PROJECT NO. RP-3

ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE

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PROJECT TITLE: Rice protection from invertebrate pests.

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OBJECTIVES AND EXPERIMENTS CONDUCTED BY LOCATION:

Objective 1: Evaluate the effectiveness of insecticidal management tools for rice water weevil, comparing registered and experimental materials, that have a fit for pest management while maintaining environmental quality compatible with the needs of society.

1.1) Rice water weevil chemical control - Ring plots.

1.1.1) Comparison of the efficacy of experimental materials versus registered standards for controlling rice water weevil.

1.1.2) Evaluation of the length of residual control provided by Dimilin® 2L.

1.1.3) Evaluation of techniques to improve the utility of registered products for rice water weevil management.

1.2) Rice water weevil control with one biorational product - Ring plots.

1.2.1) Evaluation of the efficacy of a microbial insecticide, Novodor® (*Bacillus thuringiensis tenebrionis*) for controlling rice water weevil.

1.3) Rice water weevil chemical control - Grower field plots

1.31) Evaluation of the effects of application timing on the efficacy of Dimilin 2L for controlling a natural infestation of rice water weevil in grower fields.

1.3.2) Evaluation of the effects of application rate and product placement on the efficacy of Dimilin 2L for controlling a natural infestation of rice water weevil in grower fields.

1.3.3) Evaluation of a Dimilin 2L + Warrior® T tank mix for controlling a natural infestation of rice water weevil in grower fields.

1.4) Rice water weevil control - Greenhouse studies.

1.4.1) Evaluation of the influence of Dimilin 2L on rice water weevil, applied after oviposition, to determine effects on RWW eggs and 1st instars.

1.4.2) Re-evaluation of the influence of Novodor, a new biorational product, on rice water weevil to determine efficacy.

Objective 2: To evaluate and monitor 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) Examine the influence of winter flooding on rice water weevil populations.

2.2) Study the relationship between timing, i.e., rice plant growth stage, and plant response to RWW-induced injury.

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

2.3.1) Monitor seasonal trends (timing and magnitude) in the flight activity of the rice water weevil at the RES with a black-light trap.

2.3.2) Monitor the timing and movement of rice water weevil across the Sacramento Valley with black-light traps.

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

2.5) Evaluate the usefulness of an in-field floating RWW trap (as developed at the Univ. of Arkansas) for sampling within field RWW populations.

SUMMARY OF 2000 RESEARCH BY OBJECTIVE:

Objective 1:

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

1.1.1, 1.1.2, 1.1.3, 1.2.1) Twenty-four treatments (a total of 9 different chemical products) were established in ring plots to accomplish the three sub-objectives of 1.1) and the one sub-objective of 1.2). Plots were in a replicated field study at the Rice Experiment Station (RES) near Biggs, CA. The data will be reported in its entirely for ease of comparison across treatments and the conclusion from each sub-objective will be reported. Each treatment was replicated four times. Treatment details are listed in Table 1.

Table 1. Treatment list for RWW management ring study, 2000.

Product	Rate (lbs. AI/A)	Application Timing	Timing of RWW Introduction	Date of Application
1. Furadan 5G	0.5	PPI	31 May, 7 June	17 May
2. Dimilin 2L	0.125	3-5 days*	31 May	31 May
3. Dimilin 2L	0.125	3-5 days*	2 June	31 May
4. Dimilin 2L	0.125	3-5 days*	4 June	31 May
5. Dimilin 2L	0.125	3-5 days*	6 June	31 May
6. Dimilin 2L	0.125	3-5 days*	8 June	31 May
7. Dimilin 2L	0.125	3-5 days*	10 June	31 May
8. Untreated	---	---	31 May	---
9. Untreated	---	---	2 June	---
10. Untreated	---	---	4 June	---
11. Untreated	---	---	6 June	---
12. Untreated	---	---	8 June	---
13. Untreated	---	---	10 June	---
14. Warrior T	0.03	2-3 leaf stage	31 May, 7 June	31 May
15. Warrior T	0.025	2-3 leaf stage	31 May, 7 June	31 May
16. Icon 6.2 seed trt.	0.037	pre-soaked	31 May, 7 June	19 May
17. Icon 70FS	0.0325	PPI	31 May, 7 June	17 May
18. Untreated	---	---	31 May, 7 June	---
19. Novodor + gibberellic acid	1 gallon	3 + 5 leaf	31 May, 7 June	31 May, 16 June
20. Novodor	1 gallon	3 + 5 leaf	31 May, 7 June	31 May, 16 June
21. Improved Novodor	1 gallon	3 + 5 leaf	31 May, 7 June	31 May, 16 June
22. Mustang 1.5EW	0.04	3 leaf stage	31 May, 7 June	31 May
23. Mustang 1.5EW + COC	0.04 + 1% v/v	3 leaf stage	31 May, 7 June	31 May
24. Warrior T	0.03	PPI	31 May, 7 June	17 May

* after emergence of rice through the water

Testing was conducted with 'M-202' in 8 ft^2 aluminum. The plots were flooded on 18 May and seeded on 19 May. The application timings were as follows:

17 May, pre-flood (PPI) applications
31 May, 2-3 leaf stage
7 June, 5 leaf stage

Granular treatments were applied with a "salt-shaker" granular applicator and liquid treatments were applied with a CO_2 pressurized sprayer at 14 GPA. Rice stand was evaluated and adjusted to 96 plants per 8 ft^2 ring on 3 June. The natural rice water weevil infestation was supplemented with 10 adults placed into each ring on 31 May and 5 adults each ring on 7 June for treatments 1 and 14-24. For treatments 2-13, RWW adults (15 per ring) were introduced at specified 'days after application' in order to address the question of how long Dimilin provides RWW control. The following sample dates and methods were used for this study:

Sample Dates:

Emergence/ Seedling vigor: 6 June
Adult Leaf Scar Counts: 16 June
Larval Counts: 29 June & 11 July
Rice Yield: 2 October

Sample Method:

Seedling Vigor/Emergence
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 ($\rho \leq 0.05$). Raw data reported herein.

Results:

Rice Emergence

No phytoxicity was seen from any treatment. Etiolation was seen in seedlings from treatment 19 as a result of the gibberellic acid (Table 2). This was expected from this treatment but the rate may have enhanced this effect. Most stand rating values were ~3.0 which represents a "good" stand of about 100 seedlings (before hand-thinning).

Adult Leaf Scar Counts

Adult leaf-scar damage normally is insignificant in terms of rice plant growth and development. Feeding scars are evaluated as a means to determine the effects of the treatments on adult density and to ascertain how the materials provide RWW control. In 2000, feeding scar data were collected after all of the treatments were applied. As in 1999, the Mustang treatments showed a marked effect on adult feeding, as did Warrior T. The applications were Mustang 1.5EW at 0.04 lbs. AI/A (3-leaf), Mustang 1.5EW + COC at 0.04 (3-leaf) and Warrior T 0.025 & 0.03 (2-3 leaf) (Table 2). Adult mortality from the post-flood treatments is expected since the insecticide is sprayed on to the exposed RWW adults, adult mortality is the mode of action for Mustang and Warrior. Dimilin is an ovicide, Novodor and Icon are larvicides. Overall in 2000, the 'normal' untreated, i.e., RWW infestation timing and rate similar to past years, had % adult scarring above the 20% level, that is indicative of an economic infestation that can cause a yield loss.

Larval Counts

RWW larval counts were made twice during the season. Most individuals were first through third instars with relatively few pupae captured. In the 29 June samples (1st coring date), the average densities ranged from 0 to 3.50 RWW per core (Table 3). The average numbers for the 2nd coring date of 7 July ranged from 0.05 to 2.65 RWW per core and, although there was a large range, there were few significant differences among the treatments (especially for the 2nd date). The seasonal average ranged from 0.03 to 2.28 RWW per core sample.

Experimental materials versus registered standards. The number of experimental materials available for testing in 2000 was relatively low. For this study, the appropriate untreated comparison was treatment 18 which averaged 0.83 RWW per core (Table 3). This is a lower value than some of the other untreated plots (#8 through #13 which were established for sub-objective 1.2.2) and which had a different RWW infestation pattern. Of the registered materials, Furadan provided good control, and the standard Dimilin (#2, 3) and Warrior (#14) treatments were superior. Experimental products included Mustang and Icon. RWW control from Mustang was nearly equal to Warrior. The addition of a crop oil concentrate to Mustang did not improve the activity. Icon applied as a seed treatment was marginally effective and as a PPI application it was very good and equal to Warrior. Both of these results mirror those from 1999 studies.

Length of residual control - Dimilin 2L. Dimilin controls RWW by sterilizing the females; this product has a fairly short residual in water which facilitated registration, but results in application timing being critical. Determining the number of days after application that Dimilin controls RWW was the goal of this study. Following application, RWW adults were introduced at different periods. Ring plots were covered with row-cover material to exclude naturally-occurring adults and to keep the treatments intact. RWW populations in the Dimilin-treated plots ranged (average of both sample dates) from 0.05 to 0.35 per sample (Table 3). In the untreated plots, populations ranged from 0.93 to 2.28 per sample. Examining comparable treatments, Dimilin provided 90+% RWW control at 0, 2, and 4 days after application (Fig. 1). Later timings were less efficacious with 73 to 85% control.

