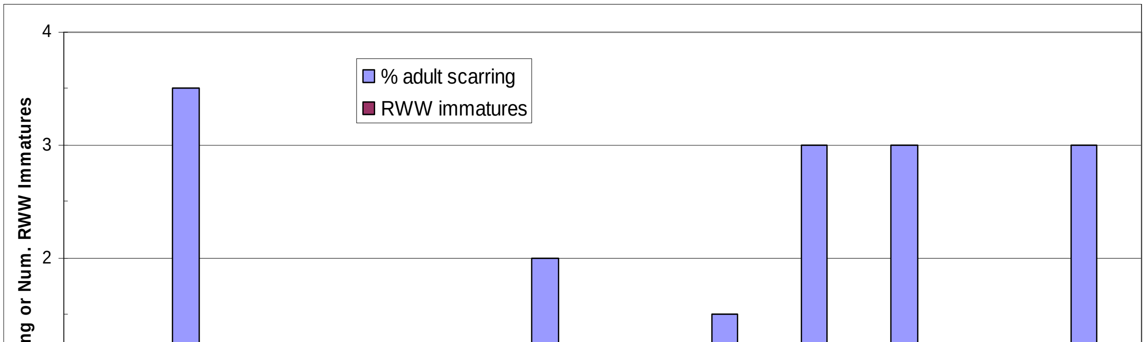

Figure 9. Incidence of rice water weevil adult scarring of rice seedlings and larval populations in 12 rice varieties; no insecticide treatment plots, 2006.

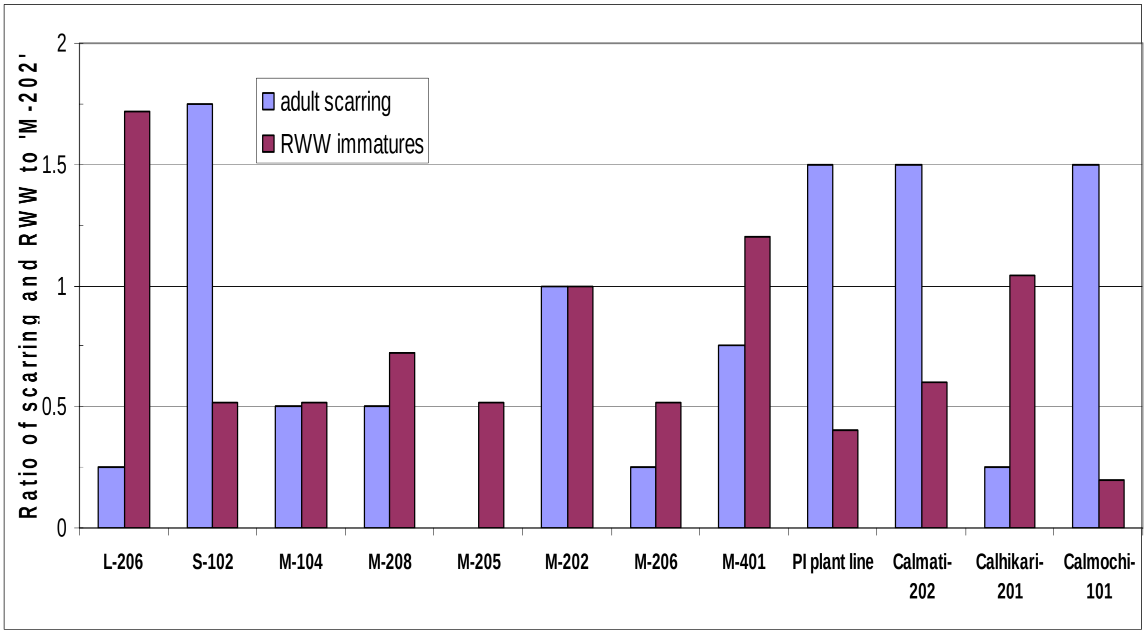

Figure 10. Comparison (setting 'M-202' as the standard) of rice water weevil adult scarring of rice seedlings and larval populations in 12 rice varieties; no insecticide treatment plots, 2006.

