PROJECT NO. RP-3

ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE

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PROJECT TITLE: Rice protection from invertebrate pests.

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OBJECTIVES AND EXPERIMENTS CONDUCTED BY LOCATION:

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

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

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

1.3) Examine the efficacy of an experimental insecticide against rice water weevil comparing water-seeded and drill-seeded systems.

1.4) Evaluation of the influence of seed soak with sodium hypochlorite (Ultra Clorox Germicidal Bleach) on activity of seed treatments for rice water weevil.

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

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

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

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

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

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

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

2.3) Evaluate the influence of rice seedling establishment methods of rice pest populations (RWW and armyworm) and on mosquito production.

2.4) Study influence of water depth on populations of Rice Water Weevil.

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

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

  3.1.1). Study the role of weed populations on armyworm populations in rice.
  3.1.2). Investigate the timing of armyworm moth flight in the rice production.

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

SUMMARY OF 2008 RESEARCH BY OBJECTIVE:

Objective 1:

1.1 - 1.4) Chemical Control of Rice Water Weevil - Ring Plots

1.1, 1.2, 1.3, 1.4) Research for subobjectives 1.1, 1.2, 1.3, and 1.4 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 eight different active ingredients) were established in ring plots to accomplish this research. Plots were in a replicated field study at the Rice Experiment Station (RES) near Biggs, CA. Treatment details are listed in Table 1.

Methods:

Testing was conducted with 'M-202' in 8 sq. ft aluminum rings. The plots were flooded on 14 May and water-seeded treatments seeded on 16 May. Two treatments were done in a drill-seeded manner and seeded on 6 May. For these, the seed was raked into the soil and the ring was watered every 5 days. A seeding rate of 90 lbs./A was used. Prior to seeding, seed was soaked for 2 hours in a 5% Clorox Ultra solution (unless otherwise noted), followed by 22 hrs. soaking in water, drained, and 24 hrs. at rest. The Clorox was for Bakanae control. The application timings were as follows:

6 May, early pre-flood treatments
14 May, pre-flood (PF) applications
5 June, 3-leaf stage treatments

Granular treatments were applied with a 'salt-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 9 adults placed into each ring on 2 June and 6 adults into each ring on 8 June. The standard production practices were used. Copper sulfate was applied in mid June for algal management, herbicides on 4 June, and nitrogen was top-dressed in July. The following sample dates and methods were used for this study:

Sample Dates:

Emergence/ Seedling Vigor/Stand Rating: 11 June
Adult Leaf Scar Counts: 11 June
Larval Counts: 1 July and 15 July
Rice Yield: 6,7 October

Sample Method:

Emergence/ Seedling Vigor/Stand Rating:
stands rated on a 1-5 scale with:
5=very good stand (>150 plants)
3=good stand (~100 plants)
1=very poor stand (<20 plants)
Adult Leaf Scar Counts: percentage of plants with adult feeding scars on either of the two newest leaves (50 plants per ring)
Larval Counts: 44 in^3 soil core containing at least one rice plant processed by washing/ flotation method (5 cores per ring per date)
Rice Yield: entire plots were hand-cut and grain recovered with a 'Vogel' mini-thresher and yields were corrected to 14% moisture.
Data Analysis: ANOVA of transformed data and least significant differences test ($\rho < 0.05$). 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. The rating ranged from 2.5 to 3.8 with a rating of 3 being a good, acceptable stand.

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. We are certain of the infestation level because we place the RWW adult into the rings. However, in some years there can also be a natural infestation. This is particularly important and interesting when dealing with seed and granular treatments. The amount of feeding varies yearly even though our methods used are identical every year because of differing conditions during this "feeding period". Feeding scars were sampled on 11 June which was 3 days after 15 adults had been placed into each ring; this allows time for the adults to feed and/or succumb to the treatment. Counts were moderate with the untreated plots averaging 21 and 22.5% scarred seedlings (water-seeded and drill-seeded, respectively). The value in the E2Y45 seed treatment (0.1 mg rate with the Clorox seed soak) was significantly the highest in the test. The value in the untreated rings was similar to that in two of the other E2Y45 seed treatments (0.025 and 0.05 mg rate without the Clorox seed soak) and in the V10170 seed treatment (with Clorox seed soak). These seed treatment products are apparently controlling RWW by killing the larvae or at least at this point in the season they are not taken up by the seedling yet at a level to kill the adults. The other treatments, including Dimilin, Mustang, Warrior (preflood and 3-leaf), Trebon, V10170 (several treatments of preflood and 3-leaf), Steward, and HGW86 seed treatment, reduced the percentage scarred seedling to less than 10% (Table 2).

Larval Counts

RWW larval counts were made twice during the season. This is done to insure that at least one of the sample dates coincides with the population peak as well as so we can look at residual control from products. Populations were higher in the first sample date than the second, although there was still a significant population at that time. RWW levels averaged 1.3 and 1.1 RWW per sample in the untreated water-seeded and drill-seeded treatments, respectively (Table 3). We generally use 1.0 RWW per core sample as the threshold for yield losses so these plots had an "economic infestation".

<u>Results.</u> Four experimental insecticide active ingredients, etofenprox (Trebon®), clothianidin (V10170), rynaxypyr (DPX-E2Y45), Indoxacarb (Steward®), and HGW86 were evaluated in 2008. We have evaluated Trebon and Steward for a few years; in 2008 we greatly expanded our efforts with clothianidin and rynaxypyr. HGW86 was tested for the initial time in rice in 2008. It is important to continue to evaluate new materials for RWW control in California. There is a developing database of environmental concerns with pyrethroid use in rice ranging from off-site movement in California (not just from rice but primarily from row crops) to drift into crayfish ponds (and mortality) in Louisiana. Given the concerns in the South, etofenprox (Trebon) and rynaxypyr seed treatment (Dermacor®) have been available under a Section 18 (emergency) registration in 2008.

Compared with the untreated water-seeded plots, all of the treated plots significantly reduced RWW populations on the first sample date; on the second sample date population in the untreated were statistically similar to that in two of the treated plots (Table 3). Results from the first sample date (with the highest populations) generally broke-out as follows: the highest populations in the untreated rings, followed by several treatments that provided 60-75% control (Trebon 3G, V 10170 2.13 SC [0.18 rate @ 3-leaf stage], E2Y45 seed treatment [0.05 mg rate without Clorox], E2Y45 seed treatment [0.1 mg rate with Clorox with water- and drill-seeding], V10170 seed treatment [0.1 rate with and without Clorox. The other 15 treatments provided 85 to 100% RWW control. Particularly noteworthy were the efficacy of the standards, Warrior, Dimilin, and Mustang applied at the 3-leaf stage, Warrior applied preflood, V10170 (50WDG and 2.13 SC formulation) applied preflood and at the 3-leaf stage (the highest rate of the three tested applied preflood had only moderate performance), Steward EC, HGW86 seed treatment, E2Y45 seed treatment (without Clorox).

Specific questions that were addressed in the Ring Study:

Are there viable experimental products for Rice Water Weevil Control? Several of the experimental products show considerable promise. Trebon applied at the 3-leaf stage was quite effective. We have worked with this product for several years and it has consistently worked well. The preflood application of this product does not appear to be effective. Steward at the 0.11 rate has provided good to excellent rice water weevil control, but it appear the registrant is not interested in pursuing this registration. HGW86 seed treatment was very effective against RWW. This is the first year I have tested this product so considerably more work needs to be done. E2Y45 seed treatment was effective and the highest rate provided slightly better control than the two lower rates. V10170 was very effective and perhaps showed the greatest promise. Applied preflood, regardless of the rate, it practically eliminated the infestation. Applied at the 3-leaf stage, the two lowest rates were very effective; the highest rate was only moderately effective (no obvious explanation for this result). As a seed treatment, V10170 was moderately effective.

Soil application of pyrethroid products. The preflood application of Warrior was registered (24c Special Local Needs) for the 2008 use-season. The activity via this application method has consistently been good in our testing. The label stipulates the application be made no more than 5 days before flooding. We have generally had excellent results with an application made up to 7 days before flooding, but there have been some inconsistencies in control with this application at the longer intervals before flooding. Environmental conditions between application and flooding undoubtedly influence the residual control results. In 2008, the application of Warrior immediately before flooding as well as an application made 8 days before flooding both provided very good RWW control.

Efficacy of a Seed Treatment in Water-Seeded Compared with Drill-Seeded Systems. Efficacy of E2Y45 seed treatment was compared with an application in a simulated drill-seeded system and a water-seeded system. With drill-seeding, there was a ~70% reduction in larval numbers compared with a ~55% reduction under water-seeded conditions (in both cases the seed was soaked with Clorox).

Influence of Seed Soak with Sodium Hypochlorite (Ultra Clorox Germicidal Bleach) on Activity of Seed Treatments for Rice Water Weevil. Research done in 2006 with V10170 seed treatment showed very unsatisfactory control of RWW larvae. These results conflicted with the results from other states. One obvious difference in the procedures we used versus the other states was the inclusion of Sodium Hypochlorite (Ultra Clorox Germicidal Bleach) in our seed soak process. Discussions with the registrant indicated this could be an important factor. In 2007, we compared performance with and without the Clorox step and indeed the differences were apparent. We repeated and expanded these studies in 2008. With V10170 seed treatment in 2008, the Clorox seed soak reduced the efficacy by 30.7% (compared with the rate active ingredient rate without the Clorox step). Similarly, with E2Y45 seed treatment, a 36.4% reduction in activity was seen.

Rice Yield

Grain moisture at harvest (percentage), grain yields (lbs. per A at 14% moisture standard), and biomass (straw + grain weight at harvest data) are shown in Table 4. Moisture values ranged from 15.9 to 17.9%. The two treatments where RWW were not controlled (drill-seeded and water-seeded untreated) had numerically the two lowest grain moisture values. Rice grain yields for the water-seeded treatments ranged from 5639 to 7702 lbs./A which was a 26.8% difference (the overall lowest and highest yield values were from the two drill-seeded treatments, untreated and E2Y45-treated, respectively). Grain yields from the Warrior 3-leaf, V10170 3-leaf (two lowest rates), Steward, E2Y45 0.1 rate without Clorox were significantly higher than in the untreated. Yields in several of the other treatments, while not statistically significant, were more than 1000 lbs./A more than in the untreated. Rice biomass at harvest ranged from 6.7 to 9.8 t/A. Treatments that protected yield also generally had more overall biomass.