Improvement of registered products. Studies were conducted to evaluate possible changes to Warrior use patterns to improve efficacy and ease of use. A rate reduction (0.03 reduced to 0.025 lbs. AI/A=3.84 reduced to 3.2 oz. product/acre) resulted in a loss of activity (Table 3). The reduction in rate reduced the percentage RWW control from 97 to 58%. However, Warrior applied as a PPI application proved effective for RWW control. This application was obviously made to bare soil, incorporated slightly and then covered with water within 24 hours. The initial RWW infestation occurred 14 days after application, but the activity of Warrior in this system was still good.

Efficacy of a microbial insecticide. Novodor was tested in ring plots in 1998 and 1999; in 1998 good RWW control was seen (equal to Furadan) whereas in 1999 the control efficacy was much less than desired. In 2000, the effectiveness was again low (Table 3). The application of gibberellic acid to the seed, to promote seedling growth and allow more of the insect-active bacteria to be deposited on the foliage, proved moderately effective.

Rice Yield

Rice grain yields ranged from 4327 to 6194 lbs./A. Overall, rice grain yields were similar between 1999 and 2000.

Experimental materials versus registered standards. Grain yield with Furadan was moderate in 2000 at 5255 lbs./A and was ~750 lbs./A more than the comparable untreated (Table 4). The standard Dimilin and Warrior treatments yielded ~5500 lbs./A. Of the experimental materials, grain yields in the Mustang treatments averaged ~5400 lbs./A and in the Icon treatments averaged 5375 lbs./A. As with the larval data, the use of a COC to Mustang did not enhance yield.

Length of residual control - Dimilin 2L. Yield protection with Dimilin was greatest with RWW infestations initiated at 2, 4, and 6 days after application (Table 4, Fig. 1). Yield increases peaked at 30.7% with RWW infestations at 4 days after application. The earlier timing (on the day of treatment) was slightly less effective for protecting yield (possibly the product activity subsided before the adults had lost their capacity to deposit eggs). Later timings were also less effective; the 10 day after application timing resulted in no yield increase. This result combines the product disappearance (breakdown) and the tolerance of larger rice plants to RWW feeding at this 10 day treatment.

Improvement of registered products. Reduction of the Warrior rate resulted in less grain yield than the full rate (0.03 lbs. AI/A) Warrior treatment (Table 4). The 3.84 oz./A rate increased grain yields by 24% compared with a 6% increase for the 3.2 oz. product/acre treatment. Additionally, the Warrior PPI treatment yielded reasonably well.

Efficacy of a microbial insecticide. Two of the three Novodor treatments were among the lowest yielding treatments; however, the Novodor application at 3 and 5 leaf stages was inexplicably a moderately high yielding treatment (RWW control with this treatment was not good) .

1.3) Rice water weevil chemical control - Grower field plots

1.3.1, 1.3.2, 1.3.3). The efficacy on RWW of Dimilin 2L and Warrior T was studied in comparison with untreated plots in 7 grower fields in 2000. Three of the sites were in Butte Co., one in Sutter Co., one in Placer Co., and two in Colusa Co.

There were three general approaches for these studies,
1.) evaluation of the effects of application timing on the efficacy of Dimilin 2L,
2.) evaluation of the effects of application rate and product placement on efficacy of Dimilin 2L,
3.) evaluation of a Dimilin 2L + Warrior T tank mix for controlling a natural infestation of rice water weevil.

For study approach 1, Dimilin 2L (8 oz./A) was broadcast applied to separate plots at the first rice emergence, 2 days after first rice emergence, 50% rice emergence, 5 days after 50% emergence, and 10 days after 50% emergence. Depending on plot availability at the particular locations, some plots were also treated with 12 oz./A. Four locations were conducted under this protocol. The second approach was designed to look at Dimilin rate and product placement. Dimilin 2L was applied at 8 and 12 oz./A both with broadcast and border product placement.

This approach was used at 3 sites. The respective treatments were applied to borders only (~50 ft) or entire basins of several acres within individually leveed plots. Dimilin + Warrior treatments were evaluated at six of the locations (four locations compared this tank mix with border and broadcast methods). Applications were generally made with 6 oz./A Dimilin 2L and 1.92 oz./A of Warrior T.

The percentage scarred plants was sampled, as previously described, in all fields in May and June. Most sampling was concentrated ~ 10 feet from the levee so as to have the highest RWW densities. Rice water weevil larval samples (using previously described procedures) were taken in June and July at a time when populations were mostly large larvae and some pupae. This timing was chosen so that late-deposited eggs would have hatched. In addition, larger larvae are easier to recover with our sample processing methods. Lastly, grain yields were estimated by hand harvesting four 10.8 ft^2 areas per plot and recovering the grain with a "Vogel" mini-thresher. The field site locations, treatments, seeding, application, and sampling dates were as follows:

County	Study Approach	Plot Size (A)	Seeding Date	Application Date(s)	Scar Counts	RWW immatures 1st Date	RWW immatures 2nd Date	Hand Harvest
Colusa-1	2, 3	39	2 May	26 May	30 May	19 June	5 July	20 Sept.
Butte-1	1, 3	148	3 May	20 May, 22 May, 24 May, 3 June	31 May	22 June	6 July	21 Sept.
Colusa-2	1, 3	64	28 Apr.	16 May, 19 May, 21 May, 1 June	30 May	15 June	26 June*	15 Sept.
Butte-2	2, 3	106	3 May	21 May	25 May	16 June	28 June	22 Sept.
Butte-3	1	95	2 May	19 May, 22 May, 24 May, 1 June	23 May	21June	6 July	29 Sept.
Sutter	1, 3	55	7 May	26 May, 3 June	1 June	23 June	10 July	25 Sept.
Placer	2, 3	52	1 May	23 May	24 May	20 June	10 July	25 Sept.

* third sampling on 7 July

1.3.1.) Two of the four study sites for the application timing approach had economic RWW populations (greater than 1 per sample in the untreated). The applications were generally applied per the protocol (minimal problems with wind, etc.). Dimilin application had a moderate effect on plant leaf scarring (Table 5). The primary activity of this product is through sterilization of the females, and some egg mortality, rather than direct larval mortality, but we have consistently seen a slight reduction in plant leaf scarring following Dimilin applications. Over all the sites, the average percentage scarred plants averaged 21.5% in the untreated plots.

Dimilin applications at first rice emergence through 50% emergence provided an increasing amount of RWW larval control, peaking at ~83% (Fig. 2). Later timings (5 and 10 days after 50% emergence) were less efficacious. The relatively poor result at 5 days after 50% emergence resulted primarily from one study location with high RWW larval populations and relatively poor control. At a second location with significant RWW populations (3.9 per sample in the untreated), the 5 days after 50% emergence application provided good (84%) control. Dimilin + Warrior (applied at first emergence) showed moderate to good results. Rice grain yields were increased by 6.5 to 11.5% by the first four Dimilin timing treatments (Fig. 2). The positive effect on grain yields was reduced as the application was delayed. The Dimilin + Warrior treatment also increased grain yields by ~10%.

1.3.2, 1.3.3) The efficacy of Dimilin 2L applied to the entire basin (broadcast) versus applied only to the first 50 feet nearest the levees (border) was compared with 8 and 12 oz./A rates. Treatments were timed for 5 days after 50% emergence. Leaf scarring in the untreated, averaged over the three locations, averaged 21.5% whereas scarring in the treated plots ranged from 6.0 to 11.5% (Table 5). RWW larval populations at all three locations were less than the accepted threshold of 1 per core sample. Therefore, no trends in terms of larval control were evident in Dimilin efficacy across the two rates or two application methods (Fig. 3). The Dimilin + Warrior treatments were slightly more effective than the Dimilin alone treatment. Again, the application method did not influence efficacy. Yield data were also inconclusive with the Dimilin (8 oz./A border treatment) providing the greatest yield increase at 15.6% (Fig. 3). Overall the 8 oz./A rate treatments of Dimilin increased yields slightly more than the 12 oz./A treatment or the Dimilin + Warrior treatments.

1.4) Rice water weevil control - Greenhouse studies.

Greenhouse tests were conducted at the University of California at Davis, from March through May, 2000. Rice, 'M-202', was used for all greenhouse studies. Rice plants were grown in 32 oz. plastic pots in a sieved soil from the RES. Each pot was filled with 20 oz. of this air dried soil and $(NH_4)SO_4$ was added (618 lb./A) based on the soil surface area of the pot. For each experiment, prepared pots were arranged randomly in a galvanized metal tank and then the tank was flooded with tap water to a level of about ½ in. below the top of each pot. Each pot was filled with industrial (non-potable) well water (water level maintained throughout experiments). Six to eight rice seeds (pre-soaked for 24 h) were sown into each pot. Copper sulfate was applied in doses of 18.5 lbs./A to the tank water as well as to the pots for algae control. Once the rice plants emerged through the water, they were thinned to two plants per pot and at the 2-3 leaf stage the appropriate treatments were applied. For studies with foliar application, the treatments were sprayed onto the rice foliage with a hand-held pump-up sprayer at 20 GPA. The pot water surface was left uncovered to allow overspray (grower field situation) into the water. For the water treatment, product was added only to the pot water. After the application of the treatments, each pot had a plastic cylinder (diam. 3.5 in. X 18.9 in. high) placed over it to cage the RWW. Untreated plants were used as controls with six pots per each treatment. Field-collected RWW adults were then introduced through a 0.5 in. diameter opening cut into the cylinder. The adults were allowed to feed and oviposit for 3 days; there were three to five adults added to each pot depending on the study and RWW availability. After this oviposition period, the cylinders and all the adults were removed. The number of feeding scars for each pot was recorded. After the plants were sprayed, they were maintained for ~ 1 month and then the pots drained. The plant roots were washed and the RWW immatures recovered and counted with the standard washing-flotation method.

