ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE

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PROJECT TITLE: Rice protection from invertebrate pests.

PROJECT LEADER AND PRINCIPAL UC INVESTIGATOR:
L. D. Godfrey, Extension Entomologist/Entomologist in Ag. Expt. Stn.;
Evan Goldman, Staff Research Associate
Department of Entomology, One Shields Avenue,
University of California, Davis 95616

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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) evaluation of experimental insecticides as a rescue treatment in rice for rice water weevil control

1.3) Efficacy of experimental products for Rice Water Weevil with a natural infestation.
1.3.a) evaluation of Coragen in replicated field plots
1.3.b) evaluation of Belay in field plots

1.4) Evaluation of a biological insecticide for Rice Water Weevil in greenhouse studies.

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

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

1.7) Management of Rice Water Weevil through control of adults infesting levees.

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) Study the impact of seeding rate and rice variety on the yield response to Rice Water Weevil damage.

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

SUMMARY OF 2011 RESEARCH BY OBJECTIVE:

Objective 1:

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

1.1, 1.2) Research for subobjectives 1.1 and 1.2 was conducted within one plot area and the results and discussion for this study will be considered together. The data will be reported in its entirety for ease of comparison across treatments and the conclusion from each sub-objective will be reported. Each treatment was replicated four times. Twenty-four treatments (a total of 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.

Methods:

Testing was conducted with 'M-202' in 10.7 sq. ft aluminum rings. The plots were flooded on 19 May and seeded on 20 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, followed by 22 hrs. in water, drained, and held for 24 hrs. The Clorox was for Bakanae control. The application timings were as follows:

13 May, early pre-flood treatments
19 May, pre-flood (PF) applications
14 June, 3-leaf stage treatments
26 June, 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 10 June and 6 adults into each ring on 22 June. The standard production practices were used. Copper sulfate for algal management and herbicides were applied in mid 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: 16 June
Adult Leaf Scar Counts: 24 June
Larval Counts: 11 July and 25 July
Rice Yield: 12,14 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: ANOVA of transformed data and least significant differences test ($\rho < 0.05$). Raw data reported herein.

Plot Design:

Randomized Complete Block

Results:

Rice Emergence

There were slight differences among treatments in terms of seedling vigor and emergence but these were almost certainly not related to the insecticide treatments (Table 2). The rating ranged from 2.63 to 3.13 which was a good stand of approximately 100 seedlings per ring. Given the poor season for germination and establishment, this stand was very good. There were, statistically, some significant differences among treatments but those with the lowest ratings, Declare at 1.54 oz. and Dimilin, were applied at the 3-leaf stage on 14 June which was only 2 days before the stand was evaluated and, of course, the treatments had no effect on the stand. Therefore, no phytotoxicity was seen from any of the treatments. We aim for 90-95 seedlings per ring and a rating of 3.0 is approximately 100 seedlings, so the stand achieved was acceptable.

Adult Leaf Scar Counts

Rice plant leaf scarring ranged from 11.5 to 86.5% across the treatments (Table 2). Research in California has shown that a damaging level of RWW larvae is associated with a scar incidence of 20-25%. The longitudinal leaf scars from RWW adults result in removal of only a small amount of leaf tissue and do not have any effects on plant growth and yield. However, these scars are very diagnostic of RWW adult damage. This damage is evaluated as a means to determine if the insecticide treatments have effects on adult RWW. These evaluations were done on 24 June which was before the rescue applications were made. The 3-leaf stage applications were made on 14 June so some leaf damage could have already occurred before the application and have been counted. The percentage leaf scarring evaluations are done by examining the two newest leaves for damage so as to minimize this confounding factor. If the leaf scarring is reduced, the insecticide most likely has toxicity to adults. This is particularly important and interesting when evaluating preflood and soil-applied treatments. If the leaf scarring is not reduced but the larval population is reduced, then the insecticide acts by directly killing larvae. Scarring was highest in Mustang Max early preflood treatment at 86.5% although the values in several other treatments were statistically the same. Leaf scarring in the untreated plots averaged 61.5% which was also in the highest group of scarring values. Values were low (less than 20%) in the Declare 1.54 oz. (the high rate of Declare had a value just over 20%), all three rates of Belay applied at the 3-leaf stage, and Mustang Max applied at the 3-leaf stage. Warrior applied at the 3-leaf stage had a leaf scarring value of 23%. Belay applied preflood did not reduce the leaf scarring as much as the Belay 3-leaf stage treatments. Dermacor applied at the 3-leaf stage reduced leaf scarring slightly more than the same product applied preflood, although the active ingredient did not affect leaf scaring as much as most of the other insecticides.

Larval Counts

RWW larval counts were made twice during the season (Table 3). This is done to insure that at least one of the sample dates coincides with the population peak as well as so we can look at residual control from products – sometimes a product initially reduces the larval population but does not provide residual control. In 2011, populations were lower than in past years but the impact of the larval feeding on the plant, i.e., plant stunting, dislodging, and chlorosis, was as severe as I have seen in recent years. In the untreated rings, several plants floated to the surface from lack of roots to anchor them. The environmental conditions after seeding were very poor. This delayed germination and emergence and there was a 2-week period after seeding with minimal activity. This resulted in the RWW infestation and 3-leaf stage applications being later, compared with seeding, than normal. Also, it lengthened the time from the preflood applications to occurrence of RWW larvae. This appears to have hindered the performance of some of the preflood treatments. Finally, root growth was likely hindered which inhibited, to some extent, larval survival and establishment as well maximized the impacts of larval feeding on the plant (root biomass was "at a premium" so any loss due to larval feeding was critically shown by the plant). This may have also inhibited the plants/roots from uptaking systemic insecticides. During a "normal" year, the rice has reached the 3-leaf stage and ready for an application ~17 days after seeding whereas this interval was 24 days in 2010.

RWW levels in the untreated plots averaged 0.65 and 0.85 per core sample in the first and second sample dates, respectively (Table 3). In both samples, these values were the highest among the 24 treatments. In the first sampling, RWW levels were lower in 16 of the treatments compared with the untreated and this value was 18 treatments in the second sampling. Looking at the average of the two sample dates, all the pyrethroid preflood and early preflood treatments were very effective. This included Warrior, Mustang Max, and Declare. The standard registered treatments, Warrior and Mustang Max at the 3-leaf stage were also very effective. Dimilin and Declare 3-leaf (both rates) were numerically slightly less effective but still overall performed well. Belay was less effective as a preflood application than the 3-leaf application. The preflood application (all three rates) of Belay did not provide acceptable RWW control whereas the 3-leaf stage applications (all three rates) performed adequately. Dermacor provided similar control of RWW with the preflood and 3-leaf stage application methods. In both cases, the 1.97 oz. rate was less effective than the 2.46 oz. rate. The rescue application timings of Belay, especially the 5.5 oz. rate, and Dermacor provided moderate control of RWW. The efficacy was less than at the 3-leaf stage as would be expected but the control seen could still be useful in some cases.

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 19.5 to 21.7% (Table 4). Grain moisture in the untreated plots was 21.2%, which was one of the highest values indicating the delayed maturity and stress from RWW. Rice grain yields ranged from ~2330 to 5800 lbs./A. Overall these yield values were very low. The yield in the untreated plots was the lowest (2330 lbs./A) and only two treatments (Dimilin and Dermacor at 5-6 leaf stage) had yields similar to the untreated. Yields in the following treatments were greater than 5000 lbs./A – Warrior (early preflood and 3-leaf), Belay (5.5 oz. both 3-leaf and preflood and 4.5 oz. 3-leaf), Mustang Max (early preflood), Declare (3-leaf at 2.05 oz.), and Dermacor (1.97 oz. at 3-leaf stage).

In summary, the effects of the treatments were as follows:

1.) Dimilin had no effect on adult feeding which is expected since it sterilizes the females and prevents viable eggs. Larval control and protection of yield were both moderate – about 70% larval control and one of the lower yields.

2.) Warrior II (as well as the other pyrethroid products) continues to provide excellent RWW control. Warrior showed very good flexibility with good results via a preflood application (either 1 week before or immediately before flooding) as well as a conventional 3-leaf stage application. The preflood applications had minimal effects on adult feeding. Larval control was universally excellent in the 95-100% range and yield values were very good (averaging ~5350 lbs./A).

3.) Mustang Max applied at either the preflood immediately before flooding, at the early preflood timing 1 week before flooding, or at the 3-leaf stage all effectively reduced RWW larval populations. Adult feeding was not affected by the two earlier timings but was reduced by 3-leaf stage application. RWW control was in the 85-93% range. Yields averaged ~4800 lbs/A which was a doubling of the yield in the untreated. The favorable results from the preflood applications were a switch from 2010 when the results were not promising with this timing and Mustang Max.

4.) The active ingredient in Declare was registered in rice several years ago but never really marketed. This active ingredient has recently been acquired by another company and they are promoting it in California rice. It is within the pyrethroid chemistry. The impacts on adult feeding were similar to the other pyrethroids – slight reduction from the preflood application and strong reduction from the 3-leaf stage application. Larval results were good albeit slightly less effective than Mustang Max and yield results were very comparable to Mustang Max. Two rates were tested for the 3-leaf stage application and there are no obvious differences between them.

5.) Belay was evaluated preflood (3 rates), at the 3-leaf stage (3 rates), and at the 5-6 leaf stage as a rescue treatment (2 rates). The preflood applications "struggled" in terms of performance. The possible reasons for this result were discussed earlier. The 3-leaf stage applications produced good results for RWW larval control and very good yield results. The rescue timing showed about 60% larval control and a good increase in yield. This clearly would not be a recommended timing but appears to have a fit in some situations. Overall, Belay did not perform as well as in previous years.

6.) Dermacor was studied using three application methods – preflood (2 rates), 3-leaf stage (2 rates) and 5-6 leaf stage (1 rate). Only the 3-leaf stage timing had any effect on leaf scarring by adults. For RWW control, there was a rate response with the preflood and 3-leaf stage applications and the high rate in both cases gave good control. The rescue timing produced about 60% RWW larval control. Grain yield with the two earlier timings averaged about 4900 lbs./A.

In summary, the registered pyrethroid products continue to provide excellent RWW control. The flexibility of preflood (with at least 5-7 days latitude of application before flooding) for Warrior is useful. Dimilin performance appears to be acceptable albeit slightly less than the pyrethroids. Belay, for the second consecutive year, provided marginal control of RWW with a preflood application. Early-season conditions for rice germination and establishment in 2010 and 2011 were poor and this could perhaps account for the less than desired performance with Belay. Belay applied at the 3-leaf stage provided good RWW control. Dermacor controlled RWW well preflood and with the 3-leaf stage application with the higher rate (2.46 oz. [0.1 lbs. AI/A]). The 1.97 oz. rate appeared to be lacking.

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

Testing in the ring plots at the Rice Experiment Station is useful to screen several 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.

1.3.a) Evaluation of Coragen in replicated field plots

In 2011, Coragen was evaluated utilizing 600 sq. ft. plots. Three rates were tested as shown below (along with an untreated) and each treatment was replicated four times. The active ingredient in Coragen is the same as in Dermacor tested in the ring study, i.e., Rynaxypyr. The treatments were applied preflood. A 5 foot untreated buffer separated all plots; rynaxapyr does not move once applied to the soil thus the integrity of the treatments was maintained even though no barrier/levees were used. Treatments evaluated were as follows:

Product	**Rate**	**Timing**
Coragen	0.08 lbs. AI.A	Preflood
Coragen	0.10 lbs. AI.A	Preflood
Coragen	0.12 lbs. AI.A	Preflood
Untreated	---	---

Methods:

Leaf scarring, RWW population levels, and grain yields were evaluated as follows on 24 June, 13 July and 27 July, and 29 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 generally good in this study except for the east end on the plot. Two Coragen plots were impacted. A very high RWW infestation was present in this area. There was not enough space for a "standard" product comparison so data collected in another study conducted in the two neighboring basins to the south were used for comparison purposes. These plots ('M-202') were treated with Warrior II at 2.56 fl. oz./A + Dermacor 2.5 fl.oz./100 lbs. seed. In this study, we were trying to achieve the very best RWW control possible thus the two product application. This was used to show the yield potential for M-202 in 2011.

The stand establishment period in 2011 was very poor. After the soil dried to allow us to set-up the plots, there was a few day period of nicer weather. This allowed us to get the plots set-up, flooded, and seeded. This was followed by another 2 weeks of poor weather and the seeds did very little in terms of germination and establishment. This also appeared to inhibit the efficacy of the preflood treatments. Why? There are two possible reasons. The cool weather, once the seedlings did establish, may have caused the plants to have small root systems and this inhibited the plant from picking up the insecticide. In addition, the cool weather lengthened the time from seeding to when the insecticide was "needed" for rice water weevil control and perhaps the insecticide dissipated in this time. RWW levels (adult feeding scars and soil core data) and yield data are shown below.

In summary, the Coragen preflood treatment did not affect leaf scarring by RWW adults (Table 5). RWW larval populations were very high in this plot. Differences in growth, due to RWW larval feeding, were obvious by mid-July. Visually, it was possible to see incremental increases in rice health (color, vigor, stand density [tillering]) with the increased Coragen rates. Even the untreated areas between plots, i.e., 5 foot buffers, showed stress compared with the treated plots "next door" showing less stress. Core data showed ~50% reduction in larvae from the 0.12 lbs. AI/A rate compared with the untreated for the first sample date (Table 5). For the second sample date, the untreated numerically had the lowest larval population and the 0.12 rate had the highest population. Initially, this does not seem possible. However, I have seen other cases under high RWW pressure where the population declines over time in the untreated (such as in this study with the first and second samples). This happens because the larvae consume all the root tissue and this causes the larvae to starve and the population declines. In plots where the roots were protected with an insecticide (and therefore larger) the population maintains over time or even increases somewhat. Overall, there were no significant differences in larval populations within sample dates. Yield data showed significant differences in percentage grain moisture at harvest and in grain yields. The yield data from the two east plots (one in the 0.08 and one in the 0.12 treatments) were deleted from the analyses because the plant stand was poor. The poor stand was noted early in the season and would have compromised the study if included. Moisture was significantly higher in the untreated and 0.08 rate than in the 0.12 rate. The higher moisture value is indicative of plant stress and delayed maturity. Grain yields showed a definitive rate response with ~41% yield increase in the 0.12 lbs. AI/A Coragen plot compared with the untreated (Table 5). The 0.10 rate plot yielded slightly less (~10%) than the 0.12 plot (although not significantly different). The yield in the 0.08 lbs AI/A plot yielded less. For comparison purposes, the yield for M-202 in the neighboring plot was 6286 lbs./A.