In summary, etofenprox, indoxacarb, rynaxypyr, and clothianidan all appear to have significant potential for RWW management. Etofenprox and clothianidan are active via application at the 3-leaf stage and clothianidan also works preflood. These use patterns are similar to those presently used for RWW in California. Indoxcarb registration will not be pursued by the registrant. Rynaxypyr and clothianidan are active as seed treatments. As such, their performance on the seed is influenced by the Sodium Hypochlorite 2-hour seed soak used as part of the Bakane management scheme. Another seed treatment material (HGW86), tested for the first time against RWW in California, was very effective and the performance was not degraded by the Sodium Hypochlorite 2-hour seed soak. Etofenprox registration will likely happen first among these possibilities (perhaps for the 2010 use season). Given the re-evaluation of pyrethroid registrations due to possible off-site movement, it is important to continue to develop alternative active ingredients and classes of chemistry. These active ingredients have some very favorable properties in terms of toxicity to non-targets, persistence, etc.

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

West Nile virus continues to be a human health concern factor in California. In 2008, to-date, 392 human cases have been confirmed in the state including 38 cases in the rice production counties. These statewide incidence numbers compare with 380 and 278 cases in 2007 and 2006, respectively. Mosquitoes, the vector of West Nile Virus, are seemingly everywhere but mosquito production in ricefields is recognized. *Culex* spp. mosquitoes are an important vector of West

Nile Virus and rice is one of the primary habitats of these types of mosquitoes. Clearly, the abatement districts manage mosquitoes effectively in order to minimize disease outbreaks, but it is incumbent on the rice industry to minimize mosquito production from flooded fields. Numerous aquatic insects and other invertebrates prey upon the aquatic stages of mosquitoes (eggs, larvae and pupae). These populations develop naturally after field flooding but can help to minimize mosquito production. However, production factors such as field draining, straw incorporation, fertilization regimes and insecticide application can alter this predator – prey (mosquito) interactions. The goal of this research is to investigate factors which maximize rice production while incorporating Best Management Practices in the IPM program to minimize the production of mosquitoes. Specifically, we studied the effects of insecticides, which are or could be useful to IPM in rice, on populations of aquatic non-target invertebrates in rice. The treatments listed in Table 5 were evaluated in this study in 2007 and 2008. Best Management Practices are in place and but these should be a working document and subject to revision if supported by research results. The use of insecticides for rice pest management can negatively impact populations of these nontarget organisms; however, there are likely differences among products in terms of these effects. Research conducted so far has allowed a fairly good understanding of the effects of registered insecticides on nontargets in rice fields. As new products are being developed, this type of research is important so as develop the underlying data necessary to allow a succinct evaluation of the product. Data from 2007 will be discussed as the 2008 data are still being quantified and summarized (several thousand specimens were collected in 2008 and cataloguing these is very time-consuming). The procedures followed in 2008 will be described; 2007 methods were very similar.

Methods:

Each plot was ~0.04 A and each treatment was replicated three times. In 2008, preflood treatments were applied on 19 May and the plots were seeded dry on 21 May immediately before the flooding. The 3-leaf stage treatments were applied on 9 June and the armyworm application timing was 10 July. Populations of non-target organisms were evaluated weekly from 5 June to 3 September. Floating barrier traps were used to collect swimming organisms for the first 4 weeks after seeding. Mosquito dip samples (25 dips in each of 5 locations per plot) were used to estimate populations of mosquito larvae and these data were collected in July and August. Finally, four quadrant samples per plot (0.55 ft^2 each) were collected weekly and these samples collected all organisms within these area. One hundred dip samples per plot, the standard used for monitoring mosquito populations, were taken weekly in July and August.

Results:

The potential of aquatic organisms to utilize and flourish in temporarily flooded aquatic systems such as rice fields is notable. The species or type of organism which predominates may vary from year to year, especially during the early-season period. Many of these organisms act as predators and mosquito larvae would be a key food source. However, unfavorable conditions can upset this balance and allow mosquito populations to flourish. The 2007 results are summarized and will be reported herein. Only the numbers of aquatic insects will be reported; I would expect the most severe effects, if any, from the insecticides to be on the aquatic insects. Sorting and counting the 2008 samples is underway and will progress through the winter.

Preflood applications: Two preflood applications were evaluated in 2007; one was a preflood only (Warrior) and the other (V10170) included a preflood and a 3-leaf stage application to the same set of plots. <u>Quadrant samples:</u> V10170 application resulted in a 24 to 45% reduction in numbers of aquatic insects compared with the untreated during the first ~6 weeks after application. At 58 days after application, there was a “bounce-back” in numbers such that there were higher levels in the treated plots than in the untreated plots. This is a common characteristic of populations once the toxic effect has dissipated. The results of Warrior contrasted with V10170. On the first sample date (16 days after application), there were ~40% more aquatic insects compared with the untreated (Fig. 1). On the next sample date, 30 days after treatment there were slightly reduced numbers of aquatic insects in the Warrior-treated plots. This effect was short-lived and was not seen in later sampling dates. It appears that the effects of Warrior applied preflood are less severe and more short-lived than that seen with V10170. <u>Floating Barrier Traps:</u> Floating barrier traps primarily capture actively swimming organisms such as beetles. Both preflood treatments, V10170 and Warrior, reduced populations of aquatic insects as sampled with floating barrier traps (Fig. 2). The most severe reductions (~90%) were in the first sample date and the reduction waned in the later sample dates. <u>Mosquito Dip Samples:</u> The effects of preflood treatments on populations of mosquitoes were erratic (Fig. 3). This result incorporates the direct mortality effects (if any) of the toxicant on mosquito larvae as well the indirect effects operating through the influence on non-target predators, i.e., fewer predators corresponds with more mosquito larvae. On the first sample date, both treatments greatly reduced mosquito numbers; on the second and third dates, there were equal numbers in the treated and untreated plots and more mosquitoes in the treated plots, respectively. At this part of the season, the number of mosquitoes is low, therefore one sampled individual can greatly alter the apparent results.

Post-flood applications: <u>Quadrant Samples:</u> Six 3-leaf treatments were compared, including the V10170 treatment which was applied preflood and at the 3-leaf stage to the same plots. At 2 weeks after application, all the treated plots had fewer aquatic insects than the untreated plots (Fig. 4). The most severe reduction was 60% from Mustang Max. On the next sample date (3 weeks), the populations were higher in five of the six treatments than in the untreated plots with the higher response being in the Mustang Max treatments (5x more than in the untreated). Again as with the preflood evaluation, this is indicative of a previous detrimental effect that has dissipated and the plots are being recolonized with the initial invading individuals flourishing due to the lack of competition resulting in the short-term flush of numbers. Trebon, Dimilin, and Steward appeared to have the least effect on aquatic insect populations. <u>Floating Barrier Traps:</u> Floating barrier trap data showed the greatest negative effects in the V10170 treatment (data not shown). However, at this point in the season, the floating traps collect swimming insects fairly inefficiently. The established plants reduce the ability of the insects to freely swim and to encounter the traps, therefore the results are not definitive. <u>Mosquito Dips:</u> Populations of aquatic stages of mosquitoes in treated plots compared with untreated plots were initially reduced (in four treatments) or equal (in two treatments). At 4 weeks after treatment, mosquito levels were higher in four of the treatments (by up to 3 times) than in the untreated and equivalent in two treatments (Warrior and Dimilin) (Fig. 5).

July armyworm application: Warrior was evaluated as a representative material that could be applied against armyworms in mid-July. At 2 and 3 weeks after application, this treatment was very damaging to populations of aquatic insects (Fig. 6). Similarly, there were significantly fewer mosquito larvae in treated plots than untreated plots for the 4 weeks following application (Fig. 7). So this product appears to have the detrimental effect of killing potential mosquito predators, but also has a useful level of direct toxicity to mosquito larvae.

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

Tadpole shrimp problems appear to be on the increase and in many years I would say this is the second most important invertebrate pest of rice. Copper sulfate (Bluestone) use is on the decline due to an increase in price and to the loss of efficacy in recent years for algal and shrimp control. Tadpole shrimp populations occur in many rice fields. Damage can range from minimal to severe but the infestations are generally spotty in distribution. Populations tend to build-up gradually from year-to-year unless control measures are used. Tadpole shrimp feed up seedling coleoptiles, roots, and leaves; the crop damage occurs from this feeding, uprooting of seedlings, and the reduction in light penetration. This pest was reported as a substantial problem in rice production in Missouri in 2008 which was a new pest situation for this area.

<u>Methods:</u>

Three studies were conducted on tadpole shrimp control in 2008.

<u>Laboratory bioassay:</u> Pyganic 5%EC is an organically-approved formulation of pyrethrins (active ingredient from chrysanthemum flowers). Besides being a “green” product, it is short-lived but broadly toxic. We thought it might be a useful product for early-season tadpole shrimp control. At this point in the season, with the frequent field draining, care must be taken to keep from releasing insecticides into the waterways. As a first step to evaluating the efficacy, a laboratory bioassay was conducted.

<u>Ring plots</u>: Two sets of ring plot studies were conducted. The first was done in the standard 8 sq. ft aluminum rings. This was a study emphasizing preflood products. The key dates were as follows:

14 May, pre-flood (PF) applications
14 May, flooding
16 May, seeding (M-202)
26 May, placed 10 tadpole shrimp into each ring, rice was in the 1-2 leaf stage
28 May, post-flood treatments

Treatments as listed in Table 6 were evaluated. Stand density was quantified on 3 July. Grain yield data were collected on 21 October at which time the plant numbers were again counted. The second ring study was designed to examine tadpole shrimp management in a rescue situation. Each treatment was replicated four times within micro-rings enclosing 1.25 sq. ft. Plots were seeded and flooded on 21 May. Applications at the 3-leaf stage were made on 2 June following the introduction of 7 tadpole shrimp per ring on 30 May. Seedlings counts were made on 4 June and again at the time of harvest on 8 October.

<u>Results:</u>

Laboratory bioassay: Tadpole shrimp were collected from a rice field and brought to the lab. Three shrimp were exposed to various concentrations of Pyganic dissolved in water within 1 pint glass jars (four replications per concentration). Mortality observations were made at 1, 2, and 3 hours. In summary, after 1 hour, concentrations of 0.5, 1.0, and 1.5% produced 100% mortality. In another study, after 1 hour of exposure, a 0.001% concentration produced 75% control and higher rates of 0.01 and 0.1% gave 100% kill. Laboratory conditions are different from field conditions but the product definitely has activity on tadpole shrimp.

Ring plots: For the first study with preflood and post-flood products, there were no significant differences in stand numbers in June or at harvest (Table 7). Grain yields ranged from ~4780 to 7300 lbs. per acre. The yield in the untreated plots was intermediate and as such did not differ significantly from any of the other treatments. Yields were higher numerically in the two Warrior-treated plots (pre- and post-flood). For the rescue study (post-flood treatments), again there were no significant differences in stand density. There were more seedlings in the untreated plots with no tadpole shrimp added compared with the untreated plots with shrimp added. Therefore, it appears that the shrimp survived and did inflict damage to the seedlings. Grain yields also did not differ significantly among treatments in this study.