1.4.1) A greenhouse study was conducted to evaluate the activity of Dimilin 2L, applied after oviposition, on RWW 1st instar larvae (newly hatched from the eggs). RWW adults collected from an overwintering site were placed on potted, flooded rice plants and allowed to oviposit for 3 days. After adult removal, a Dimilin application (=8 oz./A) was made to the rice foliage (some of the spray also went directly into the water); applications were made 2 and 4 days after adult removal. Roots and soil were sampled for RWW larvae approximately 4 weeks later.

Dimilin applied at 2 days after the completion of egg-laying completely controlled the RWW larvae whereas about 50% control was seen with an application at 4 days after oviposition (Table 5). Previous research with an application of Dimilin placed entirely into the water at 5 days after egg-laying, i.e., fully concentrated on the eggs and early instar larvae, reduced the infestation by ~70%. Earlier applications, i.e., 3 days after oviposition, etc., were even more effective. Therefore, there is an effect of the product on the eggs. In the present study, with the 4-day treatment, newly-hatched larvae would have, in all likelihood, been exposed to the active ingredient. Therefore, it is likely that Dimilin has some activity on the newly-hatched larvae. However, since some of the Dimilin went directly into the water and some of the RWW may have still been in the egg stage, it cannot be concluded that the control was not being exerted through killing the eggs.

1.4.2) Greenhouse studies continued on a biorational product, Novodor (*Bacillus thuringiensis tenebrionis*, Btt), to evaluate its efficacy on RWW. Three separate experiments were conducted in 2000. Previous work has shown that *B.t.t.* will control RWW; however, improved product formulations may facilitate performance and consistency. Given the inherent uncertainties of using chemical insecticides in the aquatic rice agroecosysem, development of a biological insecticide for RWW would appear to have some advantages. For all experiments, Novodor was applied at 1 gal/A. Product placement (on foliage versus in the water) depended on the experiment protocol.

In the first experiment, *B.t.t.* was applied at 1 and 3 days before oviposition, immediately before the beginning of oviposition, immediately after the completion of oviposition, and 2 days after the completion of egg-laying. RWW larval numbers were compared with that in untreated pots. The treatments had no effect on leaf scarring from RWW adults. However, larval control was excellent (100%) in all but the earliest timing (Fig. 4). RWW larval control with *B.t.t.* was the mode of action. In the 2nd experiment, Novodor was applied to the foliage at two rates and both treatments provided excellent RWW larval control. In a 3rd experiment, no RWW larvae were found in untreated pots, so no conclusions could be made.

Objective 2:

To evaluate the influence of 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) Examine the influence of winter flooding on rice water weevil populations.

In 2000, RWW populations were again monitored at the long-term straw management study site near Maxwell (Colusa County). At this site, winter-flooded and non-flooded comprise the main plots and straw removal treatments (burning, baling, rolled, and incorporated) are the subplots. We have been collecting data at this location for the past 6 years and the winter-flooding (except in 1998) has consistently reduced rice water weevil larval densities. In 1998, the treatments were flawed because the excessive winter rainfall caused all plots to be "winter-flooded". The straw removal treatments have shown no effects on insect levels and sampling of these sub-treatments ceased in 1998 . In 2000, we sampled the winter-flooded versus non-flooded main plots. RWW adults were sampled during the winter in the winter-flooded and non-flooded main plots. Samples were taken on the top of the levees, at the water-line, and ~15 feet into the basins. Overwintering adult populations were slightly higher on the levee tops in the winter-flooded plots (389 compared with 327) but lower at the water-line and in the basin in the winter-flooded versus non-flooded plots (water-line: 233 compared with 97; basin: 54 compared with 18 RWW). Adult scarring was evaluated on 30 May and there were 60 and 45% scarred plants in the non-flooded and winter-flooded treatments, respectively. RWW larvae were sampled on 19 June and 7 July. There were nearly twice as many RWW larvae in the non-flooded than in the winter-flooded (1.9 vs. 3.4 per core sample).

2.2) Study the relationship between timing, i.e., rice plant growth stage, and plant response to RWW-induced injury.

The recently-registered post-flood treatments (Dimilin and Warrior) can be very effective, but if not properly used they may provide poor RWW control. These products control RWW by disrupting the lifecycle of this pest. They have a short residual in the water; therefore, timing of application is critical. The other possible limitation of this short residual is that, with a prolonged RWW infestation, multiple applications may be needed for optimal control. Godfrey and co-workers in a 1998-99 study showed that the majority of RWW oviposition in CA rice occurred from the 2 to 6 leaf stages (2 to 4.5 weeks after seeding); however, during 1999, a high amount of oviposition continued to the 8+ leaf stages. The application of pre-plant Furadan controlled the insect "season-long". A "window" of control (~7 days long) is provided by an application of the post-flood materials. The key question that arose was how long during the season is RWW control needed to protect yield. Season-long control is probably not practical, but multiple applications, if warranted, can provide significant residual control.

Studies were conducted at the Rice Experiment Station in 2000. Rice, 'M-202' was seeded into 8 ft^2 aluminum enclosures on 19 May. Ring plots were covered with row cover material to exclude naturally-occurring RWW adults. Rice stand was standardized to 96 plants per 8 ft^2 (12 plants per sq. ft.). The objective of this study was to establish RWW infestations at several plant growth stages. To accomplish this, RWW adults were collected from a nearby untreated rice field and placed into the ring plots at specified times. The treatments established are shown in Table 7.

Each infestation severity (none, 0.4, and 0.6 adults/plant) was established at each timing in four replicates (the 0.6 adults/plant infestation was not done in the 2 leaf + 35 day timing). Row covers were removed in early July after the last infestation timing and after the cessation of

RWW seasonal flight. The following sample procedures were conducted:

Adult Leaf Scar Counts: amount of RWW adult feeding on the rice leaves (% of plants with feeding scars on either of the two newest leaves),
Larval Counts: RWW larval infestation level (number of larvae per 44 in^3 soil core),
Plant Photosynthesis: rice gas exchange parameters using a portable photosynthesis system,
Rice Growth: rice plant growth and development (number of leaves, number of tillers, leaf area, leaf dry biomass, root dry biomass),
Rice Yield: grain yield (grams grain per 8 ft^2 plot) at 14% moisture.

Results:

RWW Scarred Plants

RWW infestation regimes were set-up, generally, as planned. In some cases, the distinction between the moderate (0.4 adults/plant) and high (0.6 adults/plant) infestation levels was not clear, especially in terms of adult induced leaf scarring; however, the plots with the high infestation level consistently had significantly more larvae than the uninfested. For instance, with the leaf scar data from 16 June (Fig. 5), the effects of the '2 leaf+7 day' and '2 leaf+14 day' infestations can be seen. On this date, the plant had partially grown out of the RWW leaf damage from the '2 leaf' infestation, i.e., the leaf scars did not occur on the two newest leaves and were therefore not counted. A low level of leaf scars was present on the plants that had not been infested yet due to a few RWW adults getting into "sealed ring plots".

Photosynthetic Rates

Previous research by Godfrey and co-workers and by Tocco and Godfrey showed that RWW root injury can reduce photosynthetic rates by up to 34.1% with larval infestations averaging 14.6 per core sample. These studies utilized an adult RWW infestation at the 3 leaf rice growth stage. Reductions of this magnitude occurred during the period of larval feeding and subsided once pupation occurred. In the present study, gas exchange data from 30 June showed reductions in photosynthetic rates in the '2 leaf', '2 leaf+7 days', and '2 leaf+14 days' infestation timings. This represented periods of 3 to 5 weeks after adult infestation (~2 to 4 weeks after the initiation of larval feeding). On 11 July, reductions in photosynthetic rates were seen in all the high RWW infestation regimes and in the '2 leaf+14 days' to '2 leaf+35 days' timing treatments with 0.4 RWW adults per plant. On this date, RWW populations were ~25% pupae in the '2 leaf' and '2 leaf+7 day' treatments. Populations in the other treatments were nearly all larvae.

Grain Yield

A negative relationship between rice grain yield and RWW larval infestation level was found for the '2 leaf' and '2 leaf + 7 days' infestation timings (Fig. 6). These data should be considered preliminary because this is the first year of this study and there were few data points at high RWW infestation levels. If these results hold after additional years of research, this bodes well for a single, well-timed application of a post-flood material providing acceptable protection of yield. Estimated yield losses were 23.5 and 17% for the 2 leaf and 2 leaf + 7 days infestation timings, respectively. No relationships were found between rice grain yield and RWW infestation level for the 2 leaf + 14 days, 2 leaf + 21 days, and 2 leaf + 28 days infestation timings. At the 2 leaf + 35 day infestation timing, increasing larval numbers actually inexplicably increased grain yields. Only two RWW infestation treatments were conducted at this timing so results were inconclusive.