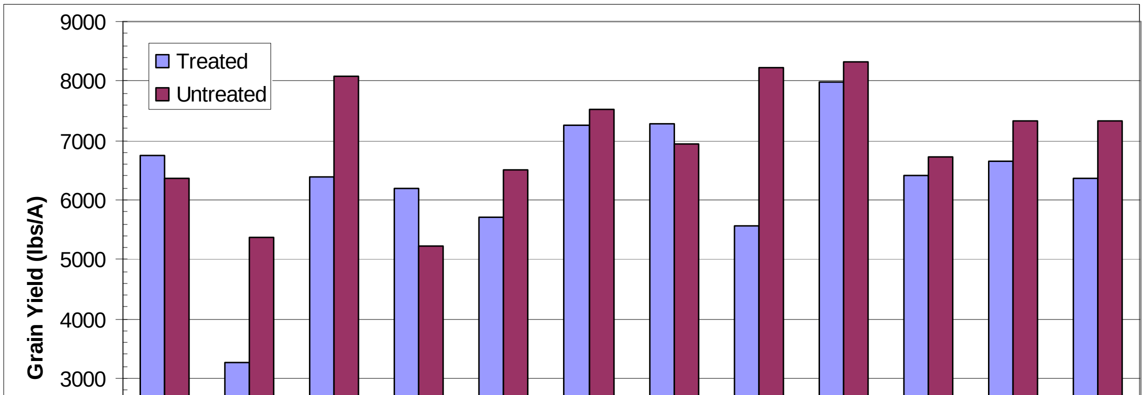

Figure 11. Grain yield of 12 rice varieties in plots treated for rice water weevil and untreated plots.

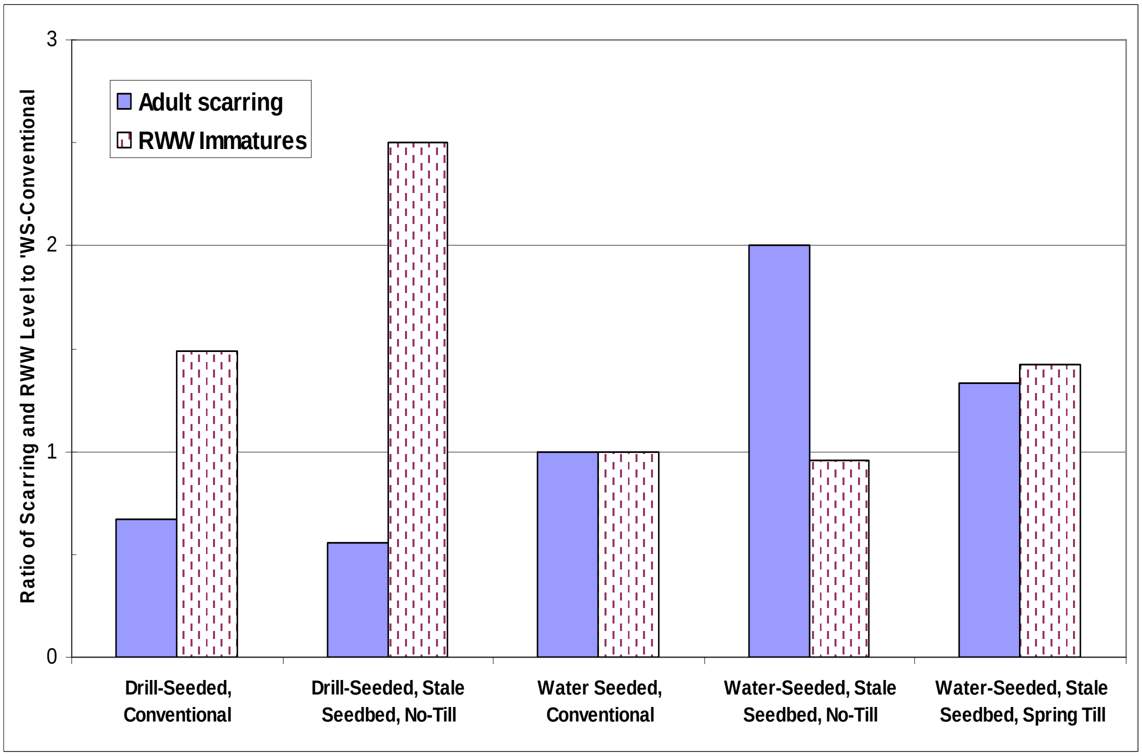

Figure 12. Influence of rice establishment method on rice water weevil adult scarring of plants and larval populations; data expressed as ratio to standard conventional water-seeded method.

