Project No. RR09-5

ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE
January 1, 2009 – December 31, 2009

PROJECT TITLE: Evaluation of adult rice water weevil sampling, within-field larval distribution and damage potential.

PROJECT LEADER: Luis Espino
Rice Farming Systems Advisor
Colusa, Glenn and Yolo Counties
UC Cooperative Extension
100 Sunrise Blvd., Suite E
Colusa, CA 95932
(530) 458-0578
laespino@ucdavis.edu

COOPERATORS: Larry Godfrey
Extension Entomologist
Department of Entomology
UC Davis

Christopher A. Greer
Rice Farming Systems Advisor
Sutter/Yuba, Placer, and Sacramento Counties
UC Cooperative Extension

Randall Mutters
Farm Advisor
Butte County
UC Cooperative Extension

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OBJECTIVES AND EXPERIMENTS CONDUCTED, BY LOCATION, TO ACCOMPLISH OBJECTIVES:

Field experiments were conducted in commercial rice fields. The objectives in all experiments were:

Objective 1: To evaluate the feasibility of using an aquatic net to sample adult rice water weevil (RWW) populations during early stages of seedling development and correlate adult numbers collected to later larval populations.

Objective 2: To validate observations regarding within-field RWW distribution. Specifically, to confirm the prevalence of RWW populations around field borders and levees.

Objective 3: To assess the effect of RWW larval populations on rough rice yield under field conditions.

SUMMARY OF 2009 RESEARCH, BY OBJECTIVE

Materials and methods were similar for all experiments. Data analyses were conducted to address each of the objectives mentioned above. Materials, methods and analyses will be generally described and results presented by objective.

Materials and Methods

Experiments were conducted in commercial rice fields located in Colusa, Maxwell, Oroville, and Princeton in the Sacramento valley of California. Planting system, variety, planting, flood, insecticide application, RWW sampling, and grain harvest dates are presented in Table 1.

At each location, plots 8 x 20 ft were established 15, 110, and 205 ft from one of the edges of the field within a basin. Treatments assigned to plots were insecticide application (treated or untreated) and distance from the field's edge (15, 110 or 205 ft). Treated and untreated plots were separated by an 8 ft buffer. Treated plots were sprayed with λ-cyhalothrin (Warrior II, Syngenta) at 0.03 lbs a.i./a before flooding. Each experiment was conducted as a randomized complete block and treatments replicated four times. In each field plots were managed in the same manner as the rest of the field.

RWW adult populations were assessed using feeding scars and an aquatic net. For feeding scars, each plot was divided in three sections and 10 plants per section were inspected. The proportion of plants with feeding scars on either of the two newest leaves was recorded. Aquatic net samples consisted of 10 sweeps with a small net (8 x 6 x 8 inches) in each plot. The number of RWW collected per sweep was recorded.

RWW immatures (larvae and pupae) were assessed using a core sampler (4 inch diameter and 4 inches deep). Plots were divided in three sections and one core sample taken from each on two sampling dates (≅ 6-8 weeks after seeding and 14 d later) as indicated in Table 1. Each core contained the roots of at least one rice plant. Cores were placed in 40 mesh screen buckets and soil washed from roots using a jet of water. Roots were discarded and screen buckets containing soil placed in water tubs. Screen buckets were then gently shaken and RWW immatures counted as they floated to the surface.

Rice yields were determined by harvesting entire plots and converting grain weights to pounds per acre at 14% moisture.

Data analysis. Proportion of plants with RWW adult feeding scars, number of RWW adults per aquatic net sample, number of RWW immatures per core per sampling date, and yields were analyzed using a two way analysis of variance (ANOVA), with fixed factors insecticide treatment and distance from the edge of the field and random factor block. Comparisons among levels of significant factors were made using Fisher least significant difference test.

Simple linear regression was used to determine the relationship between number of RWW immatures per core and proportion of plants with adult RWW feeding scars or mean number of RWW adults per aquatic net sample. Analysis of covariance (ANCOVA) was used to compare the slopes of the regression lines at different locations and determine a common slope. Simple linear regression and ANCOVA were used to explore the relationship between grain yield and mean RWW immature density per plot. The level of α used in all analyses was 0.05.

Results

Objective 1: To evaluate the feasibility of using an aquatic net to sample adult RWW populations during early stages of seedling development and correlate adult numbers collected to later larval populations.

Aquatic net sampling

Mean number of RWW adults caught per aquatic net sample (10 aquatic net sweeps) ranged from 0 to 0.9, 0.4, 0.2, and 0.5 in Princeton, Maxwell, Oroville and Colusa, respectively. Most aquatic net sweeps did not catch any RWW adults. In many occasions, RWW adults could be observed resting in rice plants under water but the aquatic net would fail at catching them. No significant differences in number of RWW adults caught with the aquatic net were found between treatments or among distances from the field's edge in any of the experiments. Averaging across all plots, mean number of RWW adults caught per aquatic net sample was 0.2, 0.05, 0.03, and 0.05 in Princeton, Maxwell, Oroville and Colusa, respectively. The low number of RWW adults caught with the aquatic net indicates that its catch-efficiency is very low. Because RWW infestations in CA are variable and RWW populations in commercial fields usually low, the aquatic net is not appropriate for decision making sampling. Additionally, using the aquatic net in fields where straw has not decomposed completely or with moderate algal development is difficult and time consuming because of debris collected by the net.