2.3.1-2.3.2) 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 2000 flight

The timing of RWW adult flight in the spring has been monitored for nearly 40 years with a black light trap at RES. Monitoring weevil flights is important to determine the levels and intervals of peak flight periods which provides useful baseline data on the timing and intensity of the spring weevil flight. The switch to an adult control program, i.e., use of post-flood insecticides, has placed even greater importance on understanding RWW flight timing. The RWW overwinters as an adult in a diapause condition, i.e., a non-reproductive state. A set of, as yet, undetermined environmental conditions breaks this diapause and the adults feed on grassy weeds and are poised to fly under the correct conditions. These flight conditions include evening spring temperatures greater than 70 F^0, fairly high humidity, and calm winds. The flight aim is newly flooded rice fields or probably weedy levees near rice fields.

The primary light trap used for monitoring RWW flight is at RES in Butte County. The conditions for RWW flight in 2000 were met in mid-May (17 to 24 May) when there was a high, distinct peak in flight (Fig. 7). Some slight activity also occurred in late April. Compared with 1998 and 1999, RWW flight was greater in numbers and more concentrated in 2000 (Fig. 5). We also monitored RWW flights in 2000 at several other sites with traps similar to RES. In 1999, we monitored flight at five other locations. In 2000, with funding from the Dept. of Pesticide Regulation to supplement the RRB funding, RWW flight was monitored at 15 locations. Data will be briefly reported herein as a comparison to the RES trap data. Traps in Colusa, Glenn, Sutter, Yuba, and Sacramento counties showed similar timings of RWW flight as the traps located in Butte county (Fig. 8). Somewhat more flight was recorded during the mid-late April period at these other locations; flight magnitude was greatest in Butte county compared with the other locations. At RES, the total RWW captured was 4158. This compares with 1069 and 1206 in 1999 and 1998, respectively. In 2000, about 90% of the flight was completed by 20 May, which is about 5 days later than normal (Fig. 9). Therefore, 2000 could be classified, in terms of RWW flight, as a slightly later and higher than normal year.

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

At present, there are no rice varieties that are resistant to RWW. Significant resources have been allocated to this over the years and some progress has been made. However, there may be differences in the susceptibility of common rice varieties to RWW. In southern rice, medium grain varieties have been shown to have higher RWW levels and respond more severely to infestation. Other rice lines support high RWW infestations, but are extremely vigorous and regrow roots so fast that yield losses are minimal. The goal of this study was to evaluate California varieties for susceptibility and response to RWW.

Studies were conducted at the RES in plots measuring 10 x 20 feet. Eight varieties were

evaluated:
1. Calmati-201,
2. Calhikari-201,
3. PI5062130 [a line under development with moderate resistance to RWW],
4. M-104,
5. M-202,
6. M-205,
7. M-402,
8. L-205).

Four replications of each variety were treated for RWW and another 4 replications of each variety were allowed to be infested with a natural population of RWW. Plots were flooded on 18 May and seeded on 19 May. RWW adult feeding scars, seedling establishment rating, larval population numbers, and grain yields were determined as described under 1.1.1. The only variation from the previously described methods was that grain yield was determined on three 10.8 ft^2 areas per plot. The number of RWW larvae per plot in the untreated plots was indicative of the conduciveness of the variety to RWW infestation and the difference in yield between the treated and untreated plots of a given variety was used to show plant response to the feeding.

Results:

The naturally-occurring RWW population was low to moderate in this plot. Data on adult feeding scars, larval population magnitude, and grain yield are shown in Table 8. RWW larval populations were effectively controlled (2.8 versus 0.4 RWW per sample) by the targeted treatment (Table 8). In untreated plots, populations were higher in the M-104 and L-205 varieties. If this result is repeatable over multiple years, this may indicate that these two varieties are more attractive (susceptible) to RWW. Grain yields across all treatments, were highest in the M-202/treated plots. Treatment for RWW, even at this relatively low infestation severity, increased grain yield by 13.8, 3.4, and 1.6% in the M-202, M-205, and PI5062130 varieties, respectively. For the other five varieties, the treated and untreated plots yielded an equal amount or in some cases the untreated plots had a yield advantage over the treated plots. A greater RWW infestation will allow a more "acid-test" for this concept.

2.5) Evaluate the usefulness of an in-field floating RWW trap (as developed at the Univ. of Arkansas) for sampling RWW populations.

The switch to post-flood insecticide treatments in 1999 has rendered most of the existing economic thresholds for RWW obsolete. This is true for California as well as for the southern rice production states. In California, by the time the adult leaf scarring threshold is met (~20%), it will in all likelihood be too late to apply Dimilin or Warrior (i.e., the eggs have already been deposited). Therefore, the need for a new sampling tool. The Univ. of Arkansas has developed a floating trap that appears to have merit in their system (Hix, R. L., D. T. Johnson, and J. L. Bernhardt. 2000. An aquatic barrier trap for monitoring adult rice water weevil (Coleoptera: Curculionidae). Fla. Ent. 83: 189-192). The goal of our study was to evaluate the utility of this trap in the California water-seeded rice system. The capacity to capture RWW adults was the first criterion and the relevance of these data for predicting subsequent larval populations was the second point.

Studies were conducted in six grower fields in Colusa, Butte and Sutter counties. Traps were placed in the fields after seeding but before rice emergence and were anchored ~5 feet from the levees. Fields were not treated for RWW. RWW adults were collected from the traps 3 times per week. The Arkansas trap and an alternative trap design were compared at 3 locations. The number of RWW larvae was determined with the standard core samples in mid-late June and again in early-mid-July.

Results:

Adult RWW were captured at five of the six locations. Peak populations were ~3.5 adults per trap per day; however, most levels were less than 1 adult per trap per day. The Arkansas designed trap appeared to effectively capture RWW adults. Algae and low water levels, i.e., field draining, were problematic for trap operations. The modified trap design was ineffective. Larval populations peaked at ~13 per core sample with most levels being in the 0 to 4 range. Most importantly, there was a relationship between the number of adults captured and the resulting larval populations (Fig. 10). More data need to be collected, especially at higher RWW pressures, to strengthen the relationship. Ultimately, an adult threshold value can be determined at which post-flood treatment need can be assessed.

Acknowledgments:

There are several people that we would like to acknowledge that contributed to the operations and success of the 2000 rice invertebrate pest management project. We thank Uniroyal Chemical Co. (Dimilin), Zeneca Ag. Products (Warrior), Aventis (Icon), FMC (Furadan and Mustang) and Abbott Laboratories (Novodor) for products; UC Cooperative Extension Sacramento Valley Farm Advisors for grower contacts and assistance; UC Davis Rice Project student assistants for their diligent work; and, numerous growers for use of their land and resources. Lastly, we are grateful to the staff at the Rice Experiment Station for study site and light trap collections and the California Rice Research Board for providing the funding necessary to achieve our objectives.

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CONCISE GENERAL SUMMARY OF CURRENT YEAR'S (2000) RESULTS:

Larry D. Godfrey, Terry D. Cuneo, and Richard Lewis

Research was conducted in 2000 on important aspects of rice water weevil (RWW) biology, cultural control, and insecticidal management. Significant progress was made on all objectives. Furadan 5G has been the standard for RWW management in rice for the last ~30 years. The 2000 use-season was the last year Furadan could legally be used in rice. Dimilin® 2L and Warrior® T were registered in 1999 and 2000 was the first year of significant use of these new products. These new products, applied after flooding, have required a change in the management scheme for the most important arthropod pest of rice in California. The goal of the 2000 research was to optimize use patterns for these new insecticidal controls such that efficacy can be maximized and growers can "get the most bang for the buck".

Chemical Controls: Two products, Dimilin® 2L and Warrior® T were registered for use on rice in 1999. Dimilin and Warrior are applied post-flood over the field to either full-basin or borders only. Research continued to refine the use of these products; in addition, efficacy of experimental products against RWW was studied. Small plot (rings) and grower field tests were conducted. In ring tests, the length of residual RWW control from a Dimilin application was monitored; RWW larval control declined when infestations occurred at greater than 4 days after application whereas protection of yield was greatest when RWW infestation occurred from 2 to 6 days after Dimilin application. A reduction in the Warrior rate, from 3.8 to 3.2 oz./A, was attempted and RWW control efficacy eroded. This product is apparently fairly rate sensitive for optimal performance. RWW control with a preplant incorporated application of Warrior was attempted and this treatment was surprisingly successful. The product was applied 2 weeks before RWW adults were introduced into the plots. Experimental products tested included Mustang®, Icon®, and Novodor®. The former two products were very effective against RWW and the latter one was moderately effective. Mustang (zeta-cypermethrin) is a pyrethroid product that is applied post-flooding. Icon (fipronil) is applied pre-plant or to the seed and is registered in the southern rice production states. Novodor is a biological insecticide of *Bacillus thuringiensis tenebrionis*. Efficacy of Dimilin and Warrior were evaluated in grower field tests at seven locations. Dimilin, applied at various plant growth stages and with two rates and placements (full basin versus border only), was evaluated as well as a Dimilin + Warrior tank mix. The timing studies showed the most effective larval control with an application at 50% rice emergence and a 8.3% yield gain from this treatment. This timing was slightly earlier than shown in studies in 1998 and 1999, indicating some environmental (seasonal) effects. Studies on Dimilin rates (8 and 12 oz./A) and placements showed no definite trends. A Dimilin + Warrior tank mix (6 + 1.92 oz./A) showed some advantages in terms of RWW larval control. Greenhouse studies were used to further define the activity of key insecticidal products. Studies with Dimilin provided evidence (however not conclusive) that this material provides some mortality of RWW larvae that are newly-hatched from the egg. Novodor, in greenhouse studies, provided 100% RWW control with applications 1 day before egg-laying to 2 days after egg-laying. An application made earlier (3 days before egg-laying) was slightly less effective.