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

Seed midge populations are very spotty but this pest can be devastating to rice stands under the right set of circumstances. Generally the conditions that promote infestations are cool temperatures/water and a period of delayed rice germination and establishment. Seed midge is ubiquitous in distribution; swarms are common in and around all rice fields. In 2008, these swarms were very common. Seeing a "swarm" however does not necessarily mean that there will be damage to the rice. The unpredictable nature of this pest makes it difficult on which to conduct research.

Methods:

Large ring plots (6 ft. diameter) were used for this research; it was thought that the smaller, "standard" sized rings would likely warm the water and lessen the chance of getting an infestation. Treatments as listed in Table 8 were evaluated. Two standards, Mustang and Warrior both applied post-flood, an experimental seed treatment, and an experimental post-flood material were included in the study. Plots were flooded on 21 May and seeded on 2 June. The delay in seeding was used to try to enhance midge populations. The adults are attracted to the flooded conditions and it was hoped the eggs and resulting larvae would be present in the plots as the seeds and/or insecticides were introduced. Stand density and grain and biomass yield data were collected on 10 October.

Results:

There were no significant differences in stand counts or yield among treatments in this study (Table 9). There was no evidence that we achieved an infestation with seed midges.

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 RWW was first reported in California in 1958. This pest spends the winter as an adult and resides in protected areas such as at the base of clumps of weeds, in soil cracks, under crop residue, etc. They are in a state of diapause which means this is a genetically-determined condition where the adults will not deposit eggs until this state is "broken". The insect may be active during warm periods and feed, but flight, egg-laying, and the rest of the life cycle will not take place until specific sets of conditions are satisfied. Several laboratory studies have tried to determine this set of conditions but no definitive results have been fond. The timing of RWW adult flight in the spring has been monitored annually since the insect was discovered in California, i.e., for ~50 years, with a black light trap at RES. The flight monitoring allows us to see the severity of flight and the peak flight periods. It is also interesting to compare RWW populations and flight trends over years, to draw some correlations with populations in the field and to form some predictions about the future. Flight only occurs during specific nights defined by evenings (6-11 pm) with warm temperatures (70-80^{0}F) and calm winds (<5 MPH). The RWW flight was fairly spread out in 2008; the first flight peak was on 11 April, followed by 25 April, and 2 May to 16 May (Fig. 8). Even a few RWW adults were still flying on 12 June. The total of 2300 RWW adults captured was comparable to 2007 (Fig. 9). The last 3 years the population has been fairly constant.

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

Host plant resistance is an accepted, cost-effective approach of IPM for important insect pests. Once achieved, it is generally environmentally acceptable, relatively stable, and easy to implement. At present, there are no rice varieties that are resistant to RWW. Rice has a tremendous genetic-base and a high degree of variability around the world. This opens up possibilities for identifying useful lines and genotypes that could be useful for managing RWW. Thousands of rice lines have been evaluated in the major rice producing states for resistance to RWW. At least two lines have been shown to have some capacity to withstand RWW; although neither of these cases would be classified as a high degree of resistance. Biotechnology offers possibilities for developing rice varieties resistant to key insect pests. In addition, hybrid rice development may be a way to incorporate some resistance into commercial rice lines.

Some tolerance to RWW has been likely bred into rice varieties. In fact, the development of well-adapted, vigorous rice cultivars that can effectively withstand insect-induced injury has helped to manage RWW. These incremental increases in rice plant tolerance, i.e., plant vigor, to RWW have been made and work continues at the Rice Experiment Station. Medium grain rice varieties, in general, have been shown to remain productive in spite of stressors, including RWW. Therefore using the same management plans for medium grain varieties and long-grain or specialty rice types 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	7. M-206
2. S-102	8. PI plant line
3. M-104	9. Calhikari-201
4. M-208	10. Calmati-202
5. M-205	11. Calmochi-101
6. M-202	12. M-401

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

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

Subobjective 2.2.1)

Methods:

Each variety was seeded into 8 plots (13 x 18 ft.); four plots were treated with Warrior preflood to control RWW on 13 May and four plots were left untreated. The study was set up as a randomized complete block design with four replicates. Plots were flooded on 13 May and seeded on 14 May. RWW adult feeding scars (11 June), seedling establishment rating (11 June), larval population numbers (2 July and 16 July), and grain yields (23 October) were determined as described previously. The amount of feeding scars was used to evaluate susceptibility to adult infestation, and the number of RWW larvae per plot in the untreated plots was indicative of the conduciveness of the variety to RWW infestation. The difference in yield between the treated and untreated plots of a given variety was used to show plant response to the feeding.

Results:

In the untreated plots, plant scarring by adult RWW varied from ~2% (Calhikari-201) to ~16% (Calmochi-101 and M-202) (Fig. 10). These cultivars were grown in replicated, randomized plots so the RWW adults had equal access to any plot. L-206, Calhikari-201, M-202, and M-401 had the highest larval populations (Fig. 11). Interestingly, Calhikari-201 was not infested to any extent by RWW adults but had the one of the highest larval populations. Overall, the naturally-occurring RWW population in this plot area was low to moderate. RWW larval infestation was lowest in the PI line under development for resistance to RWW. This resistance is classified as tolerance so the insect should still infest this line, but just inflict less damage.

Grain yields ranged from ~6600 (Calmati-202; RWW present at natural levels) to 9500 lbs./A (M-205; RWW controlled) (Fig. 12). Efforts to control RWW resulted in a yield increase, compared with the same variety, in eight of the twelve varieties with the greatest advantage in M-205 at ~1800 lbs./A. Overall, control of RWW resulted in a 240 lbs./A grain increase (averaged over variety).

Subobjective 2.2.2)

Methods:

Four varieties were selected for more detailed studies on susceptibility and responses to RWW - M-202, PI line, L-206, and Calmati-202. These varieties were grown in ring plots and infested with RWW using the procedures listed in Objective 1.1. Therefore, this study compared the performance of these four varieties under high RWW pressure and no injury from RWW.

Results:

The uninfested rings had a very low RWW infestation (a few naturally occurring adults invaded the rings) (Table 10). Among the infested rings, there was significantly less adult feeding in the PI line than in M-202 and Calmati-202. For RWW larval populations, levels were lower in L-206 than in M-202 and the PI line (Table 10). This occurred in spite of placing the same number of RWW adults into the rings, i.e., seedlings of L-206 were available to the adults and root tissue was available to RWW larvae but not accepted. For grain yields, within the uninfested rings, the yields were significantly higher in the PI line than in L-206 and Calmati-202 (intermediate in M-202). (Table 11). Grain yields were reduced by ~1700 and 1000 lbs./A in the M-202 and PI lines by RWW feeding; there was no yield reductions in the other two varieties (Table 11). As another comparison of RWW impact on yield, there were estimated 1370 and 1180 lbs./A yield losses per RWW larva in M-202 and the PI line, respectively. The other two varieties showed no estimated yield loss from RWW infestation, although the infestation was lower so this placed “bounds” on the estimate.

2.3) Evaluate the influence of rice seedling establishment methods of rice pest populations (RWW and armyworm) and on mosquito production.

The “systems study” has been ongoing at the RES for the last 4 years. The primary goal is to investigate alternative seeding and establishment methods in order to open up new opportunities for weed management. The stale seedbed and dry (drill) seeding are two of these techniques. No-till seedbed preparation may have a fit as it would reduce fuel usage. These changes in rice production need to be done without disrupting other aspects of rice agronomy and pest management. Effects on populations of invertebrates could be subtle; what a RWW adult, for instance, senses to “decide” whether to infest one plot of rice versus another is only “known” by the insect. Mosquitoes and rice water weevil populations are closely tied to the presence of water. In 2008, plots were maintained with the following variations of rice stand establishment methods: 1.) Drill-seeded no-till stale seedbed, 2.) Water-seeded conventional, and 3.) Water-seeded no-till stale seedbed.

Methods:

In 2008, we monitored RWW populations (adult scarring and larval numbers) as well as armyworm populations in this seedling establishment study. Data were collected on 10 July (adult scarring) and 14 July and 28 July (RWW immatures) using standards methods as described in Subobjective 1.1. In addition, armyworm infestation severity (15-minute visual search per plot for armyworm larvae) and mosquito populations (150 dips with the standard mosquito dipper per plot) were quantified bi-weekly from early July to early September.

Results:

RWW infestation in this plot was low; this site at the RES does not seem to have significant infestation by RWW. Other areas of the Station are much more heavily infested. The highest plant scarring seen in any plot was 27% but 18 of the 20 plots had less than 5% scarring. Similarly, RWW larval populations were low with the averages being less than 0.25 per sample. Fig. 13 shows a comparison of adult scarring and larval populations in each treatment. Data from the two stale seedbed treatments are compared with that in the conventional water-seeded plots. The seeding method and production system may influence mosquito populations. However, the amount of residue (such as burnt-down weeds), frequency of draining, water depth, timing of flooding, etc. may all influence mosquito production. Mosquito populations on 4 Sept. 2008 are shown in Fig. 13. Across all plots, populations averaged ~1.0 mosquito larvae per 150 dips. Compared to the standard water-seeded treatment, there were fewer larvae in both the no-till stale seedbed treatments.

Finally, no damage or armyworms were found in the sampling..

2.4) Study influence of water depth on populations of Rice Water Weevil.

A study was initiated in 2008 to study the influence of water depth on RWW populations. As water management of rice in California is evolving there is the possibility that this is influencing RWW populations. Studies in Arkansas showed a trend of progressively lower RWW densities where the shallower flood (2 inches) was maintained for more weeks compared with a 4 inch depth. Six plots were constructed, each 20 by 250 ft., with three planned for a 4 inch water depth and three for an 8 inch water depth. Plots were seeded on 14 May with M-202. RWW adult scarring and RWW immature populations were to be quantified using the standard techniques. In addition, water depth may likely effect mosquito population dynamics so dip samples were to be taken.

Several complicating factors affected this study. First, germination and seedling establishment was very poor in two of the six plots. Reasons for this could not be determined. The second problem was that the water depth equilibrated such that by early July there were no longer two distinct water depths. However, there were two water depths during the early part of the season which was which is likely the most important period for RWW biology. However, given these challenges, we saw no differences in RWW larval populations between the two water depths (each averaged 1.4 RWW per sample).

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.

Armyworms have developed into an important insect pest of rice in some areas. Two species of armyworms infest rice - the western yellow-striped armyworm (*Spodoptera praefica*) and the 'true' armyworm (*Pseudaletia unipuncta*). Armyworm larvae can be heavily parasitized by a couple of species of small wasps. A mid-season application of a pyrethroid insecticide can also provide armyworm control but it is an added cost and has the potential to upset the "balance" in rice fields and to promote populations of mosquitoes.

