PROJECT NO. RP-3

ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE

January 1, 2008 - December 31, 2009

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) Effects of application method on effectiveness of registered and experimental insecticides for Rice Water Weevil control.

1.2.a) evaluation of the efficacy of pyrethroid insecticides applied pre-flood for controlling rice water weevil in ring plots.
1.2.b) comparison of active ingredients applied as a seed treatment versus applied preflood or 3-leaf.

1.3) Examine the efficacy of experimental insecticides formulated as a seed treatment application.

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) Efficacy of experimental products for Rice Water Weevil under a natural infestation scenario.

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

1.7) Tadpole shrimp control – Evaluation of control 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: Conduct appropriate monitoring, exploratory research, and educational activities on emerging and new exotic rice invertebrate pests.

<u>SUMMARY OF 2009 RESEARCH BY OBJECTIVE:</u>

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 seven different active ingredients) were established in ring plots to accomplish this research. Plots were in a replicated field study at the Rice Experiment Station (RES) near Biggs, CA. Treatment details are listed in Table 1.

<u>Methods:</u>

Testing was conducted with 'M-202' in 8 sq. ft aluminum rings. The plots were flooded on 22 May and seeded on 23 May. A seeding rate of 90 lbs./A was used. Prior to seeding, seed was soaked for 2 hours in a 5% Clorox Ultra solution (unless otherwise noted), followed by 22 hrs. soaking in water, drained, and 24 hrs. at rest. The Clorox was for Bakanae control. The application timings were as follows:

19 May, early pre-flood treatments
22 May, pre-flood (PF) applications
8 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 10 adults placed into each ring on 5 June and 5 adults into each ring on 10 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:

<u>Emergence/ Seedling Vigor/Stand Rating</u>: 10 June
<u>Adult Leaf Scar Counts</u>: 11 and 18 June
<u>Larval Counts</u>: 8,9 July and 23,24 July
<u>Rice Yield</u>: 6 October

Sample Method:

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

<u>Results:</u>

Rice Emergence

There were no significant differences among treatments in terms of seedling vigor and emergence (Table 2). Therefore, no phytotoxicity was seen from any of the treatments. The rating averaged 2.6 (range of 2.1 to 3.1). We aim for 90-95 seedlings per ring and a rating of 3.0 is approximately 100 seedlings (this is a rating and not an actual count so it is an estimate), so the stand achieved was acceptable.

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. If the leaf scarring is reduced, the insecticide most likely has toxicity to adults. This is particularly important and interesting when evaluating seed and preflood treatments. If the leaf scarring is not reduced but the larval population is reduced, then the insecticide acts by directly killing larvae. All the rings have the same infestation level (based on the adults we introduce by hand); in some years there can also be a natural infestation. A natural infestation did occur in 2009 as the RWW flight was quite high in 2009. 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 10 adults had been placed into each ring; this allows time for the adults to feed and/or succumb to the treatment. A second evaluation was done on 18 June; some of the insecticides are reported to be “slow to act” thus the second count. On the first date, feeding scar incidence was high peaking at 61.5% of the seedlings having scar(s) in one of the treatments utilizing a seed-applied insecticide (Table 2). Counts were also high in the untreated plots (54%). The treatments showing the greatest reduction were V10170 preflood (all three rates) and the Warrior preflood. Percentages in the seed treatments and other preflood-treated plots were intermediate (~30-40%). At this time, the 3-leaf stage applications had not been made yet. On the 18 June sampling, counts were highest in the untreated plots at 61.5%. Scar incidence values in the seed treatments were similar to the first count (30 to 50%). The seed treatment method of application and/or the particular active ingredients used are not amenable to providing control of RWW adults. Of the treatments applied at the 3-leaf stage, V 10170 (all 3 rates), Trebon, Warrior and Mustang all substantially reduced leaf scarring to 10% or less.

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 – sometimes a product initially reduces the larval population but does not provide residual control. In 2009, populations were high and consistent in both sample dates. The level of infestation was about as high as I seen in this study. RWW levels in the untreated plots averaged 5.9 and 5.1 per core sample in the first and second sample dates, respectively (Table 3); for comparison populations averaged 1.3 in 2008. 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 (Dermacor X-100 5FS), and cyazypyr (DPX-HGW86 600FS) were evaluated in 2009. We have evaluated all these insecticides in previous years. 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 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 to volatile organic compounds affecting air quality (in the Central Valley and other areas). Given the concerns in the South, etofenprox (Trebon) and rynaxypyr seed treatment (Dermacor®) have been available under a Section 18 (emergency) registration in 2009.

The overall dataset for RWW larval populations is shown in Table 3. Discussion of the results will broken-down by the specific questions of interest.

<u>Specific questions that were addressed in the Ring Study:</u>

<u>Comparison of the efficacy of experimental materials versus registered standards for controlling rice water weevil in ring plots?</u> Data were promising from some of the treatments. Trebon applied at the 3-leaf stage was quite effective. We have worked with this product for several

years and it has generally worked well. This active ingredient is registered in California rice (not the formulated material). The marketing plan and price structure for this product are unclear at this time. V10170 applied either preflood or at the 3-leaf stage timing appears to be very active on RWW. This study could not separate the three rates (5, 6, or 12 oz.) or the two application timings in terms of efficacy as they were all very effective. RWW counts averaged 0.15 per sample with the product compared with 5.5 for the untreated (a 97% reduction). Studies utilizing a natural infestation may be better able to separate out the rates and timings due to perhaps a wider period of RWW infestation and to the grower field conditions. However, the high level of activity shown in these studies suggests this product will perform well. The two seed treatment materials (Dermacor and HGW86) were moderate in terms of RWW control. HGW86 seed treatment was very effective against RWW in 2008 whereas Dermacor was only moderate in performance. With Dermacor, there was a rate response with the highest rate providing "acceptable" RWW control (averaging 0.5 RWW per sample). HGW86 did not show a rate response with the two tested rates. The registered standards, Warrior, Mustang, and Dimilin all provided very good RWW control (Table 3).

<u>Effects of application method on effectiveness of registered and experimental insecticides for Rice Water Weevil control.</u>

<u>Soil application of pyrethroid products.</u> The preflood application of Warrior was registered (24c Special Local Needs) for the 2008 use-season and this label continues in place. 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. In 2009, Mustang was also evaluated for this use. Both Mustang and Warrior were applied immediately prior to flooding and at 3 days before flooding. The two active ingredients applied at flooding showed very good RWW control (Table 3) averaging 0.1 RWW per sample. For the "early preflood" application, efficacy with Warrior was slightly better than with Mustang (0.1 versus 0.4 RWW per sample.

<u>Comparison of active ingredients applied as a seed treatment versus applied preflood or 3-leaf.</u> Rynaxypyr was evaluated as a seed treatment and as a preflood application with a rate comparable to the middle rate tested via seed treatment (2.00 oz/100 lbs. seed). Applied as a seed treatment, RWW levels averaged 0.9 per sample and applied pre-flood the RWW population averaged 0.1 per sample. This product was been available in southern U.S. rice in 2008 and 2009 under a Section 18 registration. It has worked very well in their drill-seeded system under very high RWW pressure. We believe that the moderate, at best, performance in California is due to the water-seeded system used and that indeed appears to be the case.

<u>Examine the efficacy of experimental insecticides formulated as a seed treatment application.</u> This subobjective has already been discussed; materials applied as a seed treatment were compromised in terms of RWW control.

<u>Evaluation of the influence of seed soak with sodium hypochlorite (Ultra Clorox Germicidal Bleach) on activity of seed treatments for rice water weevil.</u> The use of sodium hypochlorite seed soak and the possible effects on insecticide activity is a factor with the seed treatments. As stated previously, without the sodium hypochlorite the activity is moderate, at best. Rynaxypyr (Dermacor X-100 5FS), and cyazypyr (DPX-HGW86 600FS) were both evaluated for this effect. In both cases, the activity was reduced by about 25% by the sodium hypochlorite seed soak.

Rice Yield

Grain moisture at harvest (percentage), grain yields (lbs. per A at 14% moisture standard), and biomass (tons per A straw + grain weight at harvest) data are shown in Table 4. Moisture values ranged from 17.3 to 20.3% (Table 4). In some years, grain from the untreated rings has a lowest moisture value; this treatment in those years produces the least amount of yield and as such matures out slightly earlier than the other rings. In 2009, the moisture values did not appear to correspond with the treatment efficacy. Rice grain yields ranged from 5833 to 9431 lbs./A. Overall these yield values were higher than many other years and the range in values are fairly large (a 38% difference between the highest and lowest yield). The highest yield was in the V10170 – 12 oz. preflood treatment (this treatment also had the highest percentage moisture and not surprising the highest biomass weight). The lowest grain yield was in the preflood Warrior treatment which had good RWW control. Rice biomass at harvest ranged from 9.3 to 14.0 t/A.

In summary, clothianidan appears to have significant potential for RWW management; it is active applied preflood as well as 3-leaf stage application. It would also be interesting to evaluate it as a "rescue" treatment, i.e., applied at about the 5-leaf stage when the larval infestation has already began. Etofenprox is active via application at the 3-leaf stage and the results from ring studies have been promising. Results from the southern U.S. rice entomologists and from commercial use of this product under a Section 18 registration have been less promising so this stresses the need to fully evaluate this product under grower field conditions before reaching a final conclusion on the efficacy. Rynaxypyr and cyazypyr efficacies as a seed treatment in water-seeded rice are moderate, at best. Cyazypyr has been evaluated only two years and only with two rates so conclusions are difficult to draw on it (effective in 2008 and not in 2009). Rynaxypyr was tested as a preflood application in 2009 and it was effective so this suggests that the seed treatment application method is limiting the performance of it. The performance of the seed treatments is additionally compromised by the use of the Sodium Hypochlorite 2-hour seed soak used as part of the Bakane management scheme. Warrior and Mustang applied preflood were both highly effective; "stressing" the product by making the application to the soil 3 days before flooding showed that Mustang may be hindered in performance more than Warrior. 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 unregistered active ingredients have some very favorable properties in terms of toxicity to non-targets, persistence, etc.

1.5) Efficacy of experimental products for Rice Water Weevil under a natural infestation scenario.

Testing in the ring plots at the Rice Experiment Station is useful to screen a number of treatments in a space- and time-conserving nature. However, before having complete confidence in how a product may perform under grower field conditions, evaluations should be done under these conditions. Of course, the limitation is that until the product is registered, applications to grower fields must be done using crop destruct and this can be costly. The mobile nature of insects such as RWW means that fairly large plots must be used which adds to the cost. Of course, registrations will not be achieved and recommendations made until adequate performance is verified.

In 2009, we applied three experimental products to single 0.25 acre plots at the Rice Experiment Station. While still more "controlled" conditions than those in grower fields, this allowed us to look at product performance with a naturally-occurring RWW population. Products evaluated were as follows:

Product	**Rate**	**Timing**
Dermacor X-100 5FS	2.5 oz./100 lbs. seed	Seed – 22 May
V10170 2.13	12 fl. oz./A	Preflood – 21 May
Trebon 3G	6 lbs./A	2-3-leaf – 5 June

Methods:

Leaf scarring, RWW population levels, and grain yields were evaluated as previously described on 18 June, 9 and 24 July, and 26 Oct., respectively. Yields were collected with the small plot harvester using four samples each 7.25 x 30 ft. long.

Results:

Stand establishment was problematic in this study. However, there were enough areas with a successful stand within each basin to allow for data collection. There was not enough space for an untreated basin so data collected in another study conducted in the neighboring two basins to the south was used for comparison purposes. RWW levels are shown in Table 5. In summary, Dermacor was ineffective, V10170 was moderately effective and Trebon was very effective. Yield data were compromised by the poor stand and will not be reported.