Overall, it was obvious that Coragen provided a high level of RWW control. The larval data were difficult to interpret. The yield results, however, showed with certainty the protection that was provided. This was a very severe RWW infestation. The 0.08 lbs. AI/A under these conditions appeared to help but was not strong enough for the highest level of protection. The two higher rates provided this with perhaps a slight advantage for the 0.12 lbs. AI/A rate but clearly this highest rate was approaching the area of diminishing returns compared with the 0.10 lbs. AI/A rate.

1.3.b) Evaluation of Belay in field plots

Two variations of Belay application, applied preflood or applied at the 3-leaf stage, were evaluated in 2011. The plots were entire basins about 50 by 300 ft. Treatment details are as follows:

Product	Rate	Timing
Belay 2.13 SC	4.5 fl. oz./A	Preflood
Belay 2.13 SC	4.5 fl. oz./A	3-leaf

Methods:

Leaf scarring, RWW population levels, and grain yields were evaluated as follows on 24 June, 13 July and 27 July, and 29 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 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 basin to the south were used for comparison purposes. The stand establishment period in 2011 was very poor. After the soil dried to allow us to set-up the plots, there was a few day period of nicer weather. This allowed us to get the plots set-up, flooded, and seeded. This was followed by another 2 weeks of poor weather and the seeds did very little in terms of germination and establishment. This also appeared to inhibit the efficacy of the preflood treatments. Why? There are two possible reasons. The cool weather, once the seedlings did establish, may have caused plants to have small root systems and this inhibited the plant from picking up the insecticide. In addition, the cool weather lengthened the time from seeding to when the insecticide was "needed" for rice water weevil control and perhaps the insecticide dissipated in this time. RWW levels (adult feeding scars and soil core data) are shown below. In summary, the Belay preflood treatment was less effective than the 3-leaf stage treatment (Table 6). The preflood treatment appears to have reduced RWW larval populations to some extent but the 3-leaf stage application was very effective (95% control). These same trends held in terms of grain yield. Belay applied at the 3-leaf stage was very effective for protecting grain yield whereas the preflood treatment was much less effective.

1.4) Evaluation of a biological insecticide for Rice Water Weevil in greenhouse studies.

Biological insecticides are used to control insect pests in numerous cropping systems. These organisms occur naturally in the environment, discovering these organisms, isolating them, learning how to culture them, etc. is an active area of research. In some cases, a metabolite/by-product is isolated from the microorganism (bacteria or fungi) and used as an insecticide. Spinosad is one example of this and now synthetic variations of this compound are available with improved efficacies; both products are now commonly used insecticides. Conversely, the microorganism can be applied directly to the crop to control pests; this is a viable aspect of pest management. The final way the microorganisms are used is through biotechnology where genes from the microbe are inserted into crop plants, so called GMO plants, to achieve pest control.

In the late 1990's, my lab evaluated a biological insecticide for RWW and it proved very effective. The organism was *Bacillus thuringiensis tenebrionis*. These studies were done in the greenhouse followed by field/ring studies. The company producing this product was subsequently sold and I later tested the "same" product and the results were consistently disappointing. Apparently, the specific bacteria strain, production process, formulation components, etc. had changed and the efficacy was lost. In 2011, we tested a related organism (*Bacillus thuringiensis galleriae)* in greenhouse studies against RWW. This subspecies of Bt had not previously been tested against RWW. This product is being developed and has been tested against other soil-borne weevil/beetle pests in the eastern U.S.

Methods:

Rice was planted in 4 in. diameter pots containing "riceland soil" in the UC-Davis greenhouses. As the seedlings broke through the water surface, three RWW adults (collected from levees during the late winter/early spring) were added per pot and the seedlings were enclosed in the clear plastic covering. Treatments included grubGONE! Granular at 1.2 g/sq ft (115 lbs/acre), 1.6 g/sq ft (134 lbs./acre), and 1.8 g/sq ft (153 lbs./acre) applied preflood and at the 3-leaf stage and the technical grade product at 0.12 g/sq ft (11.5 lbs/acre) and 0.16 g/sq ft (13.4 lbs./acre) applied preflood and at the 3 leaf stage. An untreated control and pyrethroid standard completed the treatment list. Pots were destructively sampled 3-4 weeks after infestation.

Results:

There was a rate response with the granular product as the number of larvae per pot decreased with increasing rates down to 3.5 larvae per pot. The average larval density for the untreated pots was 5. The technical grade product was not as effective averaging ~9 larvae per pot. We plan to continue these evaluations as this type of product could have an important fit for the industry.

1.5) 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 for the industry. Sustainability and environmental stewardship have been stressed by the industry and have created a viable and valuable niche. Clearly, the changes from the days of water quality concerns and conflicts with the public are monumental. 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 endorsed by groups such as the California 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.

One of the “concrete” uses for and implications of the results from this study is in mosquito management. The general public hate mosquitoes and abatement districts work diligently to minimize populations of pestiferous mosquitoes. Mosquitoes upsetting a public outdoor event commonly bring about public outcry. Rice fields inevitably produce mosquitoes since as a flooded environment this is what mosquitoes need for development; some level of infestation is going to occur. But mosquito populations can either flourish or deteriorate and this depends on the specific conditions of the aquatic situation. Some of these “conditions” such as fairly shallow water, organic matter, warm temperatures, etc. cannot be easily altered within the rice agroecosystem. However, other conditions such as maintaining a healthy complement of natural enemies of mosquito larvae is likely able to be manipulated. Mosquito larvae and pupae are not highly mobile so predators can readily capture these organisms and consume them. Using insecticides that have favorable attributes, such as low risk to these natural enemies, would be one way to achieve a high level of natural control of mosquitoes within the flooded rice system. 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 has been the most recent mosquito-vectored human disease that has been and remains a concern. There are numerous other mosquito-borne diseases that could become issues especially if climate change continues as some predict and this results in higher temperatures in northern California.

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. As new insecticides are being proposed for inclusion into rice pest management programs (such as Belay and Coragen), the fit of these into the overall system need to be determined. 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 enabled a fairly good understanding of the effects of registered insecticides on nontarget organisms in rice fields so looking at new products is a priority now. Data from 2010 will be discussed as the 2011 data are still being tabulated from preserved samples. The procedures followed are similar for each year and the exact procedures and dates used in 2011 will be given herein.

Each plot was ~0.04 A and each treatment was replicated three times. In 2011, preflood treatments were applied on 2 June immediately before flooding; the plots were seeded on 3 June. The 3-leaf stage treatments were applied on 20 June and the armyworm application timing was 21 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 organisms (animals) monitored in this study range from predators, to seed feeders (pests) to those that have neither positive or negative effects. The 2010 results are summarized and will be reported herein. Data were divided into aquatic insects and other aquatic animals (non-insect invertebrates). 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 2010 – Warrior, Dermacor, and Belay as preflood broadcast applications and Dermacor as a seed treatment.

Floating Barrier Traps: *Aquatic Insects* - Floating barrier traps primarily capture actively swimming organisms such as beetles; these traps are usable only for the first ~3-4 weeks after seeding. After that time, the plant material apparently interferes with the trap so very few organisms are captured. Therefore, only data from the preflood treatments can be collected with this tool. Populations of aquatic insects were affected (reduced) by the Warrior and Dermacor (seed) treatment applications at 9, 17, and 31 days after treatment (DAT) (Fig. 1). At 23 DAT, populations bounced back in these two treatments and were slightly higher than in the untreated. This type of cycling is common as initially there was a reduction followed by recolonization and a higher level of population growth to fill the void. I am not reporting immature stages (larvae or nymphs) vs. adults in this summary but it is possible the initial samples were mostly adults (more mobile so they could colonize the newly flooded plots and the later samples were comprised of offspring (immatures). The Belay and Dermacor preflood treatments initially (9 DAT) had no effects on populations but at 15 and 22 DAT there was a substantial reduction in insect numbers. These products were likely protected somewhat from the organisms by the soil but later had an effect. Averaged over the entire period (4+ weeks), the Dermacor seed treatment reduced numbers about 40%, compared with the untreated. *Other Aquatic Invertebrates* - Results on the non-insect aquatics were fairly similar except the effects of Dermacor preflood persisted for an additional week (Fig. 2). Warrior and Dermacor (seed) treatments were detrimental to populations at 17 DAT; there was also a slight reduction from the Dermacor at 9 DAT and from Warrior preflood at 23 DAT. Populations rebounded substantially in these two treatments at 31 DAT – the last sampling date. Averaged over the entire sampling period, only Belay slightly reduced populations of other aquatic invertebrates, i.e., not insects.

Quadrant samples: *Aquatic Insects* - With the quadrant sampling method, Dermacor preflood and seed treatment reduced populations of aquatic insects at 17, 23, and 31 DAT (Fig. 3). Belay and Warrior preflood reduced numbers of insects at 17, 31, and 51 DAT. As detailed earlier, the "bounce-back effect" was again seen with Belay and Warrior preflood. These plots were initially infested with aquatic insects, the levels declined in the second sampling date (17 DAT), and greatly rebounded in the third sample date followed by another decline. There may be one life stage of a key aquatic insect species or two that is very susceptible to these active ingredients and causing this response. The later sample dates showed no consistent trends. Averaged over the entire season, none of the preflood treatments caused any reduction in aquatic insect numbers. *Other Aquatic Invertebrates* - Similarly populations of other aquatic organisms were reduced at 9, 31 and 38 DAT by Dermacor seed treatment (Fig. 4). Belay and Warrior preflood reduced levels of other aquatic organisms (non-insects) at 17 and 31 DAT. Curiously, several of the preflood treatments also showed associated reductions in populations of these organisms in the later samples, i.e., 73 to 108 DAT. The reason for this is not clear.

Mosquito Dip Samples: Mosquito populations were low in 2010. Populations are always rare until July so sampling started in mid-July and data were collected weekly for 10 weeks. The actual numbers of mosquito larvae per treatment are shown in Fig. 5. For the preflood treatments, no mosquito larvae were sampled from untreated plots until 95 DAT (after the preflood treatments were applied in the comparison plots). However, larvae were found all the treated plots (Belay, Warrior, Dermacor preflood and seed treatments) as early as 38 DAT. At 101 DAT, mosquito larvae were found in all the treatments (three preflood insecticides, one seed treatment and the untreated); the highest numbers were in the belay and Dermacor preflood treatments.

3-Leaf stage applications:

Four different insecticides were evaluated at the 3-leaf stage application timing. In 2010 (data presented), Warrior, Dimilin, Belay, and Trebon were evaluated.

Quadrant samples: *Aquatic Insects* - For the 3-leaf stage applications, Warrior initially reduced numbers of aquatic insects at 5, 13, and 20 DAT; the reductions were by up to 80% (Fig.

6). Dimilin and Belay showed less severe impacts (generally for 1 week). Trebon initially (5 and 13 DAT) did not affect levels of aquatic insects but then this product caused a 50% reduction for weeks 3 and 4. The later samples generally showed similar populations levels in the treated and untreated plots and averaged over the entire sampling period there were no significant reductions from the treatments. *Other Aquatic Invertebrates* - With the non-insect aquatics, severe reductions were seen with Warrior, Dimilin, and Belay with Dimilin application resulting in the longest term reduction (Fig.7). Following some perturbations in the system and fluctuating populations, populations of non-insect aquatics were fairly stable comparing treated and untreated plots following 41 DAT. Averaged over the 90-day sampling period, numbers of other (non-insect) aquatic invertebrates were not impacted by the treatments.

Mosquito Dip Samples: Fig. 8 shows the number of mosquito larvae in the 3-leaf stage treated vs. untreated plots. Mosquito larvae were not found in all five treatments until 77 DAT. At that time, the highest numbers were in the untreated with Belay having the second highest populations. On the next date (83 DAT), Belay had twice the number of larvae than the untreated, but again overall populations were low.

Armyworm timing:

A late July application of Warrior was evaluated as an example product that could be applied for armyworm management.

Quadrant samples: *Aquatic Insects* – The mid-season Warrior application reduced populations of aquatic insects on five of the seven sample dates following application (Fig. 9). The greatest reduction compared with the untreated plots was 70% at 15 and 44 DAT. *Other Aquatic Invertebrates* – Populations of these organisms were not impacted as severely as aquatic insects by the mid-season Warrior application; there was a significant reduction at 22 DAT and very slight reductions on two other dates (Fig. 10). The greatest reduction was 67%.

Mosquito Dip Samples: Mosquito larvae were not found following the July armyworm timing (Warrior) until 44 DAT at which time there were 5 times more larvae in the insecticide-treated than the untreated (Fig. 11). The following date showed equal populations.

Pest Populations – The data on pest populations are summarized from the 2011 study. RWW was the only pest present in any significant numbers. As shown in Table 8, the Warrior preflood treatment 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.

Grain Yield – Yield data were also collected (not reported) but showed no meaningful results.

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

Management of tadpole shrimp has taken on added importance in recent years. The severity of infestations appears to be on the rise. Infestations have spread to new areas such as the Fall River Valley (on wild rice) and the rice production area of Missouri. Most importantly, the acre-treatments of copper sulfate (Bluestone) is about one-quarter what it was in 2000. Thus, there is the need for alternative management methods. Tadpole shrimp are an early-season pest of seedling rice. The shrimp feed on germinating seeds, dislodge seedlings that were rooting, muddy the water preventing sunlight penetration, etc. Many toxicants will kill tadpole shrimp in the laboratory; they are fairly easy to kill. However, the lab results may not mimic the field situation as in the field the shrimp will burrow into the mud offering some protection from the insecticide. We developed an improved method for research on tadpole shrimp in 2010 and that same technique was used in 2011. Rice is seeded into the standard 10.7 sq. ft. aluminum rings. A 0.75-foot diameter PVC pipe ring plot is placed inside the aluminum ring. The treatments and tadpole shrimp are placed inside both rings. Plant stands are quantified from both rings but the larger ring clearly provides a more accurate number. The shrimp (dead and alive) are counted from the smaller ring as the larger ring is too large of an area to find the shrimp. Products evaluated are detailed in Table 9.