Proportion of plants with adult feeding scars

RWW adult feeding scars were evaluated at the 3 leaf stage of rice (lsr) in water seeded fields, and at the 5 lsr (immediately after flood) in the dry seeded field (Table 1). Only data from untreated plots was used for the regression between number of RWW immatures per core and proportion of plants with feeding scars. When comparing the proportion of plants with feeding scars between treated and untreated plots, no significant differences were found in water seeded fields (Table 2). However, in one field (Princeton) there were significantly more RWW immatures per first core samples in untreated than in treated plots (Fig. 1). In the other water seeded fields (Oroville and Colusa) there were more RWW immatures per core in untreated than treated plots too, but these differences were not statistically significant (Figs. 3 and 4). In these fields the insecticide application was made pre-flood, to the soil. This incongruence between proportion of plants with feeding scars and number of RWW immatures per core indicates that the pre-plant insecticide application killed mostly larvae. This did not occur in the dry seeded field (Maxwell). Here, the insecticide application was made at the 5 lsr and the proportion of plants with feeding scars was significantly lower in treated than untreated plots (Table 2). Because foliage was treated, adult oviposition and, therefore, number of RWW immatures per core were reduced (Fig. 2). For consistency, the regression for the Maxwell field also used data from untreated plots only.

Linear regression between number of RWW immatures per first core samples and proportion of plants with feeding scars yielded significant relationships for Princeton, Maxwell, and Colusa (Table 3). ANCOVA showed that there were no statistically significant differences among slopes or intercepts of the regression lines, therefore all data was pooled and a single regression line calculated. Regression lines with the intercept forced through the origin (no intercept model) were also calculated. For the pooled data regression, the intercept was not significantly different from zero, therefore the equation for the no intercept model can be used to estimate the number of RWW immatures per first core samples based on the proportion of plants with feeding scars at the 3-5 lsr. For the Oroville location, the regression between number of RWW immatures per first core samples and proportion of plants with feeding scars was not significant. This was likely due to the low RWW population in this field (0.3 RWW immatures per first or second core sample).

The proportion of plants with adult RWW feeding scars give an indication of adult activity and were used in the past (when the insecticide carbofuran was used for RWW control) to determine if a treatment was needed. Currently, insecticides used for RWW control in water-seeded fields are applied at the 2-3 lsr. Past experiments in California water-seeded rice have shown that when feeding scars are observed at the 3 lsr, oviposition has already occurred and insecticide applications to the foliage with currently registered insecticides are not effective in reducing the number of RWW larvae in the soil. In dry-seeded fields, RWW infestations begin when the flood is applied. Using feeding scar counts made immediately after applying the flood may constitute a viable option to decide if an application is needed. In the future, if insecticides with larvicide activity are registered, it may be possible to use feeding scars to determine if an insecticide application is needed.

Objective 2: To validate observations regarding within-field RWW distribution. Specifically, to confirm the prevalence of RWW populations around field borders and levees.

To determine the distribution of RWW within rice fields, proportion of plants with adult feeding scars and number of immatures per core were analyzed for each location.

At the Princeton location RWW density was higher than at any other location. There were no significant differences in the proportion of plants with feeding scars among plots at different distances form the field's edge (Table 2). In average, the proportion of plants with feeding scars was 0.38. Significant differences were found in the number of RWW immatures per first core samples at different distances from the field's edge (Fig. 1). Significantly fewer immatures were found in the 110 ft plots, while no significant differences existed between the 15 and 205 ft plots. At the second sampling date, no significant differences were observed in the number of RWW immatures per core among distances. However, there was numerically more RWW immatures per core in the 15 ft plots than in the 110 or 205 ft plots. The distribution of RWW feeding scars and immatures per core indicate that weevils were initially distributed similarly though out the field. Later on, RWW tended to be more abundant closer to the field's edge.

At the Maxwell location, when comparing the proportion of plants with RWW feeding scars, there was a significant treatment by distance interaction ($P = 0.042$). This indicates that differences in proportion of plants with feeding scars between treated and untreated plots have to be analyzed for each distance from the field's edge. The proportion of plants with feeding scars was significantly higher in untreated than treated plots at 15 ft from the edge of the field (Fig. 5). At 110 and 205 ft, the proportion plants with feeding scars was higher in untreated plots, but not significantly so (Fig. 5). At this location, treated plots were sprayed at the 5 lsr, and therefore treated foliage was not consumed by RWW adults and presented fewer feeding scars. When comparing proportion of plants with feeding scars across distances, no significant differences were found among treated plots, but in untreated plots significantly more plants had feeding scars in plots located 15 ft from the field's edge (Fig. 5). Number of RWW immatures per first core samples was significantly higher in plots 15 ft from the field's edge than at plots at 110 and 205 ft from the field's edge (Fig. 2). No significant differences were found when comparing second core samples. Proportion of plants with RWW feeding scars and immature distribution indicate that in this location weevils were more prevalent near the edge of the field.

