PROJECT NO. RP-3

ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE

January 1, 2010 - December 31, 2010

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.
1.2.c) evaluation of an experimental insecticide as a rescue treatment in rice for rice water weevil control

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

1.4) Evaluation of the influence of applications of registered and experimental insecticides on populations of non-target invertebrates in rice.

1.5) 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.a) Studies with controlled populations of Rice Water Weevil

2.2.b) Studies with naturally-occurring populations of Rice Water Weevil

2.3) Rice water weevil impact of rice plant growth/development and grain set.

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

<u>SUMMARY OF 2010 RESEARCH BY OBJECTIVE:</u>

Objective 1:

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

1.1, 1.2) Research for subobjectives 1.1 and 1.2 was conducted within one plot area and the results and discussion for this study will be considered together. The data will be reported in its entirety for ease of comparison across treatments and the conclusion from each sub-objective will be reported. Each treatment was replicated four times. Twenty-four treatments (a total of six 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 10.7 sq. ft aluminum rings. The plots were flooded on 28 May and seeded on 29 May. A seeding rate of 100 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:

26 May, early pre-flood treatments
28 May, pre-flood (PF) applications
29 May, seed treatments
18 June, 3-leaf stage treatments
1 July, rescue (5-6 leaf stage) application

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 15 June and 6 adults into each ring on 22 June. The standard production practices were used. Copper sulfate was applied in mid June for algal management, herbicides on 14 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: 18 June
Adult Leaf Scar Counts: 24 June and 1 July
Larval Counts: 20 July and 4 August
Rice Yield: 13,14 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› • • • •••••• • • • • • • • ••• ••• •••••••• • • • • • • < 0.05). Raw data reported herein.

Plot Design:

Randomized Complete Block

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 averaged 3.1 (range of 2.6 to 3.5), which was slightly better than the ratings in previous years. 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, both, 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. In 2010, there was a moderate level natural infestation; the unfavorable spring weather delayed the RWW spring flight as well as delaying rice seeding.

The amount of feeding varies yearly (even though the methods used are identical every year) because of differing conditions during this “feeding period”. Feeding scars were sampled on 24 June which was 2 days after all the RWW adults had been placed into each ring; although the insecticide may have controlled the RWW adults, the damage would still have been counted since the damage on the two newest leaves is scored. A second evaluation was done on 1 July which should show the full effect of the treatment. On the first date, feeding scar incidence was high ranging from 24 to 79% (Table 2). A damaging level of RWW larvae is associated with feeding scar incidence of 20 to 25%. Counts declined for the second evaluation ranging from 58.5% to a low of 1%. Counts were high in the untreated plots averaging ~55% (there were two treatments that received no insecticides differing in fungicides applied as a seed treatment). Summarizing the effects of the treatments:

1.) Dimilin had no effect on adult feeding which is expected since it sterilizes the females and prevents viable eggs

2.) Warrior II applied preflood (either immediately before or several days before flooding) reduced adult feeding by about 50%, Warrior applied at the 3-leaf stage nearly eliminated adult feeding especially in the second evaluation when the full effects were seen

3.) Mustang Max applied at the 3-leaf stage effectively reduced adult feeding; however, this material applied preflood (either immediately before flooding or at the early preflood timing) was not effective

4.) Trebon applied at the 3-leaf stage was effective at reducing RWW adult feeding

5.) Belay applied preflood was marginally effective at reducing adult feeding, the effect was very weak at the first sampling date but there was about a 40% reduction in damage in the 1 July evaluation. Belay applied at the 3-leaf stage was very effective (equal to Warrior) at reducing leaf scarring by the RWW adults and as with Warrior the effect was stronger in the second evaluation than the mid-June rating

6.) Dermacor was studied using three application methods and the results differed among all three. Dermacor, applied as a seed treatment, resulted in no reduction in leaf scarring. The active ingredient is supposed to be systemic so it is interesting that there was no effect on adult leaf feeding. Dermacor applied preflood had a slight effect on adult feeding whereas Dermacor applied at the 3-leaf stage showed good effects on adult feeding. The reduction was not as significant as Warrior or Belay but was in the 75% range and equal to that seen with Trebon.

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 – in the second sampling sometimes a product initially reduces the larval population but does not provide residual control. In 2010, populations were reasonably high and overall higher in the first sampling than the second. RWW levels in the untreated plots averaged 1.7 and 1.1 per core sample in the first and second sample dates, respectively (Table 3). The two different treatments without insecticides had equal RWW populations (these differed in that one of the “untreated” had fungicides and the other one was totally untreated). We generally use 1.0 RWW per core sample as the threshold for yield losses so these plots had an “economic infestation”.

The overall dataset for RWW larval populations is shown in Table 3. Results from each product/application method will be summarized below.

1.) Larval control with Dimilin was very good as a ~75% reduction in larval populations occurred. Control was similar in both sample dates so the product had good residual.
2.) Warrior II provided very good RWW control with the 3-leaf stage application. Overall the larval reduction was similar to that seen with Dimilin but the efficacy fell-off slightly in the second sampling compared with the first evaluation. This may suggest that the persistence/residual of this treatment is limiting. Warrior applied preflood was extremely effective and the preflood application made ~1 week before flooding was among the most effective treatments in the study.
3.) Mustang Max evaluated using the same methods as Warrior was clearly less effective. In addition, Mustang Max had the gratest efficacy with the 3-leaf stage application, intermediate with the preflood (right before flooding) application, and lowest with the preflood (~1 week before flooding) application. Although Warrior and Mustang are both pyrethroid insecticides and should perform similarly, it appears that Warrior was more active in 2010.
4.) Belay was initially evaluated as a seed treatment and the activity against RWW of this application method was moderate at best. The next thrust of the research was evaluating Belay using preflood and 3-leaf stage applications at initially high rates – up to 12 oz./A. These treatments were universally very effective. In 2010, preflood and 3-leaf stage timings were evaluated both at 3.5, 4.5, and 5.5 oz./A rates. The preflood applications (all rates) were moderately effective – 40 to 60% control. The 5.5 oz. rate was somewhat more effective than the 3.5 oz. rate but the differences were not striking. Belay applied at the 3-leaf stage was very effective (up to 90-95% control). Again there was not a definite rate response – all the rates were effective. These results differ somewhat from previous years in that the preflood application was less efficacious than seen in 2008-09, albeit with higher rates but the trend was present for a high level of activity. In 2010, Belay was also researched as a rescue treatment. Presently, if the 3-leaf stage application timing is missed and it is discovered that RWW are present at damaging levels, no treatment options are available. The rescue treatment of Belay was effective.
5.) Dermacor evaluations have concentrated on seed treatments in previous years. The efficacy has been moderate to poor. In 2008-09, a couple of treatments were evaluated using this active ingredient applied at either the preflood or 3-leaf stage. In 2010, the Dermacor seed treatment showed moderate effectiveness (65-70% control) at the highest rate of 2.5 oz. per 100 lbs. seed and slight efficacy (20%) at the lower rates. With a preflood or 3-leaf stage application, Dermacor was very effective (90 to 95% control) at the 0.10 lbs. AI/A rate and moderately effective (60 to 70%) at the 0.08 lbs. AI/A rate. It is clear that the insecticide can effectively control RWW larvae but the application method (specifically the seed treatment method) inhibits the activity of the active ingredient especially in the water-seeded rice production system.

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 17.4 to 20.8% (Table 4). Grain moisture in the untreated plots was ~18.8%, approximately mid-point among the 24 treatments. This indicates that plant maturity/development was not impacted by the RWW damage. Rice grain yields ranged from ~4280 to 7200 lbs./A. Overall these yield values were about 1000-1500 lbs./A lower than in past years likely due to the late planting date and unfavorable growing season. The yield in the untreated plots averaged about 5250 lbs./A which was in the bottom 40% among the 24 treatments. Several treatments elevated grain yields by at least 1000 lbs./A including Warrior (3-leaf stage), Belay preflood (5.5 oz./A), and Belay 3-leaf stage (3.5 and 4.5 oz./A). Rice biomass at harvest ranged from 6.3 to 11.4 t/A.

In summary, Dimilin®, Warrior® II, and Mustang® Max are all still viable products for RWW control. Of these three products, Mustang Max was the least effective in 2010 but still provided effective control. Application of Warrior preflood was a very effective treatment for RWW; using this product immediately before flooding or even a few days before flooding (a more realistic scenario for growers given the length of time needed to flood fields) produced results equal to or perhaps even better than the standard 3-leaf application. Mustang Max did not show equivalent efficacy with the preflood application and does not appear to fit this type of application. Trebon® (etophenprox) applied at the 3-leaf stage was effective for RWW larval control. The control appears to arise from a high amount of control of adults supplemented by additional control of larvae. At this time, registration/marketing of this product for the California rice market appears to be "on-hold". Belay® (clothianidan) appears to have significant potential for RWW management. I have previously shown it is active applied preflood as well as 3-leaf stage application. In 2010, using lower rates of clothianidin, the preflood timing showed considerable weakness. This was partially due to the lower use rates but also other unknown reasons, i.e., weather, etc., inhibited the activity. The 3-leaf stage method with clothianidin was very effect in 2010 and as efficacious as any of the registered insecticides for RWW control. The reduction in larval numbers resulted from adult mortality and also direct control of larvae. The preflood method warrants additional research efforts. A "rescue" treatment, i.e., applied at about the 5-leaf stage when the larval infestation has already began, of clothianidin, was also shown to be effective. The control provided was in the 70% range but this is admirable given the demands placed on a product for this use. Dermacor® (rynaxypyr) efficacy as a seed treatment in water-seeded rice is moderate, at best. This result was seen in 2010 to reinforce results from previous years. However, rynaxypyr applied preflood or at the 3-leaf stage showed promise. In both cases the higher rate of the two rates tested was as effective as the best-performing treatments and the lower rate showed moderate activity. 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.

1.3) 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 2010, 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 treatment– 1 June
Belay 2.13 SC	4.5 fl. oz./A	Preflood – 28 May
Belay 2.13 SC	4.5 fl. oz./A	3-leaf – 18 June

Methods:

Leaf scarring, RWW population levels, and grain yields were evaluated as follows on 24 June and 1 July, 22 July and 5 Aug., and 27 Oct., respectively.

Adult Leaf Scar Counts: percentage of plants with adult feeding scars on either of the two newest leaves (50 plants per plot)
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: yields were collected with the small plot harvester using four samples each 7.25 x 30 ft. long and yields were corrected to 14% moisture.

Results:

Stand establishment was good in this study and a fairly high RWW infestation was present in this area. 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 (adult feeding scars and larval data) are shown in Table 5. In summary, Dermacor seed treatment and Belay preflood treatment were ineffective; Belay applied at the 3-leaf stage was effective. This latter treatment provided about 50% control which was less than that seen in the ring studies. Additional studies are needed so as to investigate this area in more detail. A higher rate would have perhaps allowed for improved control. Grain yield in the Dermacor treatment was similar (slightly lower) than in the untreated (Table 6). Belay applied at the 3-leaf stage improved yield by about 390 lbs./A. Unexplainably, the Belay preflood treatment resulted in a large increase in yield (~1700 lbs./A) compared with untreated plots.

1.4) Evaluation of the influence of applications 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 migratory waterfowl 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 http://www.calrice.org/Environment/Sustainability.htm). 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 2010, about 10% of the national human cases of West Nile Virus were confirmed from California (exceeded only by Arizona and New York). *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 7. 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 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 2009 will be discussed as the 2010 data are still being collected from preserved samples and summarized. The procedures followed are similar for each year and the exact procedures and dates used in 2010 will be given herein.

Each plot was ~0.04 A and each treatment was replicated three times. In 2010, preflood treatments were applied on 7 June and the plots were water-seeded on 8 June immediately after the flooding. Cerano 5 MEG was applied at 12 lbs. per acre following seeding. The 3-leaf stage treatments were applied on 25 June and the armyworm application timing was 28 July. Populations of non-target organisms were evaluated weekly from mid-June to late September. Floating barrier traps were used to collect swimming organisms for the first 6 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 2009 results are summarized and will be reported herein. Data were divided into aquatic insects and other aquatic animals (mostly non-insect invertebrates with an occasional tadpole or frog). 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:

Four preflood applications were evaluated in 2009 – Warrior and Belay as preflood broadcast applications, and DPX-HGW86 and Dermacor as seed treatments.

Floating Barrier Traps: Floating barrier traps primarily capture actively swimming organisms such as beetles. At 22 DAT (the day the organisms were collected from the traps; the traps were placed in the field at 15 DAT), there were no significant effects of the insecticides on levels of aquatic insects (Fig. 1) or on other aquatic animals (Fig. 2). Levels in most cases were higher in the treated plots than in the untreated plots (in fact 27 times higher for Dermacor). At 30 DAT, the population of aquatic animals (excluding insects) was greatly reduced in the Dermacor treatment compared with the untreated. At this time of the season, when the system is still "unstable" and the organisms are becoming established, there can be some wide swings in levels within a short period. Often times, one plot of the three for a treatment will have very high levels of a given organism. Numbers of aquatic insects at 30 DAT were also reduced by ~50% for the two seed treatments. There were no trends in the later samples.

Quadrant samples: With the quadrant sampling method, Belay preflood appeared to have the greatest reduction in populations of aquatic insect (Fig. 3) and other aquatic animals (Fig. 4). For instance, at 13, 29 and 36 DAT Belay reduced insect levels by an average of ~50% and there were also reductions later in the season, e.g., at 78, 85 and 114 DAT. The season average, however, showed no effects of this treatment. The two seed treatments, DPX-HGW86 and Dermacor, also showed some short-term reductions in insect numbers at 13 and 29 DAT. Results were similar for preflood treatments on populations of other animals except the effects of Warrior were more noticeable.

Mosquito Dip Samples: Mosquito populations were fairly high in 2009 and data were collected weekly for 9 weeks. Fig. 5 shows the ratio of mosquito numbers in treated vs. untreated plots. Unfortunately, mosquito populations are notoriously "clumped" and on some sample dates, no larvae were collected in samples from untreated plots (and they were collected in samples from treated plots) thus it was impossible to calculate a ratio. Therefore, the actual numbers of mosquito larvae per treatment are shown in Fig. 6. Mosquito populations always develop throughout the season and peak in the later sample dates. There was some indication that all the preflood treatments increased numbers of mosquitoes, but there were no definite (consistent) trends.

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. Data from floating barrier traps were collected for one period following the application of the 3-leaf stage treatments (10 days after treatment). There were no effects of the treatments on aquatic insects, but levels of other aquatic invertebrates were greatly reduced by Warrior. Levels of aquatic insects were higher in the Trebon and Belay treatments than in the untreated plots (Fig. 7).

Quadrant Samples: For the quadrant samples, the effects of the 3-leaf stage applications were greater with other aquatic animals than with the aquatic insects (Fig. 8 for aquatic insects & Fig. 9 for other aquatic animals). At 10 DAT, all four products significantly reduced aquatic insect levels and three of the four affected other aquatic animal levels. At 16 and 23 DAT, these reductions generally persisted. For both groups of organisms, there was a “bounce-back effect” at 30 and 37 DAT (more organisms in the treated than untreated plots) but this was followed by reductions again at 44, 51, and 59 DAT (more significant for the other aquatic animals than for the aquatic insects).

Mosquito Dip Samples: Mosquito populations in untreated plots were first sampled at 16 DAT for the 3-leaf stage treatments and consistently thereafter for the rest of the season (Fig. 10 & 11). Warrior, Dimilin and Belay appeared to have the potential to increase populations of mosquitoes when applied at the 3-leaf stage timing. Trebon did not exhibit this same effect.

July armyworm application:

Quadrant Samples: Warrior was evaluated as a representative material that could be applied against armyworms mid- to late-season. At 1 week after application, this treatment was very damaging to populations of aquatic insects and other aquatic animals (a ~90% reduction in both cases) (Fig. 12 and 13). The numbers equilibrated somewhat thereafter so the seasonal average showed only a 25% reduction.

Mosquito Dip Samples: Warrior is very toxic to mosquito larvae (this class of chemistry is used for mosquito control), thus the data showed significant reductions of mosquito numbers for 5 weeks after application (Fig. 14 and 15).