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

Maintaining a healthy rice agroecosystem continues to be an important goal of rice production. The environmental aspects of rice production have been well documented and promoted over the last several years. These attributes are key during the winter for water-fowl habitat but also critical during the production season. Best Management Practices have been developed and the environmental attributes of rice are heavily endorsed on various rice outlets (such as the CA Rice Commission). While crop protection tools are a necessary component of rice production, well-designed integrated pest management programs have been developed to minimize the use of these products, i.e., to use them only when necessary and when an economic advantage is predicted. Another facet of integrated pest management is to use products with the least environmental consequences, so called reduced risk products, when possible. This study was designed to evaluate the environmental fit of insecticides used in rice production. The criteria used were the effects on populations of non-target invertebrate organisms.

This information is useful for comparing products and for promoting the strong attributes of rice production. However, another use of these data is in terms of mosquito production in rice. Many of the non-target invertebrates sampled in this study are important predators of aquatic stages (eggs, larvae, and pupae) of mosquitoes. Mosquitoes are produced in rice fields and this is unavoidable (mosquitoes require water and the aquatic "islands" of flooded rice fields provide this habitat). The goal is to minimize the production of mosquitoes and to maintain "good neighbor" status with the surrounding human element. Besides being pestiferous, mosquitoes can transmit several diseases. West Nile virus continues to be a human health concern factor in California. The public press aspect and the urgency of this disease have diminished but it is now a component of life in the Central Valley and still a threat. In 2009, about 15% of the national human cases of West Nile Virus were confirmed from California. *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.

Methods:

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 used the last 3 years are listed in Table 6. The treatment list changes annually so experimental products that could potentially have a fit in rice can be evaluated. Best Management Practices are in place but these should be a working document and subject to revision if supported by research results. Research conducted so far has allowed a fairly good understanding of the effects of registered insecticides on nontargets in rice fields so looking at new products is a priority now. Data from 2008 will be discussed as the 2009 data are still being quantified and summarized. The procedures followed are similar for each year and the exact procedures and dates used in 2009 will be given herein.

Each plot was ~0.04 A and each treatment was replicated three times. In 2009, preflood treatments were applied on 27 May and the plots were seeded dry on 28 May immediately before the flooding. The initial stand was very poor so the field was drained to a low level of water and re-seeded on 10 June. The 3-leaf stage treatments were applied on 30 June and the armyworm application timing was 6 August. Populations of non-target organisms were evaluated weekly from mid-June to early 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 weekly in July, August, and September. Finally, four quadrant samples per plot (0.55 ft^2 each) were collected weekly and these samples collected all organisms within these area.

Results:

Non-Target Populations - The potential of aquatic organisms to utilize and flourish in temporary flooded aquatic habitats 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. A few of these organisms are pests, of course, and many of these organisms are predators of mosquito larvae. Many of the animals are simply just part of the rice agroecosystem and as such have no positive or negative effects (other than contributing to the "richness" of the system). The 2008 results are summarized and will be reported herein. Data were divided into aquatic insects and other aquatic invertebrates (everything that is not an insect). The exact numbers vary with year; in some years one species will flourish because the exact set of perfect conditions for it were present. Therefore, the data are shown as a ratio using the populations in the untreated plots as the benchmark. A value of "1" means the numbers in the untreated plots and the treatment in question were equal; less than one means more were present in the untreated plots and greater than one means more were present in the treated plot.

Preflood applications: Three preflood applications, Warrior, V10170, and DPX-HGW86, were evaluated in 2008. Floating Barrier Traps: Floating barrier traps primarily capture actively swimming organisms such as beetles. At 17 DAT (traps were present from 10 to 17 days after treatment), Warrior eliminated the insects and other invertebrates as shown by this type of trap (Fig. 1 & 2). However by 24 DAT (for insects) and 31 DAT (for the other invertebrates), this effect was gone and there was no effect of Warrior on these organisms. In the later sample dates up to 45 DAT, Warrior had no effects on levels of insects or other invertebrates in the floating traps. The other two preflood products, V10170 or HGW86, had no effects on populations of insects. They reduced populations of other invertebrates through 24 DAT. Quadrant samples: With the quadrant sampling method, the overall effects of the preflood materials on nontarget populations were also mild (Fig. 3 & 4). There were no long-term trends for reductions. At worst, a product might show a reduction in one particular sample (week) but that trend disappeared by the next sample (week). Warrior applied preflood showed the most severe effects with reductions in populations of aquatic insects (31DAT at ~40% and 52 DAT at ~75%) and of other aquatic invertebrates (31DAT at ~30% and 45 DAT at ~50%). Mosquito Dip Samples: Mosquito populations were low in 2008 and no real trends could be seen in the data.

Post-flood applications: Floating Barrier Traps: Floating barrier traps do not function well during this part of the season; the emerged rice plants impede the swimming of insect and the ability of the traps to capture them. However, they were used for a few weeks following the 3-leaf state applications. The greatest impact was, naturally, in the samples taken closest to the time of application (Fig. 5 & 6). At 3 DAT with the aquatic insects, four of the five products reduced populations (Dimilin being the exception) and for the other invertebrates, all five products reduced populations. In some cases this was 100% reduction. But by 10 DAT the negative impacts were mostly gone (only one case of a slight reduction). This occurs because the organism has some stage (usually the egg) that resists the toxicant and this hatches re-establishing the populations or alternatively it is a very mobile organism and re-infests by flight. At 17 and 24 DAT, there were some reductions at low to moderate levels in numbers of aquatic insects but these were 50% at most and not continued beyond these sample dates. Quadrant Samples: For the quadrant samples, the effects of the 3-leaf stage applications were greater with aquatic invertebrates (excluding insects) than with the aquatic insects (Fig. 7 & 8). At 10 DAT, all five products significantly reduced aquatic invertebrate levels by an average of 63%. There were some temporary reductions in the later sample dates but nothing striking. For aquatic insects, the greatest reductions were at 17 and 24 DAT (all five treatments at 17 DAT and four of the five treatments at 24DAT). These reductions were moderate in severity (generally 25-35%) and were not seen in later samples. Mosquito Dip Samples: Mosquito populations were low in 2008 and no real trends could be seen in the data.

July armyworm application: Warrior was evaluated as a representative material that could be applied against armyworms mid- to late-season. At 2 and 3 weeks after application, this treatment was very damaging to populations of aquatic insects (a 70% reduction); similar reductions were seen to populations of other invertebrate but only at 2 weeks after treatment (Fig. 9 & 10).

Pest Populations – The data on pest populations are summarized from the 2009 study. RWW was the only pest present in any significant numbers. As shown in Table 7, the preflood treatments, Warrior and V10170, provided the best control. The performance of the post-flood (3-leaf stage) materials may have been compromised by the long period of seedling establishment (seeding, draining, re-seeding, etc.) and this allowed a RWW infestation to start before the treatment was made.

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

Tadpole shrimp problems are on the increase and in recent year have surpassed armyworms as the second most important invertebrate pest of rice. Copper sulfate (Bluestone) use is on the decline due to an increase in price, and decreases in availability and efficacy. 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.

Methods:

A field study was conducted on tadpole shrimp control in 2009 in ring plots (standard 8 sq. ft aluminum rings). This was a study emphasizing registered and experimental products. The key dates were as follows:

22 May, pre-flood (PF) applications
22 May, flooding
23 May, seeding (‘M-202’)
3 June, placed 7 tadpole shrimp into each ring, rice was in the 1-2 leaf stage
4 June, post-flood treatments

Treatments as listed in Table 7 were evaluated. The number of floating seedlings, intact seedlings, and dead, floating shrimp were quantified on 8 June with the first two parameters also quantified again on 11 June. In addition, RWW larval populations were sampled 9 and 24 July. Although there were no RWW adults introduced into these rings, the high populations in 2009 resulted in a moderately-sized infestation. Therefore we took advantage of this to gain some additional data on RWW control. Grain yield data were collected on 9 October.

Results:

There were very few dead tadpole shrimp sampled (2 total). It is unclear if the killed shrimp float to the surface upon death or if some of these burrow into the muda dn cannot be discovered. Rice stand numbers (per 8 sq. ft. ring) in June ranged from 83.0 for the copper sulfate treatment to 57.75 for the Pyganic treatment (Table 8). A few floating seedlings, indicative of shrimp damage, were observed – generally higher in untreated plots and lower in the treatment areas. There is an indication that some of the experimental materials may control tadpole shrimp, but more data is needed to say this with certainty. RWW populations were fairly high especially considering that we did not infest these rings. A high natural infestation allowed for usable data. The untreated plots averaged 0.6 RWW per sample (there were two untreated sets of rings with four in each set; this number averages these along with the two sample dates). V10170 and Warrior preflood provided the best RWW control (Table 9). Several of the other products (Trebon, copper sulfate, Dermacor and Warrior postflood, appeared to provide some short-term control but this waned in the second sampling date. Grain yields ranged from ~4780 to 7300 lbs. per acre (Table 10). 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). The yield reductions likely came from a combination of RWW damage and tadpole shrimp damage (probably mostly the former).

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). In 2009, the rice water weevil flight was the highest recorded since 2001. The RWW flight was concentrated in two periods from April 17 to 21 and from May 8 to 15 (Fig. 11). On the night of April 17th over 2500 adults were captured in the light trap. This is more weevils than captured the entire season in 2008 and more than twice the number captured the entire seasons in 2002 and 2004. The April time was the first extended warm period (highest than 80F) in 2009. In contrast the flight was fairly spread out in 2008 with flights on 11 April, 25 April, and 2 May to 16 May. In total in 2009, ~6150 RWW were captured compared with 2300 in 2008.

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. M-401
3. M-104	9. Calhikari-201
4. M-208	10. Calmati-202
5. M-205	11. Calmochi-101
6. M-202	12. Calamylow-201

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 21 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 22 May and seeded on 23 May. RWW adult feeding scars (12 and 19 June), seedling establishment rating (12 June), larval population numbers (13 July and 27 July), and grain yields (26 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:

Because of the high RWW infestation in 2009, adult scarring was evaluated on two dates – 1 week apart. In the untreated plots on 12 June, plant scarring by adult RWW varied from 10.5% (Calmati-202) to more than 30% (M-208, M-104, M-205, M-202) (Fig. 112). On 19 June, overall the scarring severity increased as expected and the range of differences declined among the varieties. For instance, scarring in Calmati-202 was 28% whereas the four varieties that 1 week earlier were in the 30% range were now ~40% scarred. These cultivars were grown in replicated, randomized plots so the RWW adults had equal access to any plot. The lower values for the 12 June sampling date likely resulted because these particular cultivars were slower to establish and therefore the RWW found and infested the more vigorous varieties first. Therefore, they are all likely equally susceptible to infestation. Across varieties, the Warrior preflood application reduced the scarring by about 6 to 10%. RWW larval populations were relatively high in this plot. Numerically, M-104 had the highest infestation and overall the medium grains tended to have more weevils than Calhikari-201, Calmochi-101, Calamylow-201, and S-102 (Fig. 13). The Warrior preflood treatment was very effective in reducing RWW populations (across varieties 0.26 RWW per core sample with Warrior and 0.78 without Warrior) (Fig. 14). Looking at the two sample dates for RWW, populations declined significantly from the first to the second timing in M-104 and Calmochi-101. This could be an anomaly or could indicate something about the cultivar.

Averaged across RWW infestation, grain yields ranged from ~3000 (Calmati-202) to 5600 lbs./A (M-202) (Fig. 15). Efforts to control RWW resulted in a yield increase, compared with the same variety, in five of the twelve varieties with the greatest advantage in Calmati-202 at ~1350 lbs./A. A correlation between RWW density and grain yield showed a significant negative trend (and estimated percentage yield loss per larva) in Calamylow-201 (13.9%), Calmati-202 (25.1%), M-206 (12.2%), M-208 (1.3%), and S-102 (12.0%).