Rice Water Weevil Biology: The timing of RWW adult flight in the spring has been monitored for nearly 40 years with a black light trap at RES. Monitoring weevil flights is important to determine the levels and intervals of peak flight periods and to compare RWW trends over time (years). The switch to an adult control program, i.e., use of post-flood insecticides, has placed even greater importance on understanding RWW flight timing. The conditions for RWW flight were met in mid-May (17 to 24 May) when there was a high, distinct peak in flight. Some slight activity also occurred in late April. Compared with 1998 and 1999, RWW flight was greater in numbers and more concentrated in 2000. With funding from the Dept. of Pesticide Regulation to supplement the RRB funding, RWW flight was monitored at 15 locations. Somewhat more flight was recorded during the mid-late April period at these other locations; flight magnitude was greatest in Butte county compared with the other locations. Therefore, 2000 could be classified, in terms of RWW flight, as a slightly later and higher than normal year.

The short residual of Dimilin and Warrior in the water bring about the possibility that multiple applications may be needed to effectively manage RWW with prolonged flights and infestations. A "window" of control (~7 days long) is provided by an application of the post-flood materials. The key question that arose was how long during the season is RWW control needed to protect yield. Season-long control is probably not practical, but multiple applications, if warranted, can provide significant residual control. The cost to benefit relationship of these multiple applications is critical. Studies were conducted with RWW infestations at the 2 leaf stage and every 7 days thereafter for 5 weeks. These were "controlled" studies in rings so the infestation timing and severity could be manipulated. A negative relationship between rice grain yield and RWW infestation level was found for the 2 leaf and 2 leaf + 7 days infestation timings. Estimated yield losses were 23.5 and 17% for the 2 leaf and 2 leaf + 7 days infestation timings, respectively. No relationships were found between rice grain yield and RWW infestation level for the 2 leaf + 14 days, 2 leaf + 21 days, and 2 leaf + 28 days infestation timings. These data should be considered preliminary because this is the first year of this study; however, if these results hold after additional years of research, this bodes well for a single, well-timed application of a post-flood material providing acceptable protection of yield.

The switch to post-flood insecticide treatments in 1999 has rendered most of the existing economic thresholds for RWW obsolete. A new sampling tool (a floating trap) was developed at the Univ. of Arkansas that appears to have merit in their system for sampling in-field populations of RWW. The goal of our study was to evaluate the utility of this trap in the California water-seeded rice system. Adult RWW were captured by the trap and peak populations were ~3.5 adults per trap per day; however, most levels were less than 1 adult per trap per day. Most importantly, there was a relationship between the number of adults captured and the resulting larval populations. Additional research will determine the fit of this trap in the California system and the robustness of this relationship.

Cultural Controls: Two aspects of cultural control were studied in 2000. RWW populations were again monitored at the long-term straw management study site near Maxwell (Colusa County). Adult scarring was 60 and 45% scarred plants in the non-flooded and winter-flooded treatments, respectively and for RWW larval populations there were nearly twice as many RWW larvae in the non-flooded than in the winter-flooded (1.9 vs. 3.4 per core sample). This continues the trends seen in previous years.

The relationship between RWW damage and rice variety was also investigated. At present, there are no rice varieties that are resistant to RWW. However, there may be differences in the susceptibility of common rice varieties to RWW and studies were conducted to evaluate. Calmati-201, Calhikari-201, PI5062130 (a line under development with moderate resistance to RWW), M-104, M-202, M-205, M-402, and L-205 were grown in plots treated for RWW and in untreated plots. In untreated plots, RWW larval populations were highest in the M-104 and L-205 varieties. Grain yields across all treatments, were highest in the treated, M-202 plots. Treatment for RWW, even at this relatively low infestation severity, increased grain yield by 13.8, 3.4, and 1.6% in the M-202, M-205, and PI5062130 varieties, respectively. For the other five varieties, the treated and untreated plots yielded an equal amount or in some cases the untreated plots had a yield advantage over the treated plots.

Table 2. Chemical control ring stand rating evaluation and RWW adult leaf scar data, 2000.

Product	Rate (lbs. AI/A)	Application Timing	Stand Rating (1-5)	% Scarred Plants
1. Furadan 5G	0.5	PPI	2.75 bc	14.0 cef
2. Dimilin 2L**	0.125	3-5 days*	2.75 bc	27.0 a-d
3. Dimilin 2L**	0.125	3-5 days*	3.25 abc	26.0 a-d
4. Dimilin 2L**	0.125	3-5 days*	2.50 bc	26.0 a-d
5. Dimilin 2L**	0.125	3-5 days*	2.75 bc	24.0 a-d
6. Dimilin 2L**	0.125	3-5 days*	3.50 ab	19.0 b-e
7. Dimilin 2L**	0.125	3-5 days*	2.75 bc	19.0 b-e
8. Untreated**	---	---	3.50 ab	30.0 ab
9. Untreated**	---	---	3.25 abc	28.0 abc
10. Untreated**	---	---	2.25 c	13.0 df
11. Untreated**	---	---	3.25 abc	18.0 b-e
12. Untreated**	---	---	3.00 abc	37.0 a
13. Untreated**	---	---	3.25 abc	26.0 a-d
14. Warrior T	0.03	2-3 leaf stage	3.25 abc	2.0 f
15. Warrior T	0.025	2-3 leaf stage	3.00 abc	6.0 ef
16. Icon 6.2 seed trt.	0.037	pre-soaked	4.00 a	18.0 b-e
17. Icon 70FS	0.0325	PPI	3.00 abc	13.0 df
18. Untreated	---	---	3.00 abc	25.0 a-d
19. Novodor + gibb. acid	1 gallon	3 + 5 leaf	3.50 ab	14.0 c-f
20. Novodor	1 gallon	3 + 5 leaf	3.25 abc	17.0 df
21. Improved Novodor	1 gallon	3 + 5 leaf	3.25 abc	15.0 c-f
22. Mustang 1.5EW	0.04	3 leaf stage	4.00 a	5.0 ef
23. Mustang 1.5EW + COC	0.04 + 1% v/v	3 leaf stage	3.50 ab	1.0 f
24. Warrior T	0.03	PPI	3.50 ab	13.0 def

* after emergence of rice through the water

** infested with RWW at various intervals, see Table 1 for details

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

Table 3. RWW immature density (first and second sample dates and average) in chemical ring study, 2000.

Product	Rate (lbs. AI/A)	Application Timing	29 June Sample Date	7 July Sample Date	Seasonal Average
1. Furadan 5G	0.5	PPI	0.55 cde	0.20 b	0.38 e-i
2. Dimilin 2L**	0.125	3-5 days*	0.05 e	0.05 b	0.05 i
3. Dimilin 2L**	0.125	3-5 days*	0.20 e	0.10 b	0.15 hi
4. Dimilin 2L**	0.125	3-5 days*	0.10 e	0.21 b	0.16 hi
5. Dimilin 2L**	0.125	3-5 days*	0.15 e	0.55 b	0.35 f-i
6. Dimilin 2L**	0.125	3-5 days*	0.20 e	0.24 b	0.22 ghi
7. Dimilin 2L**	0.125	3-5 days*	0.25 de	0.10 b	0.18 hi
8. Untreated**	---	---	1.60 bc	0.45 b	1.03 c-f
9. Untreated**	---	---	3.40 a	0.68 b	2.04 ab
10. Untreated**	---	---	3.50 a	1.05 b	2.28 a
11. Untreated**	---	---	1.75 b	0.90 b	1.33 bcd
12. Untreated**	---	---	0.65 cde	2.65 a	1.65 abc
13. Untreated**	---	---	0.95 bcde	0.90 b	0.93 c-g
14. Warrior T	0.03	2-3 leaf stage	0.00 e	0.05 b	0.03 i
15. Warrior T	0.025	2-3 leaf stage	0.30 de	0.40 b	0.35 f-i
16. Icon 6.2 seed trt.	0.037	pre-soaked	0.50 de	0.50 b	0.50 e-i
17. Icon 70FS	0.0325	PPI	0.05 e	0.05 b	0.05 i
18. Untreated	---	---	0.65 cde	1.00 b	0.83 d-h
19. Novodor + gibb. acid	1 gallon	3 + 5 leaf	0.74 bcde	0.60 b	0.67 d-i
20. Novodor	1 gallon	3 + 5 leaf	1.05 b	1.00 b	1.03 cde
21. Improved Novodor	1 gallon	3 + 5 leaf	1.30 bcd	1.05 b	1.18 cde
22. Mustang 1.5EW	0.04	3 leaf stage	0.26 de	0.06 b	0.16 hi
23. Mustang 1.5EW + COC	0.04 + 1% v/v	3 leaf stage	0.20 e	0.11 b	0.16 hi
24. Warrior T	0.03	PPI	0.00 e	0.10 b	0.05 i

* after emergence of rice through the water

** infested with RWW at various intervals, see Table 1 for details

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

Table 4. Effect of RWW populations on rice grain yield in chemical ring study, 2000.