Pest Populations – The data on pest populations are summarized from the 2010 study. RWW was the only pest present in any significant numbers. As shown in Table 8, the preflood treatments, Warrior and Belay, provided the best control. However, the RWW levels were really not high enough to draw any strong conclusions. This particular field on the RES typically does not have high, damaging levels of RWW.

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

Management of tadpole shrimp has taken on added importance in recent years. Tadpole shrimp are an early-season pest of seedling rice. The shrimp feed on the germinating seed and, perhaps more importantly, dislodge seedlings and reduce stands. Copper Sulfate (Bluestone) was commonly used for algae and tadpole shrimp control. Use of this product has declined by about 60% in the 2000's due to inconsistent supply, an increasing price, and poor algal control. Therefore, tadpole shrimp management is becoming more of an issue. The study in 2010 used modified, improved methods that I believe will allow for a better evaluation. In 2009, the study was done in the aluminum rings. Although the rings are not that large (10.7 sq. ft.), we were unable to find the shrimp, dead or alive, after being exposed to the treatments. In 2010, we placed a smaller ring inside the larger one. The small ring was intended for assessments of tadpole shrimp mortality and stand counts were done in the larger ring. A naturally-occurring rice water weevil infestation also occurred so control of this pest was also evaluated. Products evaluated are detailed in Table 9.

Methods:

A field study was conducted on tadpole shrimp control in 2010 in ring plots (standard 10.7 square feet aluminum rings with a 0.75 foot diameter PVC pipe ring plot placed inside aluminum ring). This was a study emphasizing registered and experimental products. The key dates were as follows:

26 May, early pre-flood application
28 May, pre-flood (PF) applications
28 May, flooding
29 May, seeding ('M-202') and seed treatments
14 June, tadpole shrimp were collected from a neighboring field and introduced into rings – 8 shrimp were placed into each PVC pipe ring and 12 shrimp were placed into each aluminum ring; rice was in the 1-2 leaf stage
15 June, post-flood applications

Sample Dates:

Established Seedling Counts: 1 July
Tadpole Shrimp Mortality/Seedling Damage: 16 June, 21 June, 24 June
RWW Adult Leaf Scar Counts: 24 June and 1 July
RWW Larval Counts: 19 July and 2 August
Rice Yield: 18 October

Sample Method:

Established Seedling Counts: Seedlings counted in aluminum ring and PVC pipe ring at end of study
Tadpole Shrimp Mortality/Seedling Damage: floating (dead) tadpole shrimp and floating (dislodged) rice seedlings were counted
RWW Adult Leaf Scar Counts: percentage of plants with adult feeding scars on either of the two newest leaves (50 plants per both ring plots per date)
RWW Larval Counts: 44 in^3 soil core containing at least one rice plant processed by washing/ flotation method (5 cores per plot per date)
Rice Yield: entire plots were hand-cut and grain recovered with a Vogel mini-thresher and yields were corrected to 14% moisture.

Plot Design:

Randomized Complete Block

Results:

Tadpole shrimp (TPS) that were dead/floating were counted from the small PVC enclosure as well as from the larger ring. In past years, consistently finding the shrimp upon mortality has been very difficult. They either break apart quickly or perhaps bury into the mud but in either case they are difficult to find. Results were more promising in 2010 studies. In the smaller ring (PVC), Trebon, copper sulfate, and Warrior preflood appeared to produce the most TPS mortality (Table 10) and these products along with Dermacor preflood and Warrior post-flood showed promise within the larger enclosure. In terms of speed of control, the pre-flood products (Dermacor and Warrior) appeared to act the fastest. Final established seedling numbers were clearly influenced by the TPS and treatments. Within the PVC plot (where the populations and damage was concentrated), the Trebon treatment produced the highest stand (and statistically equal to treatment 1 where no TPS were introduced into the plots) (Table 11). Untreated plots where TPS were introduced had a 45-50% reduction in rice plant stand at 22.75 plants. The other six insecticide treatments produced increases in stand of 10 to 15 plants compared with the untreated. Results from the larger ring were similar although there were no significant differences. Trebon again showed good protection of seedlings; however, Belay, Dermacor, and Warrior all applied preflood were equally effective.

A naturally-occurring rice water weevil (RWW) infestation also occurred in these plots. This level of infestation was about as high as I have seen in rings with immigrating RWW adults. Scar counts from RWW adults were highest in the untreated (without TPS), Dermacor seed treatment, and untreated (with TPS) plots (Table 12). The Belay, copper sulfate, and Warrior preflood treatment reduced adult damage by up to 75% in the first scarring evaluation. The second evaluation produced similar results except that the scarring was more pronounced in the copper sulfate treatment and the Warrior treatments (preflood and post-flood) and Dermacor preflood treatment showed improved results. RWW larval counts were highest in the untreated (without TPS) and Dermacor seed treatment (Table 13). Interestedly, the RWW larval counts were lower in the untreated plots with TPS; TPS are a known predator and they may have preyed on some of the RWW adults/larvae. In some natural systems, TPS have been promoted as a beneficial organism for the control of aquatic stages of mosquitoes. RWW populations were intermediate in the Trebon and copper sulfate treatments (~60% control) and lowest in the Belay, Dermacor preflood, and Warrior (preflood and postflood). These products reduced levels by 80 to 97%. Grain yield was highest in the Dermacor preflod treatment and this yield was significantly higher than the copper sulfate and Dermacor seed treatment entries (Table 14). Differences were ~2000 lbs./A. Plots with no insecticide but with TPS also yielded poorly.

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 found. The timing of RWW adult flight in the spring has been monitored annually since the insect was discovered in California, i.e., for ~55 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 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. The flight in 2010 was delayed and altered by the cool, wet spring conditions. Peaks in flight activity occurred on 13 May and from 28 May to 4 June (Fig. 16). In total, ~1650 RWW adults were captured which was about 30% of the 2009 total.

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

Resistant cultivars are an important way to manage pests; clearly this approach is critical for disease management in rice. The ideal scenario is to develop a plant through breeding on which the disease organism will not survive/infest. This same approach is used with insect pest management and resistant cultivars have been developed for numerous insect-host plant combinations. For instance in some situations, the insect pest simply will not survive on the resistant plant exhibiting antibiosis achieved through breeding; instead the insect perishes. However, two other types of plant resistance are important in terms of managing insect pests and perhaps more important than with disease management. In the first, the insect simply will not infest the resistant cultivar plants. There is a preference or more particularly a non-preference mechanism such that the insect moves to other plants/fields. Secondly, is a tolerance mechanism that some resistant plants exhibit. In this case, the pest insect infests and feeds upon the "resistant plant" but the plant exhibits traits that allow it to withstand the feeding and still produce an unaffected yield. For instance, the plant could be very vigorous and even with insect feeding it still outgrows the damage and yields highly. These latter two approaches, although not directly toxic to the pest, are often preferred because they are more stable. The first approach that actually kills the pest has the drawback that insect pests can develop a mechanism to overcome this type of resistance (similar the developing resistance to insecticides). When this happens, additional plant breeding efforts are needed to develop new and improved resistance mechanism, i.e., trying to stay one step ahead of the insect pest.

Efforts were underway at the RES to breed rice cultivars resistant to RWW. While progress was made, it was slow and the resistance obtained was partial, at best, and the cultivars needed considerable improvement agronomically. This has been the outcome of breeding programs against RWW in other states, as well. Therefore, the RWW breeding program at the RES was curtailed. However, this breeding program addressed primarily the antibiosis approach; the other two approaches could be operating efficiently in our rice cultivars. For example, there could be characteristics of one or some varieties that impede RWW from infesting it. These could include leaf color, texture, odor, orientation, etc. The tolerance type of host plant resistance is related to healthy, vigorous rice cultivars and this is undoubtedly operating to some level in the CA cultivars. The larvae feed and inflict damage but the plants are able to compensate and outgrow the damage. What is the importance of these factors? Varieties with a level of resistance may need different thresholds for treatment or at least different amounts of concern for RWW management.

Therefore, we have been examining the response of commonly-grown California rice cultivars to RWW in terms of 1.) severity of infestation and 2.) yield loss upon infestation. Two studies were done in 2010.

2.2.a) Varietal Susceptibility to RWW – Ring Study with Controlled Populations

Methods:

In the first study, four varieties, M-202, S-102, L-206, and Calmati-202, were grown in 10.7 sq. ft. aluminum rings and infested with RWW adults as detailed in 1.1 and 1.2 These varieties were selected to represent a range of genotypes within California rice. The infested adults insured that a population was present and examining yield loss was the primary goal. The methods described in 1.1 and 1.2 for assessing adult scarring, larval populations, and yields were also used herein. Within each variety, there were treated, uninfested rings (Dermacor seed treatment at 2.5 fl. oz. per 100 lbs. seed and Warrior II at 1.28 fl. oz. per acre applied at the 3-leaf stage) and infested rings with no treatments. This was done to insure that some rings had no RWW and others had as high of population as possible.

Results:

Leaf scarring from RWW adults was separated, as expected, by the treatments infested with RWW adults vs. not infested (Table 15). In spite of our best efforts, there was a low level of infestation and some damage in the uninfested rings. Some adults naturally get into the rings; the seed treatment was supposed to eliminate these invaders but the seed treatment was only marginally effective. Therefore, some of the uninfested treatments had scarring in the first evaluation (up to 23.5%). This figure was clearly less than the infested rings that had scarring ranging from 77.0 to 54.0%. The full impact of the post-flood application of Warrior was seen in the 1 July sample date when the uninfested treatments had very low scarring values. These four treatments as a group had significantly lower scarring values than the four treatments that were infested (an average of 3.5% vs. 46.1%). The RWW larval data were even more definitive in that the treatments that were not infested essentially had no RWW larvae and the infested treatments had a sizeable infestation (1.4 RWW immature per core sample) (Table 16). There was a trend for fewer RWW larvae in Calmati-202 than in the other three varieties. This was most noticeable in the first sample date. For instance, populations were lower in M-202 in the second sample date but this likely resulted from the larval infestation removing most of the root tissue and causing the populations to decline. Grain yields were overall highest in M-202 and L-206; yields were 1100 lbs./A less in S-102 and Calmati-202 was lowest yielding (Table 17).

However, the goal of this study was to examine the yield loss from RWW across the varieties. The yield loss was highest in M-202 at ~850 lbs./A (comparing the treatment without and with RWW) and ~600 lbs./A on a per RWW larva basis (in order to compare across the other varieties). Past years' research, has shown that the medium grains are most susceptible to grain yield loss from RWW. S-102 and L-206 also suffered a yield loss from RWW in the range of 200 to 250 lbs./A comparing the treatments with and without an infestation and 110 to 160 lbs./A lbs./A per RWW larva. S-102 appeared to be slightly more susceptible to yield loss of these two varieties. Calmati-202, as discussed above, was most lightly infested with RWW among the four varieties and it also did not suffer any yield loss. There is the possibility that the level of infestation achieved simply was not high enough to impact the plant.

2.2.b) Varietal Susceptibility to RWW – Small Plot Study with Natural Populations

Methods:

The rice varieties as shown in Table 18 were grown in small plots measuring 16 x 13 ft. with four blocks. The second factor examined was RWW population – either present at naturally-occurring levels or controlled with insecticides (Warrior II at 2.56 oz./A applied on 28 May [preflood]). The methods described in 1.3 for assessing adult scarring, larval populations, and yields were also used herein. The varieties were selected to represent the range of genetic material in California cultivars as well as to include most of the commonly grown entries.

Results:

For the first leaf scarring evaluation on 17 June, there were no significant differences in percentage scarring among the varieties or comparing the treated vs. untreated (averaging 31.4%). Some significant differences were seen in leaf scarring at the second evaluation but no wide variation was seen. Averaged over the RWW status, scarring tended to be slightly higher in M-208 (38%) than in Calhikari-201 (25%). The varieties generally appeared to be equally conducive to RWW infestation. RWW larval infestation was very low in the treated plots. Populations of ~0.1 RWW larva per core or less were seen in all the varieties (treated plots) except M-205, which had very low populations in the first sample and higher levels in the second sample (actually just one block of the four unexplainably had higher levels). But overall there was a significant and undeniable difference in larval levels between treated and untreated entries for each variety. Among the varieties (untreated plots), RWW levels were highest in M-401 and up to four ties that in several of the other varieties. RWW populations were also fairly high in L-206. In M-401, it is also interesting that the RWW level was fairly constant in both samples taken about 2 weeks apart. Normally, populations especially at this high level (3+ RWW per sample) will decline over this period as the larvae decimate the root tissue and some larvae starve. This may indicate that M-205 produces a high level of root tissue and has the ability to quickly regenerate root tissue. Rice grain yield was highest in M-401 (RWW controlled) and lowest in S-102 (RWW present). There was about a 3000 lbs./A difference between these extremes. However, most importantly was the yield response the RWW infestation. RWW caused a yield loss in all the 12 varieties except L-206, M-104, and Calamylow-201. In these three entries, the yield was the same (or slightly higher) in the presence of RWW as in the RWW-controlled plots. Conversely, in the other nine varieties, the naturally-occurring RWW infestation resulted in a 594 lb./A grain yield loss. Yield losses in M-401 and M-202 were ~1500 and ~1000 lbs./A, respectively. Calhikari-201, M-205, and Calmochi-101 also had more than a 500 lbs./A yield loss from RWW damage. Since the varieties had differences in RWW populations, expressing the yield loss on loss per RWW larva is a way to fairly and in an unbiased way compare the effects of larval feeding across varieties. Using the criteria, Calhikari-201 was most impacted by RWW injury at 900 lbs./A grain loss per each RWW larvae. Since this was a fairly low yielding variety this representing a 14.2% loss per larva. M-205 and M-202 (about 750 to 800 lbs./A loss per larva and ~10.5% and Calmochi-101 (531 lbs./A loss and 8.6%) were also severely impacted. Conversely, M-206 had a very low yield loss from RWW.

In summary, the medium grain varieties typically suffer the highest yield loss from RWW and M-202 and M-205 upheld this trend. M-401 and M-206 produced interesting results in 2010. M-401 was the most heavily infested of the 12 varieties evaluated and did suffer a significant yield loss but the high yield capacity of this variety partially compensated for this loss. Conversely, M-206 was infested at a moderate level but did not show much yield loss from RWW; similarly, L-206, M-104, and Calamylow-201 did not have any measurable yield loss from RWW in spite of having infestation levels at twice that thought to cause a yield loss (based on data collected on M-202).

2.3) Rice water weevil impact of rice plant growth/development and grain set

Previous studies have shown that RWW primarily reduces rice grain yield by reducing the amount of tillering in the plants. This is especially true in the California water-seeded production system which means that the insect inflicted damage occurs before tillering is determined and initiated, i.e., green ring. In plants that are infested with significant RWW populations, the number of grains per panicle and average weight per kernel are largely unaffected but the number of panicles per unit area is reduced. While a cost-effective system of IPM of rice insect pests such as RWW presently exists in California, I believe the long-term solution to this pest should involve some form and level of host plant resistance. Developing an understanding of the manner in which the insect impacts plant productivity could be an important advancement in helping to design stable, sustainable, long-term management schemes. How does root pruning in an aquatic system negatively impact the plant and eventually lead to reduced tillering? I previously researched a root-pruning insect of field corn and the damage in this terrestrial system caused the plant to easily become drought-stressed (even with growing in well-watered soils). But in the aquatic system, other mechanisms must be operating. What controls tillering in uninjured rice plants? Perhaps a cultivar that is inherently high tillering would be less impacted by RWW in terms of effects on tillering. We conducted a preliminary study in the area in 2010 in hopes of developing some preliminary data in order to support a larger funding request from federal sources.

<u>Methods:</u>

Ten different treatments as detailed below were established in 10.7 sq. ft. aluminum rings (Table 22). These treatments were designed to set-up different amounts, and different timings relative to the plant growth stage, of plant stress from RWWs. The final factor was plant cultivar with M-202 being used for eight of the treatments and IR-36, a vigorously tillering rice line, was used for comparison purposes for two treatments. The methods described in 1.1 and 1.2 for assessing adult scarring, larval populations, and yields were also used herein. Rings were seeded on 11 June and infested with the planned number of RWW adults on 25 June.