Subobjective 2.2.2)

Methods:

Four varieties were selected for more detailed studies on susceptibility and responses to RWW - M-202, S-102, 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 with no injury from RWW.

Results:

The uninfested rings had a very low RWW infestation at about 5% scarred seedlings and less than 0.1 RWW per core sample (Table 12). This was expected and desired since they were not infested by us and they were treated with Warrior preflood. Adult feeding among varieties for the infested rings was fairly consistent at about 40%. The scarring was significantly higher in M-202 than in L-206. For RWW larvae, there were more larvae in M-202 than in the other three varieties (significantly more than L-206 in the first sample date). This result generally agredd with the adult scarring data. Grain yields were reduced by the RWW infestation in M-202 and S-

102, not really impacted in L-206 and actually better in the untreated than the treated pots in Calmati-202.

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

My laboratory has been cooperating with the other rice scientists working on developing alternative seeding and establishment methods for rice production. Improved weed management, water quality, and water usage are some of the goals of this research. However, while solving one or more problems, it is important to insure that another problem is not created. These methods involve altering water depth and timing in the rice system. The invertebrate pest populations in rice are intimately tied to water. Seedling pests such as seed midge, tadpole shrimp, etc. are favored by water. RWW adults always oviposit in the rice leaf sheaths just below the water line. Infestations of armyworms, another insect pest of rice, probably are not closely related to flooding of rice fields. Mosquitoes, of course, are definitely favored by water. It is also important to remember that a rice field is an agroecosystem. Besides these invertebrates "of interest", there are countless other species that may be influencing levels of these pests. These nontarget organisms may respond to water in countless ways. In 2009, 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 2009, we monitored RWW populations in this seedling establishment study. Data were collected on 14 July and 28 July (RWW immatures) using standards methods as described in Subobjective 1.1.

Results:

RWW infestation in this plot was relatively high as it was throughout the RES in 2009. The drill-seeded no till option had the highest RWW larval population on 14 July at 1.3 per sample. The other two treatments, drill-seeded no till stale seedbed and water-seeded no till, had only about ½ as many larvae. On 28 July, the levels were more equivalent ranging from 0.98 to 0.65 per core sample.

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

A study was initiated in 2008 and continued in 2009 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. We are cooperating with the rice entomologists in the other states on the national test.

Methods:

The study was done by sampling at multiple sites (sixteen) in each of three basins. The basins, about 6 acres total, were maintained at 3, 6, and 9 inches water depth. Plots were seeded on 14 May with M-202. RWW adult scarring (22 and 29 June) and RWW immature populations (20 July and 3 August) were to be quantified using the standard techniques. In addition, water depth was measured to verify the treatments.

Results:

As shown in Table 13, the water depths were managed is the desired levels fairly well. We were primarily concerned with having these treatments in place for the first 6 weeks after seeding. Scarring from RWW adults was higher in the rice flooded with 3 inches water than with 6 or 9 inches. Similarly, RWW larval populations were about 4 times higher in the rice grown with 3 inches of flood compared with 6 or 9 inches of water.

Objective 3: Conduct appropriate monitoring, exploratory research, and educational activities on emerging and new exotic rice invertebrate pests.

This objective is included to verify that I strive to be aware and keep abreast of issues with invasive pests that could affect the California rice industry. The exact work done under this objective could involve educational activities, pest monitoring, literature review, discussion with other experts, committee activities, etc. The industry in recent years has experienced invasive weed and disease pests. Several invertebrate pests of rice occur in other countries and even in other U.S. states, but fortunately not in California. California has strong policies and enforcement designed to keep exotic pests out of the state but unfortunately they still occur and this seems to be happening increasingly more frequent.

In January 2009, the panicle rice mite, *Steneotarsonemus spinki*, was found in California. This pest was found in the southern rice-producing states (Arkansas, Louisiana, and Texas along with New York) in July 2007 primarily in rice grown in the greenhouse and research plots. The find in California was on the UC-Davis campus infesting rice growing in greenhouses. The panicle rice mite is a “Q” rated (quarantine) pest in CA. UC-Davis, in cooperation with representatives of regulatory agencies at the federal (Animal and Plant Health Inspection Service) and state (California Dept. of Food and Agriculture) levels, worked quickly to eradicate this pest. These procedures are ongoing but in summary:
1.) A committee was appointed by the College of Agricultural and Environmental Sciences Dean’s office to develop eradication plans for this pest on the UC-Davis campus.
2.) Infested rice plants from the 13 infested greenhouses were either harvested (if at maturity), destroyed, or moved to a federally-approved quarantine facility until mature.
3.) A one-month rice-free period was instituted on the UC-Davis campus during April-May.
4.) New rice plantings starting in June 2009 were placed in noncontiguous greenhouses and originated from seed that had a cold-treatment and a fumigant treatment to kill any potential mite contamination.
5.) Sentinel rice plants were placed in greenhouses to monitor for panicle rice mites.
6.) A foliar acaricide treatment program is being used on all greenhouse rice plants.

The panicle rice mite is an important rice pest in several Asian countries (China, India, Taiwan, Korea, Philippines, and Thailand). The mite was transported to several Caribbean, Central, and South America countries in the late 1990’s and caused severe yield losses in Cuba in 1997. It has also been reported in the Puerto Rico, Dominican Republic, Haiti, Nicaragua, Costa Rica, Panama, and Colombia. This mite can move very limited distances by itself but is very readily moved on rice seeds and secondarily by wind, water, insects, agricultural machinery, and on plant debris. Movement of rice seed is the likely method of transport into and within the U.S. The PRM attacks rice plants by feeding on the inside of the leaf sheath and developing grains. Damage associated with PRM infestations in rice include plant sterility, partial panicle infertility, and grain malformation. The mite is commonly reported interacting with several rice plant pathogens that aid in the damage. To-date, the infestation in the UC-Davis greenhouses is non-existent; however, keeping this pest out of California is going to be an ongoing process.

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CONCISE GENERAL SUMMARY OF CURRENT YEARS (2009) RESULTS:
Larry D. Godfrey

Research was conducted in 2009 on the biology and management of key invertebrate pests of California rice. Rice water weevil populations were at the highest levels since the early 2000's. Therefore, data were collected on this pest in all studies we conducted in 2009. Early-season pests such as tadpole shrimp and seed midge were another priority. Research was targeted on tadpole shrimp and useful data were collected. Efforts on seed midge were thwarted due to low populations in our plots. Armyworms, the other important insect pest of rice, were not present in high enough levels for research in 2009. The goal of this research was to refine and advance IPM schemes for these rice pests while maximizing protection of the environmental aspects of the rice agroecosystem and enhancing the cost effectiveness of management efforts in rice.

Rice Water Weevil: <u>Management</u> - Studies were conducted on management of rice water weevil, several aspects of the insect's biology that could provide valuable information to assist with control efforts, and rice cultivar response to rice water weevil injury. Studies were continued in 2009 in 8 sq. ft. ring plots, small basins, and 0.25 acre plots to evaluate experimental insecticides versus registered standards for rice water weevil control. The ring plots allow numerous treatments to be evaluated in a small area under very controlled conditions. Twenty-four treatments (a total of seven different active ingredients) were evaluated in ring plots. Rice water weevil adults introduced into each ring along with a heavier than normal naturally-occurring infestation resulted in a high infestation and an "acid test" of the treatments. The standards, 3-leaf stage applications of Mustang®, Warrior®, and Dimilin®, performed well under these conditions. Furthermore, Warrior and Mustang applied preflood (day of flooding) were both highly effective; "stressing" the product by making the application to the soil 3 days before flooding showed that Mustang may be hindered in performance more than Warrior. The preflood method is a registered treatment for Warrior but not for Mustang. Of the experimental materials, clothianidan (V10170) appears to have significant potential for RWW management; it is very effective (95-98% control) applied preflood as well as 3-leaf stage application and all three rates were highly effective. It would also be interesting to evaluate it as a "rescue" treatment, i.e., applied at about the 5-leaf stage when the larval infestation has already began. Etofenprox (Trebon®) is active via application at the 3-leaf stage and the results from ring studies have been promising. Results from the southern U.S. rice entomologists and from commercial use of this product under a Section 18 registration have been less promising so this stresses the need to fully evaluate this product under grower field conditions before reaching a final conclusion on the efficacy. Rynaxypyr (Dermacor®)and cyazypyr (DPX-HGW86) efficacies as seed treatments in water-seeded rice are moderate, at best. Cyazypyr has been evaluated only two years and only with two rates so conclusions are difficult to draw on it (effective in 2008 but not in 2009). Rynaxypyr was also tested as a preflood application in 2009 and it was effective so this suggests that the seed treatment application method is limiting the performance of it. The performance of the seed treatments is additionally compromised by the use of the Sodium Hypochlorite 2-hour seed soak used as part of the Bakane management scheme. Evaluations in 0.25 acre plots showed Dermacor was ineffective, V10170 was moderately effective and Trebon was very effective. 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 unregistered active ingredients have some very favorable properties in terms of toxicity to non-targets, persistence, etc.

Biology - In 2009, the rice water weevil spring flight was the highest recorded since 2001. The RWW flight was concentrated in two periods from April 17 to 21 and from May 8 to 15. On the night of April 17th over 2500 adults were captured in the light trap. This is more weevils than captured the entire season in 2008 and more than twice the number captured the entire seasons in 2002 and 2004. Two agronomic aspects of rice production were evaluated for impacts on RWW levels. Among various seedling establishment techniques, drill-seeded no till option had twice as many RWW larvae in mid-July than the other two treatments, drill-seeded no till stale seedbed and water-seeded no till. Interestingly, the RWW levels among the three methods equilibrated later in the season. The influence of water depth during the first 6 weeks after seeding on RWW populations was studied. RWW larval populations were about 4 times higher in the rice grown with 3 inches of flood compared with 6 or 9 inches of water. Twelve rice cultivars were compared for their susceptibility to RWW infestation and to damage from RWW larvae. Soon after the time of seedling emergence through the water, plant scarring by adult RWW varied from 10.5% (Calmati-202) to more than 30% (M-208, M-104, M-205, M-202). However, 1 week later, scarring severity ranged from 30 to 40% in all varieties. The initial lower values likely resulted because these particular cultivars were slower to establish and therefore the RWW found and infested the more vigorous varieties first. Therefore, they are all likely equally susceptible to infestation. Numerically, M-104 had the highest larval infestation and overall the medium grains tended to have more weevils than Calhikari-201, Calmochi-101, Calamylow-201, and S-102. Populations declined significantly from the first to the second sample timing in M-104 and Calmochi-101. This could be an anomaly or could indicate something about the cultivar. Efforts to control RWW resulted in a yield increase, compared with untreated plots of the same variety, in five of the twelve varieties with the greatest advantage in Calmati-202 at ~1350 lbs./A. A correlation between RWW density and grain yield showed a significant negative trend (and estimated percentage yield loss per larva) in Calamylow-201 (13.9%), Calmati-202 (25.1%), M-206 (12.2%), M-208 (1.3%), and S-102 (12.0%).

Tadpole Shrimp: Seven insecticide treatments were compared for control of tadpole shrimp. Rice stands per 8 sq. ft. ring ranged from 83.0 for the copper sulfate treatment to 57.75 for the Pyganic treatment. 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). The yield reductions likely came from a combination of RWW damage and tadpole shrimp damage (probably mostly the former).