Product	Rate (lbs. AI/A)	Application Timing	Grain Yield (grams/ring)	Estimated Grain Yield (lbs./A)
1. Furadan 5G	0.5	PPI	438.2 a-f	5255
2. Dimilin 2L**	0.125	3-5 days*	413.9 b-f	4964
3. Dimilin 2L**	0.125	3-5 days*	488.3 abc	5856
4. Dimilin 2L**	0.125	3-5 days*	516.4 a	6194
5. Dimilin 2L**	0.125	3-5 days*	500.0 ab	5996
6. Dimilin 2L**	0.125	3-5 days*	453.4 a-f	5438
7. Dimilin 2L**	0.125	3-5 days*	457.8 a-e	5491
8. Untreated**	---	---	362.0 f	4342
9. Untreated**	---	---	384.5 def	4611
10. Untreated**	---	---	395.0 c-f	4738
11. Untreated**	---	---	391.5 def	4696
12. Untreated**	---	---	401.0 c-f	4809
13. Untreated**	---	---	453.2 a-f	5436
14. Warrior T	0.03	2-3 leaf stage	456.2 a-e	5579
15. Warrior T	0.025	2-3 leaf stage	408.6 b-f	4901
16. Icon 6.2 seed trt.	0.037	pre-soaked	452.8 a-f	5430
17. Icon 70FS	0.0325	PPI	441.9 a-f	5300
18. Untreated	---	---	375.1 ef	4498
19. Novodor + gibb. acid	1 gallon	3 + 5 leaf	360.7 f	4327
20. Novodor	1 gallon	3 + 5 leaf	445.6 a-f	5344
21. Improved Novodor	1 gallon	3 + 5 leaf	376.6 def	4516
22. Mustang 1.5EW	0.04	3 leaf stage	470.0 a-d	5637
23. Mustang 1.5EW + COC	0.04 + 1% v/v	3 leaf stage	435.2 a-f	5219
24. Warrior T	0.03	PPI	417.4 b-f	5006

* after emergence of rice through the water

** infested with RWW at various intervals, see Table 1 for details

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

Table 5. Overall percentage scarred plants from grower field studies with Dimilin and Warrior, 2000.

Treatment	Timing	% Scarred Plants
Timing studies	Treatment	
Dimilin 2L (8 or 12 oz./A)	1st emer.	6.0
Dimilin 2L (8 oz)	2 days after 1st emer.	8.5
Dimilin 2L (8 or 12 oz./A)	50% emer.	3.5
Dimilin 2L (8oz)	5 days after 50% emer.	5.0
Dimilin 2L (8oz)	10 days after 50% emer.	6.0
Dimilin 2L + Warrior T (6 oz.+1.92 oz.)	1st emer.	14.7
Untreated	---	35.7
Rate/placement studies	Treatment	
Dimilin 2L (8 oz./A)	broadcast	7.5
Dimilin 2L (8 oz./A)	border	8.5
Dimilin 2L (12 oz./A)	broadcast	9.0
Dimilin 2L (12 oz./A)	border	11.5
Dimilin 2L + Warrior T (6 + 1.92 oz./A)	broadcast	7.5
Dimilin 2L + Warrior T (6 + 1.92 oz./A)	border	6.0
Untreated	---	21.5

Table 6. Influence of Dimilin on early instar RWW larvae.

Treatment	Adult feeding scars (number per 2 plants)	RWW larvae per pot (2 plants)
Untreated	43	1.7
Dimilin 2 days after completion of egg-laying	27.2	0
Dimilin 4 days after completion of egg-laying	29	0.8

Table 7. Set-up of plant response study, 2000.

Timing	Factor 1 Plant Growth Stage	Date	Factor 2 RWW Infestation Severity
2 leaf stage	2 leaf	26 May	1.) 0 RWW adults per plant
2 leaf stage + 7 days	3 to 3.5 leaf stage	2 June	2.) 0.4 RWW adults per plant
2 leaf stage + 14 days	4.5 to 5 leaf stage	9 June	3.) 0.6 RWW adults per plant
2 leaf stage + 21 days	6 to 6.5 leaf stage	16 June	
2 leaf stage + 28 days	8 leaf stage	23 June	
2 leaf stage + 35 days	10 leaf stage	30 June	

Table. 8. RWW infestation severity and effects on yield of representative rice varieties.

Rice Variety	Treated for RWW	% RWW Scarred Plants	Average RWW Immatures/Sample	Grain Yield (lbs./A)	% Yield Gain from RWW Treatment
Calmati-201	Yes	11	0.0	5136.2	0
Calhikari-201	Yes	14	0.05	6865.8	0
PI5062130	Yes	17	0.3	7414.3	1.6
M-104	Yes	17	0.0	8182.0	0
M-202	Yes	31	0.26	8857.7	13.8
M-205	Yes	16	0.0	7642.1	3.4
M-402	Yes	11	0.05	8124.9	0
L-205	Yes	7	0.0	6808.3	0
Calmati-201	No	9	0.5	5610.8	---
Calhikari-201	No	15	0.3	6908.5	---
PI5062130	No	15	0.45	7299.2	---
M-104	No	21	1.0	8457.9	---
M-202	No	27	0.47	7782.3	---
M-205	No	25	0.42	7665.5	---
M-402	No	11	0.44	8450.5	---
L-205	No	13	1.0	6587.0	---
	All trted.	15.5 a	0.4 b	7376.8 a	
	All untrted.	17.0 a	2.8 a	7345.7 a	

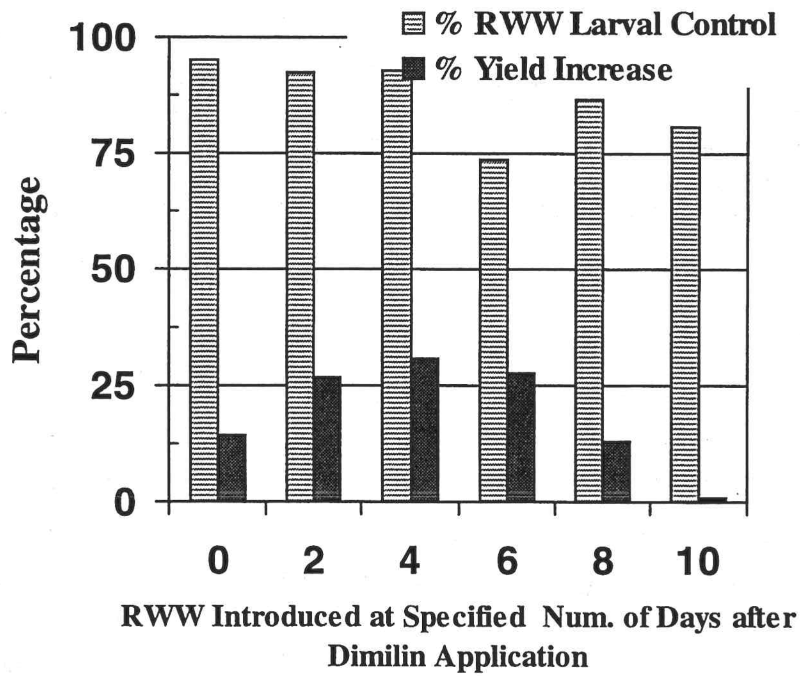

Figure 1. Effects of Dimilin application in ring plots on % RWW larval control and on grain yields; RWW adults introduced at specified days after treatment.

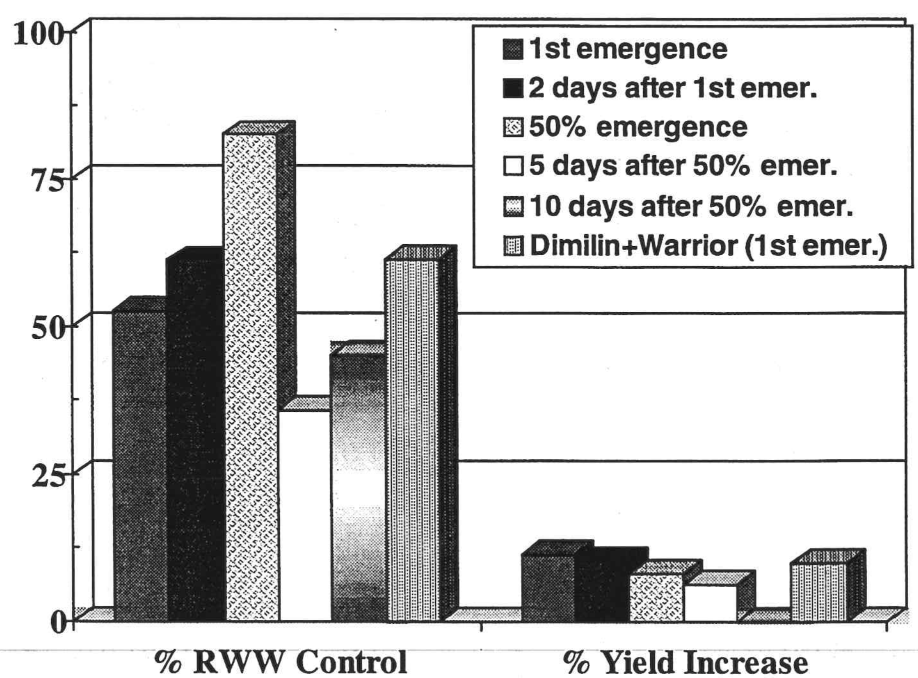

Figure 2. Influence of timing of Dimilin 2L application to grower field plots on RWW control and grain yields.