Results:

Data on leaf scarring from RWW generally fell into three levels - ~65-70% for the heavily infested rings, 1-5% for the uninfested rings, and ~40% for the rings infested at the low (0.2) rate (Table 23). Similarly, rings infested at 0.6 RWW adults per plant yielded about 4 larvae per sample and the low (0.2 rate) had ~2.5 RWW per sample (Table 24). Fewer larvae were seen on the IR-36 cultivar than M-202. Uninfested rings had larval levels as high as 0.5 per core sample. This was higher than desired and higher than anticipated given the plot location and the late seeding date. Yield parameters (number of tillers/panicles, grain weight, biomass weights, and % moisture) were largely unaffected by RWW numbers or rice cultivar. The yield potential of the plot was very low due to the late seeding date coupled with the relatively cool summer as indicated by the high grain moisture at harvest (generally 30%+). This low yield compromised the results and the study.

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 involves 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 on the UC-Davis campus infesting rice growing in greenhouses. This pest was previously found in the southern rice-producing states. 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. New procedures for growing rice were put in place on the campus and presently this pest appears to have been eradicated on the campus. This is a very small, cryptic pest and is widely distributed around the world so diligence is needed to keep California panicle rice mite-free.

Acknowledgments:

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PUBLICATIONS OR REPORTS:

Godfrey, L. D. and E. Goldman. 2010. Status of new reduced-risk insecticides for use in rice. Calif. Rice Experiment Station Field Day Report. 3 pp.

Godfrey, L. D., W. Pinkston, Kirin Basuta, and Evan Goldman. 2009. Annual report comprehensive research on rice, RP-3. 33 pp.

Godfrey, L. D. 2009. 41th Annual report to the California rice growers. Protection of rice from invertebrate pests. 5 pp.

CONCISE GENERAL SUMMARY OF CURRENT YEARS (2010) RESULTS:
Larry D. Godfrey

Research was conducted in 2010 on the biology and management of key invertebrate pests of California rice. Rice water weevil populations were reduced in 2010 because of the unfavorable spring conditions. However, damaging populations were still present in several locations, including much of the RES. This allowed us to collect data on this pest in all studies we conducted in 2010 – about seven in total. Besides studies designed on the insecticidal management of this pest, we also studied the response of California rice varieties to infestation. Most of the previous work has been done with M-202 and the response of other varieties may differ significantly. In addition, a new research thrust dealing with rice water weevil, rice plant response, was initiated. Tadpole shrimp levels have increased in recent years and this is a pest of concern in many locations. Research was conducted on this pest and techniques were refined such that a successful study was conducted. Research on this pest from 2008 and 2009 had some challenges and the modified procedures were a definite improvement. Armyworms, the other important insect pest of rice, were not present in high enough levels for research in 2010. 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: Management - 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 continued in 2010 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 six different active ingredients) were evaluated in ring plots. Rice water weevil adults were introduced into each ring along with a moderate naturally-occurring infestation resulting in an acceptable infestation. In summary, Dimilin®, Warrior® II, and Mustang® Max, the registered products, are all still viable products for RWW control. Of these three products, Mustang Max was the least effective in 2010 but still provided effective control. Application of Warrior preflood was a very effective treatment for RWW and produced results equal to or perhaps even better than the standard 3-leaf application. Mustang Max did not show equivalent efficacy with the preflood application and does not appear to fit this type of application. Trebon® (etophenprox) applied at the 3-leaf stage was effective for RWW larval control. The control appears to arise from a high amount of control of adults supplemented by additional control of larvae. At this time, registration/marketing of this product for the California rice market appears to be "on-hold". Belay® (clothianidan) appears to have significant potential for RWW management and is progressing towards registration. I have previously shown it is active applied preflood as well as 3-leaf stage application. In 2010, using lower rates of clothianidin, the preflood timing showed considerable weakness. This was partially due to the lower use rates but also other unknown reasons, i.e., weather, etc., inhibited the activity. The 3-leaf stage method with clothianidin was very effect in 2010 and as efficacious as any of the registered insecticides for RWW control. The reduction in larval numbers resulted from adult mortality and also direct control of larvae. The preflood method warrants additional research efforts. A "rescue" treatment, i.e., applied at about the 5-leaf stage when the larval infestation has already began, of clothianidin, was also shown to be effective. The control provided was in the 70% range but this is admirable given the demands placed on a product for this use. Dermacor® (rynaxypyr) efficacy on RWW as a seed treatment in water-seeded rice is moderate, at best. This result was seen in 2010 to reinforce results from previous years. However, rynaxypyr applied preflood or at the 3-leaf stage showed promise. In both cases, the higher rate of the two rates tested was as effective as the best-performing treatments and the lower rate showed moderate activity. Small plot (0.25 acre) evaluations showed efficacy (from best to worst) of Belay applied at the 3-leaf stage, Belay preflood, and Dermacor seed treatment. 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.

<u>Biology</u> - In 2009, the rice water weevil spring flight was the highest recorded since 2001. The flight in 2010 was delayed and altered by the cool, wet spring conditions. Peaks in flight activity occurred on 13 May and from 28 May to 4 June and some weevils were captured as late as July (normally 10 June is the latest flight seen). In total, ~1650 RWW adults were captured which was about 30% of the 2009 total. A study was done in 2010 so as to collect some preliminary data that would allow my lab to pursue funding from other (federal) sources. Previous studies have shown that RWW primarily reduces rice grain yield by reducing the amount of tillering in the plants (instead of affecting grain weights or number of seeds per panicle). We wanted to investigate how, mechanistically and physiologically, this occurs in the rice plant; what are the factors that affect tillering in rice and how does root pruning by the larvae impact this. Developing an understanding of the manner in which the insect impacts plant productivity could be an important advancement in helping to design stable, sustainable, long-term management schemes. Several treatments were set-up with different amounts and different timing of stress from RWW. Data are still being examined but the late seeding date and late-maturing rice crop inhibited the success of this study.

<u>Cultivar Response</u> – Resistant cultivars are an important way to manage pests and developing a rice variety that would not be feed upon and/or damaged by RWW has been a goal. Some success was made in this area by RES breeders but program has curtailed in recent years; this slow success for breeding against RWW has also been experienced in other states as well. However, developing lines that the insect will not infest, preference vs. non-preference, and cultivars that can fed upon but the plant exhibits traits that allow it to withstand the feeding and still produce an unaffected yield are also viable types of plant resistance. These types of host plant resistance are related to healthy, vigorous rice cultivars and are undoubtedly operating to some level in the CA cultivars. In this project, the response of commonly-grown California rice cultivars to RWW in terms of 1.) severity of infestation and 2.) yield loss upon infestation was examined utilizing only M-202. In controlled ring studies with four varieties, the yield loss was highest in M-202, about 1/3 as high in S-102 and L-206, and Calmati-202 was most lightly infested with RWW among the four varieties and did not suffer any yield loss. In field studies with 12 varieties, the medium grain varieties typically suffer the highest yield loss from RWW and M-202 and M-205 upheld this trend (up to a 10% loss per each RWW larva feeding on the roots). M-401 was the most heavily infested of the 12 varieties evaluated and did suffer a significant yield loss but the high yield capacity of this variety largely compensated for this loss.

Conversely, M-206 was infested at a moderate level but did not show much yield loss from RWW; similarly, L-206, M-104, and Calamylow-201 did not have any measurable yield loss from RWW in spite of having infestation levels at twice that thought to cause a yield loss (based on data collected on M-202).

Tadpole Shrimp: Nine treatments were evaluated in 2010 for tadpole shrimp mortality and protection of rice seedling stands. Trebon, copper sulfate, Warrior preflood and post-flood and Dermacor preflood produced the most tadpole shrimp mortality. Trebon again showed good performance in terms of protection of seedlings (stands); however, Belay, Dermacor, and Warrior all applied preflood were equally effective.

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. Data from 2009 are completely summarized and results for 2010 are still in progress. Mosquito populations were fairly high in 2009 (the highest we have seen in this study) and data on mosquito larvae were collected weekly for 9 weeks. Four preflood applications were evaluated in 2009 – Warrior and Belay as preflood broadcast applications, and DPX-HGW86 and Dermacor as seed treatments. Belay preflood appeared to cause the greatest reduction in populations of aquatic insects and other aquatic animals (mostly other invertebrates). For instance, at 13 to 36 DAT, Belay reduced insect levels by an average of ~50% and there were also reductions later in the season. There was some indication that all the preflood treatments increased numbers of mosquitoes, but there were no definite (consistent) trends. Dimilin, Warrior, Belay, and Trebon were evaluated with 3-leaf stage applications. At 10 DAT, all four products significantly reduced aquatic insect levels and three of the four affected other aquatic animal levels. At 16 and 23 DAT, these reductions generally persisted but at lower levels. Warrior, Dimilin and Belay appeared to have the potential to increase populations of mosquitoes when applied at the 3-leaf stage timing. Trebon did not exhibit this same effect. Warrior was evaluated as a representative material that could be applied against armyworms mid- to late-season. At 1 week after application, this treatment was very damaging to populations of aquatic insects and other aquatic animals (a ~90% reduction in both cases). The numbers equilibrated somewhat thereafter so the seasonal average showed only a 25% reduction. Warrior is very toxic to mosquito larvae (this class of chemistry is used for mosquito control), thus the data showed significant reductions of mosquito numbers for 5 weeks after application.

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. Treatment of existing rice in greenhouses followed by a rice-free period were enacted on campus to try to break the “cycle” of the mite. Rice for research purposes is again being grown on the campus using new seed handling and sanitary procedures and 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, 2010.

Product	Rate (lbs. AI/A)	Formulation per A	Timing	Notes
1. Dimilin 2L	0.125	8 fl. oz.	3-leaf	
2. Untreated	---	---	---	---
3. Warrior II	0.03	1.92 fl. oz.	3-leaf	
4. Warrior II	0.03	1.92 fl. oz.	preflood ~week before flooding	5/26/2010
5. Trebon 3G	0.18	6 lbs.	2-3-leaf	
6. Belay 2.13 SC	0.058	3.5 fl. oz.	preflood	
7. Belay 2.13 SC	0.075	4.5 fl. oz.	preflood	
8. Belay 2.13 SC	0.092	5.5 fl. oz.	preflood	
9. Belay 2.13 SC	0.058	3.5 fl. oz.	2-3 leaf	
10. Belay 2.13 SC	0.075	4.5 fl. oz.	2-3 leaf	
11. Belay 2.13 SC	0.092	5.5 fl. oz.	2-3 leaf	
12. Mustang Max EW	0.025	4.0 fl. oz.	2-3 leaf	
13. Warrior II	0.03	1.92 fl. oz.	PF	
14. Dermacor X-100 5FS	1.75 oz/100 lbs -- 0.0175 MAT		seed treatment	treated by DuPont - no Clorox
15. Dermacor X-100 5FS	2.00 oz/100 lbs -- 0.02 MAT		seed treatment	treated by DuPont - no Clorox
16. Dermacor X-100 5FS	2.50 oz/100 lbs -- 0.025 MAT		seed treatment	treated by DuPont - no Clorox
17. Dermacor X-100 5FS	0.08 lb. AI/A	2.0 fl. oz.	preflood	
18. Dermacor X-100 5FS	0.10 lb. AI/A	2.5 fl. oz.	preflood	
19. Dermacor X-100 5FS	0.08 lb. AI/A	2.0 fl. oz.	2-3 leaf	
20. Dermacor X-100 5FS	0.10 lb. AI/A	2.5 fl. oz.	2-3 leaf	
21. Mustang Max EW	0.025	4.0 fl. oz.	preflood ~week before flooding	5/26/2010
22. Mustang Max EW	0.025	4.0 fl. oz.	preflood	
23. Untreated	---	---	---	treated by DuPont but without insecticide - no Clorox
24. Belay 2.13 SC	0.092	5.5 fl. oz.	5-6 leaf	

* Clorox seed soak used except where indicated

Table 2. Rice plant stand and adult feeding damage in chemical ring study, 2010.

Product	Formulation per A	Timing	Stand Vigor/Emergence	% Scarred Plants - 24 June		% Scarred Plants - 1 July	
1. Dimilin 2L	8 fl. oz.	3-leaf	2.75	55	b-f	51	ab
2. Untreated	---	---	3.25	67.5	ab	43.5	abc
3. Warrior II	1.92 fl. oz.	3-leaf	2.63	31	gh	3	f
4. Warrior II	1.92 fl. oz.	preflood ~week before flooding	3.13	35.5	e-h	28.5	cd
5. Trebon 3G	6 lbs.	2-3-leaf	3.0	48.5	b-g	12	ef
6. Belay 2.13 SC	3.5 fl. oz.	preflood	3.13	49	b-g	37.5	bcd
7. Belay 2.13 SC	4.5 fl. oz.	preflood	3.0	34.5	fgh	28.5	cd
8. Belay 2.13 SC	5.5 fl. oz.	preflood	3.0	43.5	c-h	29	cd
9. Belay 2.13 SC	3.5 fl. oz.	2-3 leaf	3.0	36	e-h	2.5	f
10. Belay 2.13 SC	4.5 fl. oz.	2-3 leaf	3.25	39.5	d-h	1.5	f
11. Belay 2.13 SC	5.5 fl. oz.	2-3 leaf	3.13	38	d-h	1.0	f
12. Mustang Max EW	4.0 fl. oz.	2-3 leaf	3.13	39	d-h	3.5	f
13. Warrior II	1.92 fl. oz.	preflood	3.13	24	h	29	cd
14. Dermacor X-100 5FS	1.75 oz/100 lbs	seed trt. – DuPont-treated	3.5	60.5	abc	50	ab
15. Dermacor X-100 5FS	2.00 oz/100 lbs	seed trt. – DuPont-treated	3.38	52.5	b-f	53	ab
16. Dermacor X-100 5FS	2.50 oz/100 lbs	seed trt. – DuPont-treated	3.5	48	b-g	45.5	ab
17. Dermacor X-100 5FS	2.0 fl. oz.	preflood	3.0	55.5	bcde	38	bcd
18. Dermacor X-100 5FS	2.5 fl. oz.	preflood	3.13	53	b-f	26.5	de
19. Dermacor X-100 5FS	2.0 fl. oz.	2-3 leaf	3.38	48	b-g	10.5	ef
20. Dermacor X-100 5FS	2.5 fl. oz.	2-3 leaf	3.13	48.5	b-g	4.0	f
21. Mustang Max EW	4.0 fl. oz.	preflood ~week before flooding	3.0	79	a	53	ab
22. Mustang Max EW	4.0 fl. oz.	preflood	2.88	52	b-f	58.5	a
23. Untreated	---	DuPont-treated w/o insecticides	3.25	57	bcd	49	ab
24. Belay 2.13 SC	5.5 fl. oz.	5-6 leaf	3.13	68	ab	39.5	bcd

* Clorox seed soak used except where indicated. Means within columns followed by same letter

Table 3. RWW immature density (first and second sample dates and average) in chemical ring study, 2010.