Non-Target Organisms: Nine insecticide treatments (and an untreated) were compared in terms of their effects on populations of non-target invertebrates and their potential to upset naturally-occurring mosquito management. Three preflood applications, Warrior, V10170, and DPX-HGW86, were evaluated. Warrior had the most severe effects. These were short-term effects; for example, data collected from 10 to 17 days after treatment showed Warrior greatly reduced populations of aquatic insects and other invertebrates. However by 24 days (for insects) and 31 days (for the other invertebrates), this effect was gone. The other two preflood products, V10170 or HGW86, had no effects on populations of insects. For the post-flood applications, the effects of the 3-leaf stage applications were greater with aquatic invertebrates (excluding insects) than with the aquatic insects. At 10 days after treatment, all five products significantly reduced aquatic invertebrate levels by an average of 63%. Later samplings showed no strong reductions. For aquatic insects, the greatest reductions were at 17 and 24 days (all five treatments at 17 days and four of the five treatments at 24 days). These reductions were moderate in severity (generally 25-35%) and were not seen in later samples. Warrior was evaluated as a representative material that could be applied against armyworms mid- to late-season. At 2 and 3 weeks after application, this treatment was very damaging to populations of aquatic insects (a 70% reduction); similar reductions were seen to populations of other invertebrate but only at 2 weeks after treatment.

Panicle Rice Mite: In January 2009, the panicle rice mite, *Steneotarsonemus spinki*, was found in California on the UC-Davis campus infesting rice growing in greenhouses. This invasive pest is a “Q” rated (quarantine) pest in CA. UC-Davis, in cooperation with representatives of regulatory agencies at the federal (Animal and Plant Health Inspection Service) and state (California Dept. of Food and Agriculture) levels, worked quickly to eradicate this pest. A rice-free period on campus, treatment of existing rice in greenhouses, and new procedures were enacted to deal with the infestation and eradicate this pest. To-date, the infestation in the UC-Davis greenhouses is non-existent; however, keeping this pest out of California is going to be an ongoing process.

Table 1. Treatment list for RWW management ring study, 2009.

Product	Formulation per A	Timing	Notes/Dates*
1. Dimilin 2L	8 oz.	3-leaf	
2. Untreated	---	---	---
3. Warrior	3.84 fl. oz.	3-leaf	
4. Warrior	3.84 fl. oz.	Early PF	5/19/09
5. Trebon 3G	6 lbs.	3-leaf	
6. V 10170 2.13 SC	5 fl. oz.	PF	5/22/09
7. V 10170 2.13 SC	6 fl. oz.	PF	5/22/09
8. V 10170 2.13 SC	12 fl. oz.	PF	5/22/09
9. V 10170 2.13 SC	5 fl. oz.	3 leaf	
10. V 10170 2.13 SC	6 fl. oz.	3 leaf	
11. V 10170 2.13 SC	12 fl. oz.	3 leaf	
12. Mustang 1.5 EW	4.3 fl. oz.	3 leaf	
13. Warrior	3.84 fl. oz.	PF	5/22/09
14. Dermacor X-100 5FS	0.08 lb. AI/A	PF	5/22/09
15. Dermacor X-100 5FS	1.75 oz/100 lbs	Seed	DuPont-trt. - no Clorox
16. Dermacor X-100 5FS	2.00 oz/100 lbs	Seed	DuPont-trt. - no Clorox
17. Dermacor X-100 5FS	2.50 oz/100 lbs	Seed	DuPont-trt. - no Clorox
18. DPX-HGW86 - 600 FS	0.020 MAT	Seed	DuPont-trt. - no Clorox
19. DPX-HGW86 - 600 FS	0.025 MAT	Seed	DuPont-trt. - no Clorox
20. Mustang 1.5 EW	4.3 fl. oz.	Early PF	5/19/09
21. Mustang 1.5 EW	4.3 fl. oz.	PF	5/22/09
22. Dermacor X-100 5FS	2.50 oz/100 lbs	Seed	UCD-trt. - no Clorox
23. Dermacor X-100 5FS	2.50 oz/100 lbs	Seed	UCD-trt. - with Clorox
24. DPX-HGW86 - 600 FS	0.025 MAT	Seed	UCD-trt. - with Clorox

* Clorox seed soak used except where indicated

Table 2. Rice plant stand and adult feeding damage in chemical ring study, 2009.

Product	Formulation per A	Timing/Notes	Stand Vigor/Emergence	% Scarred Plants - 11 June		% Scarred Plants - 18 June	
1. Dimilin 2L	8 oz.	3-leaf	2.6	52.5	abcd	45.5	bc
2. Untreated	---	---	2.6	54.0	abc	65.5	a
3. Warrior	3.84 fl. oz.	3-leaf	2.6	36.0	def	8.5	g
4. Warrior	3.84 fl. oz.	Early PF	2.5	26.5	efgh	39.5	bc
5. Trebon 3G	6 lbs.	3-leaf	2.3	43.0	bcde	7.0	g
6. V 10170 2.13 SC	5 fl. oz.	PF	2.4	21.0	fghi	16.0	efg
7. V 10170 2.13 SC	6 fl. oz.	PF	2.3	14.5	ghi	14.0	fg
8. V 10170 2.13 SC	12 fl. oz.	PF	2.3	9.0	hi	16.0	efg
9. V 10170 2.13 SC	5 fl. oz.	3-leaf	2.6	40.5	bcde	4.0	g
10. V 10170 2.13SC	6 fl. oz.	3-leaf	3.0	52.5	efd	9.5	g
11. V 10170 2.13SC	12 fl. oz.	3-leaf	2.1	52.5	abcd	9.0	g
12. Mustang 1.5 EW	4.3 fl. oz.	3-leaf	2.6	35.0	def	9.0	g
13. Warrior	3.84 fl. oz	PF	2.3	4.5	i	19.0	defg
14. Dermacor X-100 5FS	0.08 lb. AI/A	PF	2.9	33.0	ef	34.0	bcd e
15. Dermacor X-100 5FS	1.75 oz/100 lbs	Seed –DuPont, no Clorox	3.0	43.5	bcde	50.0	abc
16. Dermacor X-100 5FS	2.00 oz/100 lbs	Seed –DuPont, no Clorox	2.8	36.0	def	31.5	cdef
17. Dermacor X-100 5FS	2.50 oz/100 lbs	Seed –DuPont, no Clorox	2.8	30.5	efg	43.0	bc
18. DPX-HGW86 - 600 FS	0.020 MAT	Seed –DuPont, no Clorox	3.0	42.0	bcde	52.0	ab
19. DPX-HGW86 - 600 FS	0.025 MAT	Seed –DuPont, no Clorox	3.1	37.5	cdef	49.5	abc
20. Mustang 1.5 EW	4.3 fl. oz.	Early PF	2.8	38.0	cdef	42.0	bc
21. Mustang 1.5 EW	4.3 fl. oz.	PF	2.4	29.0	efg	31.5	cdef
22. Dermacor X-100 5FS	2.50 oz/100 lbs	Seed – UCD, no Clorox	2.6	57.0	ab	44.0	bc
23. Dermacor X-100 5FS	2.50 oz/100 lbs.	Seed –UCD, with Clorox	2.4	61.5	a	46.0	abc
24. DPX-HGW86 - 600 FS	0.025 MAT	Seed – UCD, with Clorox	2.5	42.5	bcde	37.0	bcd

* Clorox seed soak used except where indicated

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

Table 3. RWW immature density (first and second sample dates and average) in chemical ring study, 2009.

Product	Formulation per A	Timing	RWW - Sample Date 1		RWW - Sample Date 2		Avg.
1. Dimilin 2L	8 oz	3-leaf	0.1	c	0.3	fg	0.2
2. Untreated	---	---	5.9	a	5.1	a	5.5
3. Warrior	3.84 oz.	3-leaf	0.1	c	0.1	fg	0.1
4. Warrior	3.84 oz.	Early PF	0.1	c	0.2	fg	0.1
5. Trebon 3G	6 lbs.	3-leaf	0.5	c	0.4	efg	0.4
6. V 10170 2.13 SC	5 fl. oz.	PF	0.1	c	0.2	fg	0.1
7. V 10170 2.13 SC	6 fl. oz.	PF	0.2	c	0.2	fg	0.2
8. V 10170 2.13 SC	12 fl. oz.	PF	0.1	c	0.2	fg	0.1
9. V 10170 2.13 SC	5 fl. oz.	3-leaf	0.1	c	0.3	fg	0.2
10. V 10170 2.13 SC	6 fl. oz.	3-leaf	0.0	c	0.1	g	0.0
11. V 10170 2.13 SC	12 fl. oz.	3-leaf	0.2	c	0.2	fg	0.2
12. Mustang 1.5 EW	4.3 fl. oz	3-leaf	0.1	c	0.2	fg	0.1
13. Warrior	3.84 fl. oz	PF	0.1	c	0.1	g	0.1
14. Dermacor X-100 5FS	0.08 lb. AI/A	PF	0.0	c	0.3	fg	0.1
15. Dermacor X-100 5FS	1.75 oz/100 lbs	Seed –DuPont, no Clorox	0.8	c	1.7	cdef	1.3
16. Dermacor X-100 5FS	2.00 oz/100 lbs	Seed –DuPont, no Clorox	0.8	c	1.1	defg	0.9
17. Dermacor X-100 5FS	2.50 oz/100 lbs	Seed –DuPont, no Clorox	0.3	c	0.7	efg	0.5
18. DPX-HGW86 - 600 FS	0.020 MAT	Seed –DuPont, no Clorox	3.2	b	2.0	cde	2.6
19. DPX-HGW86 - 600 FS	0.025 MAT	Seed –DuPont, no Clorox	2.8	b	2.9	bc	2.8
20. Mustang 1.5 EW	4.3 fl. oz	Early PF	0.4	c	0.4	efg	0.4
21. Mustang 1.5 EW	4.3 fl. oz	PF	0.2	c	0.1	g	0.1
22. Dermacor X-100 5FS	2.50 oz/100 lbs	Seed – UCD, no Clorox	3.5	b	3.9	ab	3.7
23. Dermacor X-100 5FS	2.50 oz/100 lbs	Seed –UCD, with Clorox	4.3	ab	5.4	a	4.9
24. DPX-HGW86 - 600 FS	0.025 MAT	Seed – UCD, with Clorox	3.5	b	2.7	abc	3.1

* Clorox seed soak used except where indicated

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

Table 4. Effect of RWW populations on rice biomass and grain yields in ring study, 2009.

Product	**Formulation per A**	**Timing**	**% Grain Moisture**		**Grain Yield (lbs./A)**		**Biomass (Straw+ Grain [t/A])**	
1. Dimilin 2L	8 oz	3-leaf	18.7	a-e	6956	bcde	11.4	bcde
2. Untreated	---	---	18.0	cd	7477	a-e	10.4	de
3. Warrior	3.84 oz.	3-leaf	20.3	a	6476	cde	12.8	abcd
4. Warrior	3.84 oz.	Early PF	18.8	a-e	7125	bcde	11.0	bcde
5. Trebon 3G	6 lbs.	3-leaf	19.9	ab	8058	a-e	12.2	abcd
6. V 10170 2.13SC	5 fl. oz.	PF	18.5	a-e	8763	ab	13.1	ab
7. V 10170 2.13SC	6 fl. oz.	PF	19.7	abc	7570	a-e	11.7	a-e
8. V 10170 2.13SC	12 fl. oz.	PF	20.2	a	9431	a	14.0	A
9. V 10170 2.13SC	5 fl. oz.	3-leaf	19.6	abc	7755	a-e	12.3	abcd
10. V 10170 2.13SC	6 fl. oz.	3-leaf	19.0	a-e	7972	a-e	12.7	abcd
11. V 10170 2.13SC	12 fl. oz.	3-leaf	18.9	a-e	7101	bcde	10.6	cde
12. Mustang 1.5 EW	4.3 fl. oz	3-leaf	20.0	a	8429	abc	12.7	abcd
13. Warrior	3.84 fl. oz	PF	18.2	bcde	5833	e	9.3	e
14. Dermacor X-100 5FS	0.08 lb. AI/A	PF	19.1	abcd	8145	abcd	12.9	abc
15. Dermacor X-100 5FS	1.75 oz/100 lbs	Seed –DuPont, no Clorox	18.8	a-e	8145	abcd	12.6	abcd
16. Dermacor X-100 5FS	2.00 oz/100 lbs	Seed –DuPont, no Clorox	19.4	abcd	8335	abcd	12.6	abcd
17. Dermacor X-100 5FS	2.50 oz/100 lbs	Seed –DuPont, no Clorox	19.0	a-e	8190	abcd	13.3	ab
18. DPX-HGW86 - 600 FS	0.020 MAT	Seed –DuPont, no Clorox	17.7	de	7363	a-e	10.8	bcde
19. DPX-HGW86 - 600 FS	0.025 MAT	Seed –DuPont, no Clorox	19.1	a-e	6087	de	12.5	abcd
20. Mustang 1.5 EW	4.3 fl. oz	Early PF	18.9	a-e	7887	a-e	12.4	abcd
21. Mustang 1.5 EW	4.3 fl. oz	PF	19.5	abcd	6912	bcde	11.2	bcde
22. Dermacor X-100 5FS	2.50 oz/100 lbs	Seed – UCD, no Clorox	19.2	abcd	8238	abcd	12.2	abcd
23. Dermacor X-100 5FS	2.50 oz/100 lbs	Seed –UCD, with Clorox	18.0	cde	7860	a-e	10.8	bcde
24. DPX-HGW86 - 600 FS	0.025 MAT	Seed – UCD, with Clorox	17.3	e	8212	abcd	11.4	bcde

* Clorox seed soak used except where indicated

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

Table 5. Results from large plot comparison of experimental products for rice water weevil control, 2009.