At the Oroville location RWW density was relatively low. The proportion of plants with RWW feeding scars was significantly higher at the 110 and 205 ft plots than at the 15 ft plots (Table 2). Similarly, RWW immature densities were higher, but not significantly so, at the 205 ft plots than at the 110 and 15 ft plots (first core samples) (Fig. 3). In this field, the 205 ft plots were close (≅ 25 ft) to a weedy levee. Higher feeding scars and RWW immature populations in the plots closer to the levee indicate that, in this field, levees were a source of RWW infestation.

At the Colusa location there were significantly more plants with feeding scars at the 15 ft plots than at the 110 and 205 ft plots (Table 2). The number of RWW immatures per first core samples was significantly higher at the 15 ft plots than at the 110 and 205 plots; and the number of RWW immatures per second core samples was significantly higher at the 15 and 110 plots than at the 205 plots (Fig. 4). Proportion of plants with RWW feeding scars and immature distribution indicate that in this location RWW populations were more prevalent near the edge of the field.

In summary, based on the number of RWW immatures and adult feeding scars at different distances from the field's edge, RWW infestations appear to be more severe near field borders and levees, specially under low to mid population densities. In only one location, Princeton, was the RWW infestation widespread through the field. RWW density in this location was higher than in all other locations, with an overall mean of 2.1 and 3.1 RWW immatures per first and second core samples, respectively. All other fields had an overall average of less than one RWW immature per first or second core sample. However, near the field's edge, RWW immature number per core was usually higher than one, a density commonly considered as threshold in California rice. At the Oroville location, statistically significant differences in RWW immature numbers were not found among distances from the field's edge. This location had the lowest RWW infestation, with an overall average of 0.3 RWW immatures per first or second core samples. These results indicate that edge and levee treatments in California rice are adequate to manage RWW populations.

Objective 3: To assess the effect of RWW larval populations on rough rice yield under field conditions.

Plot yields from all treatments and distances were compared using ANOVA. To determine the RWW density-yield relationship in California rice, linear regression analyses were conducted between grain yield and average number of RWW immatures per plot for each of the experimental locations.

At the Princeton location, no significant effect of treatment or distance from the field's edge were observed. Average yield was 10,300.3 lbs/a. Linear regression of yield versus average number of RWW immatures per first or second core sample per plot yielded a non significant relationship.

At the Maxwell location, averaging across all treatments and plot distances, yield was 8,804.4 lbs/a. ANOVA revealed a significant effect of distance from the field's edge. Yield at 15 ft plots (9665 lbs/a) was significantly higher than at 110 (8578.9 lbs/a) and 205 ft (8169 lbs/a). In this location, RWW populations were higher in plots near the field's edge, but at the same time yields were higher in these plots. Higher yields near the field's edge were likely due to differences in plant density at different distances from the field's edge. While conducting the experiment it was noticed that plots closer to the field's edge had higher plant density than plots further from the field's edge. This was not caused by RWW but was likely due to lack of uniform seeding. Because of this, the relationship between yield and RWW density was studied at each distance from the field's edge (Fig. 6). First cores were used because they had a wider range of RWW immatures per core (0 – 2.7) than second cores (0 – 1.3). ANCOVA showed that the regression lines relating yield and RWW density in first core samples had different intercepts (average yields) but statistically similar slopes (rate of yield reduction per RWW immature per core). The common slope estimate is -395.9, which indicates a reduction in yield of 395.9 lbs per each RWW immature per core (r^2=0.5).

At the Oroville location, no significant effect of treatment or distance from the field's edge were observed. Average yield was 9,722.3 lbs/a. Linear regression of yield versus number of RWW immatures per first or second core sample per plot yielded a non significant relationship. The low RWW population level in this field may explain why no effect was observed in yield.

At the Colusa location, no significant effect of treatment or distance from the field's edge were observed. Average yield was 5,130.1 lbs/a. Linear regression of yield versus number of RWW immatures per first or second core sample per plot yielded a non significant relationship. Low yields in the whole field may have masked any effect the RWW might have had on yield.

In all locations the insecticide treatment did not have a significant effect in yield. In only one location, Princeton, was there a significant effect of treatment on RWW population (Fig. 1). In all other locations no significant effect of treatment on RWW population was detected (Figs. 2-4). Past experiments and field experience have shown that λ-cyhalothrin applied pre-flood is a very effective insecticide against RWW. In our experiments λ-cyhalothrin did not produce the expected results. This was most likely due to the application of the insecticide in a small area (160 ft^2) within a large field. The insecticide may have been "diluted" because of movement of soil out of the treated area or movement of the pesticide into the water. To avoid this, future studies need to include barriers around treated plots to restrict insecticide movement out of treated areas.