Product	Formulation per A	Timing	RWW per Core Sample – 20 July		RWW per Core Sample – 4 August		Avg.
1. Dimilin 2L	8 fl. oz.	3-leaf	0.5	cde	0.21	cd	0.36
2. Untreated	---	---	1.65	ab	1.0	bc	1.33
3. Warrior II	1.92 fl. oz.	3-leaf	0.21	de	0.4	bcd	0.31
4. Warrior II	1.92 fl. oz.	preflood ~week before flooding	0.06	e	0.05	d	0.05
5. Trebon 3G	6 lbs.	2-3-leaf	0.7	b-e	0.8	bcd	0.75
6. Belay 2.13 SC	3.5 fl. oz.	preflood	1.0	b-e	0.4	bcd	0.70
7. Belay 2.13 SC	4.5 fl. oz.	preflood	0.25	de	0.3	bcd	0.28
8. Belay 2.13 SC	5.5 fl. oz.	preflood	0.53	cde	0.6	bcd	0.57
9. Belay 2.13 SC	3.5 fl. oz.	2-3 leaf	0.1	e	0.15	cd	0.13
10. Belay 2.13 SC	4.5 fl. oz.	2-3 leaf	0.4	cde	0.3	bcd	0.35
11. Belay 2.13 SC	5.5 fl. oz.	2-3 leaf	0.3	de	0.15	cd	0.23
12. Mustang Max EW	4.0 fl. oz.	2-3 leaf	0.74	b-e	0.05	d	0.40
13. Warrior II	1.92 fl. oz.	preflood	0.37	cde	0.05	d	0.21
14. Dermacor X-100 5FS	1.75 oz/100 lbs. seed	seed trt. – DuPont-treated	1.1	bcd	0.85	bcd	0.98
15. Dermacor X-100 5FS	2.00 oz/100 lbs. seed	seed trt. – DuPont-treated	1.3	abc	0.89	bcd	1.10
16. Dermacor X-100 5FS	2.50 oz/100 lbs. seed	seed trt. – DuPont-treated	0.63	cde	0.25	bcd	0.44
17. Dermacor X-100 5FS	2.0 fl. oz.	preflood	0.85	b-e	0.3	bcd	0.58
18. Dermacor X-100 5FS	2.5 fl. oz.	preflood	0.11	e	0.0	d	0.06
19. Dermacor X-100 5FS	2.0 fl. oz.	2-3 leaf	0.7	b-e	0.21	cd	0.46
20. Dermacor X-100 5FS	2.5 fl. oz.	2-3 leaf	0.05	e	0.05	d	0.05
21. Mustang Max EW	4.0 fl. oz.	preflood ~week before flooding	2.25	a	1.95	a	2.10
22. Mustang Max EW	4.0 fl. oz.	preflood	0.75	b-e	0.4	bcd	0.58
23. Untreated	---	DuPont-treated w/o insecticides	1.72	ab	1.15	ab	1.44
24. Belay 2.13 SC	5.5 fl. oz.	5-6 leaf	0.58	cde	0.1	cd	0.34

* Clorox seed soak used except where indicated

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

Table 4. Effect of RWW populations on rice biomass and grain yields in ring study, 2010.

Product	Formulation per A	Timing	% Grain Moisture		Grain Yield (lbs./A)		Biomass (Straw +Grain) (t/A)	
1. Dimilin 2L	8 fl. oz.	3-leaf	17.5	cd	5247	abc	7.7	bcde
2. Untreated	---	---	19.8	abcd	5440	abc	8.5	a-e
3. Warrior II	1.92 fl. oz.	3-leaf	20.2	abcd	6371	abc	9.4	a-e
4. Warrior II	1.92 fl. oz.	preflood ~week before flooding	20.1	abcd	5870	abc	9.4	a-e
5. Trebon 3G	6 lbs.	2-3-leaf	17.9	bcd	4319	c	6.9	de
6. Belay 2.13 SC	3.5 fl. oz.	preflood	18.8	abcd	4643	bc	7.1	bcde
7. Belay 2.13 SC	4.5 fl. oz.	preflood	17.8	bcd	4279	c	6.3	e
8. Belay 2.13 SC	5.5 fl. oz.	preflood	20.4	abc	6843	ab	10.4	ab
9. Belay 2.13 SC	3.5 fl. oz.	2-3 leaf	20.4	abc	7005	a	11.4	a
10. Belay 2.13 SC	4.5 fl. oz.	2-3 leaf	19.6	abcd	6695	ab	10.3	abc
11. Belay 2.13 SC	5.5 fl. oz.	2-3 leaf	17.4	d	5199	abc	7.5	bcde
12. Mustang Max EW	4.0 fl. oz.	2-3 leaf	18.8	abcd	6057	abc	9.2	a-e
13. Warrior II	1.92 fl. oz.	preflood	18.3	abcd	4969	abc	7.0	cde
14. Dermacor X-100 5FS	1.75 oz/100 lbs. seed	seed trt.– DuPont-treated	20.4	abc	5254	abc	8.3	a-e
15. Dermacor X-100 5FS	2.00 oz/100 lbs. seed	seed trt. – DuPont-treated	20.5	ab	6195	abc	9.8	abcd
16. Dermacor X-100 5FS	2.50 oz/100 lbs. seed	seed trt. – DuPont-treated	20.8	a	6114	abc	9.9	abcd
17. Dermacor X-100 5FS	2.0 fl. oz.	preflood	19.5	abcd	5539	abc	8.6	a-e
18. Dermacor X-100 5FS	2.5 fl. oz.	preflood	19.2	abcd	5377	abc	8.1	a-e
19. Dermacor X-100 5FS	2.0 fl. oz.	2-3 leaf	18.3	abcd	5384	abc	7.8	bcde
20. Dermacor X-100 5FS	2.5 fl. oz.	2-3 leaf	19.7	abcd	5956	abc	9.0	a-e
21. Mustang Max EW	4.0 fl. oz.	preflood ~week before flooding	18.2	abcd	4778	bc	7.4	bcde
22. Mustang Max EW	4.0 fl. oz.	preflood	17.7	bcd	4677	bc	6.9	de
23. Untreated	---	DuPont-treated w/o insecticides	18.4	abcd	5053	abc	6.3	e
24. Belay 2.13 SC	5.5 fl. oz.	5-6 leaf	18.7	abcd	4914	abc	7.5	bcde

* Clorox seed soak used except where indicated.
Means within columns followed by same letter are not significantly different; least significant
• • • • • • • • • • <0.05).

Table 5. Results (scarred plants and RWW data) from large plot comparison of experimental products for rice water weevil control, 2010.

Product	**Rate**	**% Scarred Plants – 24 June**	**% Scarred Plants – 1 July**	**RWW per Core Sample – 22 July**	**RWW per Core Sample – 5 Aug.**	**Avg.**
Dermacor X-100 5FS	2.5 oz./100 lbs. seed	26.5	32.1	2.55	1.25	1.90
Belay 2.13SC	4.5 fl. oz./A preflood	28.0	22.1	3.95	1.6	2.78
Belay 2.13SC	4.5 fl. oz./A 3-leaf stage	34.4	13.3	0.55	0.63	0.59
Untreated*	---	38.0	35.5	1.35	1.0	1.18

* 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. Yield results from large plot comparison of experimental products for rice water weevil control, 2010.

Product	**Rate**	**% Grain Moisture**	**Grain Yield (lbs./A)**
Dermacor X-100 5FS	2.5 oz./100 lbs. seed	18.4	6459
Belay 2.13SC	4.5 fl. oz./A preflood	19.5	8315
Belay 2.13SC	4.5 fl. oz./A 3-leaf stage	19.3	6989
Untreated*	---	17.6	6602

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

Table 7. Treatments evaluated in non-target study, 2008-10.

Product	**Rate (lbs. AI/A)**	**Timing**	**2008**	**2009**	**2010**
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		
6. Dimilin 2L	0.125	3-leaf	X	X	X
7. V10170	0.1 per 100 lbs. seed	seed treatment		X	
8. Trebon 3G	0.18	3-leaf	X	X	X
9. DPX-NGW86	0.1 per 100 lbs. seed	seed treatment	X	X	
10. Belay 2.13 SC	0.092	PF	X	X	X
11. Belay 2.13 SC	0.092	3-leaf	X	X	X
12. Dermacor X-100 5FS	0.10	PF			X
13. Dermacor X-100 5FS	2.50 oz/100 lbs. seed	seed treatment			X

Table 8. Rice Water Weevil population in non-target study, 2010.

Product	Rate (lbs. AI/A)	Timing	RWW per Core Sample – 26 July	RWW per Core Sample – 9 Aug.	Avg.
1. Belay 2.13 SC	0.092	PF	0.1	0.0	0.07
2. Warrior	0.03	3-leaf	0.2	0.2	0.20
3. Warrior	0.03	preflood	0.0	0.0	0.00
4. Warrior	0.03	July armyworm timing	0.1	0.3	0.23
5. Dermacor X-100 5FS	0.10	PF	0.3	0.3	0.27
6. Dimilin 2L	0.125	3-leaf	0.1	1.0	0.53
7. Untreated	---	---	0.1	0.5	0.30
8. Belay 2.13 SC	0.092	3-leaf	0.0	0.6	0.30
9. Trebon 3G	0.18	3-leaf	0.2	0.1	0.13
10. Dermacor X-100 5FS	2.50 oz/100 lbs. seed	seed treatment	0.0	0.5	0.27

Table 9. Treatments evaluated for tadpole shrimp control studies, 2010.

Product	Rate (lbs. AI/A)	Formulation per A	Timing
1. Untreated-no TPS added	---	---	---
2. Belay 2.13SC	0.09	5.5 fl. oz.	preflood
3. Dermacor X-100 5FS	0.08	2.0 fl. oz.	preflood
4. Trebon 3G	---	6 lbs.	post-flood*
5. Copper sulfate		10 lbs.	post-flood*
6. Dermacor X-100 5FS	2.50 oz/100 lbs. seed		seed treatment
7. Untreated with TPS added	---	---	---
8. Warrior II	0.03	1.92 fl. oz.	post-flood*
9. Warrior II	0.03	1.92 fl. oz.	early preflood
* 2 days after the tadpole shrimp were introduced into the rings			

Table 10. Tadpole shrimp (TPS) mortality and counts of dislodged seedlings on three sample dates as well as seasonal total, 2010.

		PVC Plot				Ring Plot			
		16 June							
Product	**Formulation per A**	**Dead TPS**		**Floating Seedlings**		**Dead TPS**		**Floating Seedlings**	
1. Untreated-no TPS	---	0	a	0	a	0	b	1.5	a
2. Belay 2.13 SC	5.5 oz. - preflood	0	a	0.25	a	0.25	b	1.5	a
3. Dermacor X-100 5FS	2.0 fl. oz. - preflood	0.75	a	0.25	a	1.25	a	3.75	a
4. Trebon 3G	6 lbs. – post-flood*	0.75	a	0.25	a	0.25	b	1.25	a
5. Copper sulfate	10 lbs. – post-flood*	0.25	a	1.0	a	0.25	b	3.0	a
6. Dermacor X-100 5FS	2.50 oz/100 lbs. seed – seed treatment	0.67	a	1.3	a	0.67	ab	3.0	a
7. Untreated with TPS	---	0.25	a	1.25	a	0.25	b	2.25	a
8. Warrior II	1.92 oz. – post-flood*	0.25	a	0.75	a	0.25	b	2.0	a
9. Warrior II	1.92 oz. – early preflood	1.25	a	0.5	a	0.75	ab	2.0	a
		21 June							
Product	**Formulation per A**	**Dead TPS**		**Floating Seedlings**		**Dead TPD**		**Floating Seedlings**	
1. Untreated-no TPS	---	0	b	0	a	0.25	a	0.5	a
2. Belay 2.13 SC	5.5 oz. - preflood	0.25	ab	0	a	0.25	a	1.25	a
3. Dermacor X-100 5FS	2.0 fl. oz. - preflood	0	b	0.25	a	0.25	a	2.0	a
4. Trebon 3G	6 lbs. – post-flood*	0.5	ab	0	a	1.0	a	0.5	a
5. Copper sulfate	10 lbs. – post-flood*	1.0	a	0	a	0.5	a	2.0	a
6. Dermacor X-100 5FS	2.50 oz/100 lbs. seed – seed treatment	0	b	0	a	0	a	1.0	a
7. Untreated with TPS	---	0.25	ab	0.25	a	0.5	a	2.25	a
8. Warrior II	1.92 oz. – post-flood*	0.25	ab	0	a	1.0	a	0.5	a
9. Warrior II	1.92 oz. – early preflood	0	b	0	a	0	a	0.25	a

		PVC Plot				Ring Plot			
		24 June							
Product	**Formulation per A**	**Dead TPS**		**Floating Seedlings**		**Dead TPS**		**Floating Seedlings**	
1. Untreated-no TPS	---	0	a	0	a	0.25	ab	0	a
2. Belay 2.13 SC	5.5 oz. - preflood	0.25	a	0	a	0.25	ab	0	a
3. Dermacor X-100 5FS	2.0 fl. oz. - preflood	0	a	0	a	0	b	0.5	a
4. Trebon 3G	6 lbs. – post-flood*	0	a	0	a	1.25	a	0.25	a
5. Copper sulfate	10 lbs. – post-flood*	0.5	a	0	a	0	b	0.25	a
6. Dermacor X-100 5FS	2.50 oz/100 lbs. seed – seed treatment	0.33	a	0	a	0.33	ab	0.67	a
7. Untreated with TPS	---	0.5	a	0	a	0	b	1.0	a
8. Warrior II	1.92 oz. – post-flood*	0.25	a	0	a	0	b	0.25	a
9. Warrior II	1.92 oz. – early preflood	0.25	a	0	a	1.0	ab	0	a
		Total – post-treatment							
Product	**Formulation per A**	**Dead TPS**		**Floating Seedlings**		**Dead TPS**		**Floating Seedlings**	
1. Untreated-no TPS	---	0	a	0	a	0.5	b	2.0	a
2. Belay 2.13 SC	5.5 oz. - preflood	0.5	a	0.25	a	0.75	ab	2.75	a
3. Dermacor X-100 5FS	2.0 fl. oz. - preflood	0.75	a	0.5	a	1.5	ab	6.25	a
4. Trebon 3G	6 lbs. – post-flood*	1.25	a	0.25	a	2.5	a	2.0	a
5. Copper sulfate	10 lbs. – post-flood*	1.75	a	1.0	a	0.75	ab	5.25	a
6. Dermacor X-100 5FS	2.50 oz/100 lbs. seed – seed treatment	1.0	a	1.33	a	1.0	ab	4.67	a
7. Untreated with TPS	---	1.0	a	1.5	a	0.75	ab	5.5	a
8. Warrior II	1.92 oz. – post-flood*	0.75	a	0.75	a	1.25	ab	2.75	a
9. Warrior II	1.92 oz. – early preflood	1.5	a	0.5	a	1.75	ab	2.25	a

* 1 day after the tadpole shrimp were introduced into the rings

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

Table 11. Established seedlings at end of study in tadpole shrimp control study – 2010.

Product	Formulation per A	Timing	Established Seedlings PVC Plot		Established Seedlings Ring Plot		Total Established Seedlings	
1. Untreated-no TPS	---	---	42.75	a	134.0	a	176.75	a
2. Belay 2.13SC	5.5 fl. oz.	preflood	30.25	ab	137.0	a	167.25	a
3. Dermacor X-100 5FS	2.0 fl. oz.	preflood	30.0	ab	140.0	a	170.0	a
4. Trebon 3G	6 lbs.	post-flood*	48.0	a	134.25	a	182.25	a
5. Copper sulfate	10 lbs.	post-flood*	33.25	ab	112.75	a	146.0	a
6. Dermacor X-100 5FS	2.50 oz/100 lbs. seed	seed treatment	37.3	ab	127.0	a	164.3	a
7. Untreated with TPS	---	---	22.75	b	100.5	a	123.25	a
8. Warrior II	1.92 oz.	post-flood*	32.75	ab	124.5	a	157.25	a
9. Warrior II	1.92 oz.	early preflood	34.0	ab	147.75	a	181.75	a

* 1 day after the tadpole shrimp were introduced into the rings
Means within columns followed by same letter are not significantly different; least significant difference test (P< 0.05).

Table 12. Rice water weevil natural infestation in tadpole shrimp treatment study, 2010.

Product	Formulation per A	Timing	% Scarred Plants – 24 June		% Scarred Plants – 1 July	
1. Untreated-no TPS	---	---	40.0	ab	21.5	b
2. Belay 2.13SC	5.5 fl. oz.	preflood	13.5	c	9.0	bcd
3. Dermacor X-100 5FS	2.0 fl. oz.	preflood	24.5	abc	8.0	bcd
4. Trebon 3G	6 lbs.	post-flood*	20.0	bc	8.0	bcd
5. Copper sulfate	10 lbs.	post-flood*	12.0	c	18.5	bc
6. Dermacor X-100 5FS	2.50 oz/100 lbs. seed	seed treatment	46.7	a	35.3	a
7. Untreated with TPS	---	---	27.0	abc	16.5	bc
8. Warrior II	1.92 oz.	post-flood*	20.0	bc	6.0	cd
9. Warrior II	1.92 oz.	early preflood	11.0	c	0.0	d

* 1 day after the tadpole shrimp were introduced into the rings

Table 13. Rice water weevil natural infestation in tadpole shrimp treatment study, 2010.