Product	Rate	% Scarred Plants	RWW - Sample Date 1	RWW - Sample Date 2	Avg.
Dermacor X-100 5FS	2.5 oz./100 lbs. seed	41	1.05	1.25	1.15
V10170 2.13	12 fl. oz./A - preflood	22	0.5	0.7	0.6
Trebon 3G	6 lbs./A – 3-leaf	30	0.25	0.15	0.2
Untreated*	---	37	1.2	0.5	0.75

* Data for untreated taken from another study conducted in the next two basins to the south and may therefore not be precisely applicable.

Table 6. Treatments evaluated in non-target study, 2007-09.

Product	Rate (lbs. AI/A)	Timing	2007	2008	2009
1. Untreated	---	---	X	X	X
2. Warrior	0.03	3-leaf	X	X	X
3. Warrior	0.03	preflood	X	X	X
4. Warrior	0.03	July armyworm timing	X	X	X
5. Mustang Max	0.025	3-leaf	X	X	
6. Dimilin 2L	0.125	3-leaf	X	X	X
7. V10170 50WD	0.19	preflood and 3-leaf	X		
8. V10170	0.19	preflood		X	X
9. V10170	0.19	3-leaf		X	X
10. V10170	0.1 per 100 lbs. seed	seed treatment	X		X
11. Trebon 3G	0.18	3-leaf	X	X	X
12. Steward EC	0.11	3-leaf	X		
13. DPX-NGW86	0.1 per 100 lbs. seed	seed treatment		X	X

Table 7. Rice Water Weevil population in non-target study, 2009.

Product	Formulation per A	Timing	RWW - Sample Date 1	RWW - Sample Date 2	Avg.
1.V10170 2.13 SC	12 fl. oz.	PF	0	0.4	0.2
2. Warrior	3.84 fl. oz.	3-leaf	0.1	1.3	0.7
3. Warrior	3.84 fl. oz.	PF	0	0.1	0.05
4. Warrior	3.84 fl. oz.	July armyworm timing	0.3	0.7	0.5
5. DPX-HGW86 - 600 FS	2.50 oz/100 lbs (0.025 MAT)	seed treatment	0.4	0.9	0.7
6. Dimilin 2L	8 fl. oz.	3-leaf	0.3	0.8	0.55
7. Untreated	---	---	0.5	0.3	0.4
8. V10170 2.13 SC	12 fl. oz.	3-leaf	0.5	0.8	0.65
9. Trebon 3G	6 lbs.	3-leaf	0.1	1.0	0.55
10. Dermacor X-100 5FS	2.50 oz/100 lbs (0.025 MAT)	seed treatment	0	0.8	0.4

Table 8. Treatments evaluated for tadpole shrimp control studies, 2009.

			Dislodged Seedlings					
Product	**Form. per A**	**Timing**	**8 June**		**11 June**		**Seedlings – 8 June**	
1. Untreated*	---	---	0.5	ab	0	b	72.0	ab
2. V10170 2.13 SC	12 fl. oz.	post-flood	0.25	b	0.5	ab	75.5	a
3. Pyganic 5EC	18 fl. oz.	post-flood	0.75	ab	0.75	ab	57.75	b
4. Trebon 3G	6 lbs.	post-flood	0.75	ab	1.25	ab	82.25	a
5. Copper sulfate	10 lbs.	post-flood	0.25	b	1.25	ab	83.0	a
6. Dermacor X-100 5FS	2.50 oz/100 lbs	seed trtment.	0.75	ab	1.25	ab	75.0	a
7. Untreated	---	---	1.5	a	1.5	a	72.5	ab
8. Warrior	3.84 fl. oz.	preflood	0	b	0	b	66.75	ab
9. Warrior	3.84 fl. oz.	post-flood	0.75	ab	1.0	ab	79.75	a

* no tadpole shrimp introduced

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

Table 9. Rice water weevil populations in study targeted for tadpole shrimp control, 2009.

Product	**Formulation per A**	**Timing**	**RWW Sample Date 1**		**RWW Sample Date 2**		**Avg.**
1. Untreated*	---	---	1.1	a	0.5	bc	0.8
2. V 10170 2.13 SC	12 fl. oz.	early post-flood	0.15	b	0.1	c	0.13
3. Pyganic 5EC	18 fl. oz.	early post-flood	0.45	b	0.3	c	0.38
4. Trebon 3G	6 lbs.	early post-flood	0.1	b	0.65	bc	0.38
5. Copper sulfate	10 lbs.	early post-flood	0.3	b	1.4	a	0.85
6. Dermacor X-100 5FS	2.50 oz/100 lbs -- 0.025 MAT	seed treatment	0.5	b	1.05	ab	0.78
7. Untreated	---	---	0.35	b	0.55	bc	0.4
8. Warrior	3.84 fl. oz.	preflood	0.05	b	0.05	c	0.05
9. Warrior	3.84 fl. oz.	early post-flood	0.25	b	0.5	bc	0.38

* no tadpole shrimp introduced Means within columns followed by same letter are not significantly different; least significant differences test (• <0.05).

Table 10. Rice yield in tadpole shrimp study, 2009.

Product	Formulation per A	Timing	% Grain Moisture		Grain Yield (lbs./A)		Biomass (Straw+ Grain [t/A])	
1. Untreated*	---	---	22.4	a	6239.7	bc	10.5	b
2. V 10170 2.13 SC	12 fl. oz.	early post-flood	21.2	ab	9493.7	a	14.6	a
3. Pyganic 5EC	18 fl. oz.	early post-flood	21.4	ab	5817.0	c	10.2	b
4. Trebon 3G	6 lbs.	early post-flood	20.5	ab	7505.6	abc	12.3	ab
5. Copper sulfate	10 lbs.	early post-flood	20.9	ab	6919.0	bc	11.7	ab
6. Dermacor X-100 5FS	2.50 oz/100 lbs -- 0.025 MAT	seed treatment	20.1	b	7250.9	abc	11.4	ab
7. Untreated	---	---	20.7	ab	7861.3	abc	12.7	ab
8. Warrior	3.84 fl. oz.	preflood	21.6	ab	8569.0	ab	13.0	ab
9. Warrior	3.84 fl. oz.	early post-flood	20.7	ab	8146.9	abc	13.5	ab

* no tadpole shrimp introduced

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

Table 11. RWW adult feeding damage in variety susceptibility comparison to RWW study, 2009.

Variety	RWW Infestation	% Scarred Plants		RWW Immatures 9 July		RWW Immatures 24 July		RWW Immatures Average	
M-202	None	6.75	c	0.1	c	0.1	b	0.1	c
S-102	None	3.0	c	0	c	0.05	b	0.03	c
L-206	None	1.0	c	0.05	c	0	b	0.03	c
Calmati-202	None	5.5	c	0.05	c	0.1	b	0.08	c
M-202	Introduced	45.5	a	3.4	a	1.6	a	2.5	a
S-102	Introduced	42.5	ab	2.85	ab	1.15	a	2	ab
L-206	Introduced	33.25	b	1.45	bc	1.3	a	1.38	bc
Calmati-202	Introduced	41.0	ab	3.05	ab	0.65	ab	1.85	ab

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

Table 12. Effect of RWW populations on rice biomass and grain yields in variety comparison to RWW – ring study, 2009.

Variety	RWW Infestation	% Moisture		Grain Yield (lbs./A)		Biomass - Straw + Grain (t/A)	
M-202	None	20.8	a	8481.2	a	13.03	a
S-102	None	16.6	de	8151.6	a	11.68	ab
L-206	None	18.5	bc	7353.3	ab	10.25	bcd
Calmati-202	None	17.8	cde	3227.0	d	8.65	d
M-202	Introduced	19.7	ab	7513.5	ab	11.58	abc
S-102	Introduced	16.4	e	6387.1	bc	9.24	cd
L-206	Introduced	18.1	cd	7425.0	ab	10.10	cd
Calmati-202	Introduced	19.1	bc	4996.2	c	10.71	bcd

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

Table 13. Rice water weevil populations in water depth study, 2009.

Water Depth	% Scarred Plants – 22 June	% Scarred Plants – 29 June	Water Depth (in.) – 29 June	RWW - Sample Date 1	RWW - Sample Date 2	Avg.
1. 3 inches	30.2	28.2	4.1	2.5	2.2	2.25
2. 6 inches	22.4	18.9	6.3	0.7	0.4	0.55
3. 9 inches	22.2	16.2	10.1	0.2	0.6	0.4

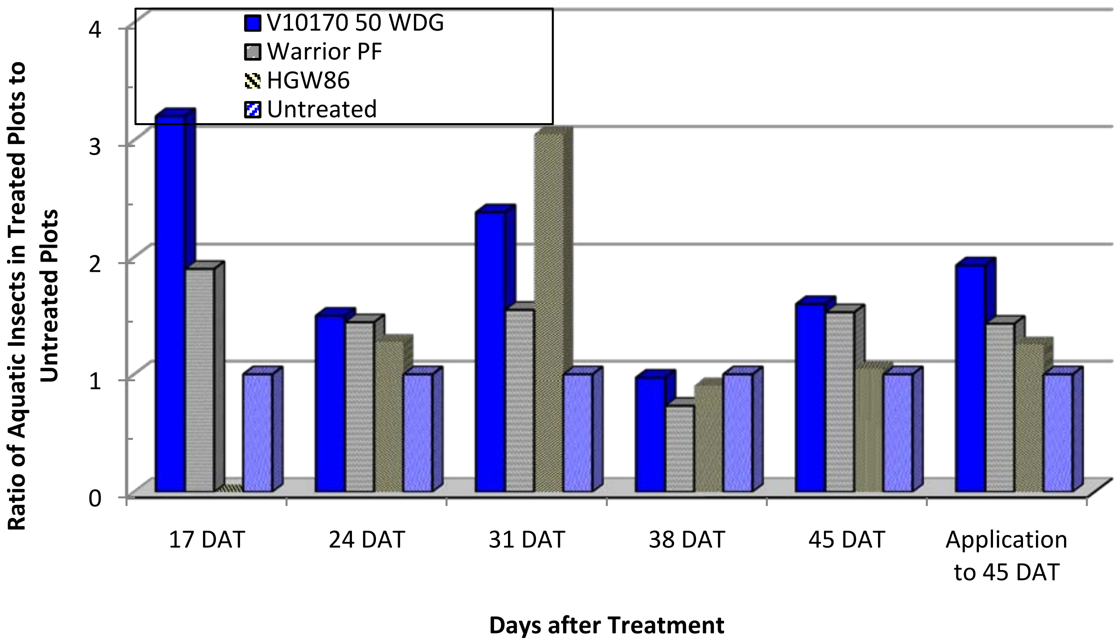

Figure 1. Influence of preflood insecticide applications on populations of aquatic insects from floating barrier trap samples in rice, 2008.