In summary, in only one location was a significant RWW density-yield relationship identified. At the Princeton location, RWW population levels were higher than in the other locations, but a

RWW effect on yield was not detected. This field was planted with the variety M-401, a late maturing variety (≅ 100 days to 50% heading), while the other locations were planted with M-206, an early maturing variety (78-86 days to 50% heading). The longer period of growth of the variety M-401 may allow plants to overcome or compensate for RWW injury. The Oroville location had a very low RWW population that may not be enough to cause yield reductions. At the Colusa location, problems with stand establishment and fertility may have masked RWW effects on yield.

The estimate of yield reduction per RWW immature from the Maxwell location is similar to estimates obtained in past experiments in California. Compared to estimates of yield reduction per RWW immature per core from southern rice, this estimate is very high. This has been explained by the fact that in the California water-seeded system infestations start much earlier than in the southern drill-seeded system, where the flood is not applied until early tillering. However, the estimate of yield reduction presented in this report originated from a dry-seeded field. RWW infestations in this field may have started when flush irrigation was applied after planting to promote rice emergence and growth. This would imply that RWW control in dry-seeded rice in California would be needed earlier than when the flood is applied. As dry-seeding becomes more common in California, more studies are needed to confirm these observations.

PUBLICATION OR REPORTS

n/a

CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESULTS

The main goal of this project is to improve management guidelines for the rice water weevil (RWW), the most important insect pest of California rice. Research was conducted to study potential RWW adult sampling methods, within-field larval distribution and RWW effect on grain yield. Experiments were conducted in plots established in four commercial rice fields with different management systems. RWW populations were high in one location and low to moderate in the other three.

RWW adult sampling. Two methods were employed to sample RWW adult populations, a small aquatic net and feeding scars. Results indicate that the aquatic net is not appropriate for decision making sampling. No relationship was found between number of adults caught with the aquatic net and larval populations. This is due to the low catch-efficiency of the aquatic net. Additionally, the use of an aquatic net is hampered by the presence of straw residue and algae in the water during sampling.

In three locations a good relationship was found between proportion of plants with RWW adult feeding scars at the 3 leaf stage of rice and later larval populations. Pooling together the data from these locations, this relationship can be expressed as *Number of RWW larvae = 6.18*Proportion of plants with feeding scars*. Feeding scars constitute good indicators of adult activity; however, they can not be used for decision making sampling with currently registered insecticides for RWW control. In the future, if insecticides with larvicide activity become available, it may be possible to use feeding scars to determine if an insecticide application is needed.

Within-field RWW larval distribution. Based on the number of RWW larvae and adult feeding scars at different distances from the field's edge, RWW infestations appear to be more severe near field borders and levees, specially under low to mid population densities. In only one location was the RWW infestation widespread through the field. RWW density at this location was higher than in all other locations, with more than two RWW larvae per core. All other locations had a RWW population of less than one larva per core. However, near the field's edge, number of RWW larvae per core was usually higher than one, a density commonly considered as threshold in California. These results confirm that edge and levee treatments in California rice are adequate to manage RWW populations.

RWW effect on grain yield. In only one location was a significant RWW density-yield relationship identified. At this location, a dry-seeded field, yield reduction per RWW larvae per core was estimated to be 396 lbs/a. The lack of a density-yield relationship at other locations may be due to differences in variety, low RWW populations or crop establishment problems that may have masked yield reductions. In summary, RWW's high estimate of yield reduction per larva under field conditions and its prevalence around borders and levees indicate that current RWW management guidelines for California are appropriate.

Table 1. Agronomic information and important dates for RWW experiments, 2009

Info/Operation	Location			
	Princeton	Maxwell	Oroville	Colusa
Planting system	Water-seeded with early dry down	Dry-seeded	Water-seeded	No till, stale seedbed, water-seeded
Variety	M-401	M-206	M-206	M-206
Planting date	24 April	15 May	22 May	8 June
Flooding date	24 April	17 June	22 May	8 June
Dry down	5 May – 17 May	n/a	n/a	n/a
Insecticide application	23 April	15 June	21 May	6 June
Feeding scars and aquatic net sampling	19 May (25 daf[1], 3 lsr[2])	22 June (5 daf, 5 lsr)	8 June (17 daf, 3 lsr)	23 June (15 daf, 3 lsr)
First RWW larval sampling	10 June (7 waf[3])	10 July (3 waf)	1 July (6 waf)	21 July (6 waf)
Second RWW larval sampling	23 June (9 waf)	27 July (6 waf)	17 July (8 waf)	3 August (8 waf)
Harvest	10 October	8 October	10 October	8 October

[1] daf : days after flood
[2] lsr: leaf stage of rice
[3] waf: weeks after flood

Table 2. Mean proportion of plants with RWW feeding scars, 2009

Factor	Level	Location			
		Princeton	Maxwell	Oroville	Colusa
Treatment	Treated	0.38	0.02 a	0.13	0.19
	Untreated	0.37	0.11 b	0.18	0.18
	P	0.760	< 0.001	0.085	0.789
Distance	15 ft	0.33	0.14 a	0.10 b	0.33 a
	110 ft	0.42	0.03 b	0.15 a	0.13 b
	205 ft	0.38	0.03 b	0.23 a	0.09 b
	P	0.127	< 0.001	0.002	< 0.001

Means followed by different letters within the same column are significantly different.

