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. To determine the most effective control of rice invertebrate pests while maintaining environmental quality.

1.1 Control of rice water weevil (RWW) using insecticides

Methods

Eighteen treatments (a total of 10 different active ingredients) were established in ring plots at the Rice Experiment Station (RES) in Biggs, CA (table 1). Testing was conducted with variety M206 in 10.7 ft^2 aluminum rings. The plots were flooded and seeded at a rate of 150 lbs/a on 29 May. Prior to seeding, seed was soaked for 2 h in 5% Clorox Ultra solution followed by 22 h in water, drained, and held for 24 h. Applications were made pre-flood on 28 May, at the 3 leaf stage of rice (lsr) on 15 June (2.5 weeks after seeding), and at the 5-6 lsr on 22 June (3.5 weeks after seeding).

Treatments were applied with a CO_2 pressurized sprayer at 15 GPA. Natural RWW infestation was supplemented with 5 adults placed into each ring on 20 June followed by 3 more RWW adults added on 28 June. Standard production practices were used.

Sampling Dates
Adult leaf scar counts: 5 July and 12 July (5 and 6 weeks after seeding)
Larval samples: 23 July and 6 August (8 and 10 weeks after seeding)
Rice yield: 5 October

Sampling Methods
Adult leaf scar counts: percentage of plants with adult feeding scars on either of the two newest leaves (50 plants per ring per date).
Larval counts: 44 in^3 soil core containing at least one rice plant processed by washing and flotation method (5 cores per ring per sampling date).
Rice yield: entire ring plots were hand harvested and threshed. Yields corrected to 14% moisture.

Statistics:
Plot design: Randomized complete block, four replications.
Data analysis: Analysis of variance, mean separation using Tukey's test ($\alpha = 0.05$).

Results

This year, RWW populations were low. We had difficulties collecting enough RWW adults to infest the rings. The untreated rings had a total RWW immature density of 1.25 larvae/core. Last year the untreated rings had a density of 5.25 larvae/core. Additionally, we experienced problems with stand establishment in several of the rings. Rings where stand was very poor were not considered in the analysis.

The highest leaf scaring during the first sampling date was found in rings treated with Belay at the 3 lsr. However, larval populations in these rings were significantly lower than the untreated. This seems to indicate that Belay did not affect adults, but did affect larvae. The other treatments were not significantly different from the untreated (table 2). During the second sampling date, no significant differences were observed among treatments, with an average of 16% of plants showing RWW feeding scars.

RWW larval counts were made twice during the season (table 3). The two larval counts were added and then compared among treatments to give a better estimate of control. All treatments significantly reduced the total number of larvae/core with respect to the untreated, and statistically, no differences were detected among treatments. Nevertheless, a few trends are clear. The low rate of Dimilin reduced the RWW immature density only by 72%, while the high rate was 100% effective. Warrior applied pre-flood or at the 3 lsr was very effective. As seen in previous years, Belay applied pre-flood was not as effective as when applied at the 3 lsr stage. As a rescue treatment, Belay reduced the RWW by 92%, providing good control. Coragen seemed to work better when applied pre-flood or at the 3 lsr, but control was poor when used as a rescue treatment at the 5-6 lsr. The organic products tried this year were effective, most of them giving over 90% control. Interestingly, Intrepid seemed to give good control when applied at the 3 lsr. Last year Intrepid was tested at the 5-6 lsr timing, simulating an early armyworm application, resulting in no control.

Yield or biomass was not significantly affected by any of the treatments (table 4). In general, the untreated rings had low yields and low biomass, while some of the treated rings had the highest yields and biomasses. Belay, Warrior, and Pyganic resulted in yields that ranged from 5,500 to 6,200 lb/a.

Conclusions

- RWW pressure was low. The number of RWW larvae/core in untreated rings was much lower than previous years.
- All treatments reduced RWW populations significantly.
- Dimillin worked best at the 16 oz/a rate.
- Belay worked well at the 3 lsr and as a rescue treatment. Its performance as pre-flood treatment was not bad, however, in previous years Belay has not worked well pre-flood. This year, Belay may have worked better due to the low level of RWW infestation.
- Coragen worked well pre-flood and at the 3 lsr, but its performance as rescue treatment was poor.
- Intrepid worked well when applied at the 3 lsr. This treatment needs to be explored further with higher RWW infestation levels.
- The organic treatments tested this year seemed to work well, however, it may be due to the low RWW pressure experienced.