Methods:

A field study was conducted on tadpole shrimp control in 2011 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. Four replicates in a randomized complete block design were used.

The key dates were as follows:

19 May, pre-flood (PF) applications
19 May, flooding
20 May, seeding (‘M-202’)
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 ~2 leaf stage
15 June, post-flood applications

Sample Dates:

Established Seedling Counts: 24 June
Tadpole Shrimp Mortality/Seedling Damage: 16 June
RWW Adult Leaf Scar Counts: 24 June
RWW Larval Counts: 12 July and 26 July
Rice Yield: 11 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.

<u>Results:</u>

There were few significant differences in numbers of floating seedlings (16 June) and numbers of established seedlings (24 June) among the treatments (Table 10). The initial TPS infestation on 2 June did not result in many survivors and by the time the plots were reinfested on 14 June, the seedlings had largely rooted and were tolerant of the damage. Floating seedlings ranged from 9.75 to 4.0 (a significant difference) and established seedlings ranged from 130 to 104.25 (not significantly different) (Table 10).

A naturally-occurring rice water weevil (RWW) infestation also occurred in these plots. In the early sampling, all insecticide treatments significantly reduced RWW numbers compared with the two untreated entries (copper sulfate which is not classified as an insecticide had intermediate RWW numbers) (Table 11). On 26 July, RWW larval counts were still high in the untreated plots. Weevil numbers increased in all treatments except Dermacor preflood and Warrior preflood. Grain yields were numerically highest in the Dermacor and Belay preflood treatments and lowest in the copper sulfate treatment (Table 12). The losses were likely due mainly to RWW injury although there may have been some slight TPS feeding as well. Comparing the two untreated entries, the one without TPS had a ~1775 lbs./A yield loss and the addition of TPS (in the untreated with TPS added) suffered a ~2600 lbs./A yield loss.

1.7) Management of Rice Water Weevil through control of adults infesting levees.

Rice water weevils commonly infest levees in advance of moving into flooded fields. Some adults may spend the winter on the levees gaining protection within the weed growth and soil cracks. In addition, adults overwintering in other locations (fencerows, lawns, ditchbanks, etc.) may pinpoint levees for infestation after spring flights and wait there until fields are flooded. Considering these observations, perhaps the adults could be controlled on the levees using insecticides or some other means before they ever move into the flooded fields. That was the idea behind this study conducted in 2011.

<u>Methods:</u>

A grower cooperator field was used for this study. Two 1800 ft. long levees were divided into 80 ft. long plots. Ten treatments were designed with each replicated four times. The treatments included applications of Warrior II, Aza-Direct, Aza-Direct + Warrior, and Botanigard. These five treatments (including the untreated) were duplicated on mowed and unmowed levee sections. Conditions for this study were not ideal in 2011. The high amounts of precipitation and delayed planting resulted in excessive weed growth (4-5 feet tall) on the levels. Some vegetative growth was desired so as to entice the RWW to the levees, but excessive weed growth undoubtedly hindered insecticide coverage. Therefore, mowed and unmowed treatments were included. Aza-Direct contains the natural product Azadirachtin which reportedly agitates insects causing them to move/crawl more. Botanigard contains the insect toxic fungus *Beauveria bassiana*. Rice water weevil feeding scars on seedlings and RWW larval populations were monitored as previously described.

<u>Results:</u>

Data have not been summarized and analyzed yet. Rice water weevil populations were not evenly distributed across the field (concentrated in the northwestern corner of field) which will complicate the analyses.

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.

RWW adults infest rice fields immediately after flooding in the spring. For this process, they largely crawl off levees and into the water. However, they readily fly and this likely moves the adults from overwintering sites (protected areas such as at the base of clumps of weeds, in soil cracks, under crop residue, etc.) and on to the levees. During the winter, they are in a state of diapause - a genetically-controlled condition where the adults will not deposit eggs until the diapause 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 needed to break the diapause 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. It appears that RWW adults do not fly as readily as they did soon after they moved into California. My predecessor researching rice insects used to commonly collect adults numbering as high as 40,000 using this same method. Since this pest has fully invaded the rice production area now, long-range flight is not as critical to its existence. However, they still fly "locally" to find more favorable conditions. 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 <u>only</u> occurs during specific nights defined by evenings (6-11 pm) with warm temperatures (70-80^{0}F) and calm winds (<5 MPH). In 2011, RWW spring flight was the concentrated for about a week from 29 April to 6 May (Fig. 12). Flight was monitored for ~100 nights and more than 90% of these had no flight. Most (71%) of the seasonal total was collected on May 4 and 5 which were mid-80's to 90^{0}F days and nights with lows in the upper 50's. The flight in 2011 was greatly delayed and reduced by the cool, wet spring. The total number of RWW collected (415) was the lowest for the last 14 years (Fig. 13).

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

Rice varieties differ from one another in numerous ways such as yield potential, response to nutrients, disease susceptibility, days to maturity, growth patterns, leaf shape and orientation, optimal seeding rate, etc. These responses result due to the specific combination of physiological, morphological, and biochemical properties of the variety. These responses can be assessed and quantified in field plots, i.e., variety trials, but frequently additional details about the variety arise after it is grown and observed in commercial settings. It is likely that rice varieties differ in their responses to insect pests and pest-induced injury. In this case, the cultivar response as well as the response of the insect to the cultivar (since the insects are living, reacting, mobile animals) is involved. Resistant cultivars are an important way to manage pests and can be extremely cost-effective. In terms of insect pests, resistance can take the form of antibiosis (some “natural chemical” in the plant inhibits the insect), nonpreference (something in the variety deters the insect from infesting it), and tolerance (the plant is very vigorous and simply outgrows the feeding and damage from the insect pest). All three of these methods have pros and cons and in many cases of combination of these approaches is expressed by the variety. These latter two approaches, although not directly toxic to the pest, are often preferred because they are more stable. The first approach actually kills the pest having the drawback that insect pests can develop mechanisms to overcome this type of resistance (similar to developing resistance to insecticides). When this happens, additional plant breeding efforts are needed to develop new and improved resistance mechanisms, i.e., trying to stay one step ahead of the insect pest.

Developing a rice variety that is resistant to RWW has been impossible so far. Thousands of rice genotypes have been evaluated and two lines were found with a low level of resistance. This resistance was likely not high enough to prevent damage and the need for control tools. There have been some reports from China of more success but nothing definitive. Efforts have been underway in California and the southern rice area but results have been limited. While clearly no resistance to RWW exists, there could be characteristics of one or some varieties that impede RWW from infesting it and/or alter the damage response. 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 2011.

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 preflood) 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 14). However, within the infested treatments, there was a separation with significantly more scarring on M-202 and S-102 than on L-206 and Calmati-202. In spite of our best efforts, there was a low level of infestation and some damage from adults in the uninfested rings. Therefore, the uninfested treatments averaged about 20% leaf scarring (Table 14). This figure was clearly less than the infested rings that had scarring ranging from 79.0 to 57.0%. The level of scarring in the uninfested rings should not have had any effects on yield. This is reinforced by the fact that RWW larval populations were virtually nonexistent on the uninfested treatments. On the first sample date, the four uninfested treatments as a group had significantly fewer RWW larvae than three of the infested treatments. On the second sample date, populations had declined in three of the four infested treatments and therefore these did not differ from the uninfested treatments. This likely occurred because the larvae had decimated the root systems and this resulted in some starvation of larvae. I suspect this may have also been a factor in the M-202 treatment on the first sample date. Some of these rings "struggled" in terms of germination and establishment and, coupled with the high degree of leaf scarring, this likely inhibited root growth and larval survival.

Grain yields were overall highest in M-202 and L-206; yields were ~2000 lbs./A less in S-102 and Calmati-202 was lowest yielding (Table 15). 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 ~3375 lbs./A (comparing the treatment without and with RWW). Past years' research, has shown that most medium grains are highly susceptible to grain yield loss from RWW. The other varieties also suffered severe yield losses. Calmati-202 and L-206 showed yield losses from RWW in the 2000 lbs./A range. S-102 was least affected by this pest with a 1300 lbs./A difference.

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

<u>Methods:</u>

The rice varieties as shown in Table 16 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 fl. oz./A [applied preflood on 19 May] + Dermacor 2.5 fl. oz./100 lbs. seed [applied at seeding on 20 May]). 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.

<u>Results:</u>

For the leaf scarring evaluation, values ranged from 46.5% to 22.0% (Table 17). There were some slight differences statistically in the values but no strong trends across the treatment or varieties. The insecticides that were used generally do not affect RWW adults or feeding so that was expected. In past years, some varieties have been fed upon by RWW adults more than others but that trend was not seen in 2011. Overall, the level of infestation and leaf scarring was lower than desired. The insecticide treatments generally controlled RWW very well; the treated plots had 0.15 RWW larvae or less in all cases for both sampling dates (Table 17). In several cases, no larvae were found. For the plots not treated, populations were numerically highest in M-202 (sample date 1) and M-206 (sample date 2). RWW levels ranged from 0.3 (M-208) to

1.05 (M-202) in the first date and from 0.2 (M-208 and Calhikari-201) to 1.45 (M-206) in the second sample. M-105 which was a new entry in 2011 had RWW populations in the intermediate range. Overall, populations were generally in the ~0.5 RWW per sample range which was less than in 2010.

Overall, there was ~275 lbs./A yield loss from RWW averaged across the varieties. Rice grain yield was highest in M-401 (RWW controlled) at 6560 lbs./A and lowest in M-104 (RWW present) at 4780 lbs./A. This difference was more compressed than in past years likely because the upper end of the yield range was limited by the poor start in the spring and the lower yield values were not depressed as much as usual since the RWW populations were somewhat moderate. However, most importantly was the yield response the RWW infestation. RWW caused a yield loss in ten of the twelve varieties, except M-208 and Calmati-202. In these varieties, the yield was the same (or slightly higher) in the presence of RWW as in the RWW-controlled plots. M-105, examined in 2011 for the first time, had one of the highest yield loss values at 570 lbs./A.

In summary, yield losses from RWW were more modest in 2011 than in past years in this study but they were also more universal across varieties. Some of the medium grain varieties suffered significant yield losses from RWW as has been seen in the past; this included M-105 which was newly-introduced in the study in 2011. Two of the specialty rice varieties Calhikari-201 and Calmochi-101 were severely impacted. The one long grain in the study, L-206, had a high yield loss value. Similarly, the one short grain, S-102, suffered a ~470 lbs./A yield loss. In past years, there has been more separation in responses among the varieties and among the grain types. Much of these differences, I believe, stem from the quick establishment and early-season growth of some of the varieties. This allows them to develop large root systems before the infestation with RWW occurs and this helps the varieties to withstand the feeding. This early-season growth in 2011 was mitigated by the poor spring conditions and this likely helped account for the more uniform response across varieties.

2.3) Study the impact of seeding rate and rice variety on the yield response to Rice Water Weevil feeding.

A new study was started in 2011 based on some of our findings from the varietal susceptibility to RWW efforts in recent years. These results were reinforced by those from Dr. Luis Espino (http://www.carrb.com/10rpt/2010%20RP16%20Espino.pdf). In summary, yield losses from RWW had been much higher in M-202 than in M-206 even though the larval infestation results were the inverse. In addition, the Espino study in grower fields showed minimal yield losses with M-206 from RWW even with high larval pressure. Most of the previous work with yield losses and RWW has been conducted at the RES with M-202 (or even older varieties) and with a 100 lbs./A seeding rate. Obviously, newer varieties are commonly utilized now and growers often use higher than 100 lbs./A seeding rates. These factors likely influence the response to RWW feeding and based on our observations these factors may reduce the yield impacts.

Methods:

The following study was set-up in 2011 to explore these relationships. Two rice varieties, M-202 and M-206, and four seeding rates, 50, 100, 150 and 200 lbs./A. These were planted in 10 by 20 foot plots (flooded on 2 June and seeded on 3 June). RWW infestation was approached in two ways. First, one-half the plots were treated Warrior II at 2.56 fl. oz./A applied preflood and Dermacor 2.5 fl. oz./100 lbs. seed applied on the seed. This was to control a natural infestation of RWW, if it occurred. In the untreated plots, three rings (10.7 sq. ft.) were placed per plot and infested with either a low or a high RWW rate, as well as an insecticide treatment for the third entry. Six replicates of each treatment were utilized. The measurements collected included RWW leaf scarring, RWW larval levels, and grain yields as previously detailed. In addition, the number of tillers/panicles per treatment was estimated.

Results:

Data are still being summarized and analyzed although the study progressed fairly well. The natural RWW infestation was very low (typical for this part of the RES) but the introduced RWW in the rings created a usable infestation.

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 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 has subsequently been eradicated from the greenhouses and new policies put in place. The need for these new policies for seed handling is frequently questioned but so far we have stressed their importance and kept them in place. At the federal level (APHIS), this pest was deregulated in the summer 2011. The panicle rice mite is a "Q" rated (quarantine) pest in CA and CDFA still considers it a threat. The APHIS decision was made due to pressure/desires from the southern U.S. rice area. In 2009 and 2010, CDFA sampled 10% of grower rice fields after heading for panicle rice mite. In 2010, several collections of a mite were made which the mite taxonomy expert in the U.S. identified as the same genus (*Steneotarsonemus*) but definitely not *S. spinki*. The exact species name for these mites could not be determined. The role these mites might be having in the California rice agroecosystem is not known.

Finally, in 2011 production season, several reports of "pecky" rice were received. These appear to be caused by environmental conditions as opposed to biotic agents (stink bugs, etc.) but this is something that warrants attention in the upcoming years.