Table 3. Linear regressions between RWW immatures/first core sample and proportion of plants with feeding scars, 2009

Regression/ Parameter	Location			
	Princeton	Maxwell	Colusa	Pooled
Intercept model	y=1.5+3.4*x	y=0.4+3.8*x	y=0.1+4.6*x	y=0.4+5.2*x
P, r^2	0.047, 0.111	0.018, 0.154	< 0.001, 0.352	< 0.001, 0.34
No intercept model	y=6.8*x	y=5.1*x	y=5.023*x	y=6.18*x

Fig. 1. Mean number of RWW immatures/core sample ± SEM by treatment and distance from field's edge, Princeton, 2009. Bars with different letters within a group indicate means that are significantly different.

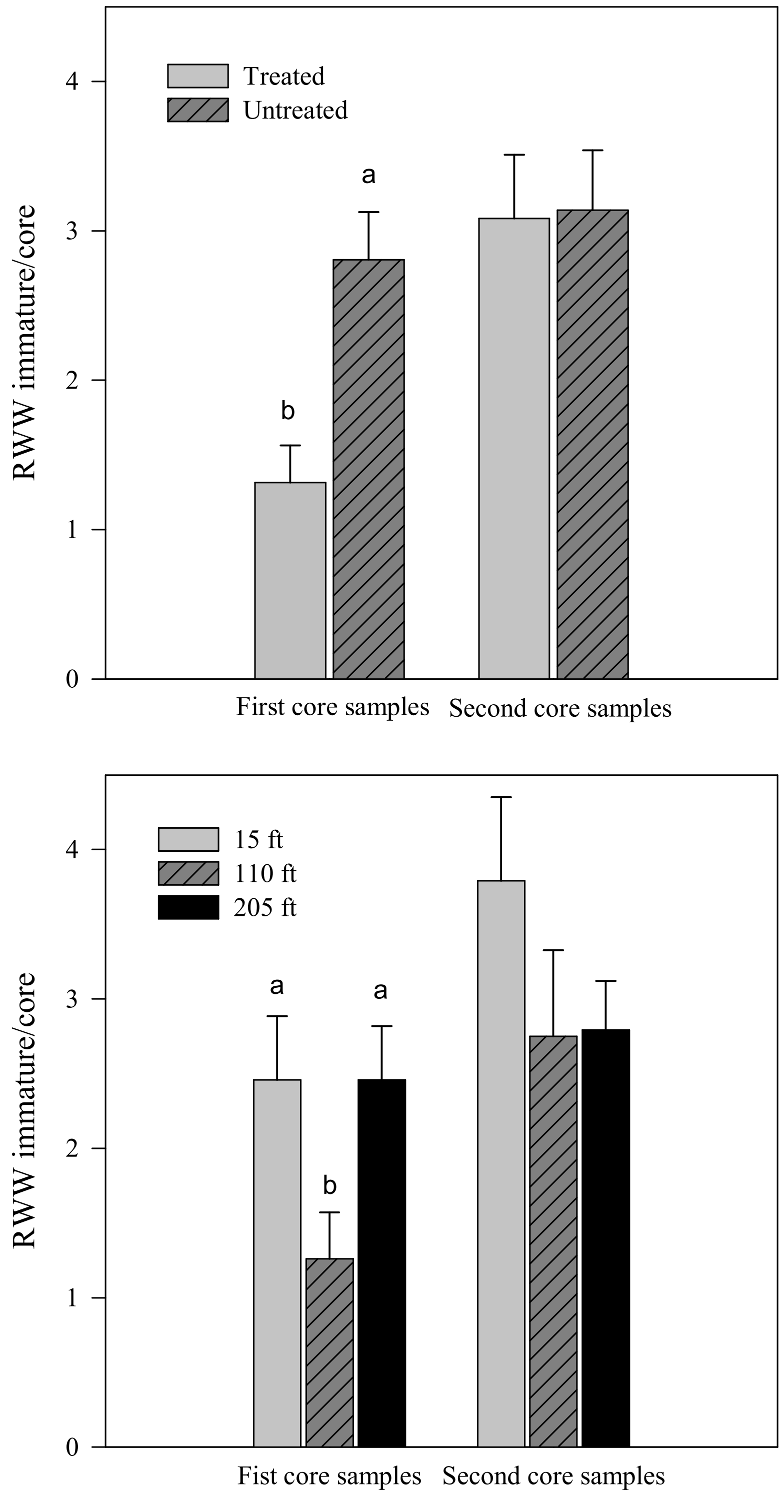

Fig. 2. Mean number of RWW immatures/core sample ± SEM by treatment and distance from field's edge, Maxwell, 2009. Bars with different letters within a group indicate means that are significantly different.