1.2 Control of tadpole shrimp (TPS) using insecticides

TPS are aquatic crustaceans adapted to live in vernal pools. Conditions in rice fields, and their seasonality, make them a great habitat for this arthropod. TPS have been a problem in California rice since the 1940s. Insecticides have been used to control them, and they have evolved resistance to some of the insecticides used in the past (organophosphates). Recently, tolerance to pyrethroid insecticides has been observed in some areas. New alternatives for control are needed.

Methods

Leveed plots were established in a basin with high levels of TPS at the RES. Water was started on 27 May and plots were flooded by 29 May. Seeds of rice variety M206 soaked for 1 h in a 5% sodium hypochlorite solutione were seeded on 1 June at a 150 lbs/a seeding rate. The area seeded in each plot was 175 ft^2 (18 ft l x 9 ft w). The area flooded (area seeded plus ditches next to levees) was 318 ft^2 (22 ft l x 14 ft w). Insecticide rates were calculated using the area flooded. Treatments were applied on 5 June, except for the application of Coragen pre-flood, which was applied on 26 May. Pesticides were applied using a pressurized, CO_2 backpack sprayer.

Sampling method
TPS natural populations were counted in each plot using a 0.785 ft^2 PVC ring randomly placed on the plots at each evaluation date. Using an aquarium fish net (6x4 in), three scoops were taken from within the ring, with care not to pick up mud, and TPS counted. Additionally, for the Corage pre-flood treatment, 20 TPS were introduced into cages (5x6.25x4.5 in) on 5 June. Cages were made of fine netting and contained 1 inch of soil. The cage netting kept the TPS in but allowed water movement through the cage. At each evaluation date, the cages were removed from the water and TPS quickly counted.

TPS numbers were recorded before the treatments and every day for 3 days after the treatments.
Stand counts on two one-square foot area per plot were taken three weeks after seeding.
Rice yield: All plots were harvested using a small plot combine on 24 October. The area harvested per plot was approximately 120 ft^2. Yields were converted to lbs/a at 14% grain moisture.

Statistics
Plot design: The experiment was conducted as a randomized complete block with 11 treatments and 4 replications.
Data analysis: Analysis of variance was used to detect differences among treatment means for stand, TPS ring counts and yield. Tukey's honestly significant difference test was used to compare means of significant effects. The level of α used for all analyses was 0.05.

Results

TPS shell length was on average 5.8 mm on the day the treatments were applied. The number of TPS/ft^2 was similar in all plots before the treatments, except for the Coragen treatment (table 5). Coragen was applied pre-plant, and at the time the treatments were made (9 days after the water was started and 7 days after plots were flooded) very few survivors were observed. Several treatments reduced the number of TPS 24 h after application, but there was quite a bit of variability and none were statistically different than the control. Two days after the application, Warrior, Dimilin at 8 oz, Coragen, Belay, and Sevin completely controlled TPS. Three days later, Dimilin at 4 oz also completely controlled TPS. Dimilin at 2 oz reduced the population significantly when compared with the control (91%), but there were a few survivors. These results are similar to last year, and suggest that Dimilin works well when TPS are small (aprox 4 mm shell length), but may take longer to control larger shrimp.

In Coragen trated plots, the number of TPS introduced in cages 7 days after flood was reduced by 10, 20, and 22.5% 8, 9, and 10 days after flood. This indicates that the mortality of TPS due to Coragen occurs early after the TPS emerge. Another possibility is that the product stays bound to the soil. Since the cages did not have treated soil, TPS may not have been exposed to the product.

Stand was significantly lower in the untreated plots (table 6). The best stands were achieved with Coragen, Belay, and Sevin. Other products did not have a significantly higher stand than the control. Yields were not significantly affected by the treatments. Yield can be affected by several factors, such as fertility, weed control, water management, etc. Additionally, under low densities, plants can compensate by producing more tillers. Therefore, it may be difficult to detect an effect of the treatments on yield.