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PUBLICATIONS OR REPORTS:

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CONCISE GENERAL SUMMARY OF CURRENT YEARS (2011) RESULTS:
Larry D. Godfrey

Research was conducted in 2011 on the biology and management of key invertebrate pests of California rice. Rice water weevil populations were reduced in 2011, as they were in 2010, because of the unfavorable spring conditions. However, some of our plots at RES had very high infestations although others had more limited populations. In many of our studies, we introduce rice water weevil adults to insure a usable infestation; these were successful. Overall, we were able to conduct all the studies we had planned in spite of the poor spring and delayed seeding window; the late start did impact our yields and compromised some of the results. Besides studies designed on insecticidal management of rice water weevil (six in total), we also studied the response of California rice varieties to infestation (three studies). Most of the previous work has been done with M-202 and the response of other varieties may differ significantly. Tadpole shrimp is an increasing concern and we have been recently refining our methods of research on this pest. We continued tadpole shrimp management studies in 2011. Armyworms, another important insect pest of rice, were present in several areas in 2011 but no studies were conducted. 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 (RWW), 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. For the management efforts, work was done in aluminum ring plots (10.7 sq. ft.), small field plots (~600 sq. ft.), 0.25 acre plots, greenhouse studies, and grower fields 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 with weevil adults introduced to insure an infestation. Twenty-four treatments (a total of six different active ingredients) were evaluated in ring plots. Three "new" products were evaluated. The results and comparisons are useful and indicates that a product has potential but clearly the conditions are "artificial". Follow-up studies are needed to fully evaluate the products. In summary, the registered pyrethroid products, Warrior® II and Mustang® Max, continue to provide excellent RWW control. The flexibility of preflood (with at least 5-7 days leeway of application before flooding) for Warrior is useful. Declare® is a new pyrethroid that is being marketed; it was also effective for RWW control. Dimilin performance appears to be acceptable albeit slightly less than the pyrethroids. Belay® (clothianidan), for the second consecutive year, provided marginal control of RWW with a preflood application. Early-season conditions for rice germination and establishment in 2010 and 2011 were poor and this could perhaps account for the less than desired performance with Belay. Belay applied at the 3-leaf stage provided very good RWW control. Dermacor® (rynaxypyr) controlled RWW well preflood and with the 3-leaf stage application with the higher rate (2.46 oz.). The 1.97 oz. rate appeared to be lacking. A "rescue" treatment of clothianidin and rynaxapyr, i.e., applied at the 5 to 6 leaf stage when the larval infestation has already began, was evaluated and also shown to be moderately effective. Belay® is progressing towards registration, perhaps in 2011. Interest in rynaxapyr has been rekindled by the manufacturer; this active ingredient is registered in southern rice and used heavily. Three rates of Coragen (another rynaxapyr formulation) were evaluated in replicated small field plots. Coragen provided a high level of RWW control although some variation made the larval data difficult to interpret. The yield results, however, showed with certainty the protection that was provided from this very severe RWW infestation. The two highest rates of Coragen resulted in 30%+ grain yield increases over the untreated. Small plot (0.25 acre) evaluations were also conducted with Belay. The results were similar to those from the ring plot studies. The preflood treatment appears to have reduced RWW larval populations to some extent but the 3-leaf stage application was very effective (95% control). These same trends held in terms of grain yield; Belay applied at the 3-leaf stage was very effective for protecting grain yield (40% increase). A biological insecticide for RWW was evaluated in greenhouse studies. This bacteria, *Bacillus thuringiensis galleriae,* is a related subspecies to one that we evaluated in the late 1990's. Treatments included various rates of the formulated product and of the technical grade product applied preflood and at the 3 leaf stage. The formulated product showed activity, i.e., a rate response, whereas the technical grade product was not as effective. The final RWW management study involved trying to control adults on the levees before they move into the flooded fields. Two 1800 ft. long levees were divided into 80 ft. long plots. The treatments (each replicated four times) included applications of Warrior II, Aza-Direct, Aza-Direct + Warrior, and Botanigard and untreated on mowed and unmowed levee sections. 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. The unregistered active ingredients that are moving towards registration, biological insecticides under investigation, and new approaches to using insecticides for RWW, i.e., levee treatments, represent a intensive effort to develop alternatives.

<u>Biology</u> - In 2011, RWW spring flight was concentrated for about a week from 29 April to 6 May. Flight was monitored for ~100 nights and more than 90% of these had no flight. Most (71%) of the seasonal RWW total was collected on May 4 and 5. The flight in 2011 was greatly delayed and reduced by the cool, wet spring. The total number of RWW collected (415) was the lowest for the last 14 years.

<u>Cultivar Response</u> – Rice varieties differ from one another in numerous ways such as yield potential, response to nutrients, disease susceptibility, days to maturity, growth patterns, leaf shape and orientation, optimal seeding rate, etc. It is likely that rice varieties differ in their responses to insect pests and pest-induced injury. While clearly no resistance to RWW exists, there could be characteristics of some varieties that impede RWW from infesting and/or alter the damage response. 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. 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 2011. In controlled ring studies with a high RWW infestation, the yield loss was highest in M-202 at ~3375 lbs./A. Calmati-202 and L-206 showed yield losses from RWW in the 2000 lbs./A range and S-102 was least affected. In small plot studies with 12 varieties (untreated vs. treated for RWW), all varieties were equally infested with RWW. In past years, some varieties have been fed upon by RWW adults more than others but that trend was not seen in 2011. RWW larval populations were numerically highest in L-206, M-202, and M-206. RWW caused a yield loss in ten of the twelve varieties, except M-208 and Calmati-202. M-105, examined in 2011 for the first time, had one of the highest yield loss values at 570 lbs./A. A new study was started in 2011 based on some of our findings from our studies in recent years. Yield losses from RWW

had been much higher in M-202 than in M-206 even though the larval infestation results were the inverse. Most of the previous work with yield losses and RWW has been conducted at the RES with M-202 (or even older varieties) and with a 100 lbs./A seeding rate. Obviously, newer varieties are commonly utilized now and growers often use higher seeding rates. These factors likely influence the response to RWW feeding and damage.

Tadpole Shrimp: Nine treatments were evaluated in 2011 for tadpole shrimp mortality and protection of rice seedling stands. Registered and experimental materials were included as well as standard copper sulfate. There were few significant differences in numbers of floating seedlings and established seedlings among treatments. Unfavorable spring for rice establishment caused a delayed and uneven germination which made treatments difficult to evaluate.

Non-Target Organisms: This study was designed to evaluate the environmental fit of insecticides used in rice production and the effects on populations of non-target invertebrate organisms. Best Management Practices developed for rice and mosquito management issues are uses for these data. Six 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 in 2011. Data from 2010 are completely summarized and results for 2011 are still in progress. Mosquito populations were relatively low in 2010 and data on mosquito larvae were collected weekly for 10 weeks. Four preflood treatments were evaluated in 2010 – Warrior and Belay as preflood broadcast applications, and Dermacor as a broadcast and a seed treatment. All these treatments negatively impacted populations of aquatic invertebrates with most of the effects taking place during the first 30 days after application. Populations of mosquitoes were too low to draw any conclusions. Warrior, Belay, Dermacor and Trebon were evaluated as 3-leaf stage treatments. For aquatic insects, Warrior reduced numbers at 5, 13, and 20 days after treatment; the reductions were by up to 80%. Dimilin and Belay showed less severe impacts (generally for 1 week). For other aquatic invertebrates (not insects), severe short-term reductions were seen with Warrior, Dimilin, and Belay with Dimilin application resulting in the longest term reduction. Warrior was evaluated as a representative material that could be applied against armyworms mid- to late-season. The mid-season Warrior application reduced populations of aquatic insects on five of the seven sample dates following application with the greatest reduction being 70% at 15 and 44 days after treatment. Populations of other aquatic invertebrates were not impacted as severely by the mid-season Warrior 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 pest has subsequently been eradicated from the greenhouses and new policies put in place. At the federal level (APHIS), this pest was deregulated in the summer 2011; however, CDFA still considers it a quarantine pest. In 2010, several collections of a mite were made from rice panicles which the mite taxonomy expert in the U.S. identified as the same genus (*Steneotarsonemus*) but definitely not *S. spinki*. The exact species name for these mites could not be determined. The role these mites might be having in the California rice agroecosystem is not known. Finally, in 2011 production season, several reports of “pecky” rice were received. These appear to be caused by environmental conditions as opposed to biotic agents (stink bugs, etc.). However, keeping exotic pests out of California is going to be an ongoing process.

Table 1. Treatment list for RWW management ring study, 2011.

Product	Formulation per A (fl. oz.)	Timing	Application Date
1. Dimilin 2L	8	3-leaf	14-Jun
2. Untreated	---	---	---
3. Warrior II	1.92	3-leaf	14-Jun
4. Warrior II	1.92	preflood - ~week before flooding	13-May
5. Warrior II	1.92	preflood	19-May
6. Belay 2.13 SC	3.5	preflood	19-May
7. Belay 2.13 SC	4.5	preflood	19-May
8. Belay 2.13 SC	5.5	preflood	19-May
9. Belay 2.13 SC	3.5	2-3 leaf	14-Jun
10. Belay 2.13 SC	4.5	2-3 leaf	14-Jun
11. Belay 2.13 SC	5.5	2-3 leaf	14-Jun
12. Mustang Max EW	4	2-3 leaf	14-Jun
13. Mustang Max EW	4	preflood - ~week before flooding	13-May
14. Mustang Max EW	4	preflood	19-May
15. Declare	1.54	2-3 leaf	14-Jun
16. Declare	2.05	2-3 leaf	14-Jun
17. Declare	2.05	preflood	19-May
18. Dermacor X-100 5FS	1.97	preflood	19-May
19. Dermacor X-100 5FS	2.46	preflood	19-May
20. Dermacor X-100 5FS	1.97	2-3 leaf	14-Jun
21. Dermacor X-100 5FS	2.46	2-3 leaf	14-Jun
22. Belay 2.13 EC	3.5	5-6 leaf	26-Jun
23. Belay 2.13 SC	5.5	5-6 leaf	26-Jun
24. Dermacor x-100 5FS	2.46	5-6 leaf	26-Jun

Table 2. Rice plant stand and adult feeding damage in chemical ring study, 2011.

Product	Formulation per A (fl. oz.)	Timing	Stand Vigor/ Emergence		% Scarred Plants - 24 June	
1. Dimilin 2L	8	3-leaf	2.63	b	83	ab
2. Untreated	---	---	3.0	ab	61.5	abcd
3. Warrior II	1.92	3-leaf	2.88	ab	23	gh
4. Warrior II	1.92	early preflood	2.88	ab	52.5	de
5. Warrior II	1.92	preflood	3.0	ab	54.5	de
6. Belay 2.13 SC	3.5	preflood	3.0	ab	54	de
7. Belay 2.13 SC	4.5	preflood	2.75	ab	46.5	ef
8. Belay 2.13 SC	5.5	preflood	3.0	ab	56	de
9. Belay 2.13 SC	3.5	2-3 leaf	3.0	ab	11.5	h
10. Belay 2.13 SC	4.5	2-3 leaf	3.13	a	14	gh
11. Belay 2.13 SC	5.5	2-3 leaf	2.88	ab	18.5	gh
12. Mustang Max EW	4	2-3 leaf	3.0	ab	16.5	gh
13. Mustang Max EW	4	early preflood	2.88	ab	86.5	a
14. Mustang Max EW	4	preflood	2.75	ab	78	abc
15. Declare	1.54	2-3 leaf	2.63	b	16.5	gh
16. Declare	2.05	2-3 leaf	2.88	ab	22	gh
17. Declare	2.05	preflood	3.0	ab	45.5	ef
18. Dermacor X-100 5FS	1.97	preflood	3.13	a	57.5	de
19. Dermacor X-100 5FS	2.46	preflood	3.0	ab	65	abcd
20. Dermacor X-100 5FS	1.97	2-3 leaf	3.0	ab	30	fgh
21. Dermacor X-100 5FS	2.46	2-3 leaf	3.13	a	33	fg
22. Belay 2.13 EC	3.5	5-6 leaf	2.75	ab	80.5	abc
23. Belay 2.13 SC	5.5	5-6 leaf	2.88	ab	71	abcd
24. Dermacor x-100 5FS	2.46	5-6 leaf	3.0	ab	79	abc

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

Table 3. RWW immature density (first and second sample dates and average) in chemical ring study, 2011.

Product	Formulation per A (fl. oz.)	Timing	RWW per Core Sample – 11 July		RWW per Core Sample – 25 July		Avg. RWW per Core Sample
1. Dimilin 2L	8	3-leaf	0.15	bcd	0.3	ab	0.225
2. Untreated	---	---	0.65	a	0.85	a	0.75
3. Warrior II	1.92	3-leaf	0	d	0	b	0
4. Warrior II	1.92	early preflood	0	d	0	b	0
5. Warrior II	1.92	preflood	0.05	cd	0	b	0.025
6. Belay 2.13 SC	3.5	preflood	0.52	ab	0.4	ab	0.46
7. Belay 2.13 SC	4.5	preflood	0.35	abcd	0.85	a	0.6
8. Belay 2.13 SC	5.5	preflood	0.25	abcd	0.55	ab	0.4
9. Belay 2.13 SC	3.5	2-3 leaf	0.05	cd	0.5	ab	0.275
10. Belay 2.13 SC	4.5	2-3 leaf	0.1	bcd	0.05	b	0.075
11. Belay 2.13 SC	5.5	2-3 leaf	0.35	abcd	0.15	b	0.25
12. Mustang Max EW	4	2-3 leaf	0.2	bcd	0	b	0.1
13. Mustang Max EW	4	early preflood	0	d	0.1	b	0.05
14. Mustang Max EW	4	preflood	0.05	cd	0.15	b	0.1
15. Declare	1.54	2-3 leaf	0.15	bcd	0.1	b	0.125
16. Declare	2.05	2-3 leaf	0.3	abcd	0.15	b	0.225
17. Declare	2.05	preflood	0	d	0.1	b	0.05
18. Dermacor X-100 5FS	1.97	preflood	0.45	abc	0.25	b	0.35
19. Dermacor X-100 5FS	2.46	preflood	0.15	bcd	0.15	b	0.15
20. Dermacor X-100 5FS	1.97	2-3 leaf	0.3	abcd	0.45	ab	0.375
21. Dermacor X-100 5FS	2.46	2-3 leaf	0.2	bcd	0.15	b	0.175
22. Belay 2.13 EC	3.5	5-6 leaf	0.42	abcd	0.44	ab	0.43
23. Belay 2.13 SC	5.5	5-6 leaf	0.2	bcd	0.25	b	0.225
24. Dermacor x-100 5FS	2.46	5-6 leaf	0.35	abcd	0.2	b	0.275

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

Table 4. Effect of RWW populations on rice biomass and grain yields in ring study, 2011.