Product	Formulation per A	Timing	RWW per Core Sample – 19 July		RWW per Core Sample – 2 August		Avg.
1. Untreated-no TPS	---	---	2.5	a	1.4	ab	1.95
2. Belay 2.13SC	5.5 fl. oz.	preflood	0.1	b	0.7	ab	0.4
3. Dermacor X-100 5FS	2.0 fl. oz.	preflood	0.2	b	0.2	b	0.2
4. Trebon 3G	6 lbs.	post-flood*	0.4	b	1.0	ab	0.7
5. Copper sulfate	10 lbs.	post-flood*	0.9	ab	0.7	ab	0.8
6. Dermacor X-100 5FS	2.50 oz/100 lbs. seed	seed treatment	1.7	ab	2.0	a	1.85
7. Untreated with TPS	---	---	0.8	b	1.1	ab	0.95
8. Warrior II	1.92 oz.	post-flood*	0.1	b	0.1	b	0.1
9. Warrior II	1.92 oz.	early preflood	0.0	b	0.1	b	0.05

* 1 day after the tadpole shrimp were introduced into the rings

Table. 14. Yield results from tadpole shrimp study – 2010.

Product	Formulation per A	Timing	% Grain Moisture		Grain Yield (lbs./A)		Biomass (straw + grain) (t/A)	
1. Untreated-no TPS	---	---	24.75	a	7466	ab	12.3	a
2. Belay 2.13SC	5.5 oz./A	preflood	24.15	a	7657	ab	12.8	a
3. Dermacor X-100 5FS	2.0 fl. oz.	preflood	25.7	a	8666	a	13.8	a
4. Trebon 3G	6 lbs.	post-flood*	25.375	a	7346	ab	12.6	a
5. Copper sulfate	10 lbs.	post-flood*	25.85	a	6200	b	10.6	a
6. Dermacor X-100 5FS	2.50 oz/100 lbs. seed	seed treatment	24.47	a	6744	b	10.9	a
7. Untreated with TPS	---	---	24.6	a	6966	ab	10.7	a
8. Warrior II	1.92 oz.	post-flood*	25.95	a	6804	ab	12.3	a
9. Warrior II	1.92 oz.	early preflood	24.9	a	7947	ab	13.3	a

* 1 day after the tadpole shrimp were introduced into the rings

Table 15. RWW adult feeding damage in variety susceptibility comparison to RWW study, 2010.

Variety	RWW Status	% Scarred Plants - 24 June		% Scarred Plants - 1 July		Average
M-202	Not present	8.5	c	7.0	b	7.8
S-102	Not present	23.5	c	5.0	b	14.3
L-206	Not present	9.5	c	0.0	b	4.8
Calmati-202	Not present	11.0	c	2.0	b	6.5
M-202	Present	77.0	a	50.5	a	63.8
S-102	Present	61.3	ab	48.0	a	54.7
L-206	Present	54.0	b	44.0	a	49.0
Calmati-202	Present	59.0	ab	42.0	a	50.5

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

Table 16. RWW population level in variety susceptibility comparison to RWW study, 2010.

Variety	RWW Status	RWW Immatures per Core Sample – 19 July		RWW Immatures per Core Sample – 2 August		Average
M-202	Not present	0.1	b	0	c	0.0
S-102	Not present	0	b	0.05	c	0.03
L-206	Not present	0	b	0	c	0.0
Calmati-202	Not present	0	b	0	c	0.0
M-202	Present	2.0	a	0.8	b	1.4
S-102	Present	1.5	ab	1.7	a	1.6
L-206	Present	2.3	a	1.1	ab	1.7
Calmati-202	Present	0.98	ab	0.95	b	0.97

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

Table 17. Yield data in variety susceptibility comparison to RWW study, 2010.

Variety	RWW Status	% Grain Moisture		Grain Yield (lbs./A)		Yield Loss from RWW	Yield Loss per RWW Immature	Biomass (Straw+Grain) (t/A)	
M-202	Not present	22.7	a	7802.7	a	848.1	605.8	12.6	a
S-102	Not present	17.6	cd	6433.0	bc	252.7	158.0	9.8	bc
L-206	Not present	19.3	b	7302.3	ab	183.7	108.1	9.2	bc
Calmati-202	Not present	18.1	bcd	5226.5	c	---	---	9.2	bc
M-202	Present	22.0	a	6954.6	ab			10.8	ab
S-102	Present	17.1	d	6180.3	bc			8.9	bc
L-206	Present	18.9	bc	7118.6	ab			8.5	c
Calmati-202	Present	18.5	bc	5489.7	c			9.6	bc

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

Table 18. California rice cultivars evaluated in small plot study designed to evaluate susceptibility to RWW, 2010.

Variety	RWW Controlled	RWW Present at Natural Levels
1. L-206	X	X
2. S-102	X	X
3. M-104	X	X
4. M-208	X	X
5. M-205	X	X
6. M-202	X	X
7. M-206	X	X
8. M-401	X	X
9. Calhikari-201	X	X
10. Calmati-202	X	X
11. Calmochi-101	X	X
12. Calamylow-201	X	X

Table 19. RWW adult feeding damage in small plot variety susceptibility comparison to RWW study, 2010.

Variety	RWW Status	% Scarred Plants - 17 June		% Scarred Plants – 24 June		Average
L-206	Controlled	30.0	a	46.0	a	38.0
M-104	Controlled	23.5	a	28.0	bc	25.8
M-208	Controlled	32.5	a	39.0	abc	35.8
Calmati-202	Controlled	30.0	a	35.0	abc	32.5
Calhikari-201	Controlled	21.0	a	24.0	bc	22.5
M-401	Controlled	35.5	a	22.5	c	29.0
M-205	Controlled	34.5	a	23.0	bc	28.8
M-202	Controlled	33.0	a	40.0	ab	36.5
M-206	Controlled	23.5	a	30.0	abc	26.8
S-102	Controlled	34.0	a	33.5	abc	33.8
Calmochi-101	Controlled	38.0	a	30.0	abc	34.0
Calamylow-201	Controlled	30.0	a	30.0	abc	30.0
L-206	Present	27.0	a	26.0	bc	26.5
M-104	Present	39.5	a	24.5	bc	32.0
M-208	Present	31.5	a	37.0	abc	34.3
Calmati-202	Present	33.5	a	30.5	abc	32.0
Calhikari-201	Present	31.5	a	26.0	bc	28.8
M-401	Present	26.0	a	33.5	abc	29.8
M-205	Present	33.5	a	32.5	abc	33.0
M-202	Present	38.0	a	34.5	abc	36.3
M-206	Present	21.5	a	31.0	abc	26.3
S-102	Present	37.5	a	40.0	ab	38.8
Calmochi-101	Present	33.0	a	27.0	bc	30.0
Calamylow-201	Present	36.0	a	40.0	ab	50.5

Table 20. RWW population level in small plot variety susceptibility comparison to RWW study, 2010.

Variety	RWW Status	RWW Immatures per Core Sample – 21 July		RWW Immatures per Core Sample – 6 August		Average
L-206	Controlled	0.06	d	0.00	c	0.03
M-104	Controlled	0.00	d	0.05	c	0.03
M-208	Controlled	0.00	d	0.05	c	0.03
Calmati-202	Controlled	0.10	cd	0.05	c	0.08
Calhikari-201	Controlled	0.25	cd	0.00	c	0.13
M-401	Controlled	0.10	cd	0.05	c	0.08
M-205	Controlled	0.05	d	0.95	b	0.50
M-202	Controlled	0.15	cd	0.00	c	0.08
M-206	Controlled	0.15	cd	0.00	c	0.08
S-102	Controlled	0.05	d	0.00	c	0.03
Calmochi-101	Controlled	0.05	d	0.00	c	0.03
Calamylow-201	Controlled	0.05	d	0.00	c	0.03
L-206	Present	2.24	ab	1.39	b	1.81
M-104	Present	1.50	bcd	0.60	b	1.05
M-208	Present	1.41	bcd	0.80	b	1.11
Calmati-202	Present	1.30	bcd	1.50	b	1.40
Calhikari-201	Present	1.25	bcd	0.40	bc	0.83
M-401	Present	3.55	a	3.20	a	3.38
M-205	Present	0.70	bcd	0.90	b	0.80
M-202	Present	1.35	bcd	1.00	b	1.18
M-206	Present	1.85	bc	0.45	bc	1.15
S-102	Present	1.30	bcd	0.65	b	0.98
Calmochi-101	Present	1.00	bcd	0.90	b	0.95
Calamylow-201	Present	1.44	bcd	0.83	b	1.13

Table 21. Yield data in small plot variety susceptibility comparison to RWW study, 2010.

Variety	RWW Status	% Moisture		Grain Yield (lbs./A)		Grain Yield Loss from RWW (lbs./A)	Grain Yield Loss per RWW Larva (lbs./A)	% Yield Loss per RWW Larva
L-206	Controlled	16.4	ab	6068	g-j	0	---	---
M-104	Controlled	15.5	ab	6502	d-h	0	---	---
M-208	Controlled	17.1	a	7520	b	402	363.4	4.8
Calmati-202	Controlled	9.7	d	6312	e-j	215	153.2	2.4
Calhikari-201	Controlled	14.6	ab	6346	e-i	743	900.5	14.2
M-401	Controlled	10.0	cd	8375	a	1472	436.0	5.2
M-205	Controlled	16.7	ab	7253	bc	613	765.7	10.6
M-202	Controlled	18.1	a	7532	b	930	791.9	10.5
M-206	Controlled	18.4	a	6703	c-g	43	37.1	0.6
S-102	Controlled	17.3	a	5798	hijk	330	338.1	5.8
Calmochi-101	Controlled	15.4	ab	6206	e-j	505	531.1	8.6
Calamylow-201	Controlled	16.8	ab	6749	c-g	0	---	---
L-206	Present	16.9	ab	6153	e-j			
M-104	Present	15.1	ab	6646	c-g			
M-208	Present	16.9	ab	7118	bcd			
Calmati-202	Present	10.5	cd	6097	f-j			
Calhikari-201	Present	15.6	ab	5603	jk			
M-401	Present	13.2	bc	6903	bcde			
M-205	Present	16.3	ab	6641	c-g			
M-202	Present	17.9	a	6602	c-g			
M-206	Present	17.1	a	6661	c-g			
S-102	Present	17.4	a	5468	k			
Calmochi-101	Present	16.5	ab	5702	ijk			
Calamylow-201	Present	15.3	ab	6852	b-f			

Table 22. RWW treatments investigated in tillering study, 2010.

Trt.	Cultivar	RWW Infestation (Num. per Plant)	Intended Damage	When
1	M-202	0.2 RWW	slight damage	infest at 3-4 leaf stage
2	M-202	0.6 RWW	severe damage	infest at 3-4 leaf stage
3	M-202	0.0 RWW	slight hand pruning of roots	4 leaf stage - soon after plants break through water
4	M-202	0.0 RWW	severe hand pruning of roots	4 leaf stage - soon after plants break through water
5	M-202	0.0 RWW	none	---
6	M-202	0.6 RWW	treat with insecticide at 7-10 days after infestation to stop damage	infest at 3-4 leaf stage
7	M-202	0.6 RWW	treat with insecticide at 21 days after infestation to stop damage	infest at 3-4 leaf stage
8	M-202	0.0 RWW	severe hand pruning of roots	at green ring stage (or a few days before)
9	IR-36	0.0 RWW	none	---
10	IR-36	0.6 RWW	severe damage	infest at 3-4 leaf stage

Table 23. Leaf scarring and RWW levels in RWW / rice tillering study, 2010.

Trt.	Cultivar	RWW Infestation (Num. per Plant)	% Scarred Plants - 29 June		% Scarred Plants – 6 July		Average Scarring	RWW Immatures per Core Sample – 13 August	
1	M-202	0.2 RWW	41.5	c	41.5	b	41.5	2.55	ab
2	M-202	0.6 RWW	70.0	ab	68.0	a	69.0	3.74	a
3	M-202	0.0 RWW	4.0	d	4.0	c	4.0	0.45	c
4	M-202	0.0 RWW	4.0	d	2.0	c	3.0	0.4	c
5	M-202	0.0 RWW	8.0	d	4.5	c	6.3	0.5	c
6	M-202	0.6 RWW	73.5	a	69.0	a	71.3	0.3	c
7	M-202	0.6 RWW	66.5	ab	69.5	a	68.0	4.25	a
8	M-202	0.0 RWW	3.0	d	1.0	c	2.0	0.2	c
9	IR-36	0.0 RWW	1.5	d	2.0	c	1.8	0.2	c
10	IR-36	0.6 RWW	57.0	b	72.0	a	64.5	1.9	bc

Table 24. Rice yield data from RWW / rice tillering study, 2010.

Trt.	Cultivar	RWW Infestation (Num. per Plant)	Number of Stems per Ring		% Moisture		Grain Yield (lbs./A)		Biomass (straw + grain) (t/A)	
1	M-202	0.2 RWW	272.8	b	31.0	a	3103	a	8.7	bc
2	M-202	0.6 RWW	403.0	a	33.4	a	2360	a	10.1	ab
3	M-202	0.0 RWW	340.5	ab	28.6	a	2549	a	11.1	a
4	M-202	0.0 RWW	345.5	ab	27.8	a	2556	a	11.1	a
5	M-202	0.0 RWW	310.8	ab	27.3	a	2767	a	11.5	a
6	M-202	0.6 RWW	362.3	ab	28.5	a	2359	a	10.3	ab
7	M-202	0.6 RWW	362.5	ab	29.6	a	2411	a	9.0	b
8	M-202	0.0 RWW	333.3	ab	27.5	a	2573	a	9.8	ab
9	IR-36	0.0 RWW	362.8	ab	38.5	a	1807	a	7.0	c
10	IR-36	0.6 RWW	355.3	ab	30.5	a	2251	a	5.0	d

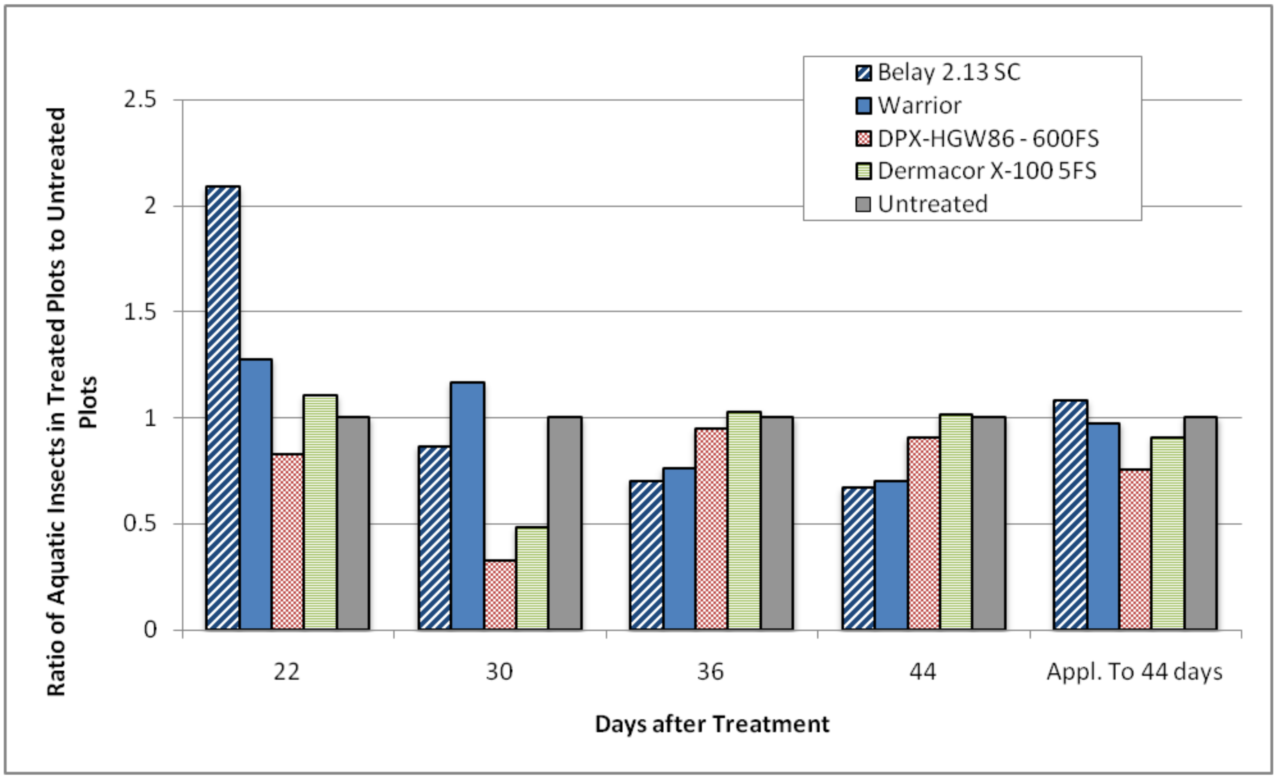

Figure 1. Influence of preflood insecticide applications on populations of aquatic insects from floating barrier trap samples in rice, 2009.