TPS feed on developing seedlings. Research indicates that small germinating seeds and seedlings with a coleoptyle and radicle are more susceptible to injury by TPS than seedlings that already have a spike or prophyll. Also, small TPS (4 mm shell length or less) are less likely to injure seedlings. In this trial, TPS were 5.7 mm and seedlings were starting to show the spike by the time the treatments were made. Regression analyses of the number of TPS and stand per plot indicate that injury occurred before and one day after treatments were made (fig. 1). The regression showed that for each day of infestation during the period of seedling susceptibility, each TPS reduced the stand approximately 2%.

Conclusions

- Complete control of TPS 2 days after post-flood treatments was obtained with Warrior at 2.56 oz/a, Dimilin at 8 oz/a, Coragen pre-flood at 3 oz/a, Belay at 2 oz/a, and Sevin at 1.5 qt /a.
- One day later, Dimilin at 4 oz/a resulted in complete control.
- The low rates of Dimilin killed TPS more slowly than other insecticides tested. A rate of 8 oz/a seems to be effective.
- Reduced label rates of Coragen and Belay were tested and proved to be effective.
- Large TPS were introduced in Coragen-treated plots when post-flood treatments were made. Mortality of TPS in these cages was low, indicating that the insecticidal effect of Coragen occurs soon after flood or that the insecticide is bound to the treated soil.
- Stand three weeks after seeding was above 30 plants/ft2 for plots treated with Dimilin at 8 oz/a, Coragen pre-flood at 3 oz/a, Belay at 2 oz/a, and Sevin at 1.5 qt/a.
- Stand in the untreated plots was 16 plants/ft^2.
- Regression analysis of density and stand seem to indicate that one TPS/ft^2/day is capable of reducing stand by 2%.

1.3 Control of armyworms using insecticides

1.3.1 Field trials

Methods

Several insecticides were tested for armyworm control in two commercial rice fields in Glenn County. Plots 10x20 ft were established in areas of the field where armyworms were present. Trial one was treated on 21 June and trial two on 26 June. Armyworm populations were evaluated before treatments were made, and 3, 7, and 10 days after treatments. Insecticides were applied using a pressurized, CO_2 backpack sprayer.

Sampling methods
To evaluate the armyworm infestation before the treatments, 10, 1-ft^2 quadrants were thoroughly inspected and the number of larvae found recorded. A sample of 10 larvae were collected, identified to species, and their head capsule measured to determine their approximate larval stage. The efficacy of treatments was determined by performing 4, up-to-1 minute armyworm searches per plot, and the number of searches with armyworms present was recorded. Each search covered an area about 3 ft^2. Defoliation was estimated by randomly selecting 50 leaves and counting the number that showed armyworm feeding.

Statistics
Plot design: Randomized complete block, four replications.
Data analysis: Analysis of variance, mean separation using Tukey's range test ($\alpha = 0.05$).

Results

At both trial locations, all armyworms collected were true armyworm.

Trial 1 (Road 61, Glenn County)
On average, this trial had a larval density of 1.7 larvae/ft^2. Half the larvae sampled were second instar, 33% were third instar, and 16% were first instar. Three days after treatments were made, larvae could not be found in plots treated with Intrepid (table 7). A week after treatments were made, larvae could not be found in plots treated with Intrepid or Dimilin. At the end of the experiment, control in plots treated with Intrepid, Dimilin or Coragen was satisfactory. A few larvae were found in plots treated with Intrepid and Dimilin. Given that these are 10x20 ft plots, it is possible that larvae from untreated plots or from plots treated with Warrrior, or from outside the experiment area, had moved into these plots. Defoliation tended to be higher in the untreated plots and in plots treated with Warrior (fig. 2).

Trial 2 (Road 47, Glenn County)
Armyworm density in this trial was 5.4 larvae/ft^2. Almost 60% of the larvae were fifth instar, 35% were fourth instar, and 5% were third instar.