Product	Formulation per A (fl. oz.)	Timing	% Grain Moisture		Grain Yield (lbs./A)		Biomass (Straw+Grain) (t/A)	
1. Dimilin 2L	8	3-leaf	20.75	bc	3509.3	bc	5.32	ef
2. Untreated	---	---	21.2	ab	2329.8	c	4.35	f
3. Warrior II	1.92	3-leaf	19.9	cdefgh	5610.5	a	8.22	abc
4. Warrior II	1.92	early preflood	19.65	fgh	4719.6	ab	7.30	abcde
5. Warrior II	1.92	preflood	19.98	cdefgh	5735.9	a	8.70	ab
6. Belay 2.13 SC	3.5	preflood	19.85	defgh	3980.3	ab	6.24	cdef
7. Belay 2.13 SC	4.5	preflood	20.35	cdefgh	4810.3	ab	7.51	abcde
8. Belay 2.13 SC	5.5	preflood	20.03	cdefgh	5253.6	ab	7.18	abcde
9. Belay 2.13 SC	3.5	2-3 leaf	19.58	fgh	4812.3	ab	7.43	abcde
10. Belay 2.13 SC	4.5	2-3 leaf	19.9	cdefgh	5804.2	a	8.93	a
11. Belay 2.13 SC	5.5	2-3 leaf	19.83	efgh	5337.7	ab	7.99	abcd
12. Mustang Max EW	4	2-3 leaf	19.53	gh	4841.8	ab	7.38	abcde
13. Mustang Max EW	4	early preflood	19.88	cdefgh	5119	ab	7.71	abcd
14. Mustang Max EW	4	preflood	20.18	cdefgh	4449.6	ab	6.51	bcdef
15. Declare	1.54	2-3 leaf	19.98	cdefgh	4699.7	ab	7.07	abcde
16. Declare	2.05	2-3 leaf	20.08	cdefgh	5221	ab	7.74	abcd
17. Declare	2.05	preflood	19.5	h	4771.3	ab	7.05	abcde
18. Dermacor X-100 5FS	1.97	preflood	20.43	cdefgh	4977.5	ab	7.45	abcde
19. Dermacor X-100 5FS	2.46	preflood	19.68	fgh	4530	ab	6.74	abcde
20. Dermacor X-100 5FS	1.97	2-3 leaf	20.4	cdefgh	5335.9	ab	7.71	abcd
21. Dermacor X-100 5FS	2.46	2-3 leaf	19.93	cdefgh	4753.1	ab	7.23	abcde
22. Belay 2.13 EC	3.5	5-6 leaf	20.7	cdef	4354.5	ab	6.34	bcdef
23. Belay 2.13 SC	5.5	5-6 leaf	20.73	bcd	4821.5	ab	7.13	abcde
24. Dermacor x-100 5FS	2.46	5-6 leaf	21.7	a	3637.1	bc	5.78	def

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

Table 5. Results from large plot Coragen study for rice water weevil control, 2011.

Product	Rate (lbs. AI/A)	% Scarred Plants – 24 June		RWW per Core Sample – 13 July		RWW per Core Sample – 27 July		Avg. RWW	% Moisture		Grain Yield (lbs./A) *	
Coragen	0.08	37.25	a	1.7	a	1.74	a	1.7	19.9	ab	4750.5	bc
Coragen	0.10	31.25	a	2.5	a	1.75	a	2.1	18.4	bc	6043.9	ab
Coragen	0.12	35.75	a	1.25	a	2.6	a	1.9	18.2	c	6647.0	a
Untreated	---	41.0	a	2.63	a	1.5	a	2.1	20.5	a	3933.8	c

* M-202 yielded 6286 lbs./A in neighboring plot treated with Warrior PF + Dermacor seed trt.

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

Table 6. Results from Belay large plot comparison study for rice water weevil control, 2011.

Product	Rate (lbs. AI/A)	% Scarred Plants – 24 June	RWW per Core Sample – 13 July	RWW per Core Sample – 27 July	Avg. RWW	% Moisture	Grain Yield (lbs./A)
Belay 2.13 SC	0.075	69.3	1.3	1.0	1.15	19.3	4078
Belay 2.13 SC	0.075	19.7	0.1	0.05	0.08	18.3	6749
Untreated*	---	41	2.7	1.5	2.1	18.2	3985

* Data for untreated taken from another study conducted in the two basins to the south.

Table 7. Treatments evaluated in non-target study, 2009-11.

Product	Rate (lbs. AI/A)	Timing	Rationale	2009	2011	2011
1. Untreated	---	---	Comparison	X	X	X
2. Warrior	0.03	3-leaf	Registered standard	X	X	X
3. Warrior	0.03	preflood	Registered standard	X	X	X
4. Warrior	0.03	July armyworm timing	Registered standard	X	X	X
5. Dimilin 2L	0.125	3-leaf	Registered standard	X	X	
6. V10170	0.1 per 100 lbs. seed	seed treatment	Under development; discontinued as seed trtment	X		
7. Trebon 3G	0.18	3-leaf	Under development; discontinued	X	X	
8. DPX-NGW86	0.1 per 100 lbs. seed	seed treatment	Under development; discontinued as seed trtment	X		
9. Belay 2.13 SC	0.092	Preflood	Under development; on registration track	X	X	X
10. Belay 2.13 SC	0.092	3-leaf	Under development; on registration track	X	X	X
11. Dermacor X-100 5FS	0.10	Preflood	Under development; considered for registration		X	X
12. Dermacor X-100 5FS	2.50 oz/100 lbs. seed	seed treatment	Under development; discontinued as seed trtment		X	

Table 8. Rice Water Weevil population in non-target study, 2011.

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	0.53	0.07	0.3
2. Warrior II	0.03	3-leaf	0.2	0.13	0.17
3. Warrior II	0.03	preflood	0	0	0.0
4. Warrior II	0.03	July armyworm timing	0.07	0.27	0.17
5. Coragen	0.12	PF	0.13	0.07	0.2
6. Belay 2.13 SC	0.092	3-leaf	0.33	0.13	0.23
7. Untreated	---	---	0.2	0	0.10

Table 9. Treatments evaluated for tadpole shrimp control studies, 2011.

Product	**Rate (lbs. AI/A)**	**Formulation per A**	**Timing**
1. Untreated-no TPS added	---	---	---
2. Belay 2.13SC	0.07	4.5 fl. oz.	preflood
3. Dermacor X-100 5FS	0.1	2.46 fl. oz.	preflood
4. Mustang Max EW	0.025	4	post-flood*
5. Copper sulfate		10 lbs.	post-flood*
6. Belay 2.13SC	0.07	4.5 fl. oz.	post-flood*
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.	preflood
* 1 day after the tadpole shrimp were introduced into the rings			

Table 10. Evaluation of treatments against tadpole shrimp (TPS), 2011.

			Floating Seedlings					
Product	**Formulation per A**	**Timing**	**Small Ring**		**Large Ring**		**Total**	
1. Untreated-no TPS added	---	---	2.25	a	7.5	a	9.75	a
2. Belay 2.13SC	4.5 fl. oz.	preflood	2	a	6.75	ab	8.75	a
3. Dermacor X-100 5FS	2.46 fl. oz.	preflood	1	a	3	b	4	b
4. Mustang Max EW	4 fl. oz.	post-flood*	1.5	a	4.5	ab	6	ab
5. Copper sulfate	10 lbs.	post-flood*	1.5	a	5.5	ab	7	b
6. Belay 2.13SC	4.5 fl. oz.	post-flood*	1.5	a	5.5	ab	7	ab
7. Untreated with TPS added	---	---	2.25	a	7.25	a	9.5	a
8. Warrior II	1.92 fl. oz.	post-flood*	2.25	a	4.5	ab	6.75	ab
9. Warrior II	1.92 fl. oz.	preflood	1.25	a	4.5	ab	5.75	ab
			Established Seedlings					
Product	**Formulation per A**	**Timing**	**Small Ring**		**Large Ring**		**Total**	
1. Untreated-no TPS added	---	---	31.75	a	94.5	a	126.25	a
2. Belay 2.13SC	4.5 fl. oz.	preflood	32.75	a	90.5	a	123.25	a
3. Dermacor X-100 5FS	2.46 fl. oz.	preflood	22.75	a	89	a	111.75	a
4. Mustang Max EW	4 fl. oz.	post-flood*	29.25	a	92.5	a	121.75	a
5. Copper sulfate	10 lbs.	post-flood*	23.5	a	106.5	a	130	a
6. Belay 2.13SC	4.5 fl. oz.	post-flood*	29	a	83.75	a	112.75	a
7. Untreated -TPS added	---	---	32.5	a	90.5	a	123	a
8. Warrior II	1.92 fl. oz.	post-flood*	23.25	a	111.75	a	135	a
9. Warrior II	1.92 fl. oz.	preflood	21.25	a	83	a	104.25	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. Rice water weevil natural infestation in tadpole shrimp treatment study, 2011.

Product	Product per A	Timing	RWW per Core Sample – 12 July		RWW per Core Sample – 26 July		Avg
1. Untreated-no TPS added	---	---	0.6	a	0.8	ab	0.7
2. Belay 2.13SC	4.5 fl. oz.	preflood	0.05	b	0.35	ab	0.2
3. Dermacor X-100 5FS	2.46 fl. oz.	preflood	0.05	b	0.05	ab	0.05
4. Mustang Max EW	4 fl. oz.	post-flood*	0	b	0.25	ab	0.13
5. Copper sulfate	10 lbs.	post-flood*	0.35	ab	0.8	ab	0.58
6. Belay 2.13SC	4.5 fl. oz.	post-flood*	0.05	b	0.3	ab	0.18
7. Untreated - TPS added	---	---	0.6	a	0.9	a	0.75
8. Warrior II	1.92 fl. oz.	post-flood*	0.05	b	0.8	ab	0.43
9. Warrior II	1.92 fl. oz.	preflood	0	b	0	b	0.0

* 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. Yield results from tadpole shrimp study – 2011.

Product	Product per A	Timing	% Grain Moisture		Grain Yield (lbs./A)		Biomass (straw + grain) (t/A)	
1. Untreated-no TPS added	---	---	20.4	a	3991.9	abc	6.7	ab
2. Belay 2.13SC	4.5 fl. oz.	preflood	19.9	a	5229.8	a	8.1	ab
3. Dermacor X-100 5FS	2.46 fl. oz.	preflood	20.0	a	5767.4	a	8.9	a
4. Mustang Max EW	4 fl. oz.	post-flood*	19.9	a	4996.6	abc	7.4	ab
5. Copper sulfate	10 lbs.	post-flood*	20.7	a	3120.6	c	5.9	b
6. Belay 2.13SC	4.5 fl. oz.	post-flood*	20.0	a	5078.6	ab	7.8	ab
7. Untreated - TPS added	---	---	20.5	a	3169.4	bc	5.5	b
8. Warrior II	1.92 fl. oz.	post-flood*	20.2	a	4931.7	abc	8.0	ab
9. Warrior II	1.92 fl. oz.	preflood	20.5	a	4403.2	abc	6.6	ab

* 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. 13. Treatment list for RWW levee study.

Treatment	Product per Acre
Mowed Plots	
1) Control	---
2) Warrior II	2.56 fl. oz.
3) Aza-Direct	1 pint per 100 gallons
4) Warrior + Aza-Direct	2.56 + 1 pt.
5) Botanigard	2 pints per 3 gallons
Unmowed Plots	
6) Control	---
7) Warrior II	2.56 fl. oz.
8) Aza-Direct	1 pint per 100 gallons
9) Warrior + Aza-Direct	2.56 + 1 pt.
10) Botanigard	2 pints per 3 gallons

Table 14. RWW adult feeding damage and larval populations in variety susceptibility comparison to RWW study, 2011.

Variety	RWW Status	% Scarred Plants - 24 June		RWW per Core Sample – 12 July		RWW per Core Sample – 26 July		Average
M-202	Not present	26	c	0	c	0.1	b	0.05
S-102	Not present	19.5	c	0.05	c	0.1	b	0.08
L-206	Not present	13.5	c	0	c	0	b	0
Calmati-202	Not present	19	c	0	c	0.1	b	0.05
M-202	Present	77.5	a	0.25	bc	0.2	b	0.23
S-102	Present	79	a	0.75	ab	0.35	b	0.55
L-206	Present	57	b	0.85	a	0.85	a	0.85
Calmati-202	Present	58.5	b	0.85	a	0.3	b	0.58

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

Table 15. Yield data in variety susceptibility comparison to RWW study, 2011.

Variety	RWW Status	% Grain Moisture		Grain Yield (lbs./A)		Yield Loss from RWW	Biomass (Straw+Grain) (t/A)	
M-202	Not present	18.2	b	6133.5	a	3369.4	9.2	a
S-102	Not present	15.7	d	4160.4	b	1300.4	6.6	bc
L-206	Not present	17.3	bc	6102.8	a	2154.3	7.7	b
Calmati-202	Not present	16.3	cd	3920.5	bc	1974.8	6.1	cd
M-202	Present	20.2	a	2764.1	cd		5.3	cde
S-102	Present	16.9	c	2860	cd		4.9	de
L-206	Present	19.3	a	3948.5	bc		5.6	cde
Calmati-202	Present	18.2	b	1945.7	d		4.6	e

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

Table 16. California rice cultivars evaluated in small plot study designed to evaluate susceptibility to RWW, 2011.

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-105	X	X
5. M-208	X	X
6. M-205	X	X
7. M-202	X	X
8. M-206	X	X
9. M-401	X	X
10. Calhikari-201	X	X
11. Calmati-202	X	X
12. Calmochi-101	X	X

Table 17. RWW adult feeding damage and larval populations in small plot variety susceptibility comparison to RWW study, 2011.