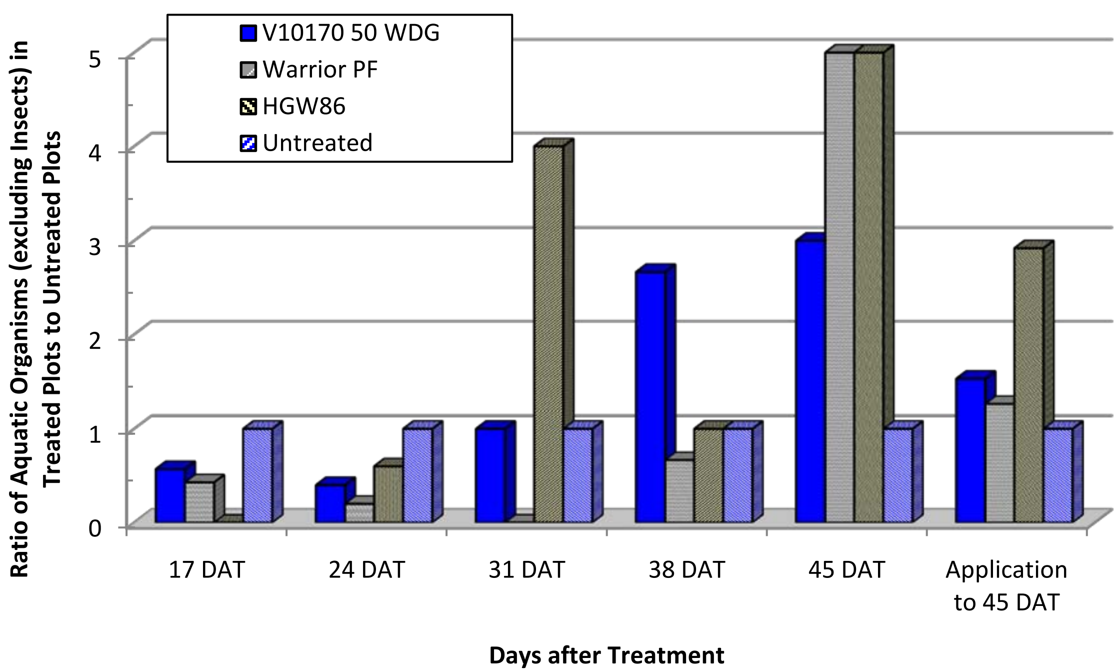

Figure 2. Influence of preflood insecticide applications on populations of aquatic invertebrates from floating barrier trap samples in rice, 2008.

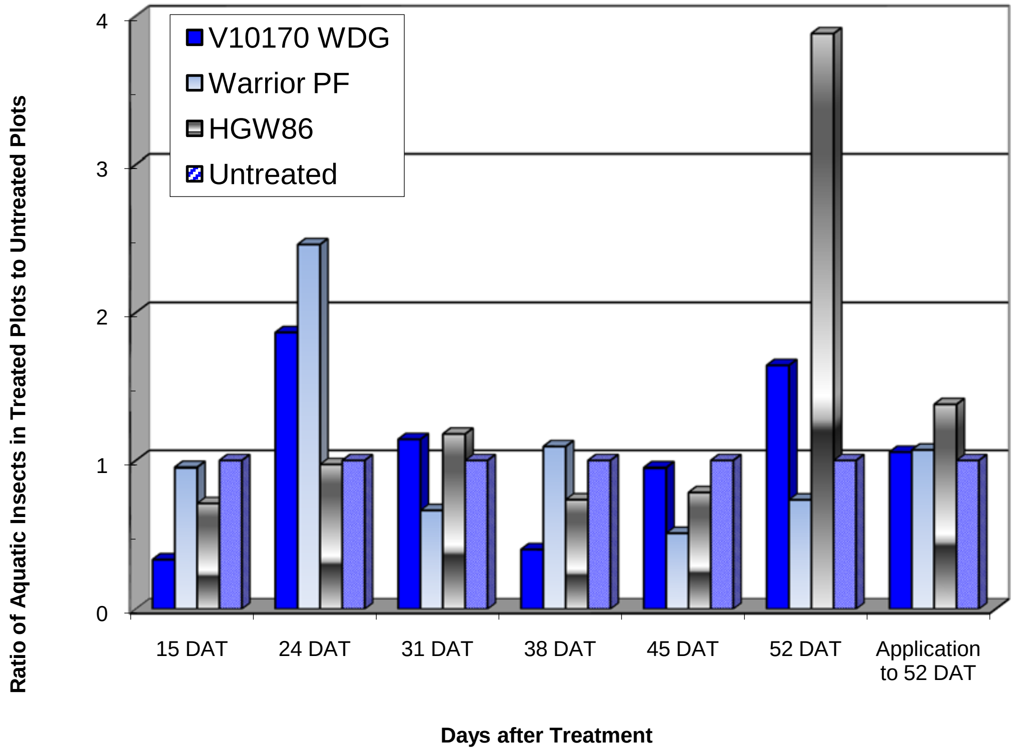

Figure 3. Influence of preflood insecticide applications on populations of aquatic insects from quadrant samples in rice, 2008.

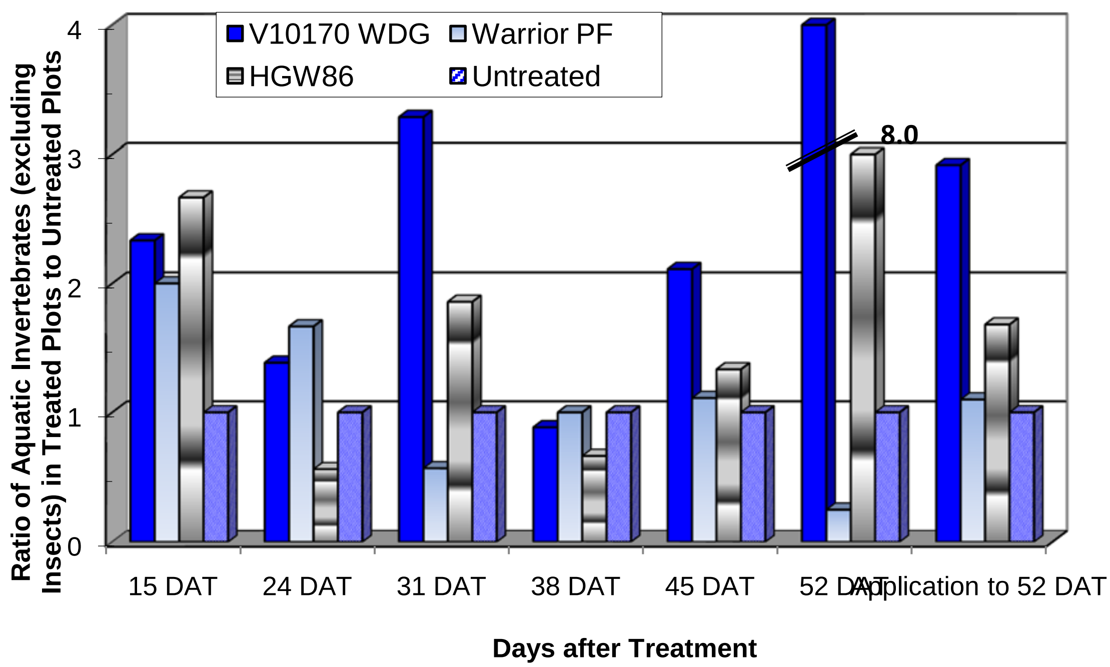

Figure 4. Influence of preflood insecticide applications on populations of aquatic invertebrates from quadrant samples in rice, 2008.

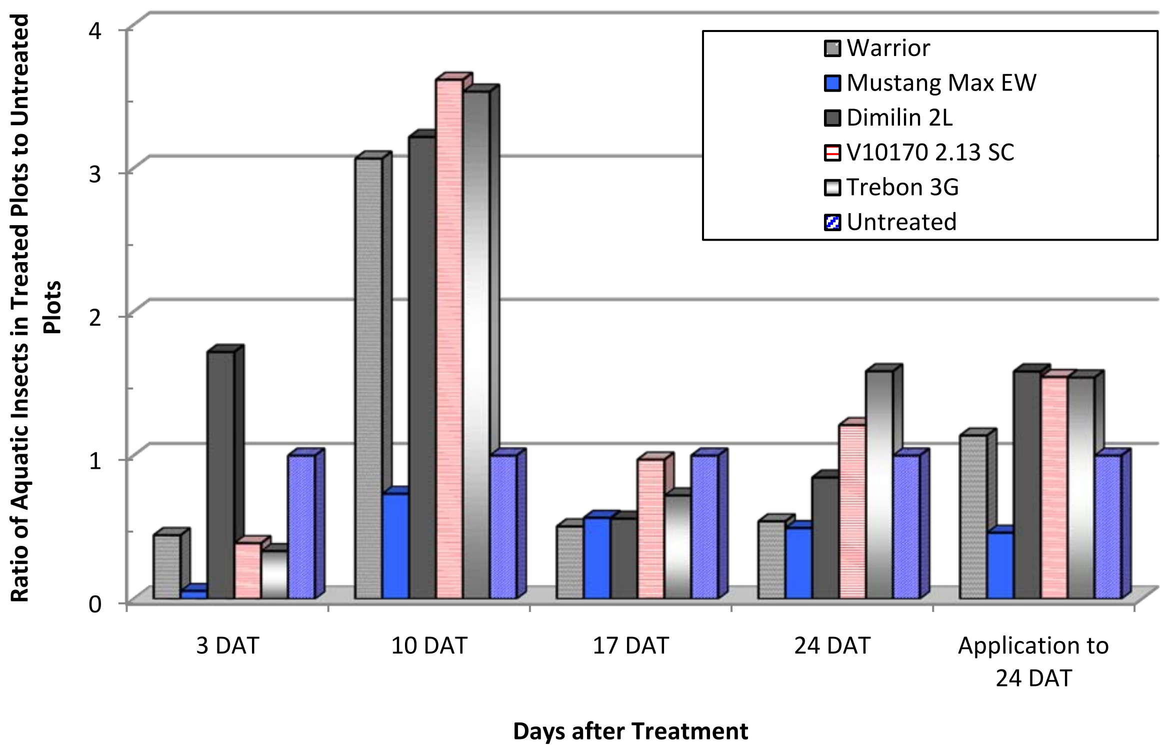

Figure 5. Influence of post-flood (3-leaf) insecticide applications on populations of aquatic insects from floating barrier trap samples in rice, 2008.