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

In 2008, armyworm infestations were very low at the Rice Experiment Station and therefore additional studies could not be conducted.

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

Rice has several attributes that make it amenable to invertebrate pest problems, especially from exotic pests from other countries. It is an important crop world-wide, grown in so many countries, and as a commodity freely traded world-wide. California has strong policies and enforcement designed to keep exotic pests out of the state. However, these infestations still occur although not as frequently as they would without the regulatory actions. Several nonvertebrate pests of rice occur in other countries and even in other U.S. states, but fortunately not in California. Some of these are extremely serious pests that would cause crop yields, increase costs of production, and have possible trade implications. The rice panicle mite was an issue for rice in 2007 as this pest was found in the Southern rice production states (primarily in rice grown in the greenhouse and research plots. Monitoring efforts were undertaken in California and this pest was not found. The incidence of this pest in the South was much reduced in 2008 and again none were found in California. We continued our efforts and diligence for exotic pests of rice in 2008.

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CONCISE GENERAL SUMMARY OF CURRENT YEARS (2008) RESULTS:

Larry D. Godfrey

Research was conducted in 2008 on the biology and management of key invertebrate pests of California rice. Concentrated efforts continued on rice water weevil (RWW) and research intensified on early-season invertebrate pests, including tadpole shrimp and seed midge. Studies on armyworm, an important pest of rice in recent years, were hindered by the lack of armyworm infestations in 2008. The goal of this research was to refine and advance IPM schemes for these pests of rice and to maximize the management in light of the environmentally sensitive nature of the rice agroecosystem. The cost effectiveness of management efforts in rice was also carefully considered. Four overall themes provided direction for the 2008 research program.
1.) CA-DPR has placed pyrethroid insecticides into reevaluation based on their propensity to accumulate and move off-site on organic sediment. Therefore, studies continued to develop alternative active ingredients and classes of chemistry for arthropod pest control.
2.) Best Management Practices have been developed and put forth for the industry to aid in mitigation of mosquito populations. This area has taken on added importance with the emphasis on West Nile Virus in California. A study was continued to evaluate the effects of registered and experimental rice insecticides on insect and other invertebrate populations in the rice system. The potentially negative effects, i.e., reducing populations of insects which could be acting as predators on mosquito larvae and helping to keep populations in check, and the positive effects, i.e., direct toxicity of the insecticide on mosquitoes in rice, were both evaluated.
3.) Early-season invertebrate pests have been common in recent years. Copper sulfate use, as a management tool for these pests, has declined in recent years due the supply, costs, and efficacy. Pyrethroid insecticides have partially filled this void, but other management techniques were sought. Studies were done on seed midge and tadpole shrimp control.
4.) Exotic pests moving into California are unfortunately becoming a more common occurrence. Thus far, the rice system has avoided being infested by several potentially serious invertebrate pests that occur in other parts of the U.S and in other countries. The rice panicle mite was found in the southern U.S. rice belt in 2007. Communication and education on this pest were hastened in 2008.

Significant progress was made on all objectives. AW populations were overall low and research on this pest could not be done; however, this was not a key objective in 2008.

Rice Water Weevil: Studies were continued in 2008 in ring plots to evaluate experimental insecticides versus registered standards for RWW control and to optimize the use patterns of the existing products to facilitate management. Twenty-four treatments (a total of eight different active ingredients) were established in ring plots to accomplish this research. Research continued on four experimental insecticide active ingredients; etofenprox (Trebon®), indoxacarb (Steward®), rynaxypyr (Dermacor®), and clothianidan; the first two productswere applied as 3-leaf stage applications and the latter two products as seed treatments (clothianidan was also tested as a preflood and 3-leaf treatment). HGW86 was evaluated against RWW as a seed treatment in 2008; this was the initial evaluation of this product. Four specific questions were addressed in these studies, including are these experimental materials efficacious against RWW, how effective is the newly-registered preflood application of Warrior and how long of a lag period between application and flooding can be used, are there viable options for RWW control in a drill-seeded system, and finally what is the effect of a sodium hypochlorite seed soak on the efficacy of seed treatments for RWW. In summary, etofenprox, indoxacarb, rynaxypyr, and clothianidan all appear to have significant potential for RWW management. Etofenprox and clothianidan are active via application at the 3-leaf stage and clothianidan also works preflood. Indoxcarb registration in rice will not be pursued by the registrant. Rynaxypyr and clothianidan are active as seed treatments. As such, their performance on the seed was influenced (reduced) by the Sodium Hypochlorite 2-hour seed soak used as part of the Bakane management scheme. Another seed treatment material (HGW86), tested for the first time against RWW in California, was very effective and the performance was not degraded by the Sodium Hypochlorite 2-hour seed soak. Etofenprox registration will likely occur first among these experimentals (perhaps for the 2010 use season). Warrior applied preflood (immediately before the flood) was very effective for RWW control; similarly, an application 7 days before the flood was also effective. The label stipulates the application at 5 days or less before the flood so the label is consistent with maximizing performance. Rynaxypyr seed treatment was effective against RWW in a drill-seeded system albeit slightly less effective than in a water-seeded system. Grain yields from the Warrior 3-leaf, clothianidan 3-leaf (two lowest rates), Steward, rynaxypyr (0.1 milligram rate without Sodium Hypochlorite) were significantly higher than in the untreated. Yields in several of the other treatments, while not statistically significant, were 1000 lbs./A more higher than in the untreated. It is important to continue to develop alternative active ingredients and classes of chemistry and these active ingredients have some very favorable properties in terms of toxicity to non-targets, persistence, etc.

West Nile virus continues to be a human health concern factor in California. Mosquitoes, including the *Culex* spp. vector of West Nile Virus, are produced in many places including in ricefields. Clearly, the abatement districts manage mosquitoes effectively to minimize disease outbreaks, but everything the rice industry can do to minimize mosquito production is a benefit. Numerous aquatic insects and other invertebrates prey upon the aquatic stages of mosquitoes and can help to minimize mosquito production. However, agronomic factors such as field draining, straw incorporation, fertilization regimes, and insecticide application can alter these populations. The goal of this research was to investigate the effects of insecticides, which are or could be useful in rice IPM, on populations of aquatic non-target invertebrates in rice. Several insecticides and timings, including two preflood, six 3-leaf stage, and one mid-season application, were investigated using three different sampling methods to assess invertebrate levels. For the 3-leaf treatments, there was a short-term reduction in levels of aquatic insects following application. At 2 weeks after application, all the treated plots had fewer aquatic insects than the untreated plots with the most severe reduction being 60% from Mustang Max. However, at 3 weeks, the populations were higher in five of the six treatments than in the untreated plots – as much as 5x more than in the untreated. Populations of aquatic stages of mosquitoes in treated plots compared with untreated plots were initially reduced (in four treatments) or equal (in two treatments). At 4 weeks after treatment, mosquito levels were higher in four of the treatments (by up to 3 times) than in the untreated and equivalent in two treatments.

RWW biology was studied in terms of adult flight, relative susceptibility of commonly grown rice varieties to RWW infestation and yield losses, and the influence of rice seedling establishment methods of invertebrate pest IPM. The RWW flight was fairly spread out in 2008; the first flight peak was on 11 April, followed by 25 April, and 2 May to 16 May; even a few RWW adults were flying on 12 June. The total of 2300 RWW adults captured was comparable to 2007. The last 3 years the population has been fairly constant. The susceptibility of twelve and four California-grown rice varieties to RWW was compared in field and ring plots, respectively. Susceptibility was studied via 1.) will RWW opt to infest the rice variety and 2.) if infested, will the variety suffer a yield loss and to what extent. In the field plots, plant scarring by adult RWW varied from ~2% (Calhikari-201) to ~16% (Calmochi-101 and M-202). RWW larval infestation was lowest in the PI line under development for resistance to RWW. This resistance is classified as tolerance so the insect should still infest this line, but just inflict less damage. RWW control resulted in a yield increase, compared with the same variety without controls, in eight of the twelve varieties with the greatest advantage in M-205 at ~1800 lbs./A. Overall, control of RWW resulted in a 240 lbs./A grain increase (averaged over variety). For the more controlled ring study, RWW larval populations were lower in L-206 than in M-202 and the PI line. Alternative seeding and establishment methods are being designed to open up new opportunities for weed management in rice. We have been monitoring these changes to insure there is no impact on pest management at one study site at the RES. RWW infestation in this plot was low; the highest plant scarring in any plot was 27% but 18 of the 20 plots had less than 5% scarring. Similarly, RWW larval populations were low with the averages being less than 0.25 per sample. The seeding method and production system may also influence mosquito populations. Mosquito populations on 4 Sept. 2008 were lower in both the no-till stale seedbed treatments then the standard water-seeded treatment

Early-Season Invertebrate Pests: Tadpole shrimp problems appear to be on the increase; copper sulfate (Bluestone) use has declined in recent years. Tadpole shrimp populations occur in many rice fields and populations tend to build-up gradually from year-to-year unless control measures are used. Three studies were conducted on tadpole shrimp control in 2008. A laboratory bioassay of Pyganic 5%EC, an organically-approved formulation of pyrethrins, was conducted. Two sets of ring plot studies were also conducted; one emphasizing preflood products and the second was designed to examine tadpole shrimp management in a rescue situation. Tadpole shrimp were introduced into the rings to insure an infestation. Management of seed midge populations was studied with two standards, Mustang and Warrior both applied post-flood, an experimental seed treatment, and an experimental post-flood material. There was no evidence that we achieved an infestation with seed midges.

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. California has strong policies and enforcement designed to keep exotic pests out of the state. The rice panicle mite was an issue for rice in 2007 as this pest was found in the Southern rice production states (primarily in rice grown in the greenhouse and research plots). Monitoring efforts were undertaken in California and this pest was not found. The incidence of this pest in the South was much reduced in 2008 and again no mites were found in California. We continued our efforts and diligence for exotic pests of rice in 2008.

Table 1. Treatment list for RWW management ring study, 2008.