Variety	RWW Status	% Scarred Plants - 24 June		RWW per Core Sample – 13 July		RWW per Core Sample – 27 July		Average
M-105	Controlled	33	abc	0.05	e	0	d	0.03
Calhikari-201	Controlled	30.5	abc	0	e	0.05	d	0.03
Calmati-202	Controlled	25	abc	0	e	0.05	d	0.03
Calmochi-101	Controlled	25	abc	0	e	0	d	0
L-206	Controlled	34.5	abc	0	e	0	d	0
M-104	Controlled	22.5	c	0	e	0	d	0
M-202	Controlled	25	abc	0.15	de	0.11	d	0.13
M-205	Controlled	30	abc	0	e	0.05	d	0.03
M-206	Controlled	32	abc	0	e	0.15	d	0.08
M-208	Controlled	28.5	abc	0	e	0.05	d	0.03
M-401	Controlled	24.5	bc	0.05	e	0.05	d	0.05
S-102	Controlled	39.5	abc	0.11	de	0	d	0.06
M-105	Present	29	abc	0.35	bcde	0.5	cd	0.43
Calhikari-201	Present	22	c	0.35	bcde	0.2	d	0.28
Calmati-202	Present	30	abc	0.35	bcde	0.41	cd	0.38
Calmochi-101	Present	38	abc	0.4	bcde	0.55	bcd	0.48
L-206	Present	45.5	ab	0.9	ab	1.2	ab	1.05
M-104	Present	46.5	a	0.75	abc	0.35	cd	0.55
M-202	Present	33.5	abc	1.05	a	0.65	bcd	0.85
M-205	Present	36.5	abc	0.55	abcde	0.35	cd	0.45
M-206	Present	32	abc	0.8	abc	1.45	a	1.13
M-208	Present	35.5	abc	0.3	cde	0.2	d	0.25
M-401	Present	24	bc	0.65	abcd	0.95	abc	0.8
S-102	Present	30.5	abc	0.85	abc	0.53	cd	0.69

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

Table 18. Yield data in small plot variety susceptibility comparison to RWW study, 2011.

Variety	RWW Status	% Moisture		Grain Yield (lbs./A)		Grain Yield Loss from RWW (lbs./A)
M-105	Controlled	17.7	efg	6250.8	ab	570.8
Calhikari-201	Controlled	17.4	fg	6042.0	abc	488.3
Calmati-202	Controlled	20.4	a	4959.1	ef	0
Calmochi-101	Controlled	17.4	g	6231.6	ab	485.6
L-206	Controlled	17.8	efg	6288.5	ab	418.6
M-104	Controlled	19.3	abcd	4886.5	ef	106.9
M-202	Controlled	17.9	efg	6286.0	ab	28.6
M-205	Controlled	17.9	efg	6256.8	ab	199.3
M-206	Controlled	18.1	cdefg	6438.6	a	571
M-208	Controlled	18.8	bcedfg	5615.8	abcdef	0
M-401	Controlled	18.8	bcdef	6558.1	a	437.3
S-102	Controlled	17.4	fg	5840.8	abcdef	467.6
M-105	Present	18.8	bcde	5680.0	abcdef	
Calhikari-201	Present	17.8	efg	5553.7	abcdef	
Calmati-202	Present	19.9	ab	5167.0	cdef	
Calmochi-101	Present	17.6	efg	5746.0	abcdef	
L-206	Present	18.4	cdefg	5869.9	abcd	
M-104	Present	19.4	abc	4779.6	f	
M-202	Present	17.5	efg	6257.4	ab	
M-205	Present	17.8	efg	6057.5	abc	
M-206	Present	17.5	efg	5867.6	abcd	
M-208	Present	18.0	defg	5914.7	abcd	
M-401	Present	18.4	cdefg	6120.8	abc	
S-102	Present	18.2	cdefg	5373.2	bcdef	

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

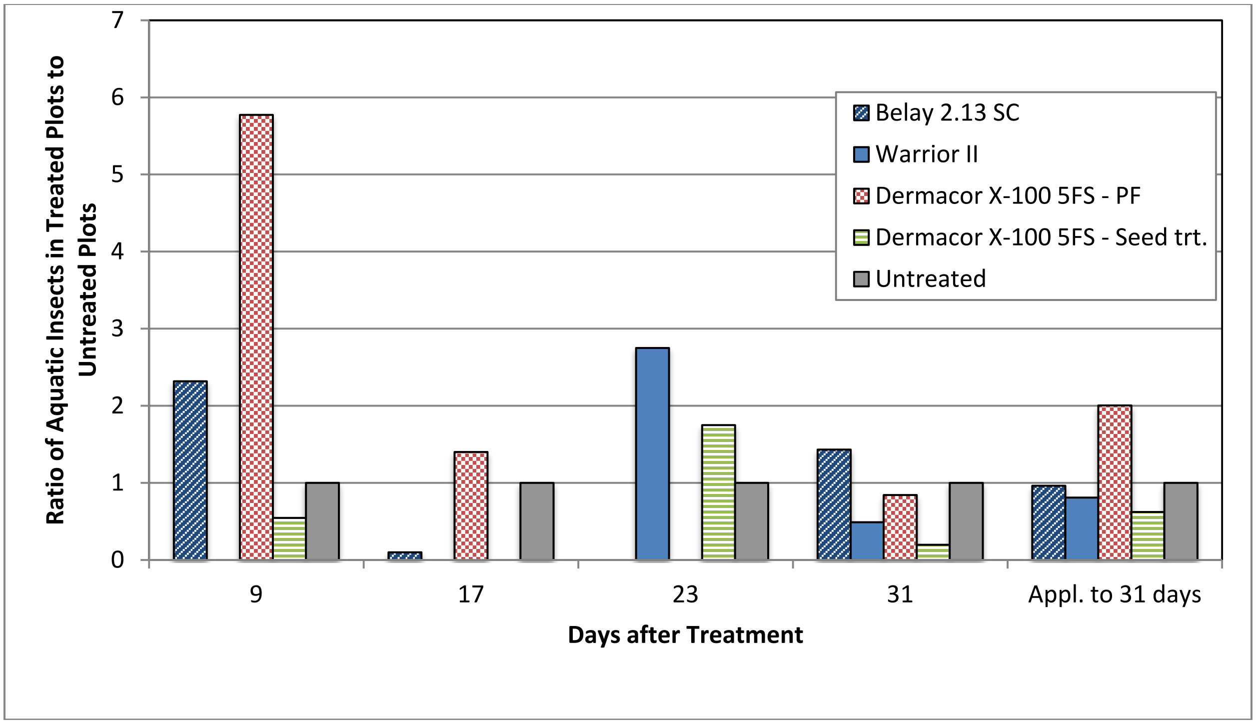

Figure 1. Influence of preflood insecticide applications on populations of aquatic insects from floating barrier trap samples in rice, 2010.

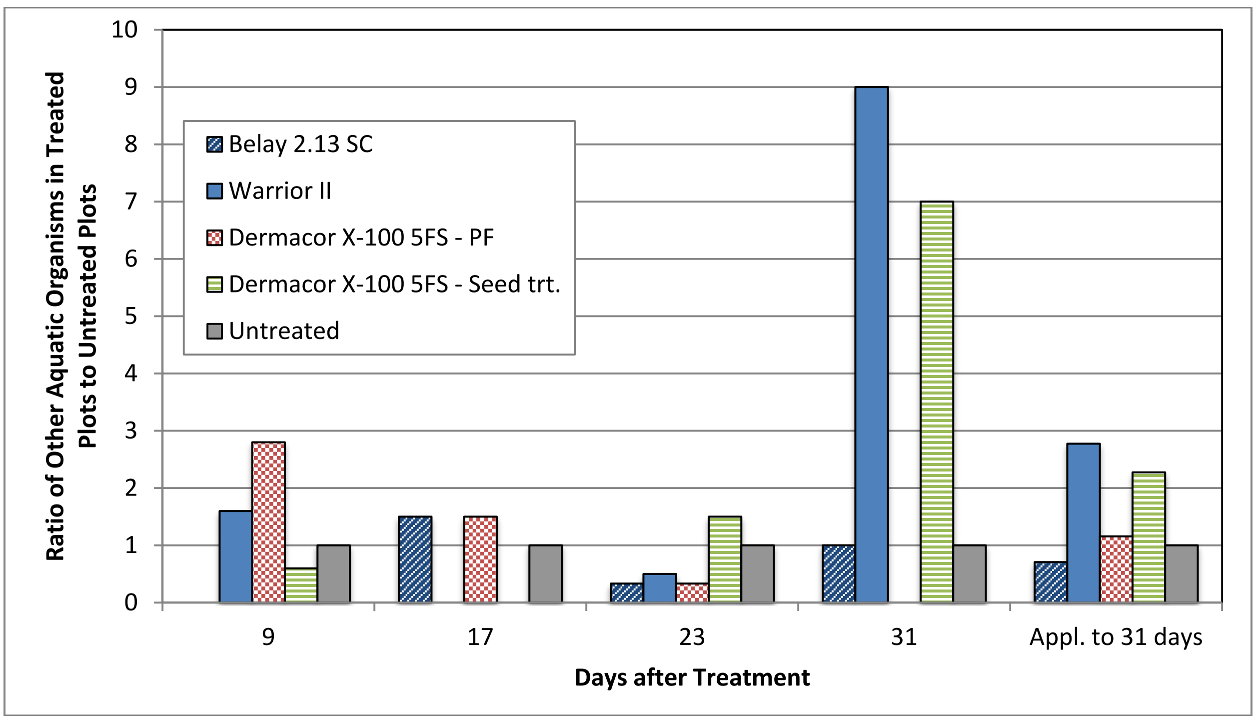

Figure 2. Influence of preflood insecticide applications on populations of aquatic animals (excluding insects) from floating barrier trap samples in rice, 2010.

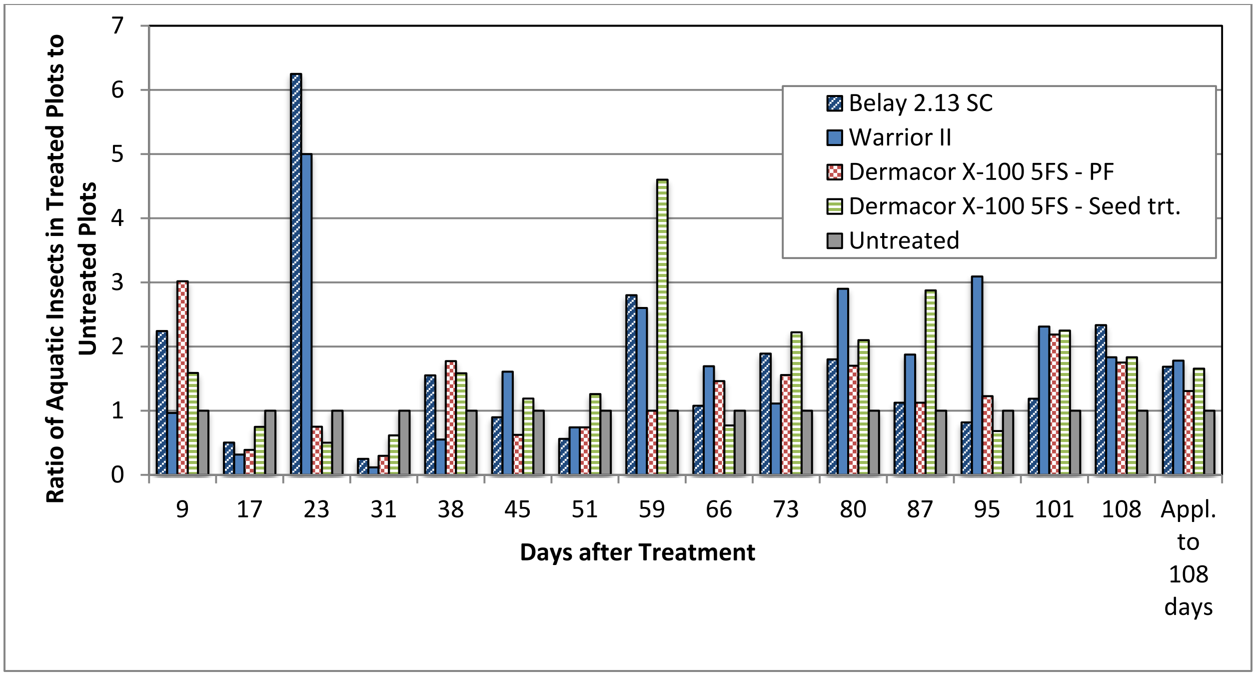

Figure 3. Influence of preflood insecticide applications on populations of aquatic insects from quadrant samples in rice, 2010.

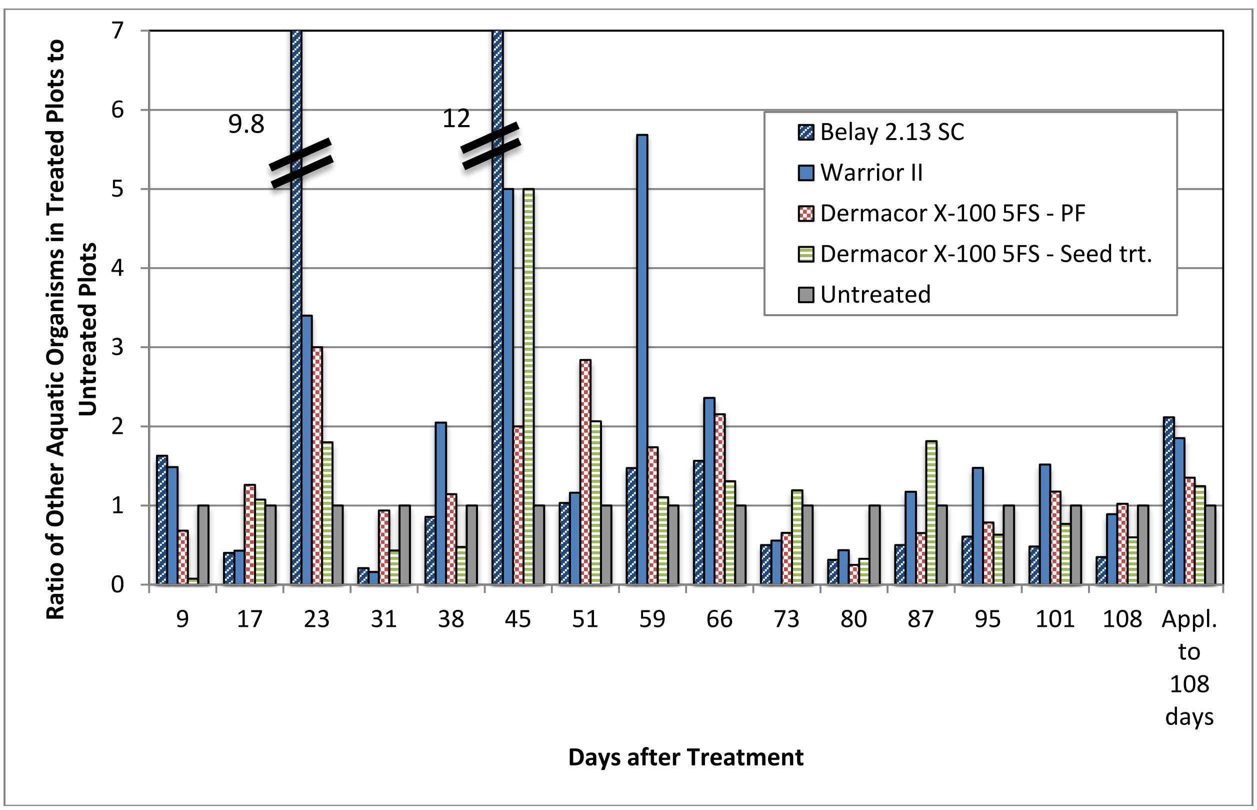

Figure 4. Influence of preflood insecticide applications on populations of aquatic animals (excluding insects) from quadrant samples in rice, 2010.