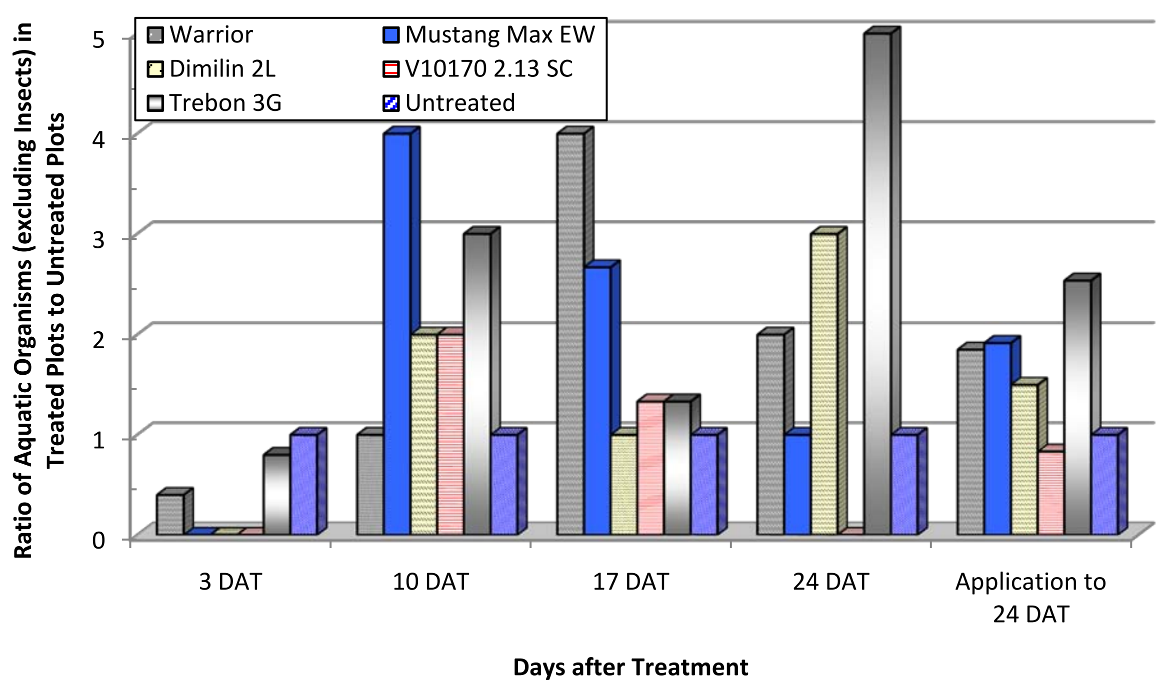

Figure 6. Influence of post-flood (3-leaf) insecticide applications on populations of aquatic organisms from floating barrier trap samples in rice, 2008.

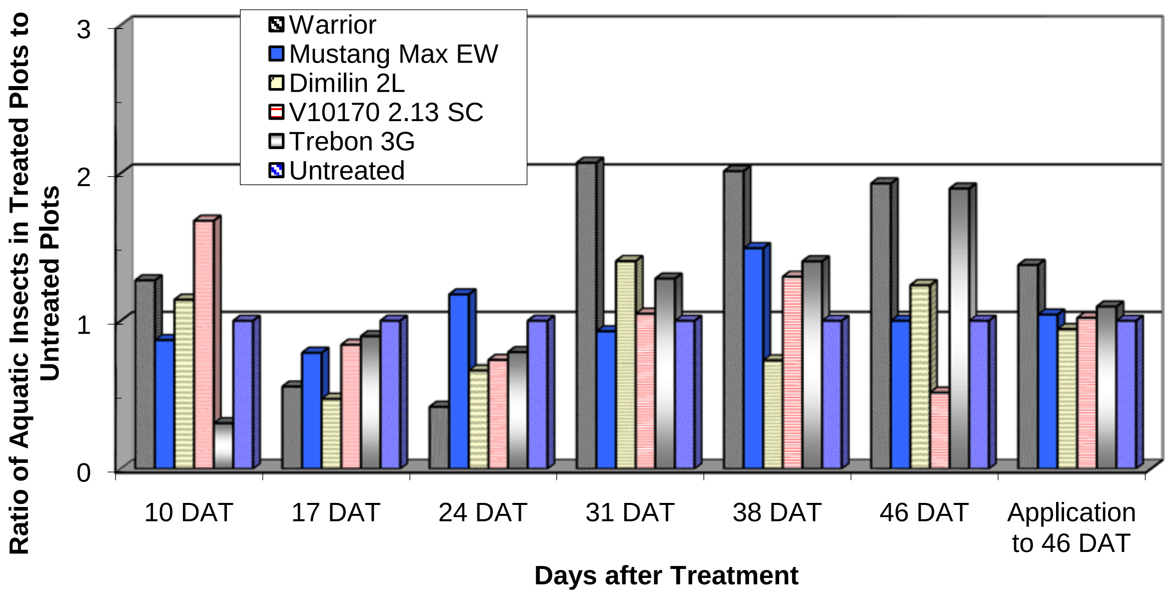

Figure 7. Influence of post-flood (3-leaf) insecticide applications on populations of aquatic insects from quadrant trap samples in rice, 2008.

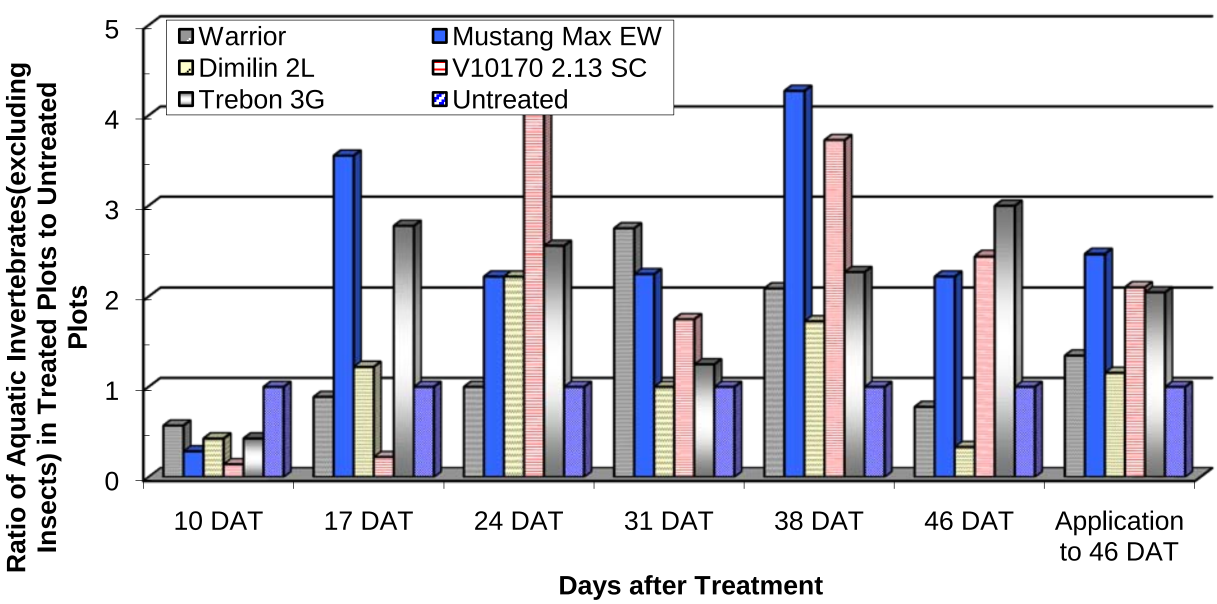

Figure 8. Influence of post-flood (3-leaf) insecticide applications on populations of aquatic invertebrates, excluding insects, from quadrant trap samples in rice, 2008.

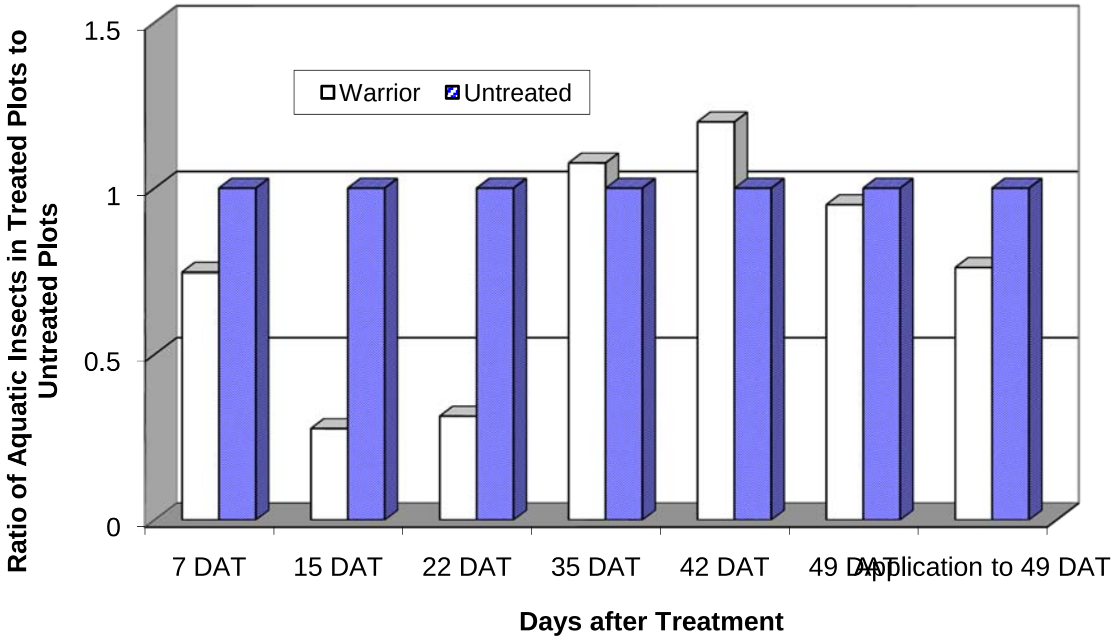

Figure 9. Influence of insecticide applications (armyworm timing) on populations of aquatic insects from quadrant trap samples in rice, 2008.

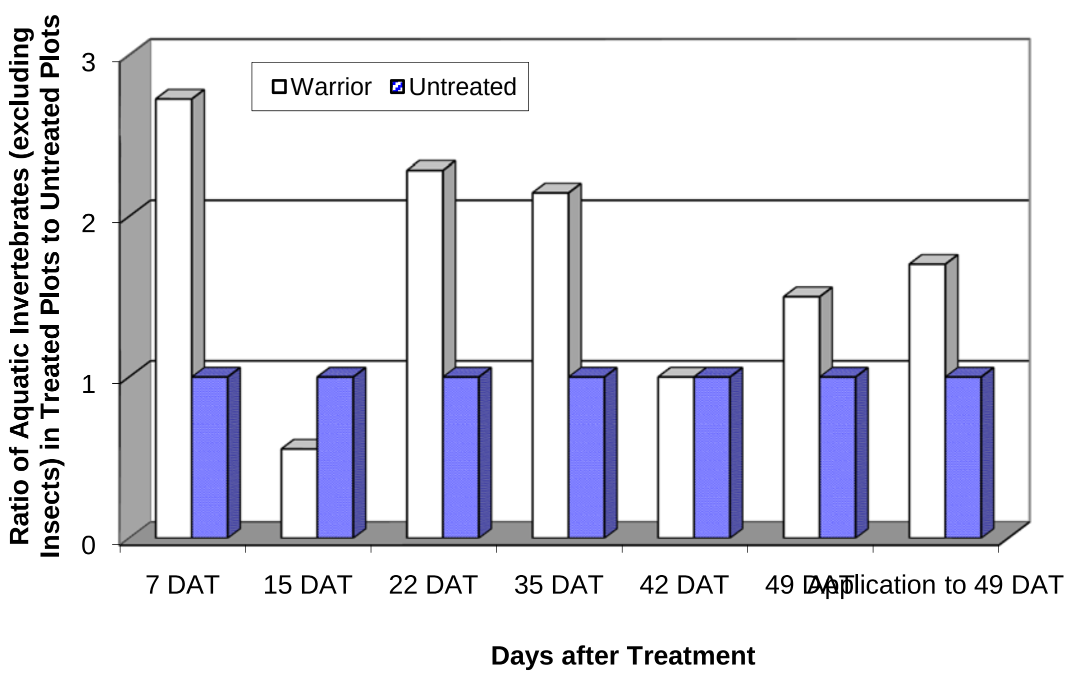

Figure 10. Influence of insecticide applications (armyworm timing) on populations of aquatic invertebrates, excluding insects from quadrant trap samples in rice, 2008.