Product	Rate (lbs. AI/A)	Formulation per A	Timing
1. Dimilin 2L	0.125	8 fl. oz	3-leaf
2. Untreated	---	---	---
3. Warrior	0.03	3.84 fl. oz.	3-leaf
4. Warrior	0.03	3.84 fl. oz.	PF - week before flooding
5. Trebon 3G	0.18	6 lbs.	2-3-leaf
6. V 10170 50WDG	0.093	3 oz.	PF
7. V 10170 50WDG	0.145	4.6 oz.	PF
8. V 10170 50WDG	0.18	5.7 oz.	PF
9. V 10170 2.13 SC	0.093	5.6 fl. oz	2-3 leaf
10. V 10170 2.13 SC	0.145	8.7 fl. oz.	2-3 leaf
11. V 10170 2.13 SC	0.18	10.8 fl. oz.	2-3 leaf
12. Mustang Max EW	0.025	4 fl. oz	2-3 leaf
13. Warrior	0.03	3.84 fl. oz	PF
14. Steward EC	0.11	11.3 fl. oz.	2-3 leaf
15. HGW86 seed treatment*	0.1 milligrams AI per target		seed treatment
16. E2Y45 seed treatment*	0.025 milligrams AI per target		seed treatment
17. E2Y45 seed treatment*	0.05 milligrams AI per target		seed treatment
18. E2Y45 seed treatment*	0.1 milligrams AI per target		seed treatment
19. E2Y45 seed treatment	0.1 milligrams AI per target		drill-seeded seed treatment
20. Untreated - drill-seeded	---	---	--- (drill-seeded)
21. V10170 5SC	0.1 per 100 lbs. seed		seed treatment
22. V10170 5SC*	0.1 per 100 lbs. seed		seed treatment
23. E2Y45 seed treatment	0.1 milligrams AI per target		seed treatment
24.E2Y45	0.25		2-3 leaf

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

Table 2. Rice plant stand and adult feeding damage in chemical ring study, 2008.

Product	Rate (lbs. AI/A)	Stand Rating (1-5)	% Scarred Plants	
1. Dimilin 2L	0.125 – 3-leaf	2.8	4.5	def
2. Untreated	---	3.0	21.0	b
3. Warrior	0.03 – 3-leaf	2.8	2.0	ef
4. Warrior	0.03 – early PF	2.8	5.5	def
5. Trebon 3G	0.18 – 3-leaf	2.8	1.0	f
6. V 10170 50WDG	0.093 – PF	3.5	3.0	ef
7. V 10170 50WDG	0.145 – PF	2.5	4.0	def
8. V 10170 50WDG	0.18 – PF	3.0	1.0	f
9. V 10170 2.13 SC	0.093 – 3-leaf	3.0	7.0	def
10. V 10170 2.13 SC	0.145 – 3-leaf	3.0	7.5	def
11. V 10170 2.13 SC	0.18 – 3-leaf	2.8	6.0	def
12. Mustang Max EW	0.025 – 3-leaf	2.8	1.5	f
13. Warrior	0.03 – PF	2.8	2.0	ef
14. Steward EC	0.11 – 3-leaf	2.8	8.0	def
15. HGW86 seed treatment*	0.1 milligrams AI per target	3.3	8.5	def
16. E2Y45 seed treatment*	0.025 milligrams AI per target	3.8	18.0	bc
17. E2Y45 seed treatment*	0.05 milligrams AI per target	3.3	22.0	b
18. E2Y45 seed treatment*	0.1 milligrams AI per target	3.0	9.5	de
19. E2Y45 seed treatment – drill-seeded	0.1 milligrams AI per target	2.5	30.5	a
20. Untreated - drill-seeded	---	2.8	22.5	b
21. V10170 5SC	0.1 per 100 lbs. seed	2.8	19.0	bc
22. V10170 5SC*	0.1 per 100 lbs. seed	2.8	11.5	cd
23. E2Y45 seed treatment	0.1 milligrams AI per target	2.5	20.0	b
24.E2Y45	0.25	3.0	3.0	ef

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

Means within columns followed by same letter are not significantly different; least significant differences test ($\rho < 0.05$).

Table 3. RWW immature density (first and second sample dates and average) in chemical ring study, 2008.

		RWW per Core Sample					
Product	**Rate (lbs. AI/A) & Timing**	**7 July**		**25 July**		**Average**	
1. Dimilin 2L	0.125 – 3-leaf	0.0	d	0.05	d	0.03	e
2. Untreated	---	1.6	a	1.05	a	1.30	a
3. Warrior	0.03 – 3-leaf	0.0	d	0.00	d	0.00	e
4. Warrior	0.03 – early PF	0.2	cd	0.00	d	0.10	de
5. Trebon 3G	0.18 – 3-leaf	0.4	cd	0.10	d	0.25	cde
6. V 10170 50WDG	0.093 – PF	0.0	d	0.15	d	0.08	e
7. V 10170 50WDG	0.145 – PF	0.0	d	0.05	d	0.03	e
8. V 10170 50WDG	0.18 – PF	0.0	d	0.00	d	0.00	e
9. V 10170 2.13 SC	0.093 – 3-leaf	0.0	d	0.00	d	0.00	e
10. V 10170 2.13 SC	0.145 – 3-leaf	0.1	d	0.10	d	0.05	e
11. V 10170 2.13 SC	0.18 – 3-leaf	0.6	cd	0.65	abc	0.63	bc
12. Mustang Max EW	0.025 – 3-leaf	0.1	d	0.00	d	0.05	e
13. Warrior	0.03 – PF	0.1	d	0.10	d	0.1	e
14. Steward EC	0.11 – 3-leaf	0.0	d	0.10	d	0.05	e
15. HGW86 seed treatment*	0.1 milligrams AI per target	0.0	d	0.05	d	0.03	e
16. E2Y45 seed treatment*	0.025 milligrams AI per target	0.2	cd	0.30	bc	0.25	cde
17. E2Y45 seed treatment*	0.05 milligrams AI per target	0.5	cd	0.21	bc	0.33	cde
18. E2Y45 seed treatment*	0.1 milligrams AI per target	0.1	d	0.10	d	0.10	e
19. E2Y45 seed treatment	0.1 milligrams AI per target	0.5	cd	0.15	d	0.33	cde
20. Untreated - drill-seeded	---	1.4	ab	0.80	ab	1.10	a
21. V10170 5SC	0.1 per 100 lbs. seed	0.6	cd	1.05	a	0.83	ab
22. V10170 5SC*	0.1 per 100 lbs. seed	0.6	cd	0.25	bc	0.43	bcde
23. E2Y45 seed treatment – drill-seeded	0.1 milligrams AI per target	0.8	bc	0.35	abc	0.58	bcd
24.E2Y45	0.25	0.1	d	0.10	d	0.10	e

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

Means within columns followed by same letter are not significantly different; least significant differences test ($\rho < 0.05$).

Table 4. Effect of RWW populations on rice biomass and grain yields in chemical ring study, 2008.

Product	Rate (lbs. AI/A) & Timing	% Moisture		Grain Yield (lbs./A)		Biomass - Straw + Grain (t/A)	
1. Dimilin 2L	0.125 – 3-leaf	16.6	bcd	7557.9	ab	9.2	abcd
2. Untreated	---	15.9	d	5994.4	cde	7.6	def
3. Warrior	0.03 – 3-leaf	16.7	bcd	7702.6	a	9.1	a-e
4. Warrior	0.03 – early PF	16.7	bcd	6654.9	a-e	8.9	a-e
5. Trebon 3G	0.18 – 3-leaf	17.9	a	5639.2	de	7.4	ef
6. V 10170 50WDG	0.093 – PF	17.4	ab	6922.8	abcd	9.0	a-e
7. V 10170 50WDG	0.145 – PF	17.1	abc	6994.8	abcd	8.7	a-e
8. V 10170 50WDG	0.18 – PF	16.6	bcd	6595.6	a-e	7.9	b-f
9. V 10170 2.13 SC	0.093 – 3-leaf	17.2	abc	7743.0	a	9.6	ab
10. V 10170 2.13 SC	0.145 – 3-leaf	16.7	bcd	7540.8	ab	9.2	abcd
11. V 10170 2.13 SC	0.18 – 3-leaf	16.5	bcd	6155.1	bcde	7.7	def
12. Mustang Max EW	0.025 – 3-leaf	17.1	abc	6997.1	abcd	8.8	a-e
13. Warrior	0.03 – PF	17.1	abc	7075.7	abcd	9.3	abc
14. Steward EC	0.11 – 3-leaf	16.5	bcd	7687.1	a	9.8	a
15. HGW86 seed treatment*	0.1 milligrams AI per target	16.5	bcd	7173.1	abc	9.1	a-e
16. E2Y45 seed treatment*	0.025 milligrams AI per target	16.3	bcd	6850.4	a-e	8.4	a-f
17. E2Y45 seed treatment*	0.05 milligrams AI per target	17.0	abc	6850.5	a-e	8.8	a-e
18. E2Y45 seed treatment*	0.1 milligrams AI per target	17.0	abcd	7692.4	a	9.8	a
19. E2Y45 seed treatment	0.1 milligrams AI per target	16.9	abcd	7833.5	a	9.3	abc
20. Untreated - drill-seeded	---	16.1	cd	5439.2	e	6.7	f
21. V10170 5SC	0.1 per 100 lbs. seed	16.5	bcd	6800.5	a-e	8.4	a-f
22. V10170 5SC*	0.1 per 100 lbs. seed	16.3	bcd	6426.9	a-e	7.9	b-f
23. E2Y45 seed treatment – drill-seeded	0.1 milligrams AI per target	16.7	bcd	6886.5	a-e	8.4	a-f
24.E2Y45	0.25	16.3	cd	6867.4	a-e	9.1	a-e

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

Means within columns followed by same letter are not significantly different; least significant differences test ($\rho < 0.05$).

Table 5. Treatments evaluated in non-target study, 2007 and 2008.

Product	Rate (lbs. AI/A)	Timing	2007	2008
1. Untreated	---	---	X	X
2. Warrior	0.03	3-leaf	X	X
3. Warrior	0.03	preflood	X	X
4. Warrior	0.03	July armyworm timing	X	X
5. Mustang Max	0.025	3-leaf	X	X
6. Dimilin 2L	0.125	3-leaf	X	X
7. V10170 50WD	0.19	preflood and 3-leaf	X	
8. V10170 50WD	0.19	preflood		X
9. V10170 5SC	0.19	3-leaf		X
10. V10170 5SC	0.1 per 100 lbs. seed	seed treatment	X	
11. Trebon 3G	0.18	3-leaf	X	X
12. Steward EC	0.11	3-leaf	X	X

Table 6. Treatments evaluated for tadpole shrimp control studies, 2008.