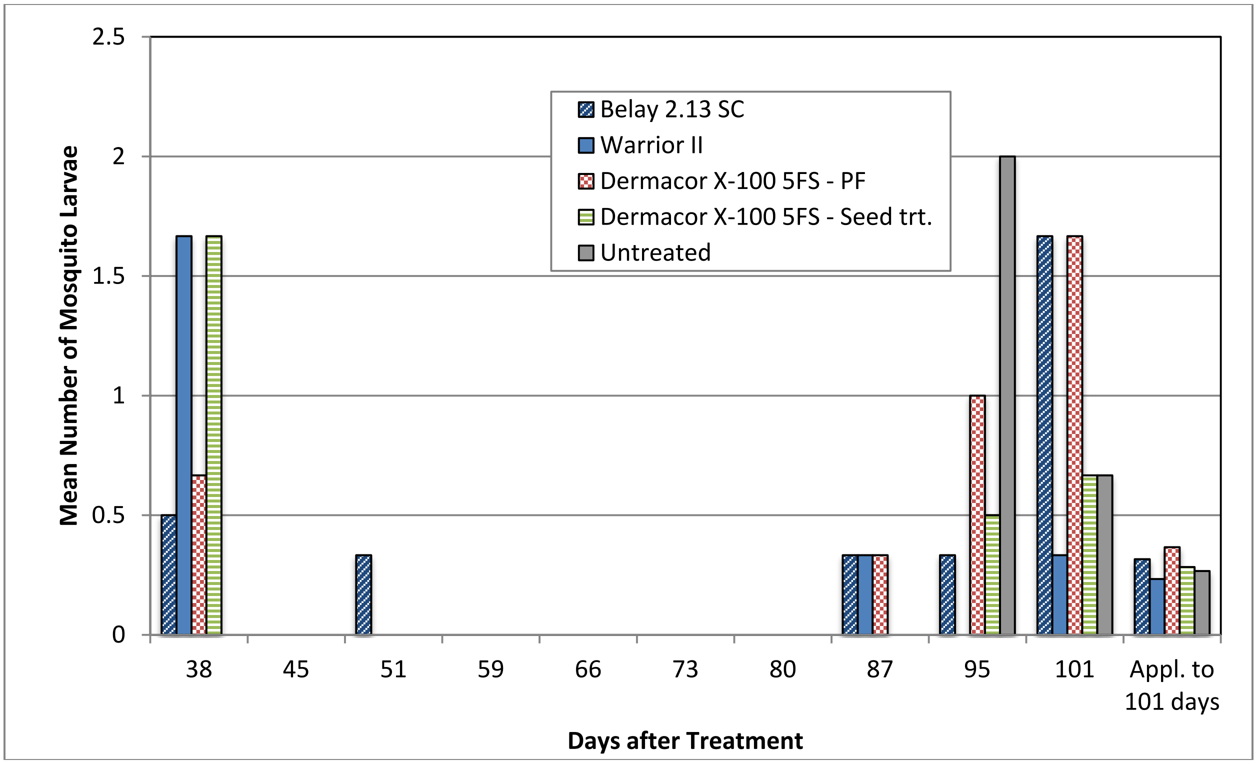

Figure 5. Influence of pre-flood applications on mosquito larval populations from dip samples, 2010.

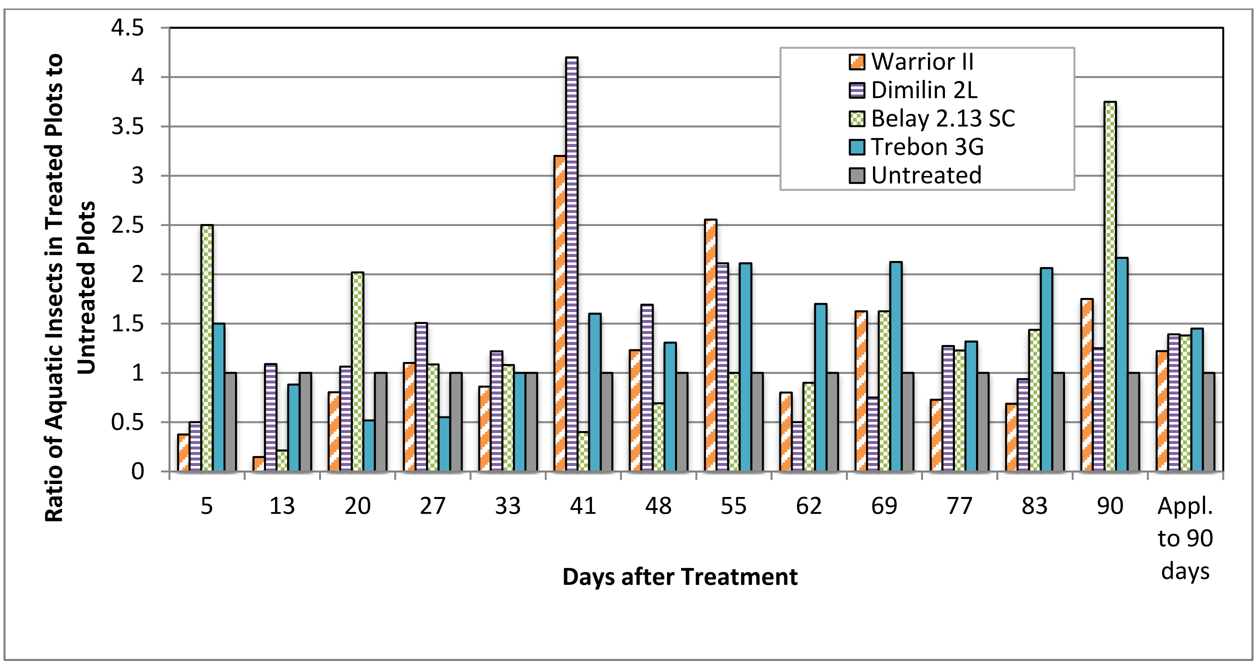

Figure 6. Influence of post-flood (3-leaf) insecticide applications on populations of aquatic insects from quadrant trap samples in rice, 2010.

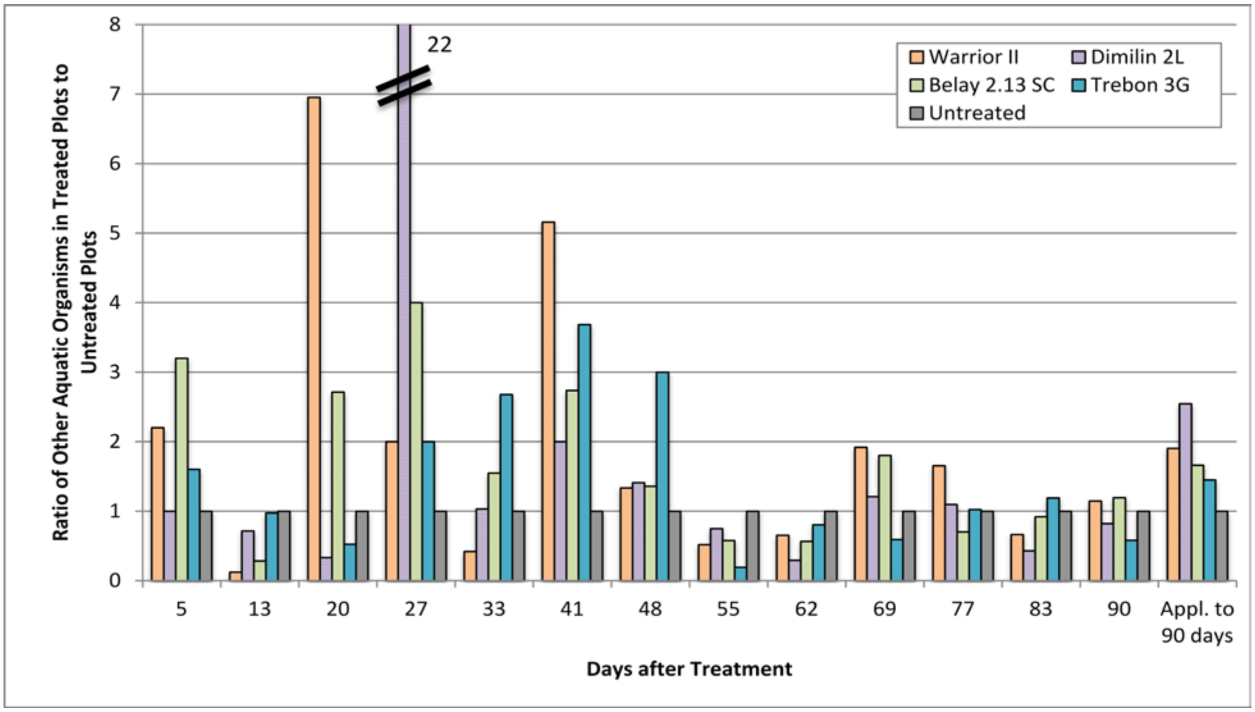

Figure 7. Influence of post-flood (3-leaf) insecticide applications on populations of aquatic animals (excluding insects) from quadrant trap samples in rice, 2010.

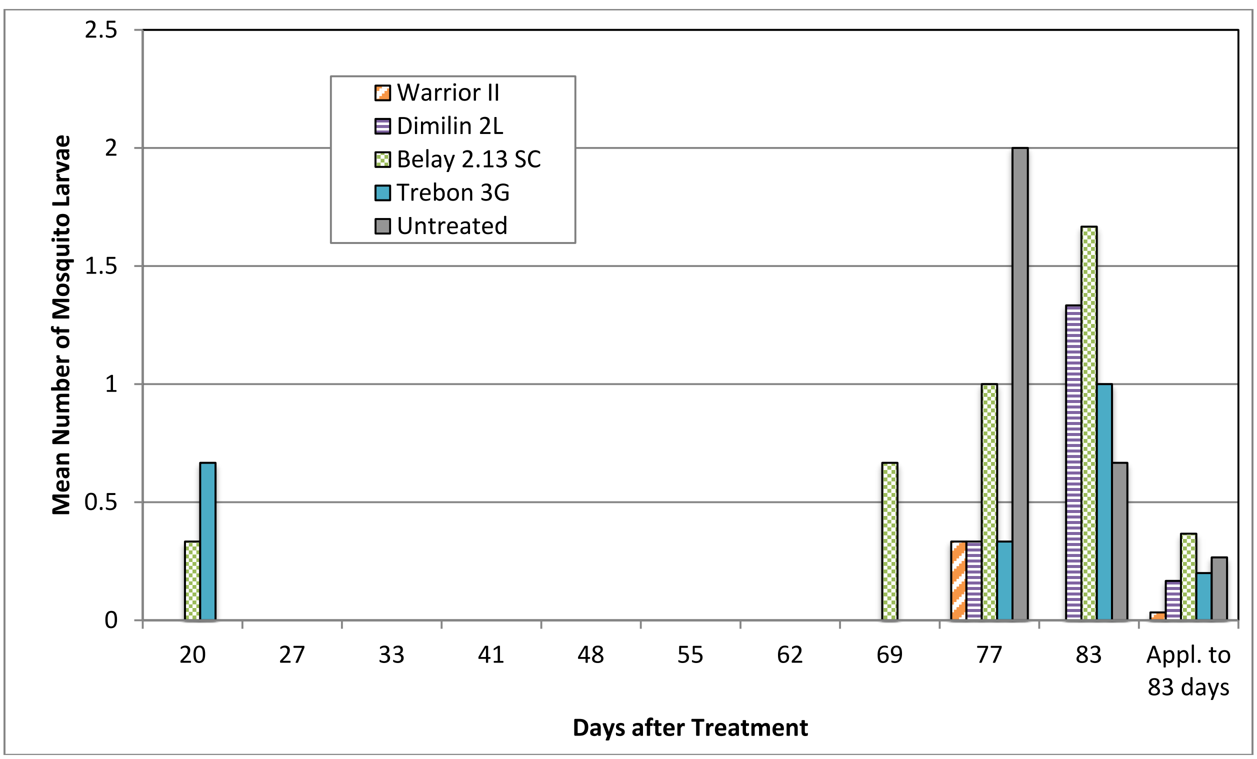

Figure 8. Influence of post-flood (3-leaf) insecticides applications on populations of mosquito larvae from dip samples, 2010.