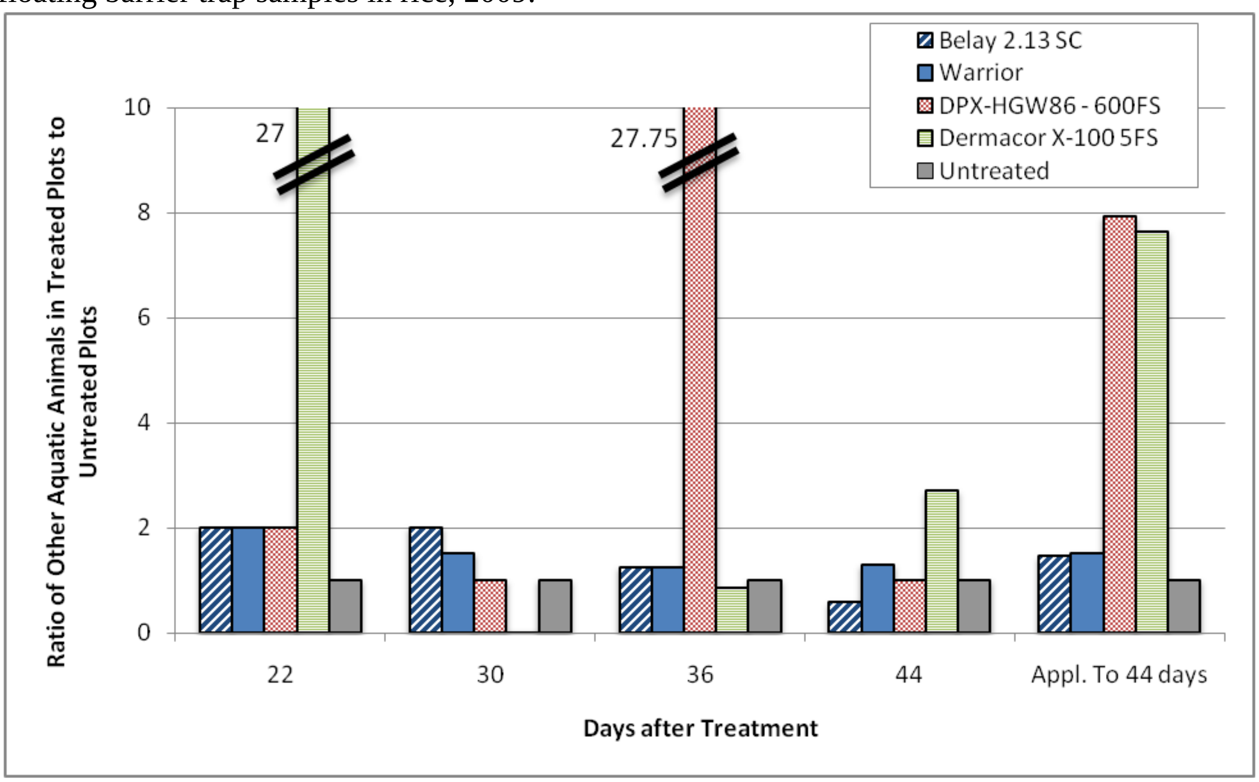

Figure 2. Influence of preflood insecticide applications on populations of aquatic animals (excluding insects) from floating barrier trap samples in rice, 2009.

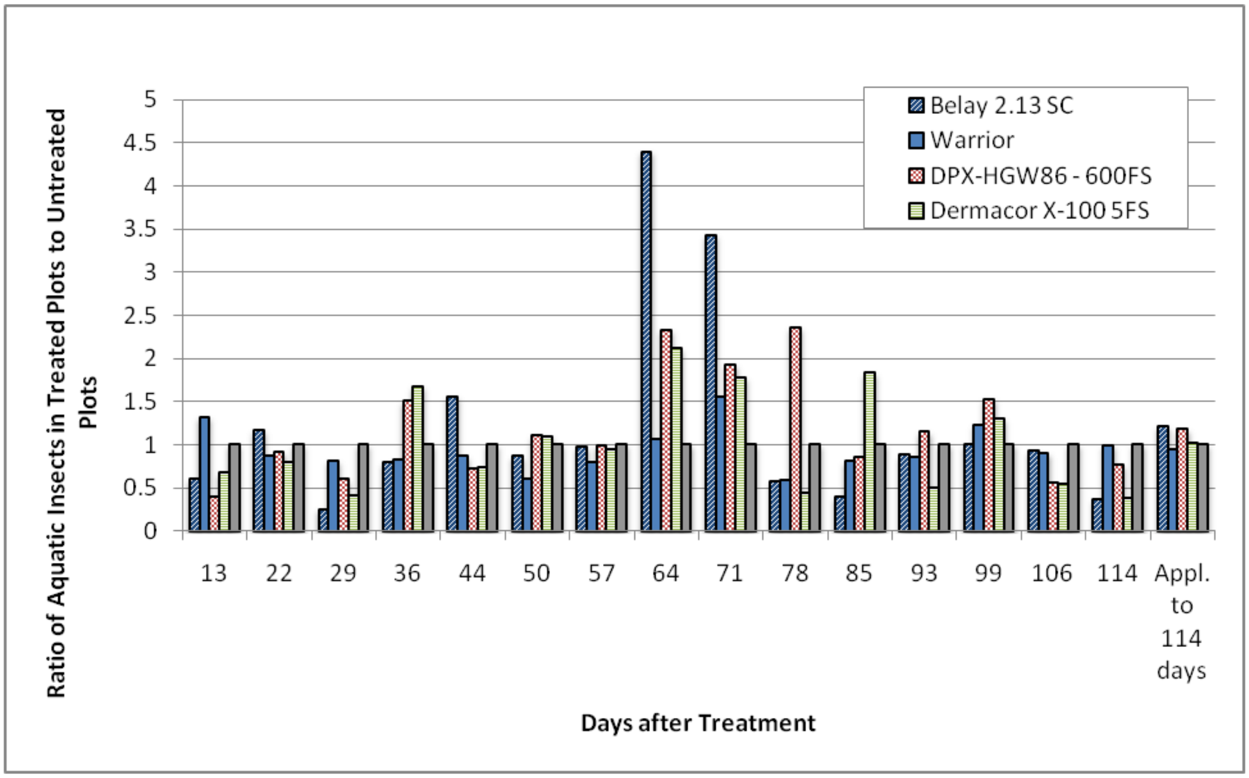

Figure 3. Influence of preflood insecticide applications on populations of aquatic insects from quadrant samples in rice, 2009.

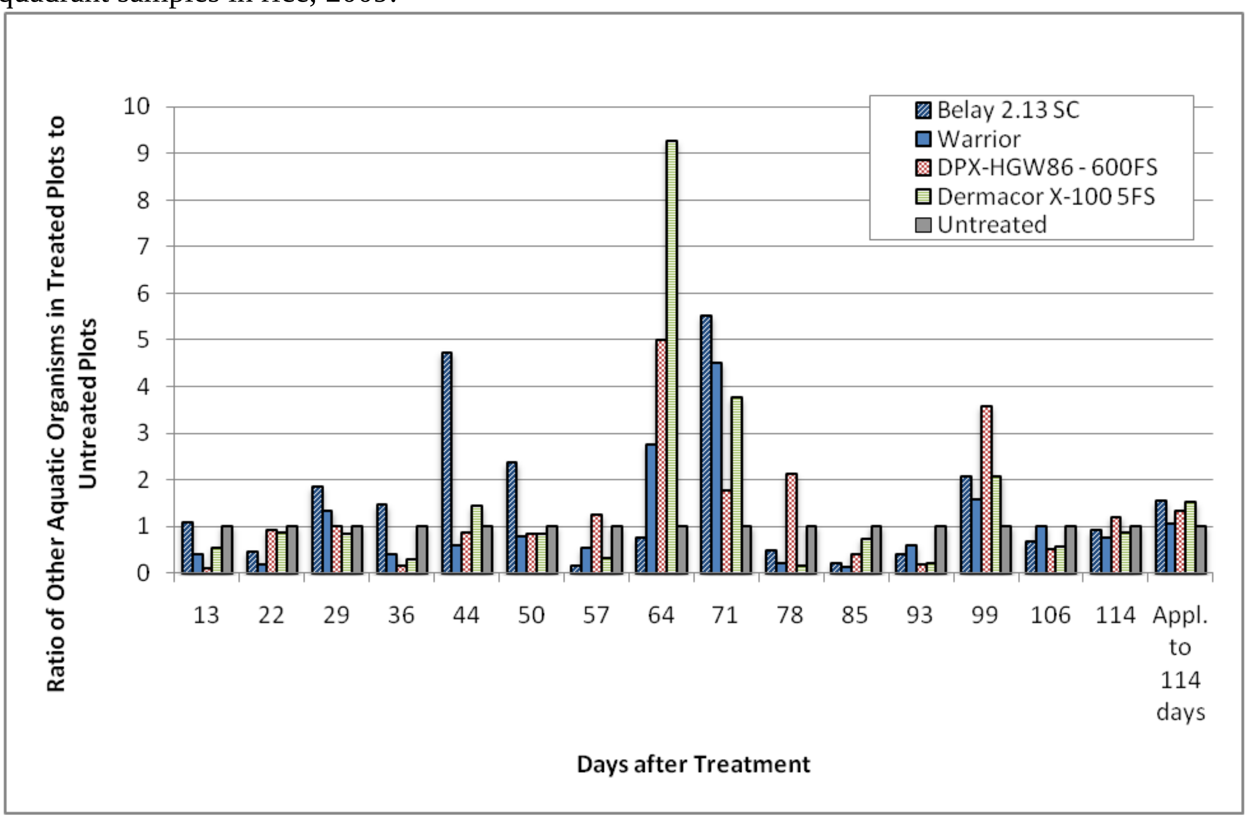

Figure 4. Influence of preflood insecticide applications on populations of aquatic animals (excluding insects) from quadrant samples in rice, 2009.

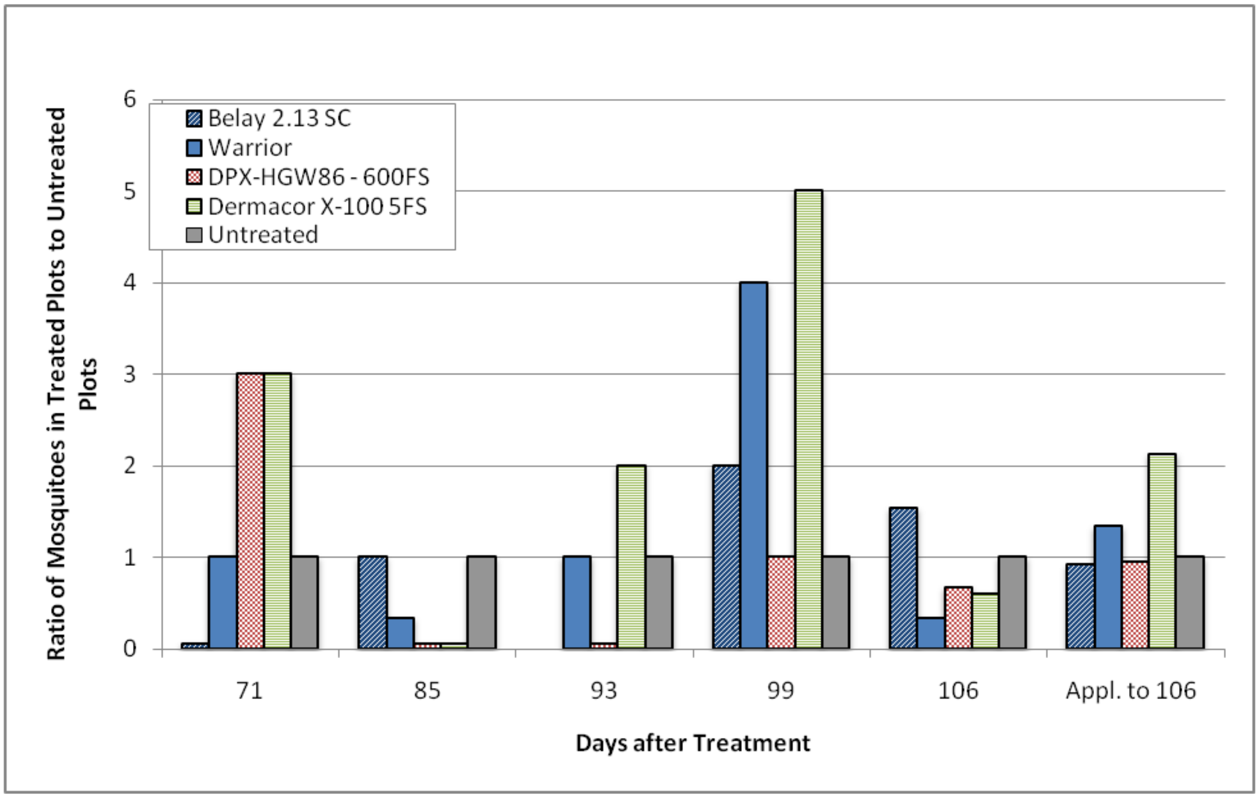

Figure 5. Influence of preflood insecticide applications on populations of mosquito larvae from mosquito dip samples in rice, 2009.

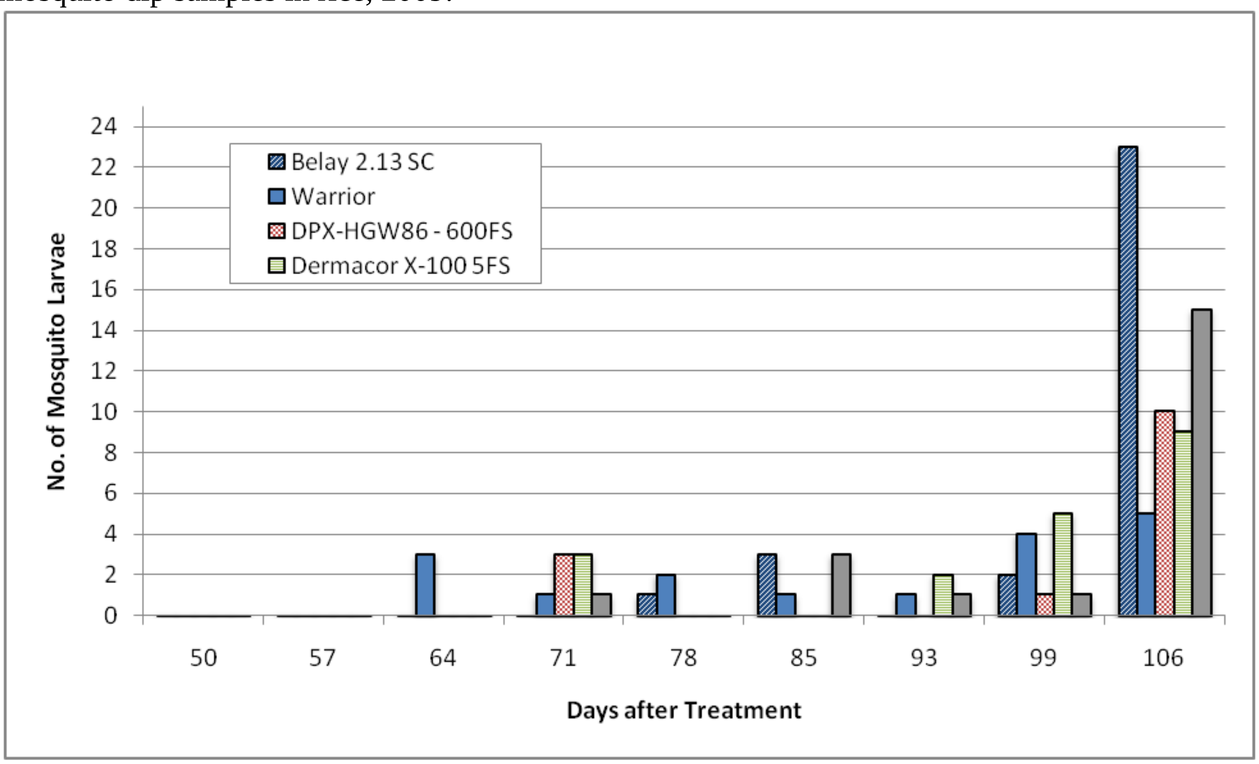

Figure 6. Influence of preflood insecticide applications on populations of mosquito larvae from mosquito dip samples in rice, 2009.