Product	Rate (lbs. AI/A)	Formulation per A	Timing
Study 1 – 8 sq. ft. rings			
1. Warrior	0.03	3.84 fl. oz.	PF
2. V 10170 50WDG	0.18	5.7 oz.	2-3 leaf
3. V 10170 50WDG	0.18	5.7 oz.	PF
4. Trebon 3G	0.18	6 lbs.	2-3 leaf
5. Copper sulfate		10 lbs.	2-3 leaf
6. Dimilin 2L	0.125	8 fl. oz.	2-3 leaf
7. Untreated	---	---	---
8. Pyganic 5EC		18 fl. oz.	2-3 leaf
9. Warrior	0.03	3.84 fl. oz.	2-3 leaf
Study 2 – 1.25 sq. ft. rings			
1. Untreated-without TPS	---	---	---
2. V 10170 2.13 SC	0.18	10.8 fl. oz.	2-3 leaf
3. Mustang Max EW	0.18	4 fl. oz.	2-3 leaf
4. Trebon 3G	0.18	6 lbs.	2-3 leaf
5. Copper sulfate		10 lbs.	2-3 leaf
6. Dimilin 2L	0.125	8 fl. oz.	2-3 leaf
7. Untreated with TPS	---	---	---
8. Pyganic		18 fl. oz.	2-3 leaf
9. Warrior	0.03	3.84 fl. oz.	2-3 leaf

Table 7. Plant density and yield results for tadpole shrimp control studies, 2008.

Product	**Formulation per A**	**Stand Density**	**Stand Density at Harvest**	**Grain Yield (lbs./A)**		**Biomass - Straw + Grain (t/A)**	
Study 1 – 8 sq. ft. rings							
1. Warrior	3.84 fl. oz.-PF	79.0	30.0	7297.5	a	6.8	a
2. V 10170 50WDG	5.7 oz.- 2-3 leaf	63.5	28.3	4783.5	c	5.4	ab
3. V 10170 50WDG	5.7 oz. -PF	83.0	33.0	6690.9	ab	6.2	ab
4. Trebon 3G	6 lbs. - 2-3 leaf	68.5	36.3	6861.3	ab	6.9	a
5. Copper sulfate	10 lbs. - 2-3 leaf	62.0	34.5	5612.9	bc	5.6	ab
6. Dimilin 2L	8 fl. oz. - 2-3 leaf	79.5	33.8	6203.3	ab	5.1	b
7. Untreated	---	64.5	30.3	6386.2	ab	6.3	ab
8. Pyganic 5EC	18 fl. oz. - 2-3 leaf	71.0	30.5	6713.8	ab	5.9	ab
9. Warrior	3.84 fl. oz. - 2-3 leaf	93.5	35.5	7130.6	a	6.8	a
Study 2 – 1.25 sq. ft. rings							
1. Untreated*	---	4.5	4.5	10024.4	a	14.5	a
2. V 10170 2.13 SC	10.8 fl. oz. - 2-3 leaf	3.3	2.5	10339.9	a	15.7	a
3. Mustang Max EW	4 fl. oz. - 2-3 leaf	4.5	2.0	12037.8	a	17.1	a
4. Trebon 3G	6 lbs. - 2-3 leaf	4.3	2.3	9152.2	a	13.1	a
5. Copper sulfate	10 lbs. - 2-3 leaf	3.8	2.0	9507.9	a	13.1	a
6. Dimilin 2L	8 fl. oz. - 2-3 leaf	6.3	3.8	11193.5	a	17.4	a
7. Untreated	---	2.0	3.5	9624.1	a	15.7	a
8. Pyganic	18 fl. oz. - 2-3 leaf	3.0	3.3	7136.6	a	10.7	a
9. Warrior	3.84 fl. oz. - 2-3 leaf	2.8	4.0	12405.7	a	18.1	a

* no tadpole shrimp introduced.

Means within columns (for each study) followed by same letter are not significantly different; least significant differences test ($\rho < 0.05$).

Table 8. Treatments evaluated for seed midge control, 2008.

Product	**Rate (lbs. AI/A)**	**Formulation per A**	**Timing**
1. V 10170 2.13 SC	0.18	10.8 fl. oz./A	5-7 days after seeding
2. Mustang Max EW	0.18	4 fl. oz./A	5-7 days after seeding
3. E2Y45 seed treatment	0.1 milligrams active per target		seed treatment
4. Warrior	0.03	3.84 fl. oz.	5-7 days after seeding
5. Untreated	---	---	---

Table 9. Stand density and yield results for midge control study, 2008.

Product	Formulation per A	Stand Density at Harvest	Grain Yield (lbs./A)	Biomass - Straw + Grain (t/A)
1. V 10170 2.13 SC	10.8 fl. oz./A	64.0	5890.1	8.3
2. Mustang Max EW	4 fl. oz./A	77.7	7305.7	10.1
3. E2Y45 seed treatment	0.1 milligrams active per target	63.0	6831.4	8.6
4. Warrior	3.84 fl. oz.	70.0	7153.2	9.2
5. Untreated	---	77.7	6320.0	8.2

No significant differences among means within columns; least significant differences test ($\rho < 0.05$).

Table 10. RWW adult feeding damage in variety susceptibility comparison to RWW study, 2008.

				RWW Immatures					
Variety	**RWW Infestation**	**% Scarred Plants**		**2 July**		**16 July**		**Average**	
M-202	None	0.0	c	0.05	c	0.0	b	0.03	c
PI	None	0.0	c	0.0	c	0.0	b	0.0	c
L-206	None	0.0	c	0.0	c	0.0	b	0.0	c
Calmati-202	None	0.0	c	0.0	c	0.05	b	0.03	c
M-202	Introduced	21.5	a	1.65	ab	0.85	a	1.25	a
PI	Introduced	12.5	b	1.95	a	0.4	ab	1.18	a
L-206	Introduced	18.5	ab	0.8	bc	0.2	b	0.5	bc
Calmati-202	Introduced	20.0	a	1.5	ab	0.3	b	0.9	ab

Means within columns followed by same letter are not significantly different; least significant differences test ($\rho < 0.05$).

Table 11. Effect of RWW populations on rice biomass and grain yields in variety comparison to RWW – ring study, 2008.

Variety	RWW Infestation	% Moisture		Grain Yield (lbs./A)		Biomass - Straw + Grain (t/A)	
M-202	None	15.7	ab	6575.4	ab	7.7	ab
PI	None	15.2	bc	6808.9	a	8.8	a
L-206	None	13.9	cd	4825.4	b	4.9	c
Calmati-202	None	13.6	cd	4822.7	b	6.8	bc
M-202	Introduced	17.4	a	4865.1	b	6.3	bc
PI	Introduced	14.5	bc	5812.0	ab	7.3	ab
L-206	Introduced	13.7	cd	5108.4	ab	5.0	c
Calmati-202	Introduced	13.4	c	5099.9	ab	7.1	ab

Means within columns followed by same letter are not significantly different; least significant differences test ($\rho < 0.05$).

Table 12. Comparison of yield responses among varieties to RWW – ring study, 2008.

Variety	Yield Loss from RWW (lbs./A)	Yield Loss per 1.0 RWW (lbs./A)
M-202	1710	1368
PI	997	1178
L-206	0	---
Calmati-202	0	---

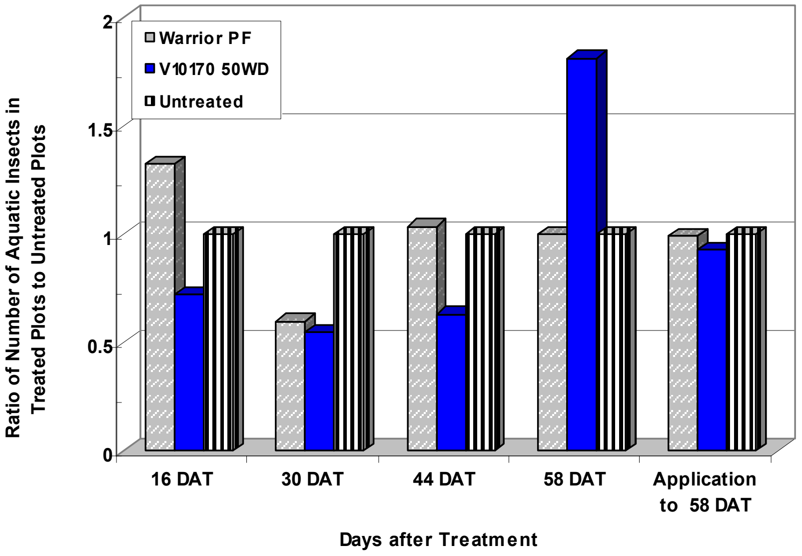

Figure 1. Influence of pre-plant insecticide applications on populations of aquatic insects from quadrant samples in rice, 2007.

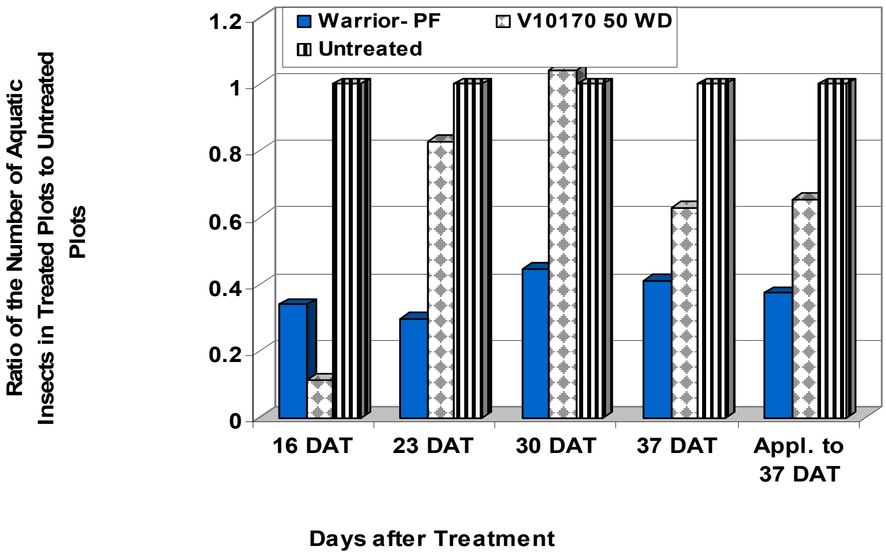

Figure 2. Influence of preflood insecticide applications on populations of aquatic insects from floating barrier traps in rice, 2007.

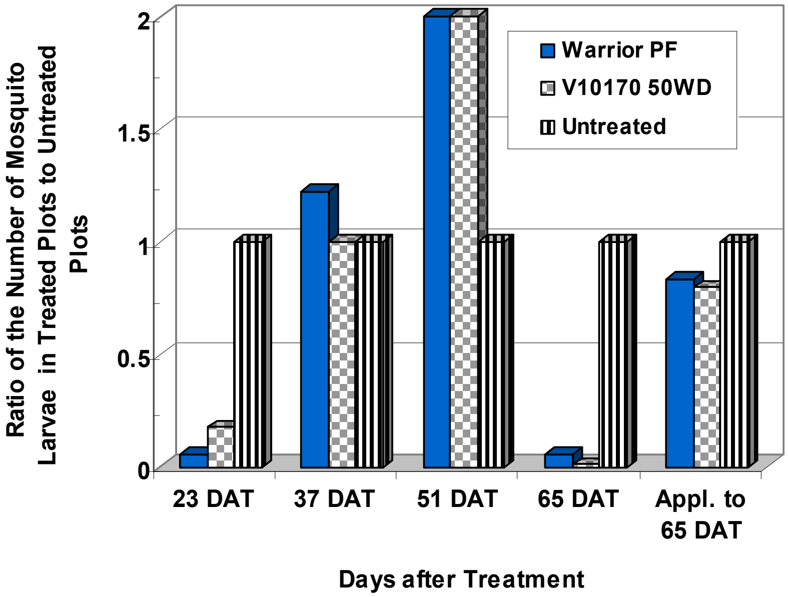

Figure 3. Influence of preflood insecticide applications on populations of mosquito larvae in rice, 2007.