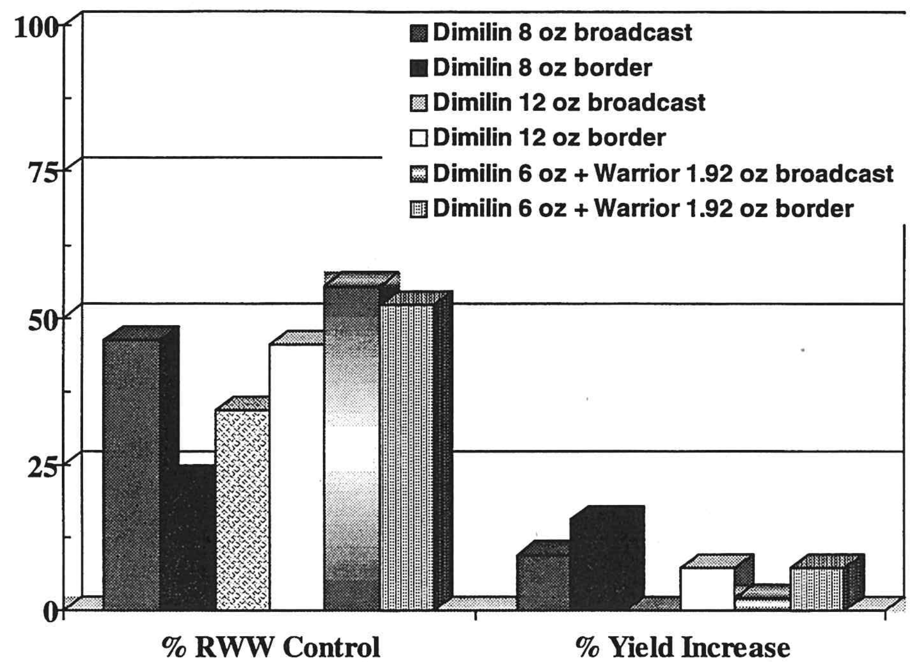

Figure 3. Influence of Dimilin 2L rate and application placement and a Dimilin+Warrior tank mix on RWW control and grain yields in grower field plots.

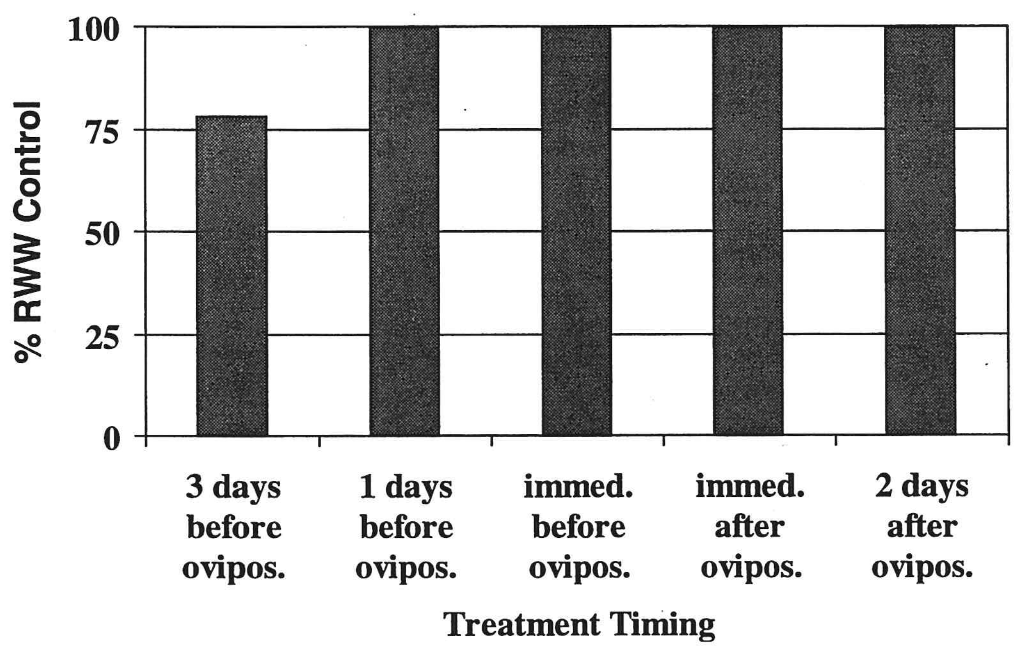

Figure 4. Efficacy of *Bacillus thuringiensis tenebrionis* on rice water weevil larvae in greenhouse studies.

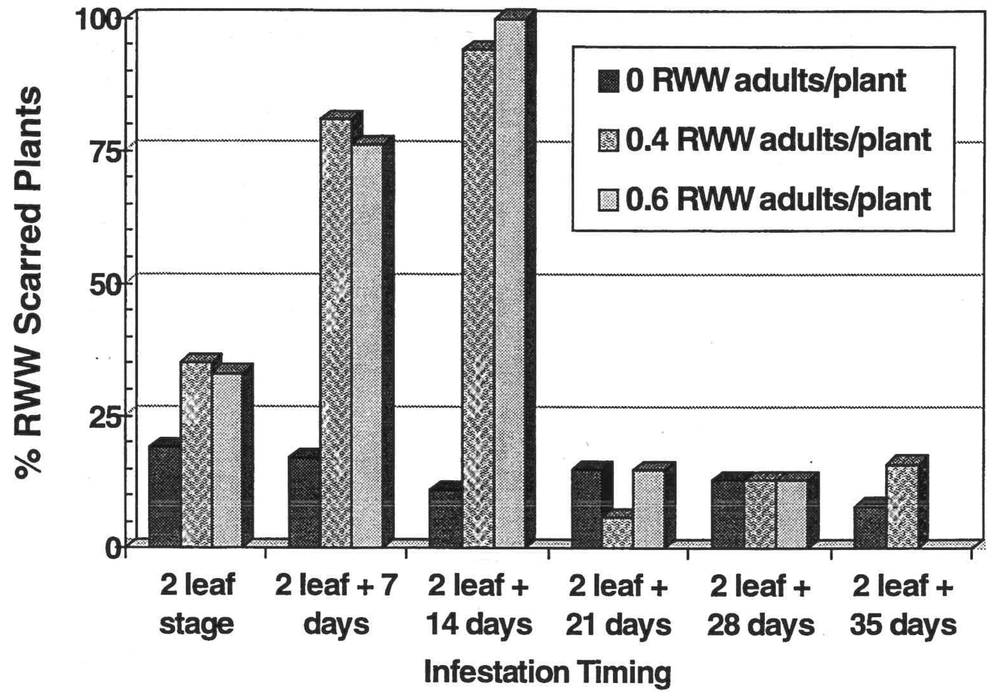

Figure 5. RWW induced plant scar data from plant response by infestation timing study.

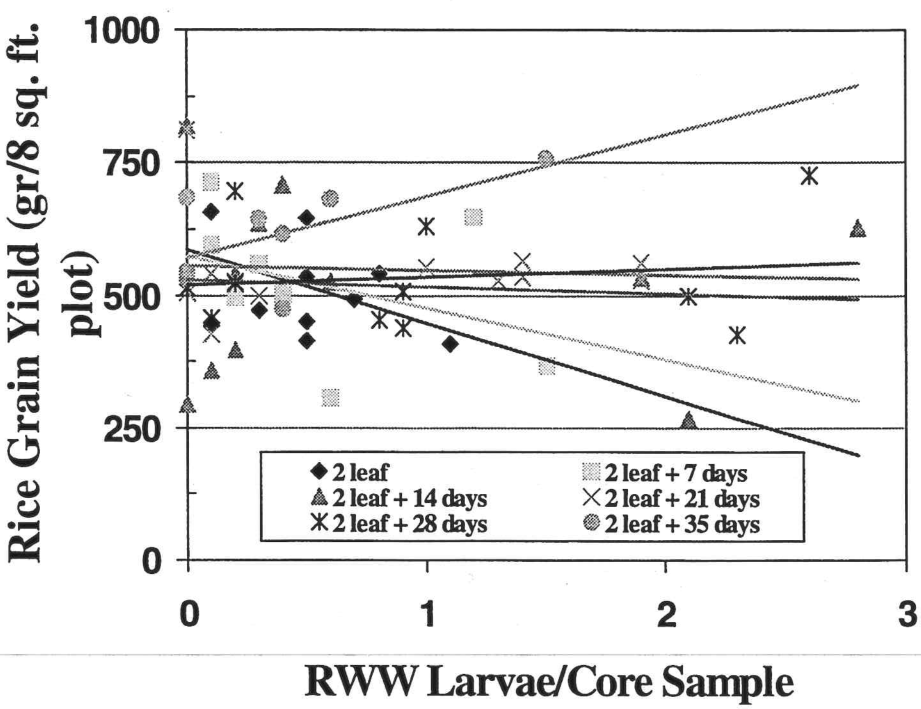

Figure 6. Effect of RWW larval infestation on rice grain yield with adult infestations initiated at several plant growth stages.