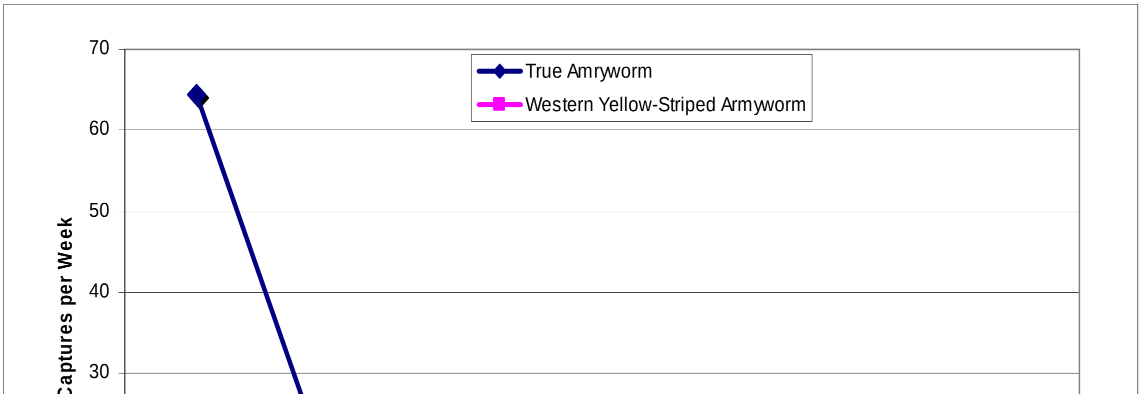

Figure 13. Armyworm (true and western yellow-striped species) moth captures in pheromone traps placed adjacent to rice fields, 2006.

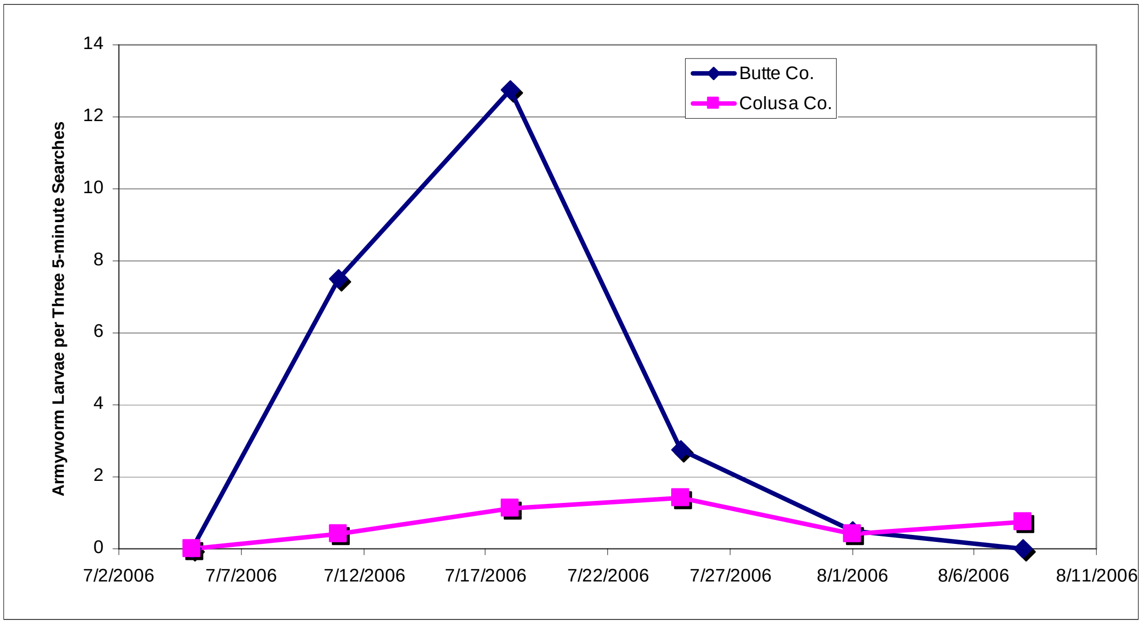

Figure 14. Armyworm (true and western yellow-striped species) larval populations in rice fields, 2006.