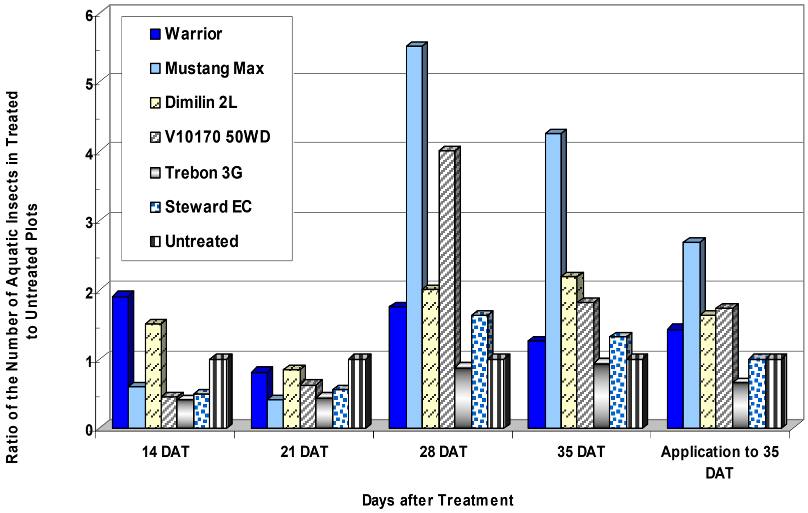

Figure 4. Influence of post-flood (3-leaf) insecticide applications on populations of aquatic insects from quadrant samples in rice, 2007.

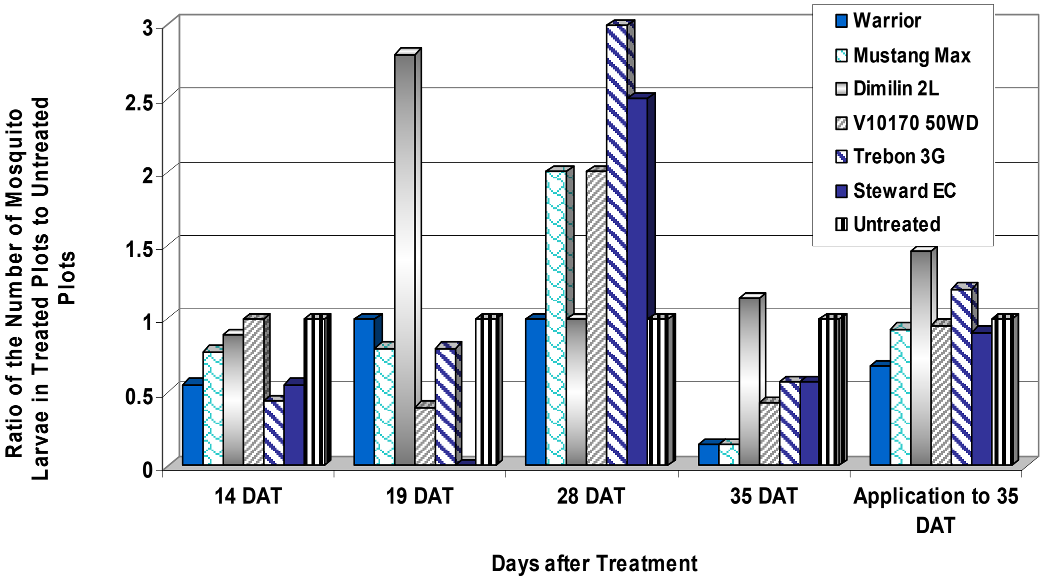

Figure 5. Influence of post-flood (3-leaf) insecticide applications on populations of mosquito larvae in rice, 2007.

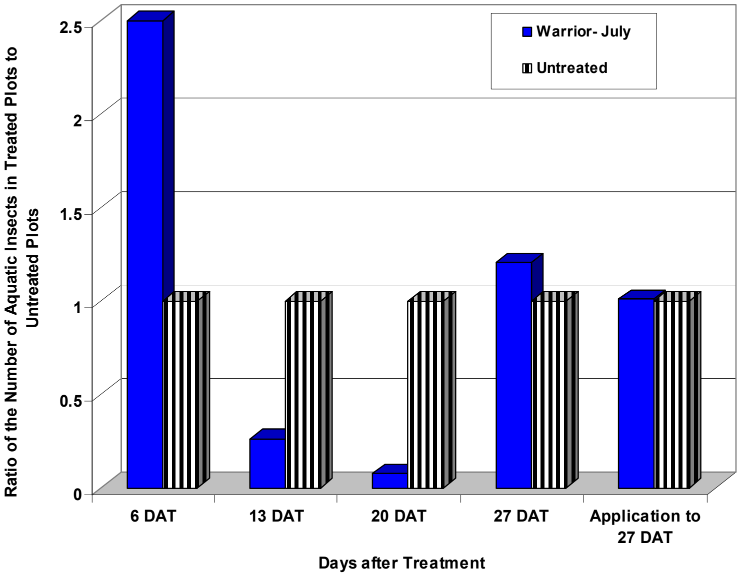

Figure 6. Influence of July armyworm insecticide application on populations of aquatic insects from quadrant samples in rice, 2007.

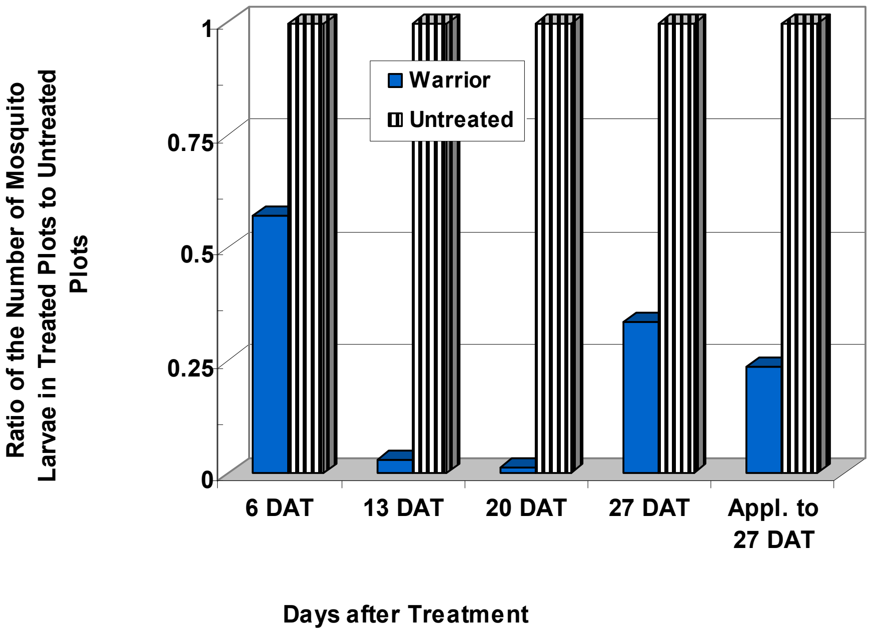

Figure 7. Influence of July armyworm insecticide application on populations of mosquito larvae in rice, 2007.

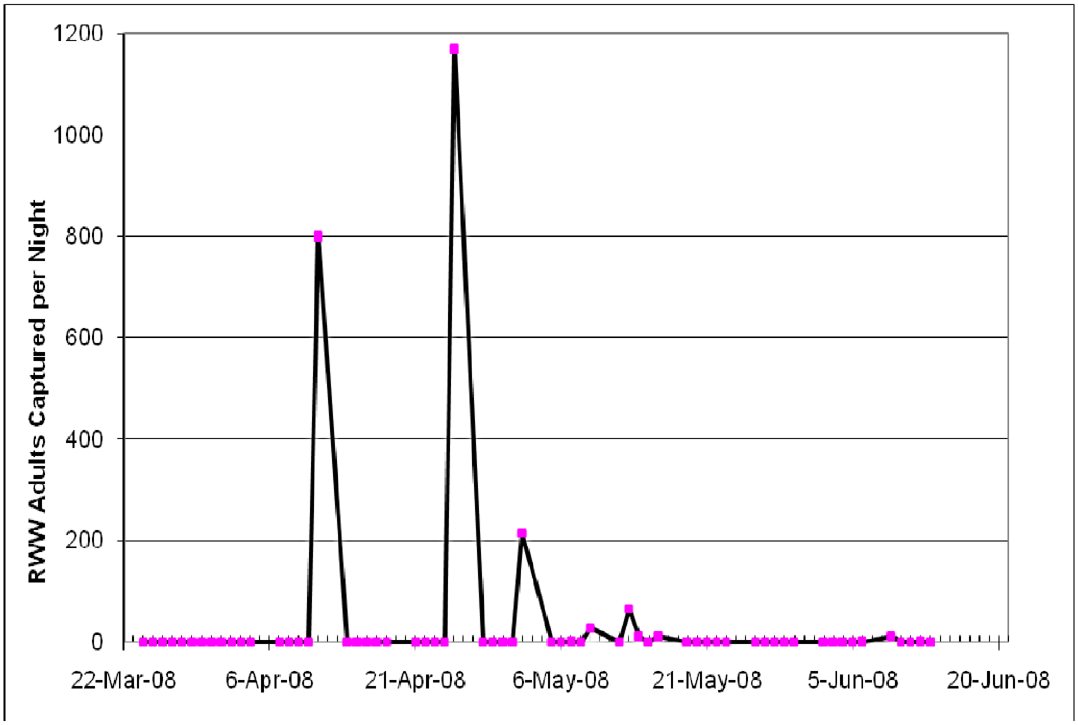

Figure 8. Rice water weevil flight pattern from light trap monitoring at the Rice Experiment Station, 2008.