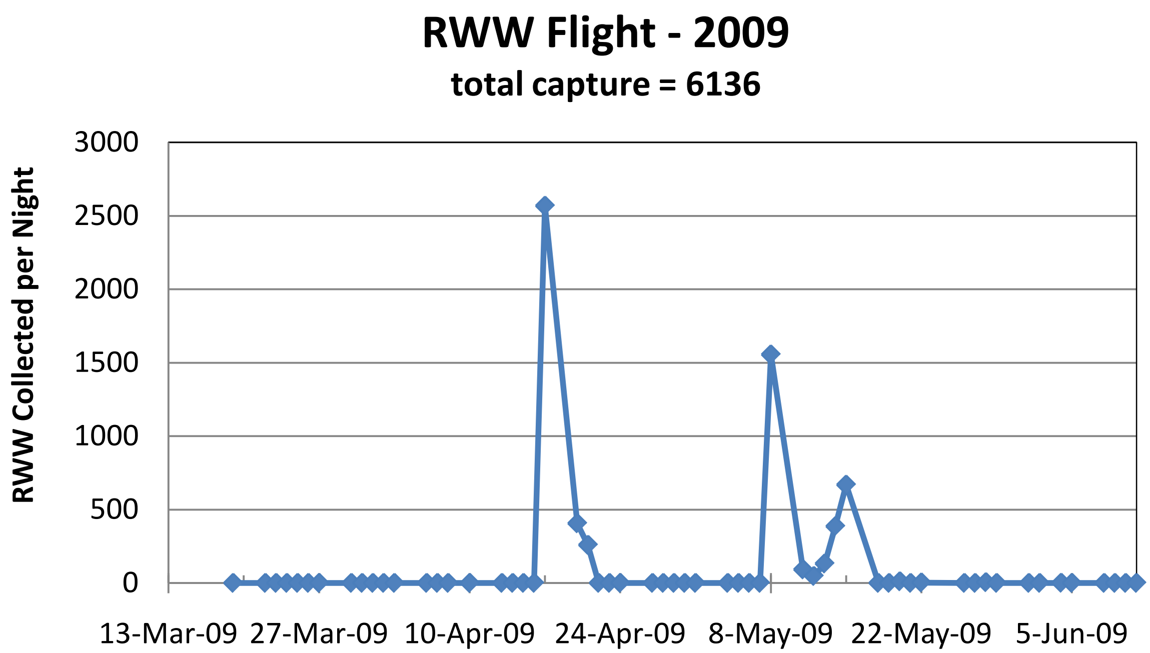

Figure 11. Rice Water Weevil adult flight in 2009.

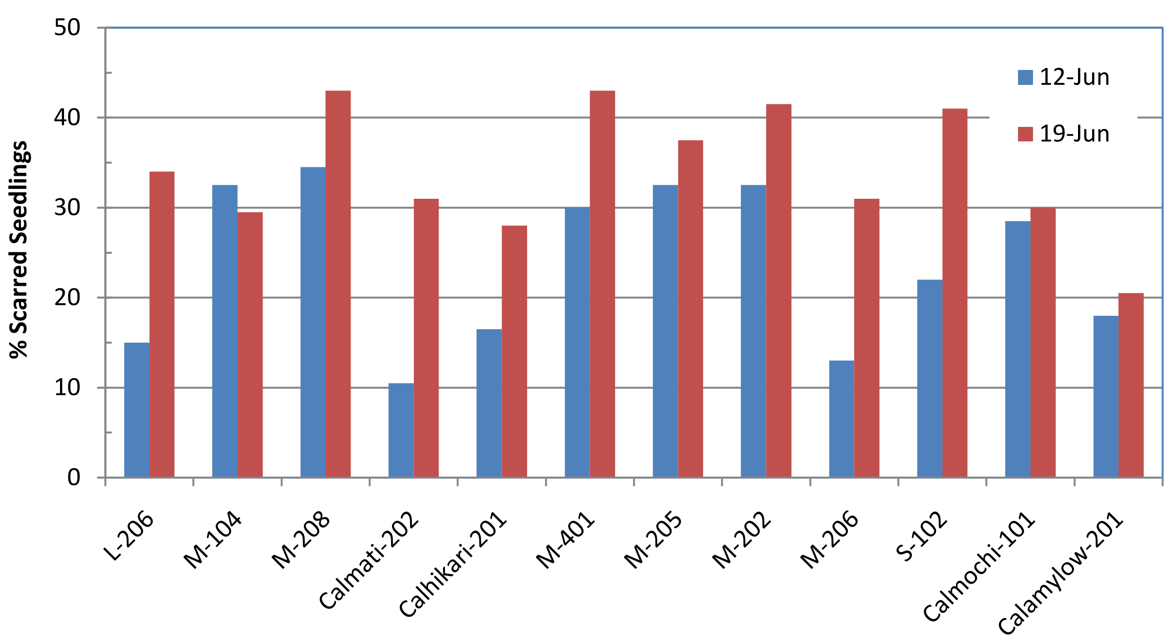

Figure 12. Percentage scarred seedlings (untreated plots) by RWW on two sample dates in variety susceptibility study, 2009.

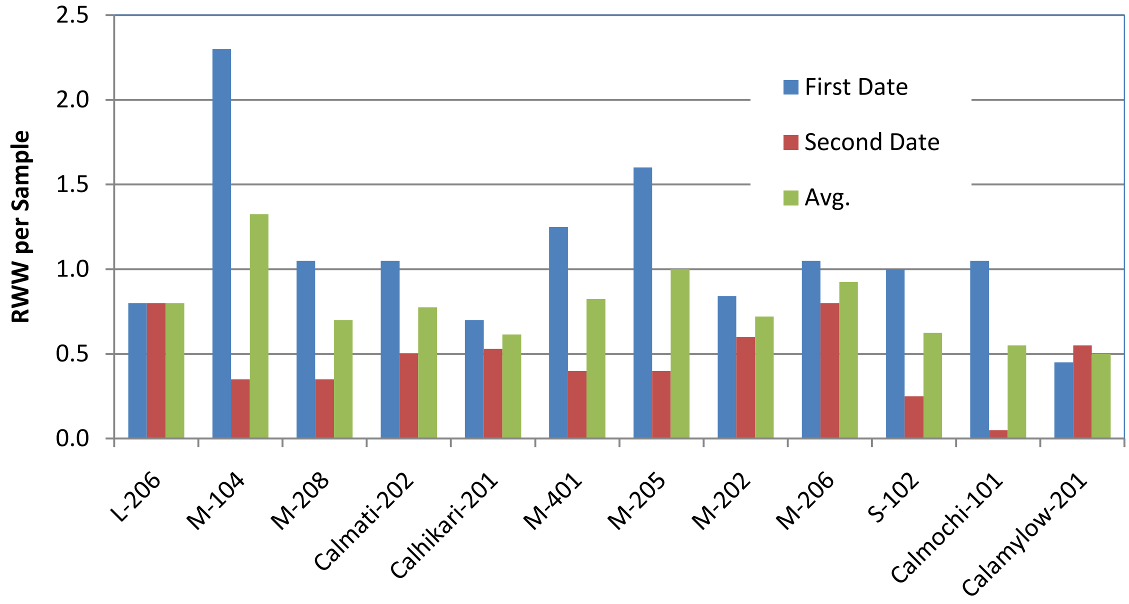

Figure 13. RWW populations (untreated plots) on two sample dates in variety susceptibility study, 2009.

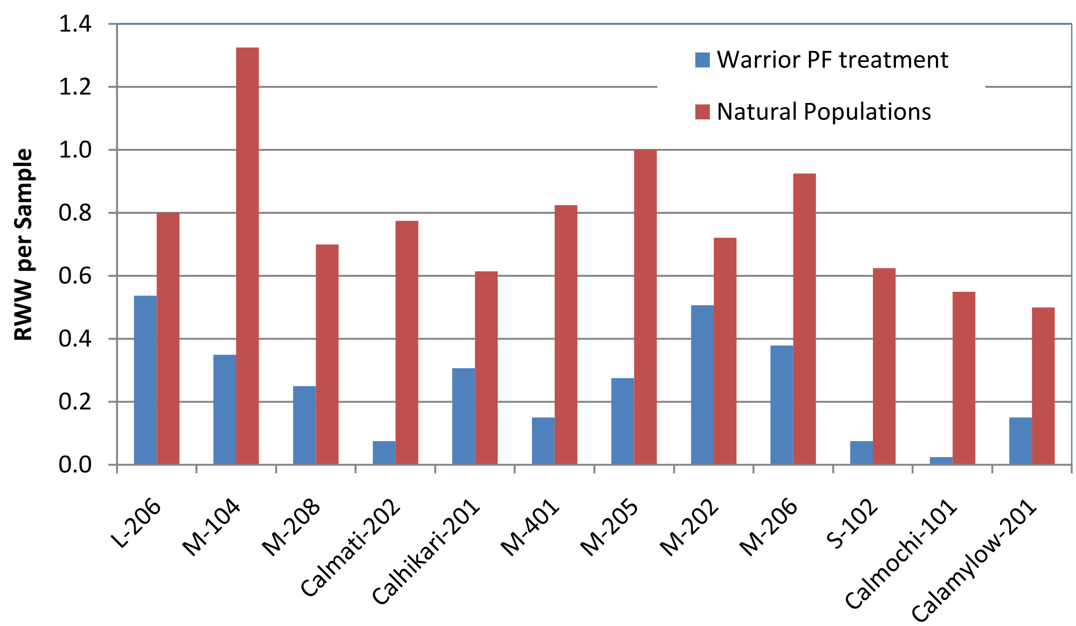

Figure 14. RWW populations, averaging both sample dates, in variety susceptibility study, 2009.

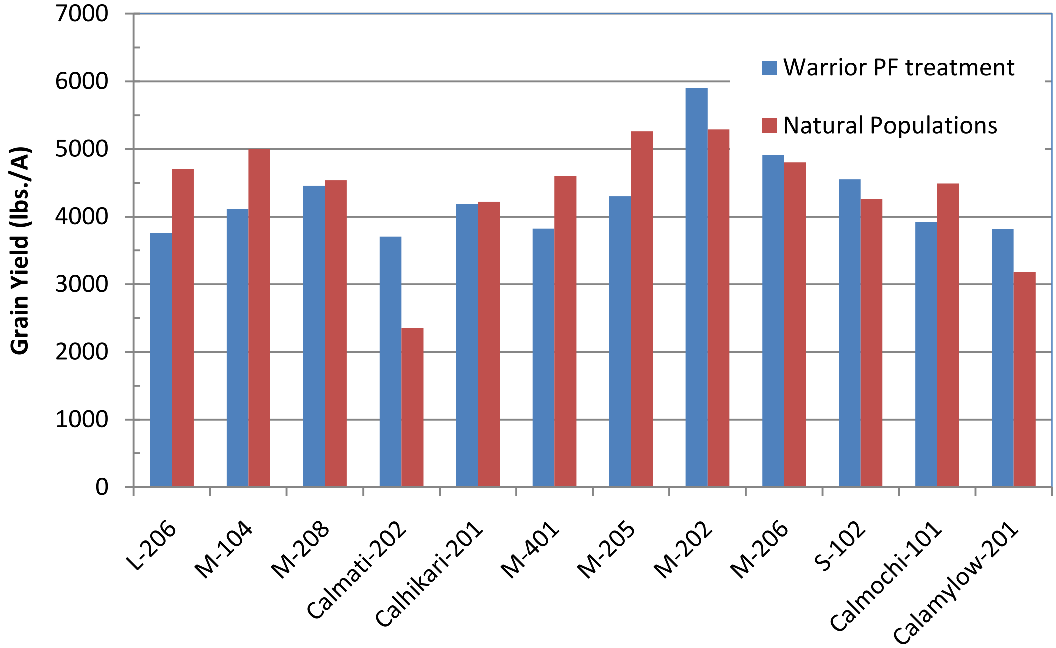

Figure 15. Grain yield separated by RWW treatment in variety susceptibility study, 2009.