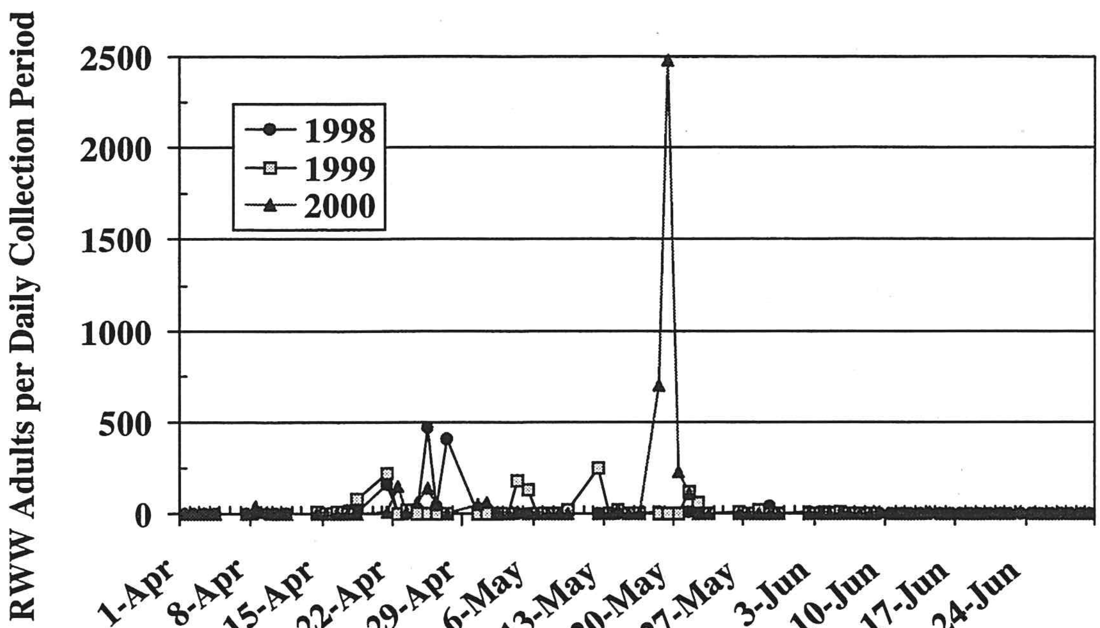

Figure 7. Rice water weevil flight (as monitored with a black light trap) at the Rice Experiment Station in 1998, 1999, and 2000.

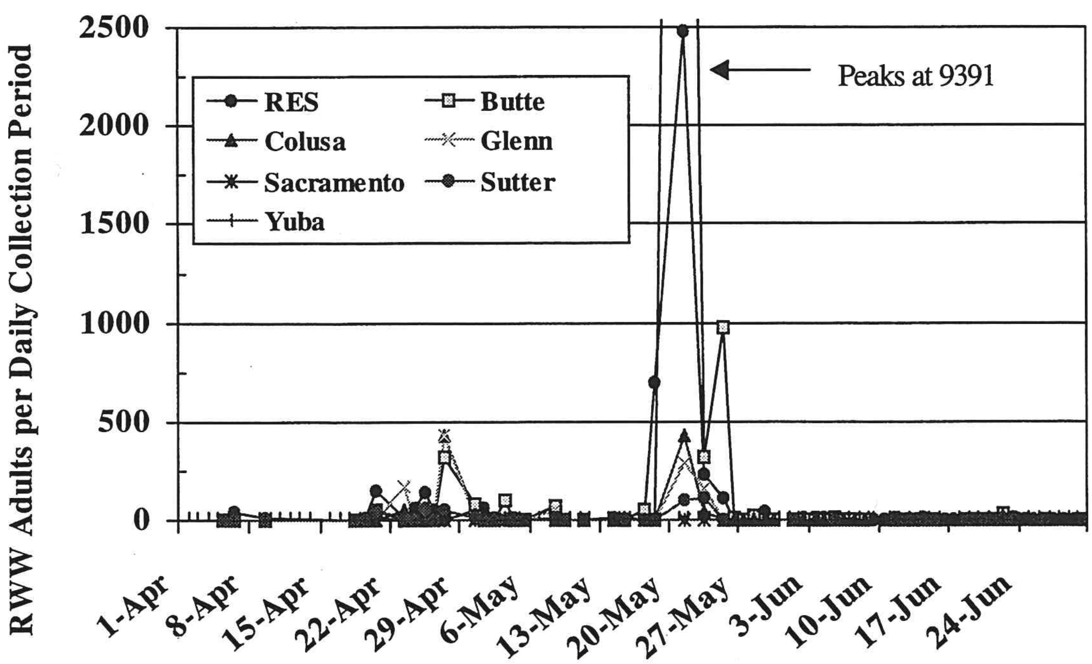

Figure 8. Rice water weevil flight as monitored with 15 black light traps across the Sacramento Valley rice production area, 2000.

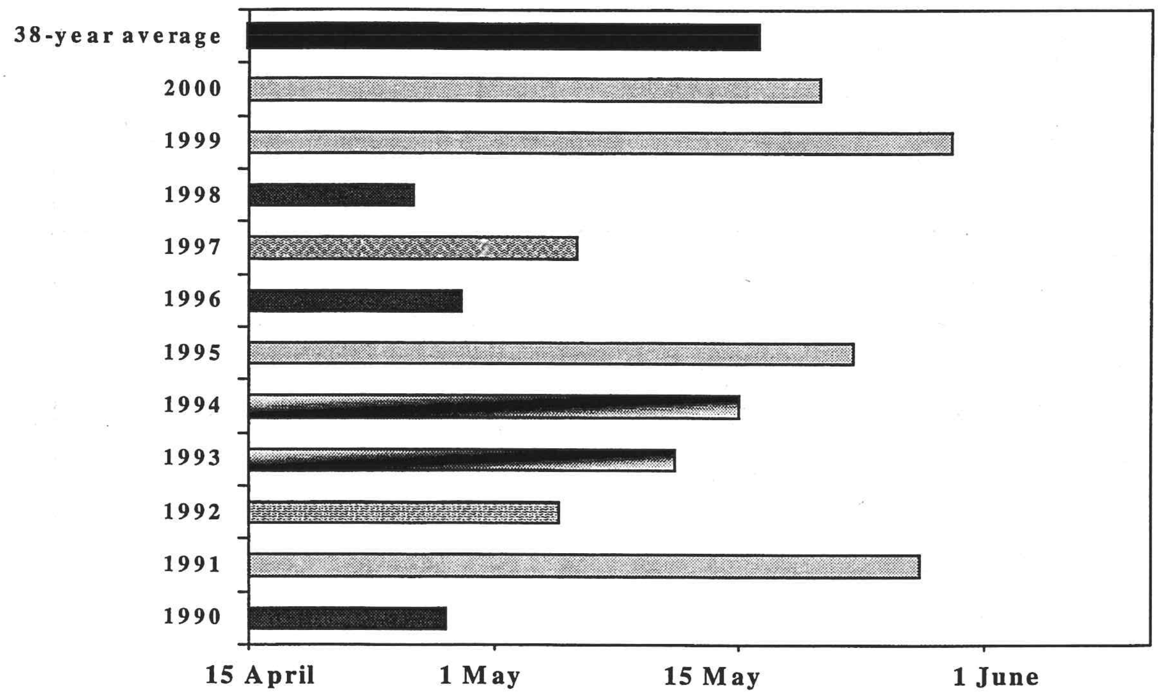

Figure 9. Duration of rice water weevil adult flight in the Sacramento Valley (RES) as indicated by light traps; bars indicate completion of 90% of the flight.

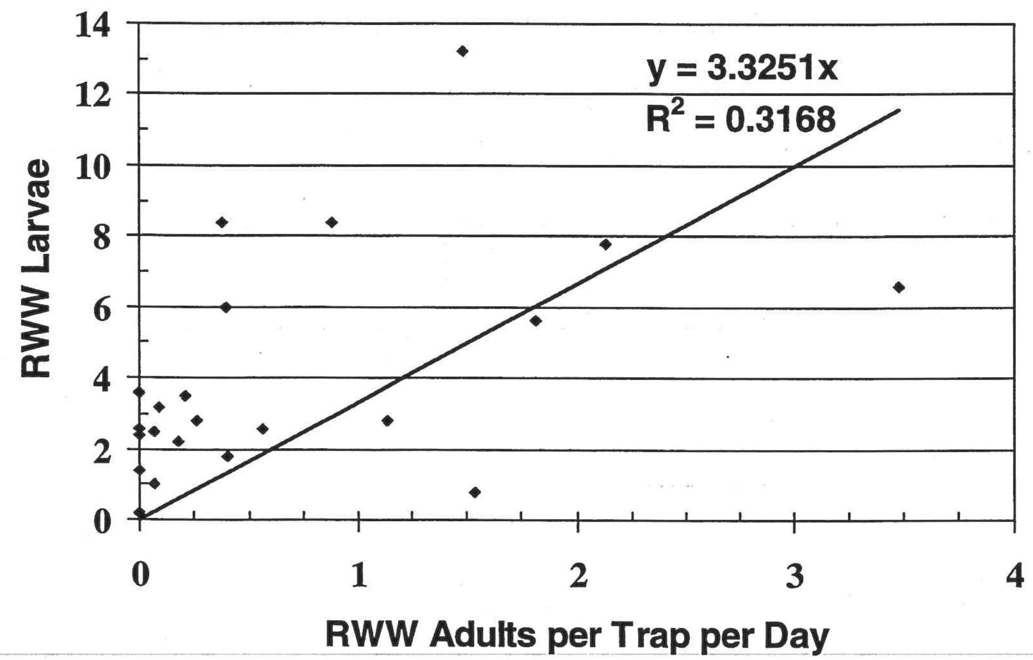

Figure 10. Relationship between number of rice water weevil adults collected per day with an in-field floating trap and the resulting number of larvae per core sample, 2000.