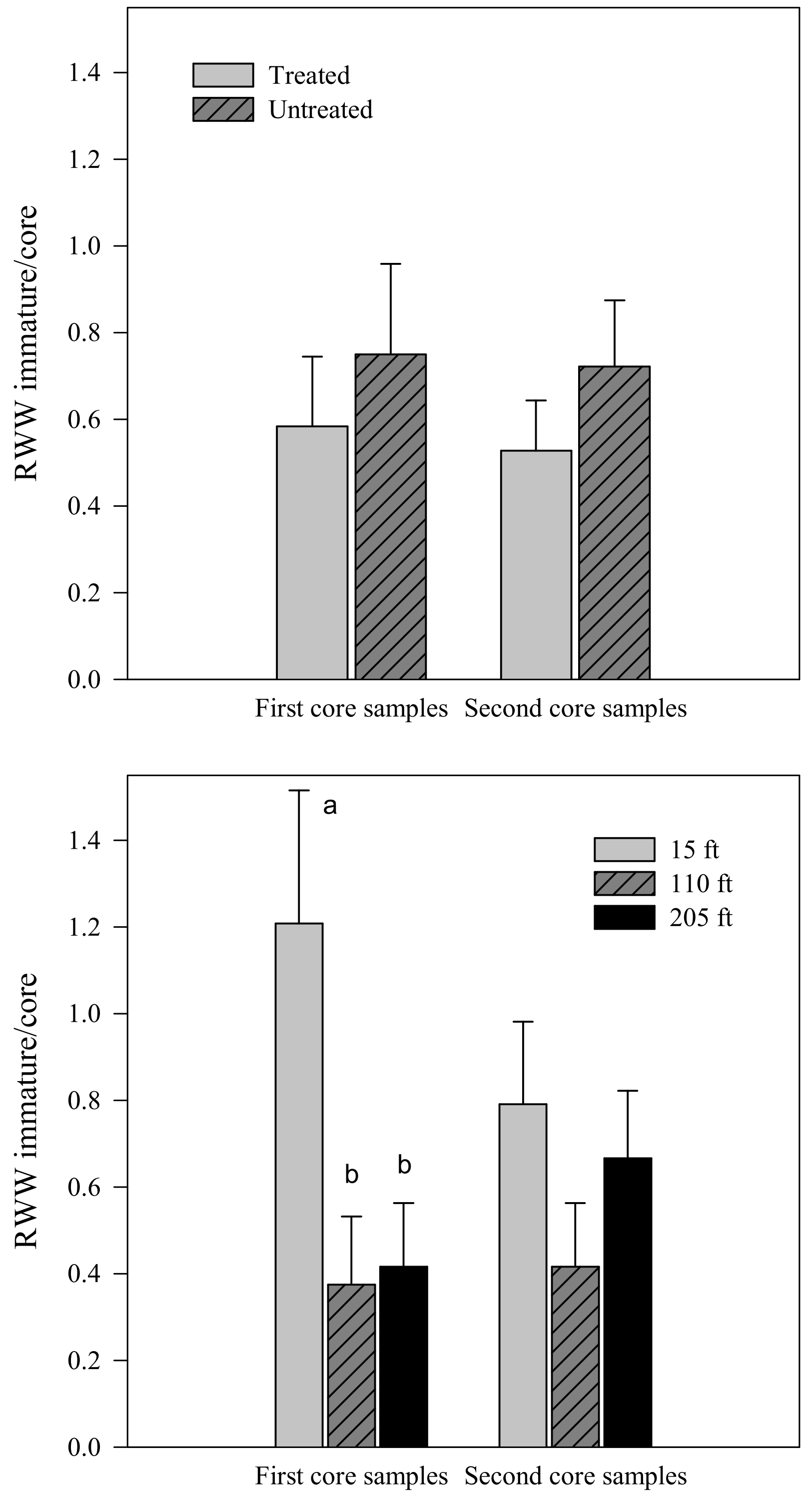

Fig. 3. Mean number of RWW immatures/core sample ± SEM by treatment and distance from field's edge, Oroville, 2009.