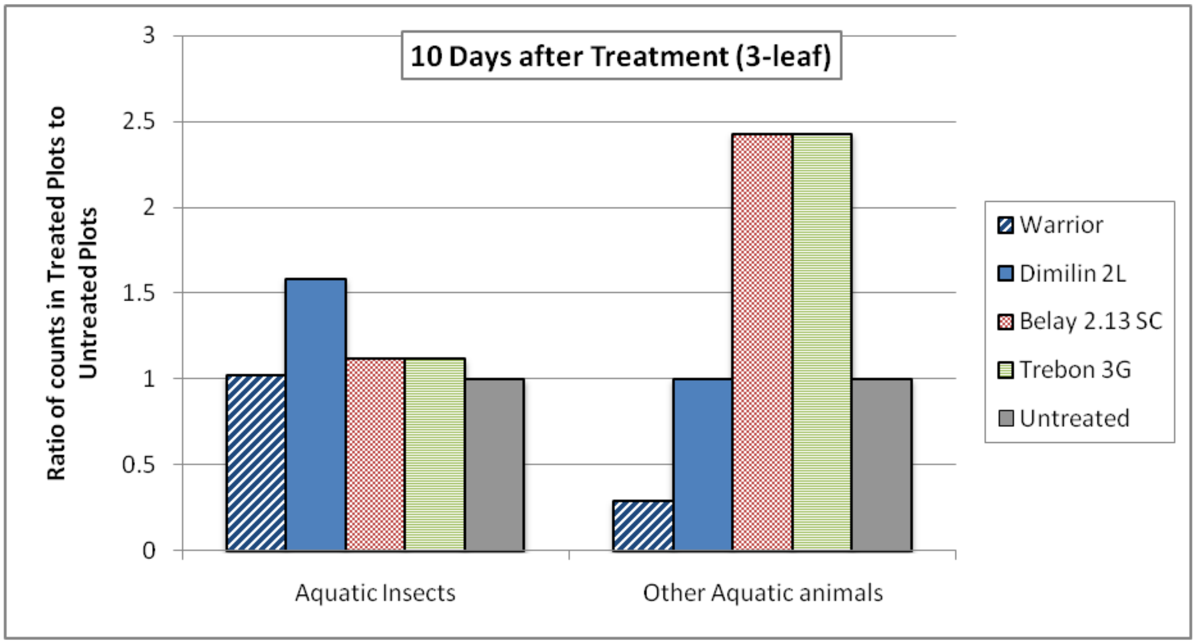

Figure 7. Influence of post-flood (3-leaf) insecticide applications on populations of aquatic insects from floating barrier trap samples in rice, 2009.

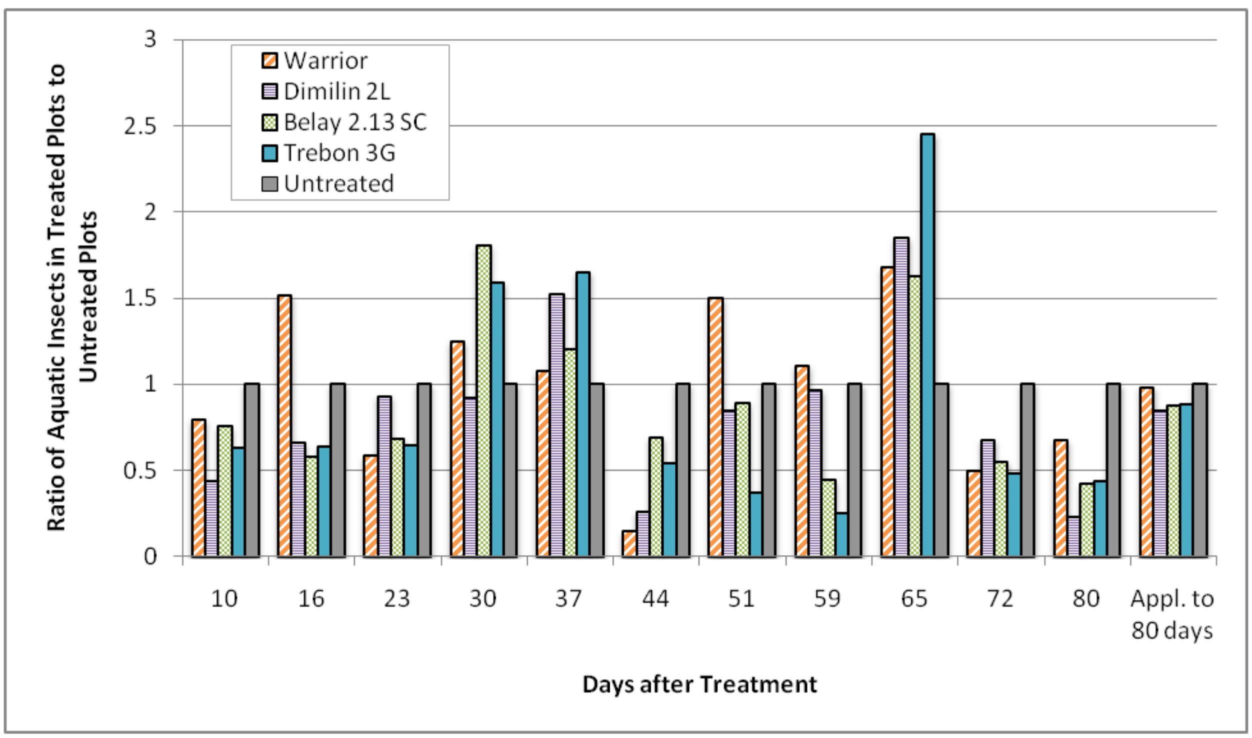

Figure 8. Influence of post-flood (3-leaf) insecticide applications on populations of aquatic insects from quadrant trap samples in rice, 2009.

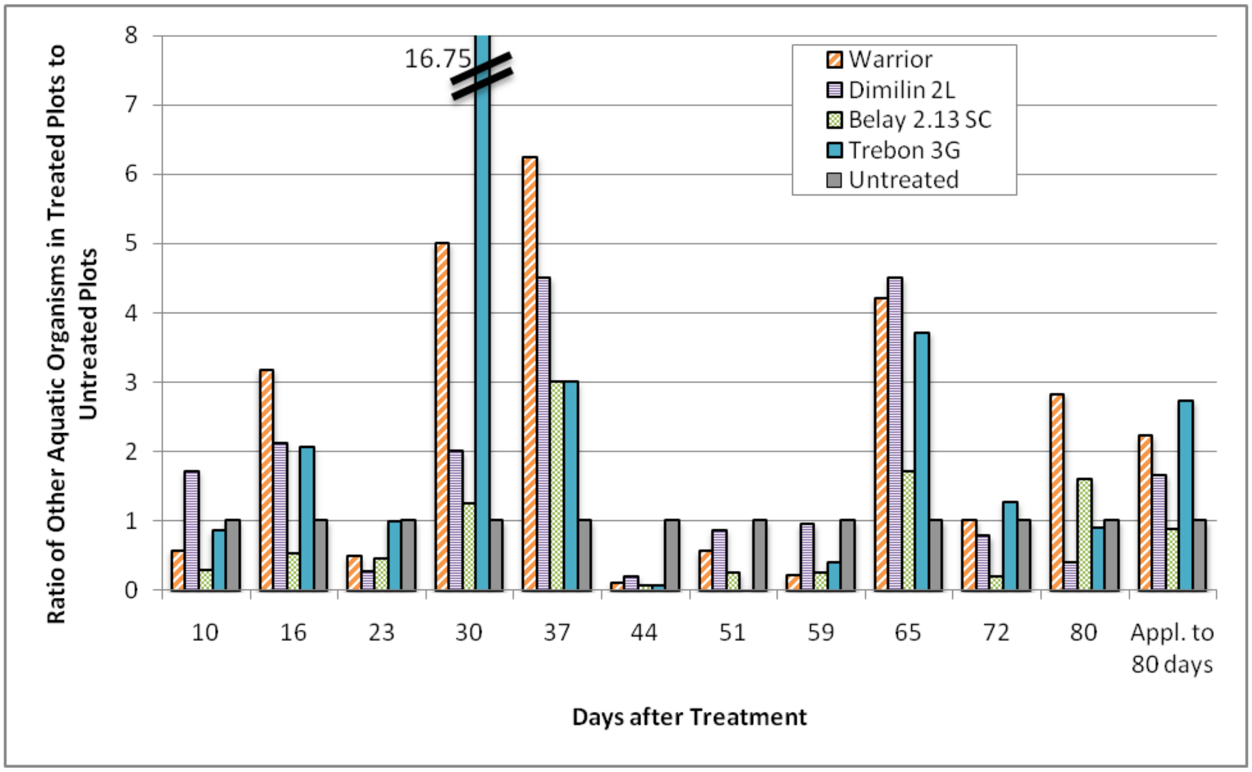

Figure 9. Influence of post-flood (3-leaf) insecticide applications on populations of aquatic animals (excluding insects) from quadrant trap samples in rice, 2009.

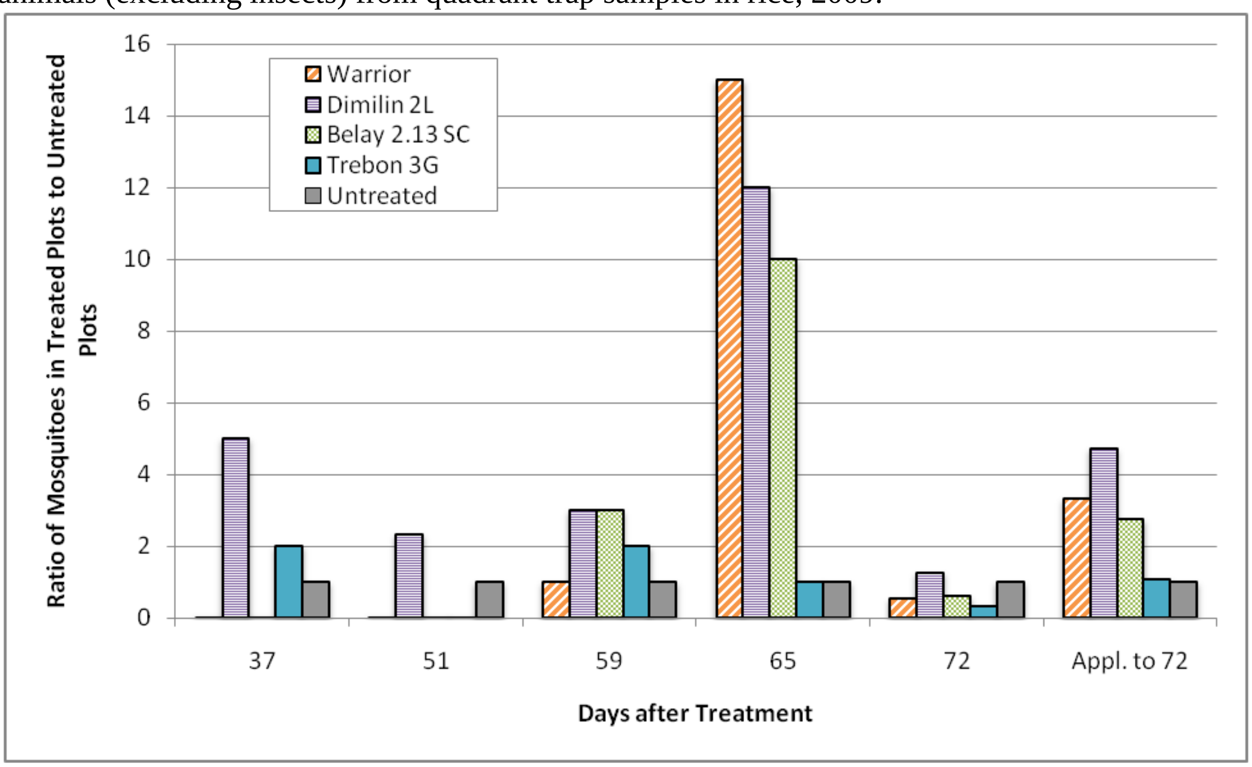

Figure 10. Influence of postflood (3-leaf stage) insecticide applications on populations of mosquito larvae from mosquito dip samples in rice, 2009.

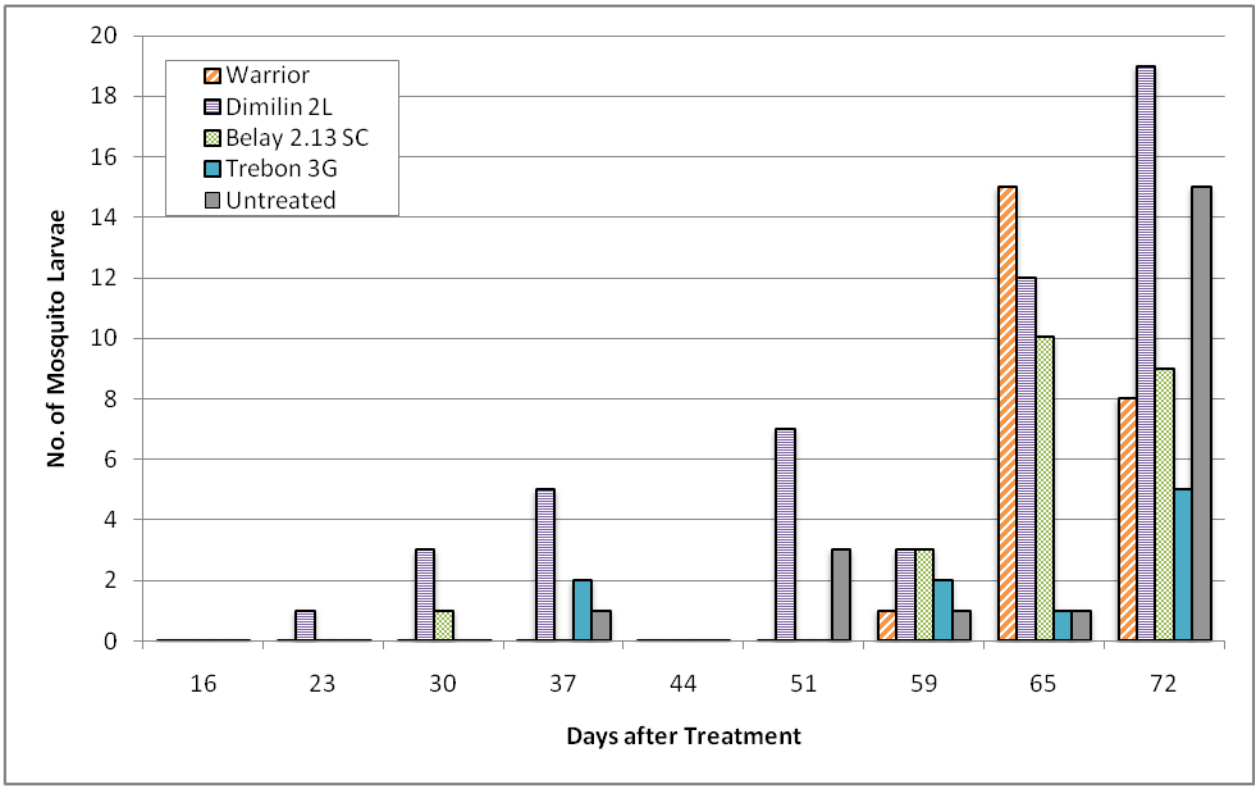

Figure 11. Influence of postflood (3-leaf stage) insecticide applications on populations of mosquito larvae from mosquito dip samples in rice, 2009.