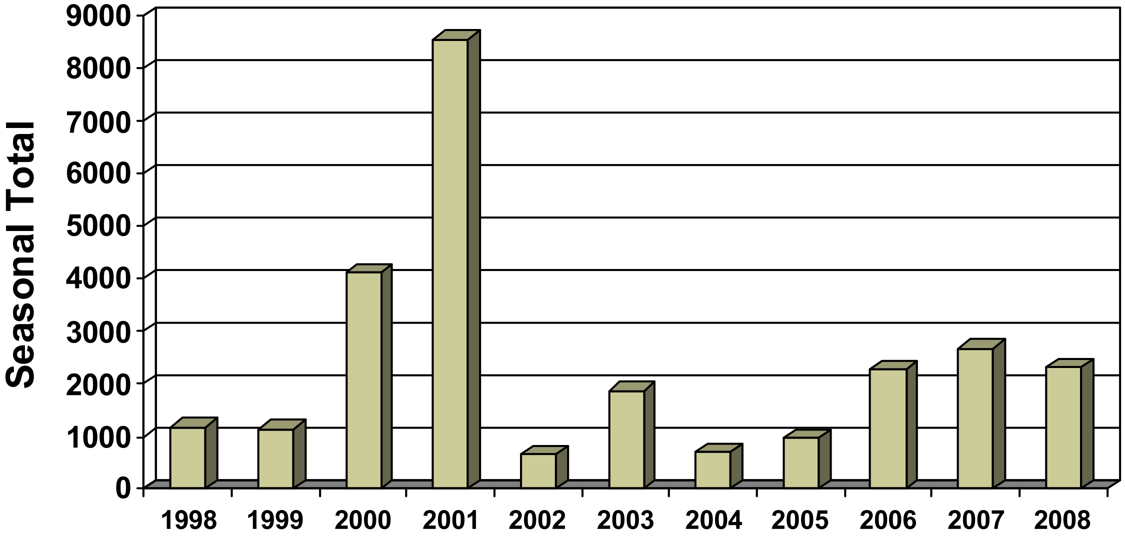

Figure 9. Comparison of RWW flight magnitude from light trap monitoring, RES, 1998 to 2008.

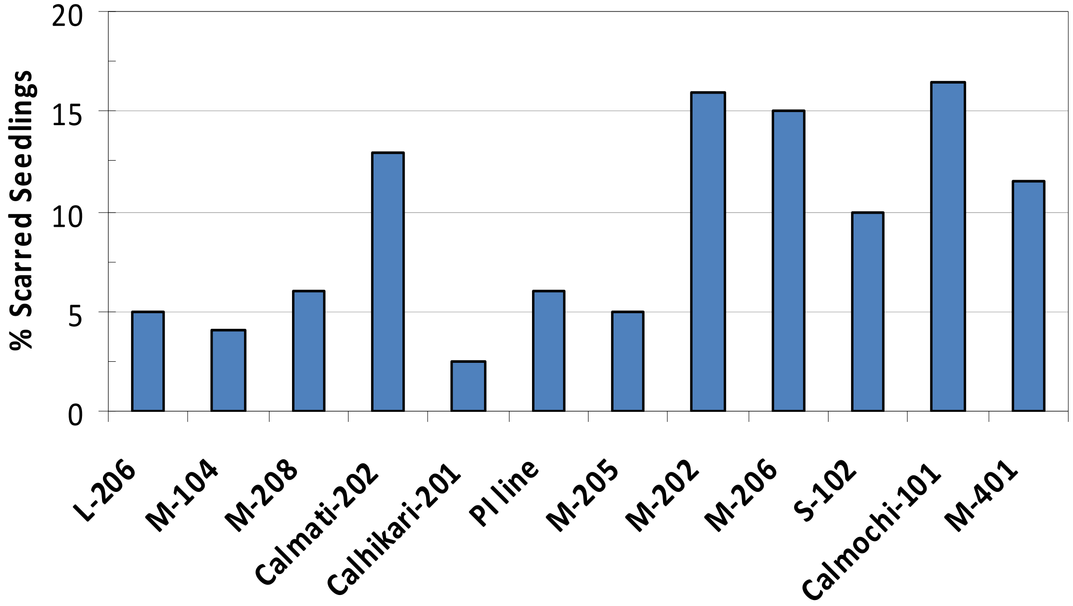

Figure 10. Seedling rice plant scarring by rice water weevil adults from rice variety susceptibility study, 2008.

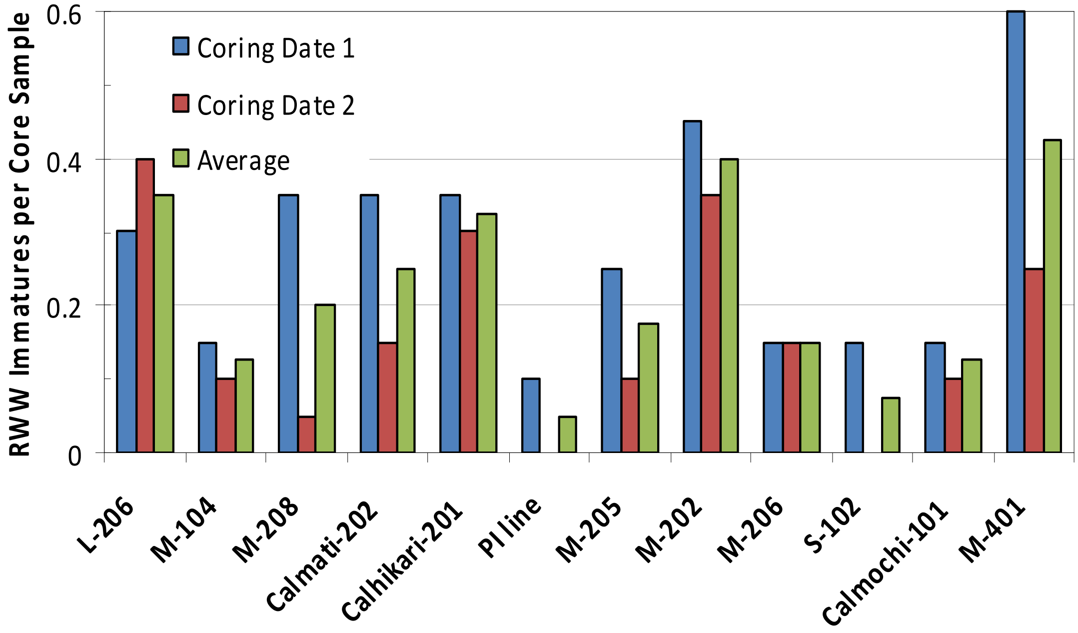

Figure 11. Rice water weevil larval populations from rice variety susceptibility study, 2008.

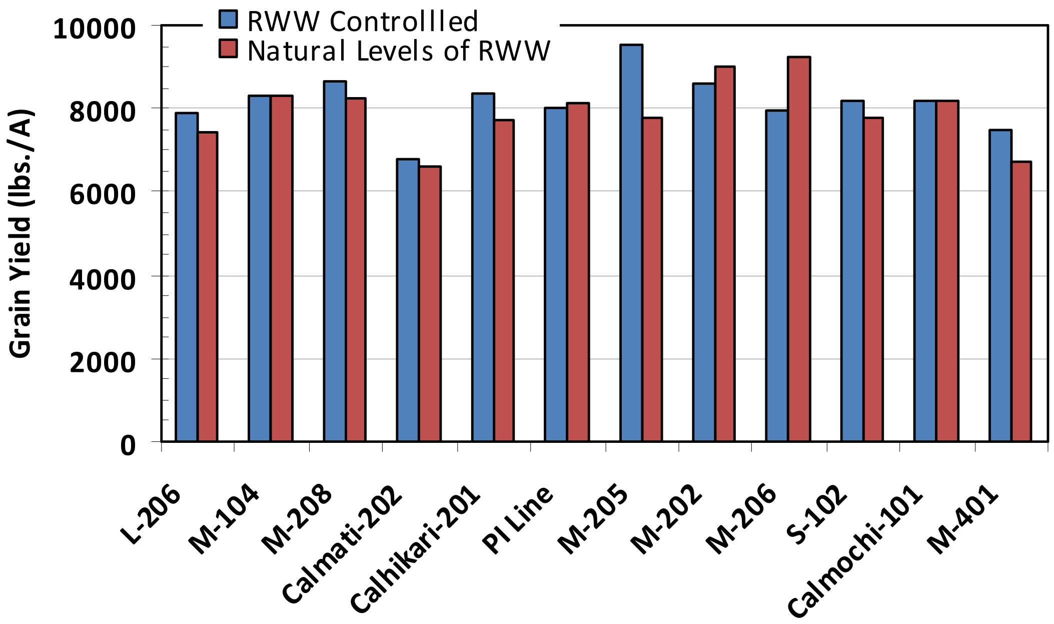

Figure 12. Rice grain yields from study designed to evaluate rice variety susceptibility to rice water weevil, 2008.

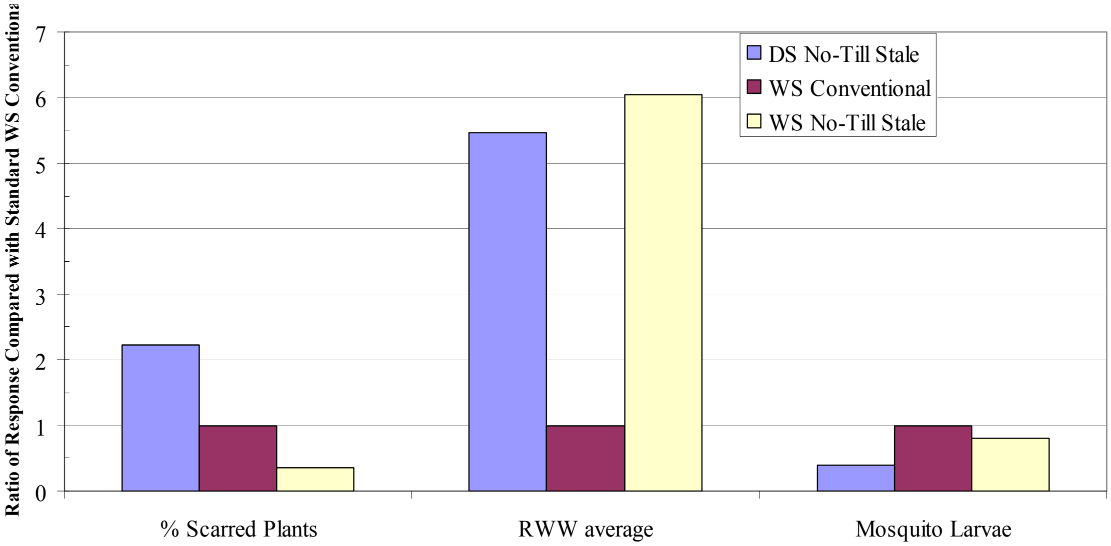

Figure 13. Incidence of plant scarring from RWW, larval RWW populations, and mosquito populations in the Systems study, 2008; averages in DS and WS no-till treatments compared with standard WS conventional.