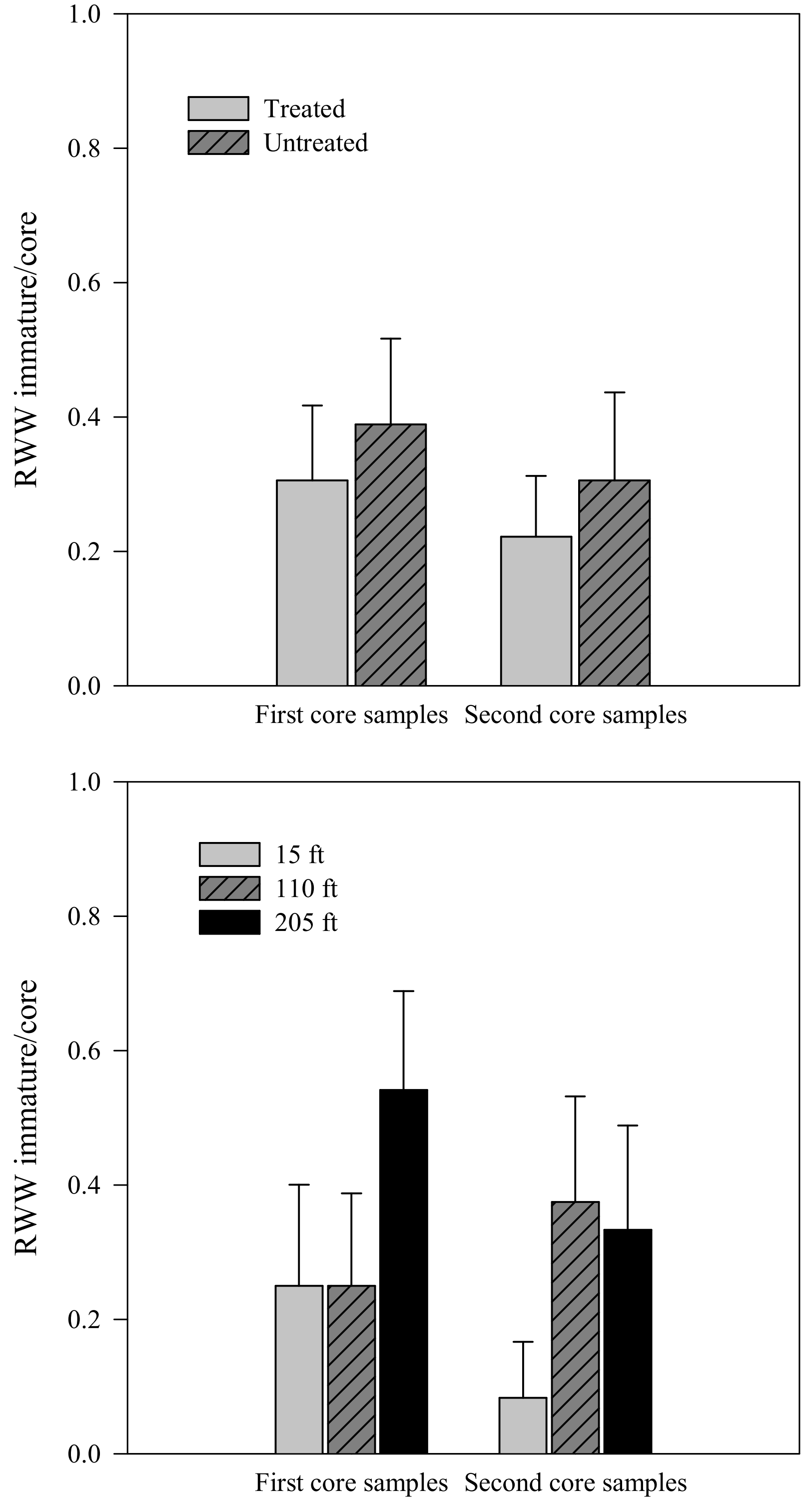

Fig. 4. Mean number of RWW immatures/core sample ± SEM by treatment and distance from field's edge, Colusa, 2009. Bars with different letters within a group indicate means that are significantly different.