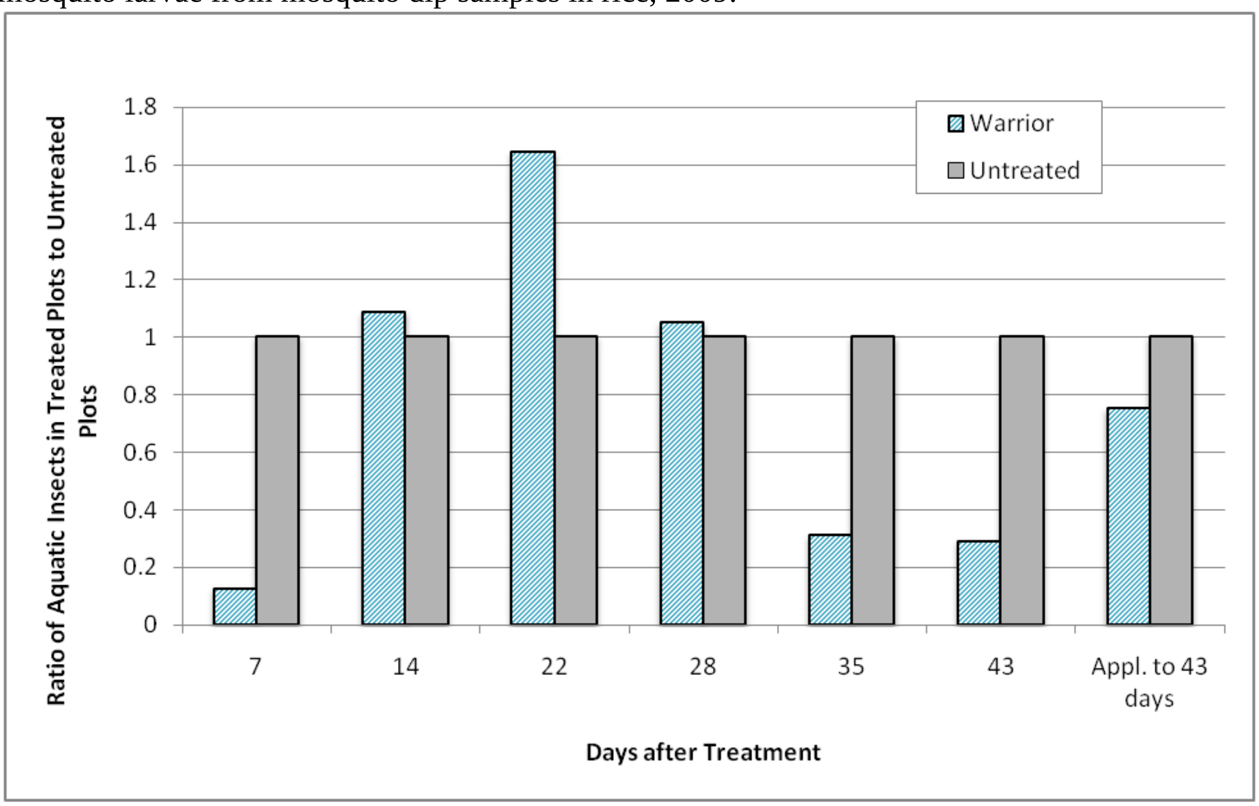

Figure 12. Influence of insecticide applications (armyworm timing) on populations of aquatic insects from quadrant trap samples in rice, 2009.

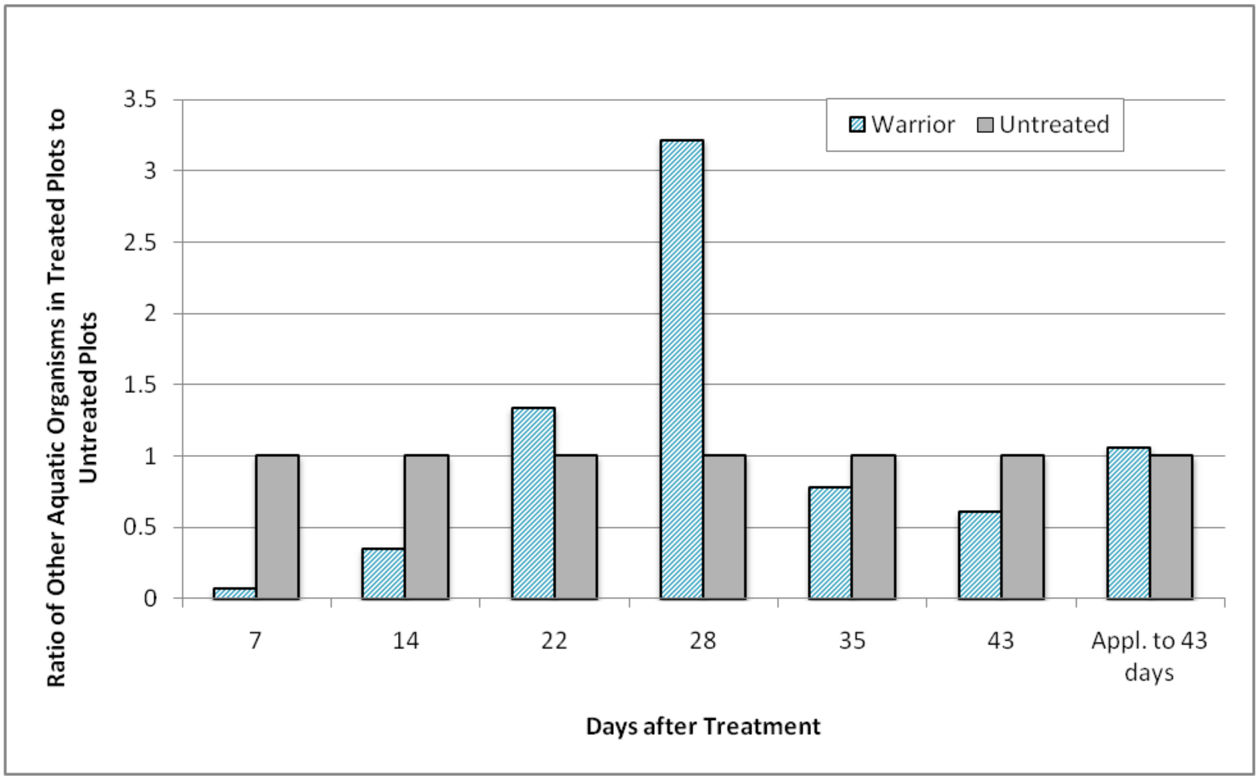

Figure 13. Influence of insecticide applications (armyworm timing) on populations of aquatic animals (excluding insects) from quadrant trap samples in rice, 2009.

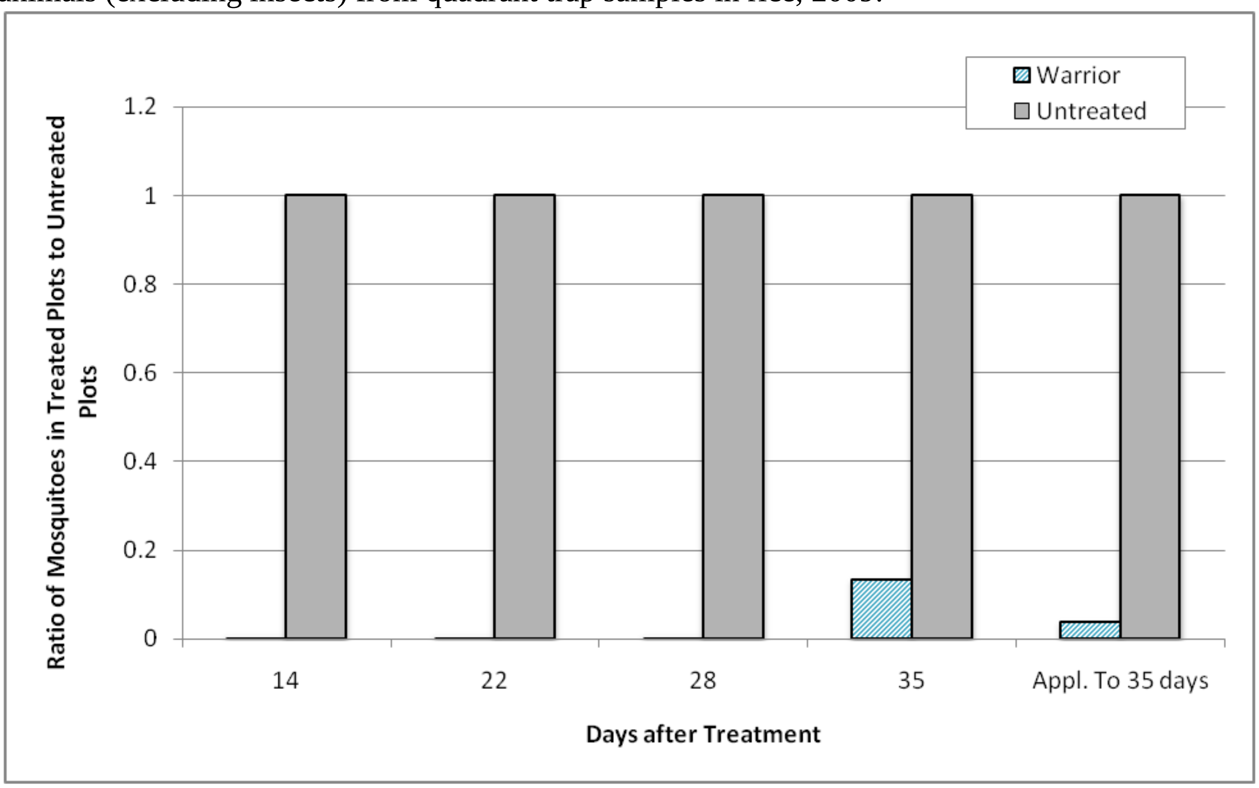

Figure 14. Influence of insecticide applications (armyworm timing) on populations of mosquito larvae from mosquito dip samples in rice, 2009.

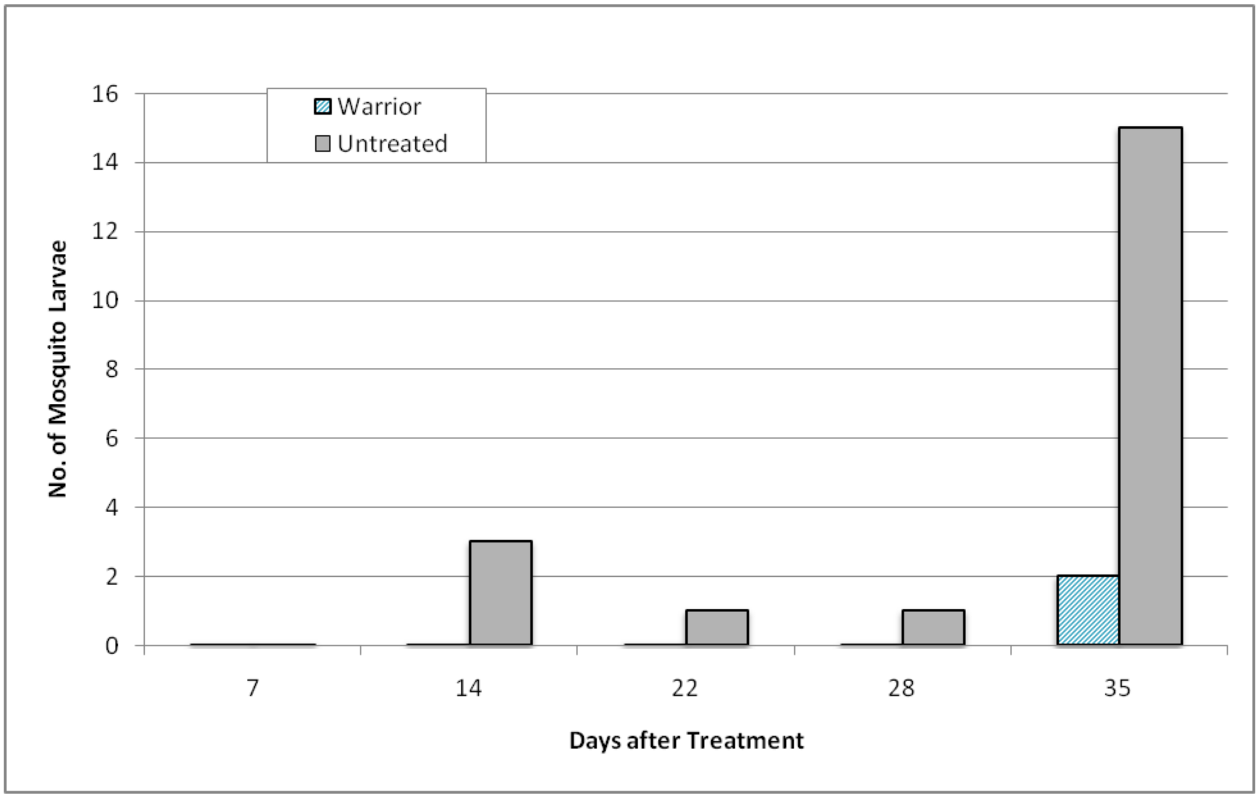

Figure 15. Influence of insecticide applications (armyworm timing) on populations of mosquito larvae from mosquito dip samples in rice, 2009.

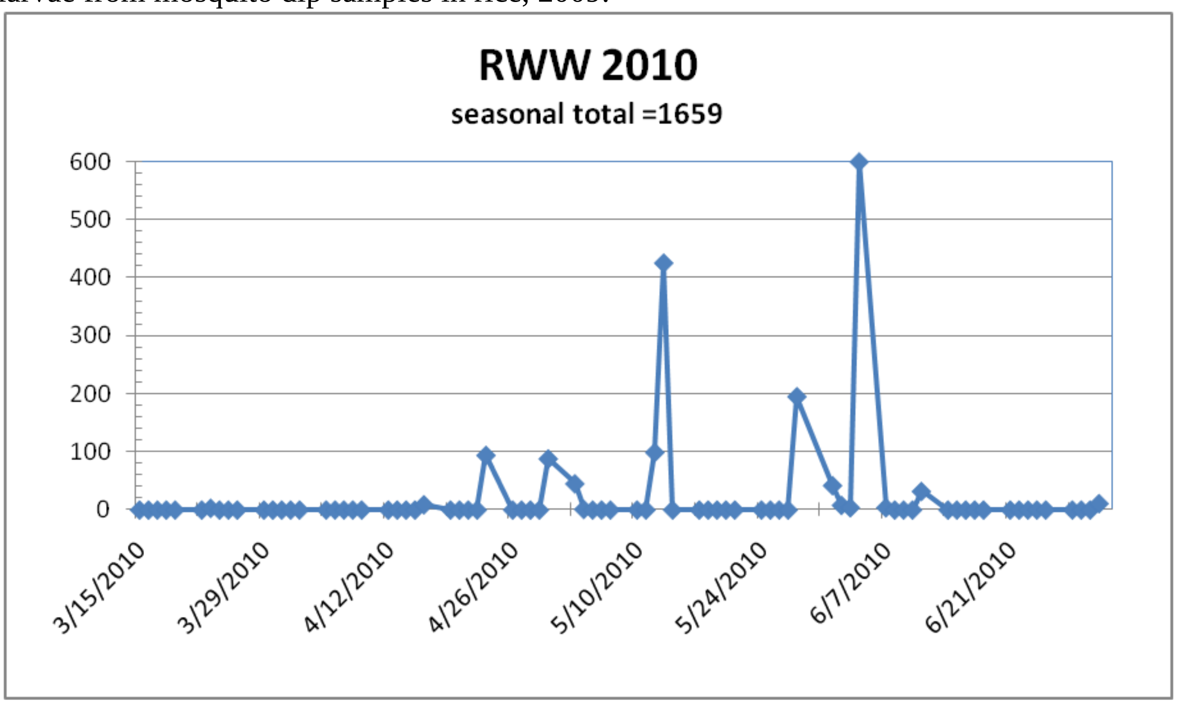

Figure 16. Rice water weevil flight as monitored with black light trap at RES, 2010.