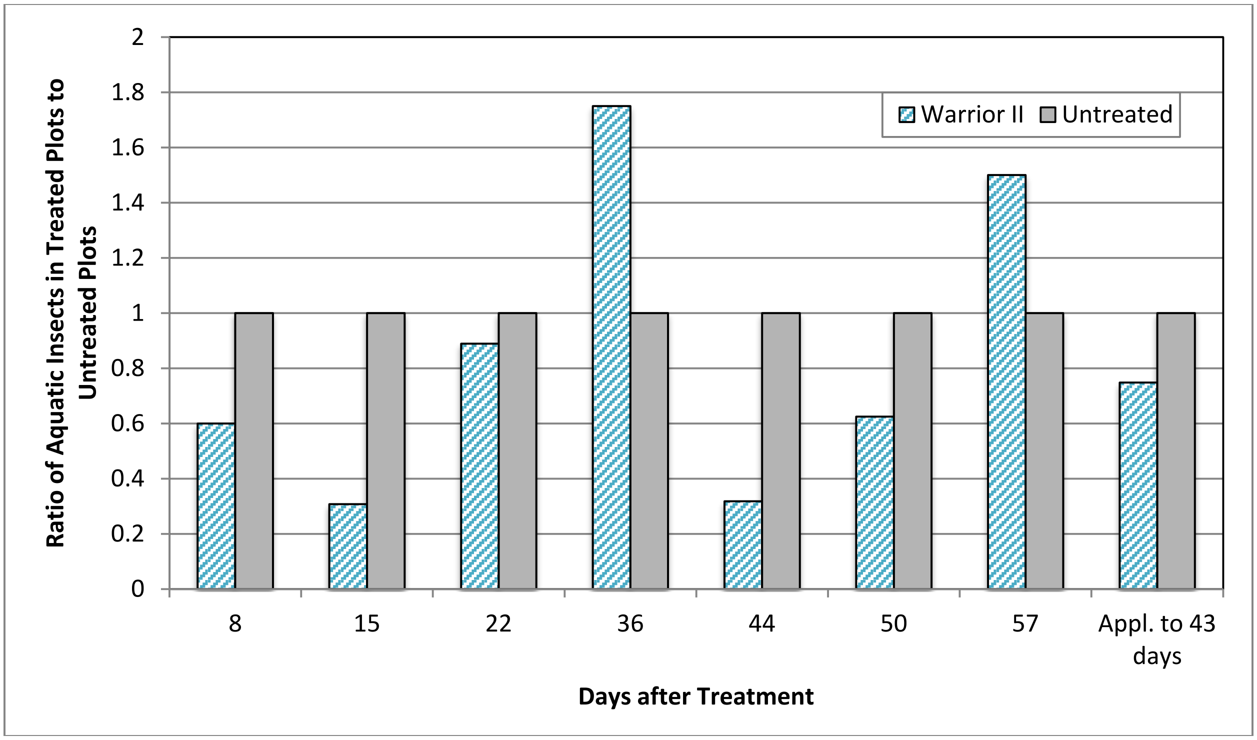

Figure 9. Influence of insecticide applications (armyworm timing) on populations of aquatic insects from quadrant trap samples in rice, 2010.

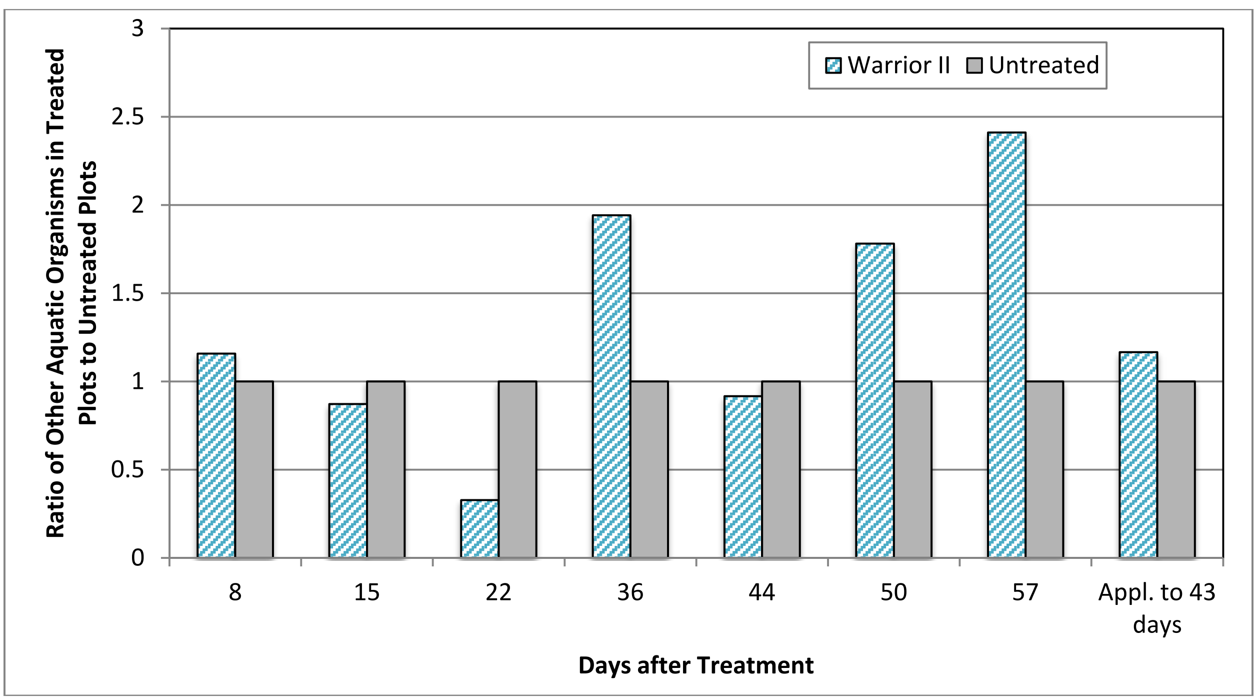

Figure10. Influence of insecticide applications (armyworm timing) on populations of aquatic animals (excluding insects) from quadrant trap samples in rice, 2010.

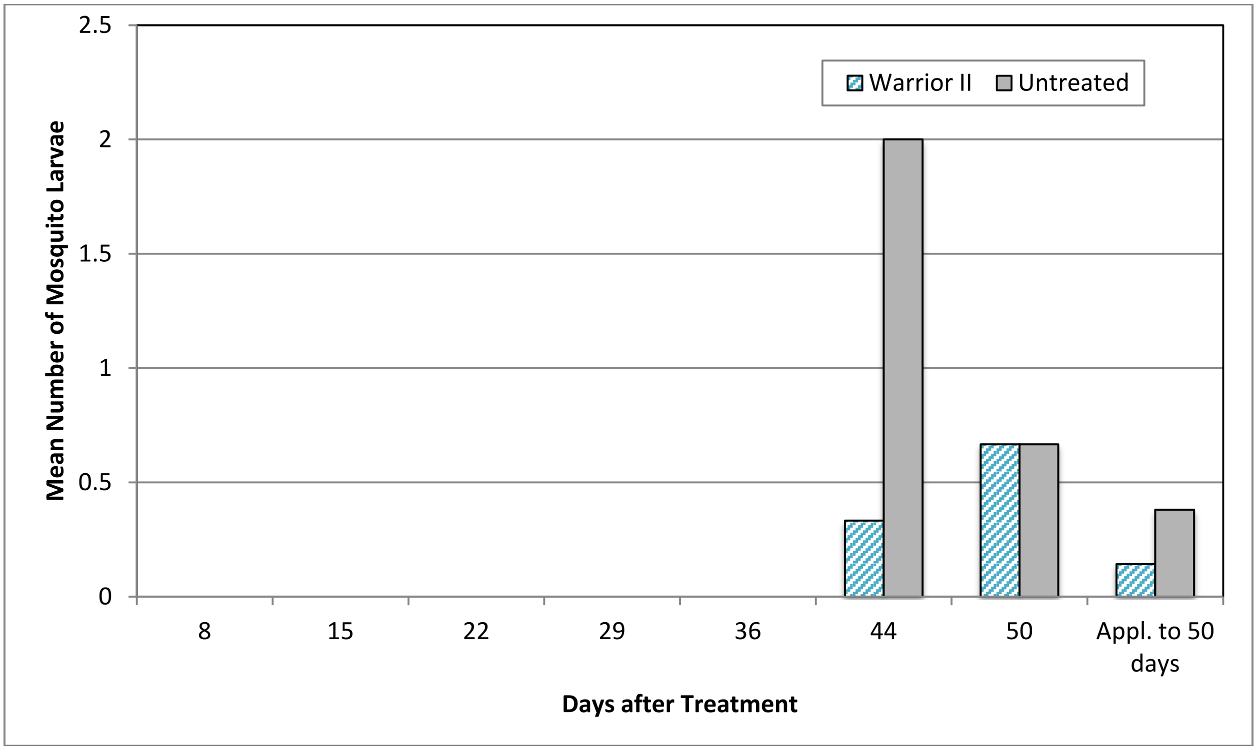

Figure 11. Influence of insecticide applications (armyworm timing) on populations of mosquito larvae from dip samples, 2010.

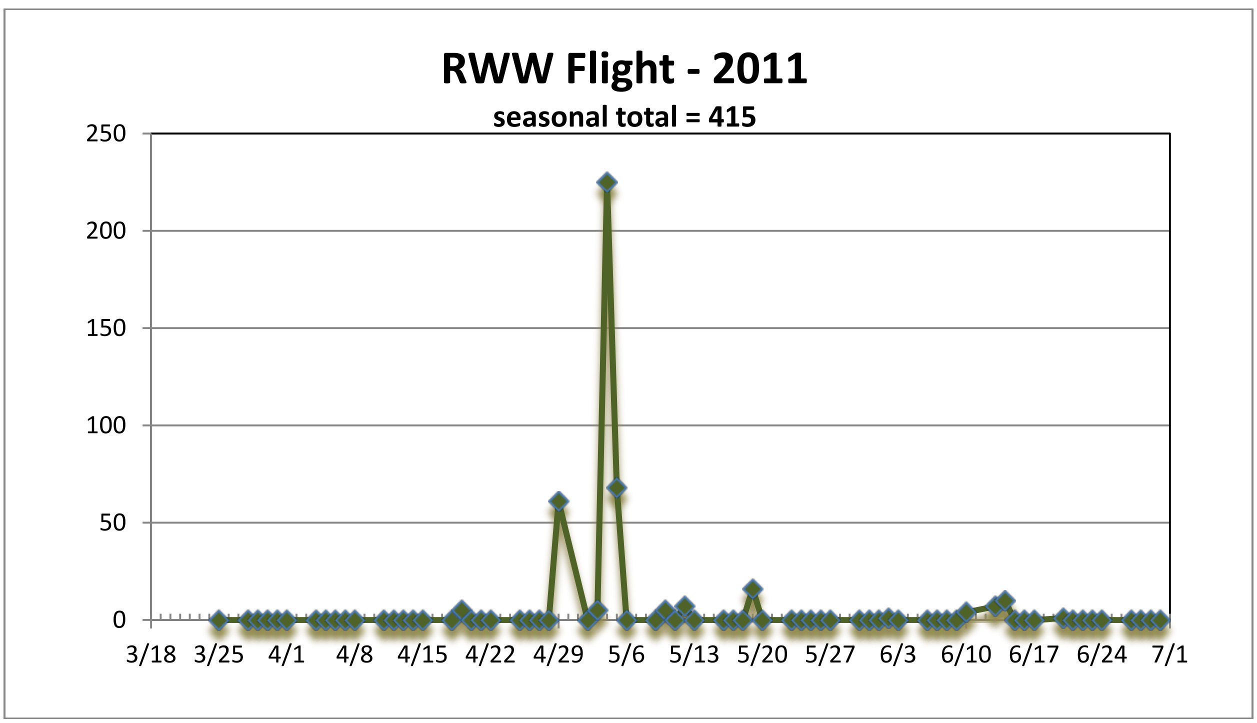

Figure 12. Rice Water Weevil flight incidence in spring,2011 at Rice Experiment Station, Butte Co.

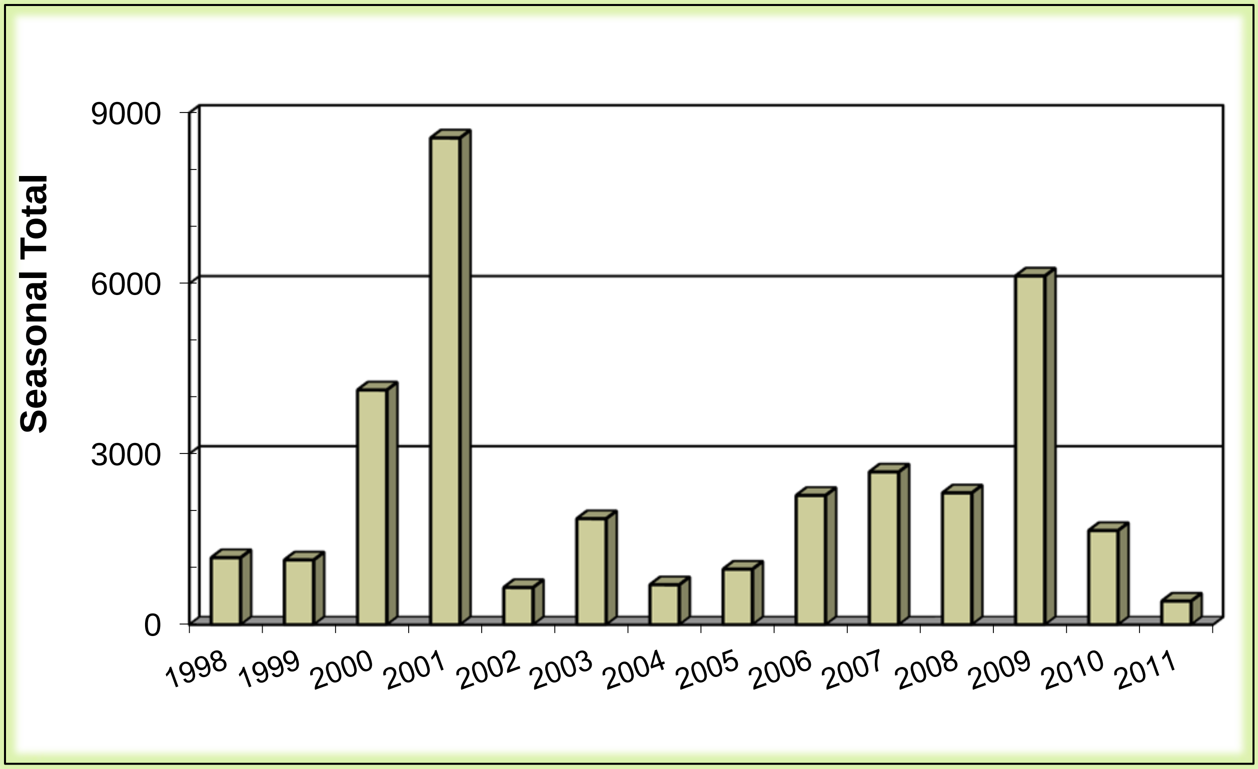

Figure13. Comparison of Rice Water Weevil flight totals from light trap sampling at the Rice Experiment Station, 1998-2011.