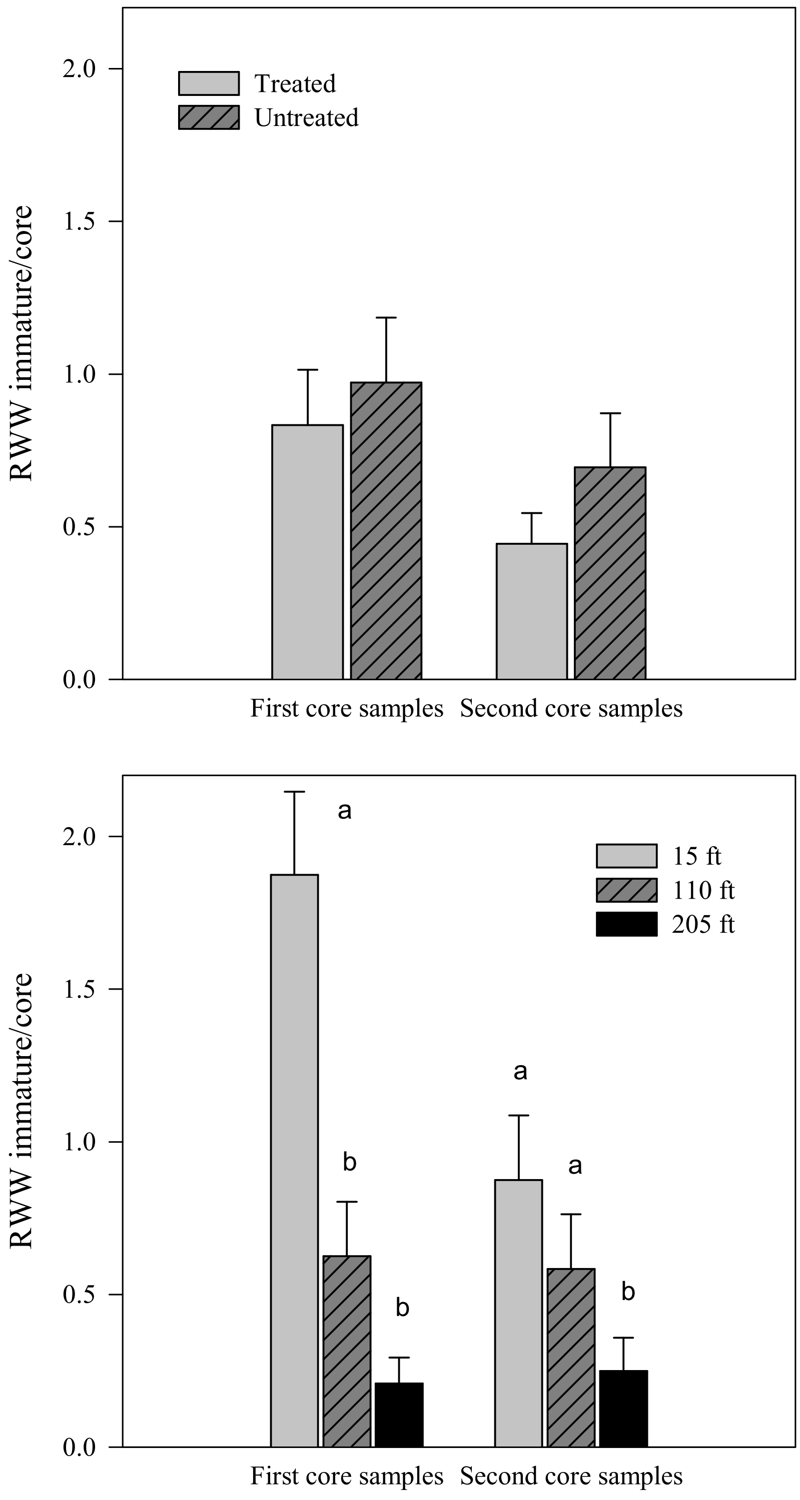

Fig. 5. Mean proportion of plants with adult RWW feeding scars ± SEM, Maxwell, 2009. Bars representing untreated plots at different distances with different letters indicate means that are significantly different. For each distance, bars with a * indicate a significant difference between treated and untreated means.

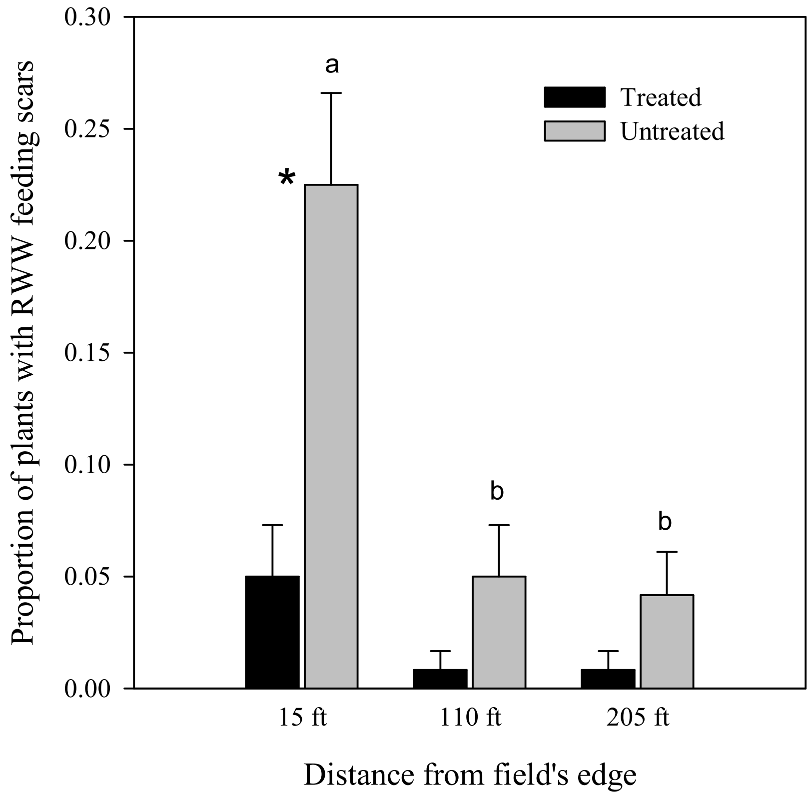

Fig. 6. RWW density-yield relationship at three distances from the field's edge, Maxwell, 2009.