Larvae in this trial were large. Three days after treatment, none of the insecticides significantly reduced the number of searches with larvae present (table 7). A week after the treatments, plots treated with Prevathon, Coragen, and Intrepid had significantly fewer larvae finds than the untreated. Dimilin was lower, but not significantly lower. Warrior and the untreated did not differ significantly. After 10 days, the number of larvae finds was in plots treated with Warrior was similar to the untreated plots. Larvae finds in plots treated with Intrepid, Dimilin, Coragen and Prevathon were significantly lower than in untreated plots.

Control with Prevathon, Intrepid and Dimilin after 10 days was close to 90% or better. While in Trial 1 Coragen provided 100% control, in this trial Coragen resulted in only 77% control. Larvae were large and likely some were going into pupation as the trial progressed. Larger larvae are more difficult to control, and this may account for the lower levels of control than in Trial 1. Prevathon has the same active ingredient as Coragen, chlorantraniliprole, however, it provided better control (though statistically Coragen and Prevanthon were similar). Given the concentration of both products, the amount of chlorantraniliprole applied was the same for both treatments.

Defoliation trended down in all treatments as the trial progressed (fig. 2). Overall, Intrepid, Dimilin, Coragen and Prevathon seemed to slightly reduce defoliation.

Conclusions

- Intrepid, Dimilin, Coragen and Prevathon reduced the number of armyworm finds.
- In trial 1, Intrepid provided good control 3 days after the treatment was applied.
- In trial 2, where larvae were larger than trial 1, levels of control were smaller.
- Warrior was not significantly different than the untreated control at the end of both trials.

1.3.2 Greenhouse trial

Experiments conducted in the southern US have shown that chlorantraniliprole (the active ingredient in Coragen) applied as a seed treatment can control stem borers mid season. In California, chlorantraniliprole is not used as a seed treatment but is labeled for pre-flood applications. This greenhouse study was conducted to explore the effect chlorantraniliprole applied pre-flood on armyworms that infest rice later in the season.

Dimilin is labeled for RWW and armyworms. The Dimilin RWW application timing is at the 3 lsr. In this study we also wanted to test if an application of Dimilin targeting RWW could have residual effect on armyworms later in the season.

Methods

Seeds of M206 rice were water seeded on 6 September on small tubs (aprox 12x24x6 in). The amount of seed used was the equivalent of 150 lb/a. Treatments were applied pre-flood on 6 September, at the 3 lsr on 24 September, or at 5 lsr on 1 October. Additionally, a Coragen seed treatment was also included. Each treatment was applied to four tubs.

Late instar western yellowstriped armyworms and adults collected from the field were reared on small cages in the greenhouse to obtain eggs. Small larvae that hatched from these eggs were transferred to rice seedlings where they fed until used in the experiment.

On 2 October, five first or second instar armyworms were transferred to each tub. The number of live and dead armyworms, and the number of chewing marks on leaves were counted 1, 7, and 10 days after the armyworms were introduced in each tub.

Statistics
Plot design: Completely randomized design, four replications.
Data analysis: Analysis of variance, mean separation using Tukey's range test ($\alpha = 0.05$).

Results

Both western yellowstriped armyworms and true armyworms can be found in rice fields. However, the true armyworm is the predominant species and the one causing outbreaks. In the trial, we used western yellowstriped armyworms because true armyworms were not found by the time the trial was conducted. We expect the results would be similar if true armyworm was used, however, the study will need to be repeated to confirm this.

First or second instars were used to try to mimic an early infestation. In the field, armyworm moths lay eggs in weeds or rice plants in levees and around rice fields. These larvae initially feed on these weeds and then move to rice plants. If a pre-flood or 3 lsr application had enough residual activity, most likely it would affect early instar larvae moving into the field.

Three and seven days after the infestation, very few armyworms could be found in the untreated tubs (table 8). Ten days after the infestation, no worms could be found in untreated tubs. Dead worms were only found one day after the infestation. This trend indicates that worms were leaving the tubs or may have been consumed by natural enemies inside the greenhouse.

One day after the infestation, significantly more worms were found in the untreated tubs than in the Coragen treated tubs, where in fact, no worms could be found. The same trend was observed 3 and 7 days after infestation. In all Coragen treatmetns, significantly less feeding marks were found in all evaluation dates,

One day after the infestation, for the Dimilin treatment at the 3 lsr, the number of live armyworms found was not significantly different than the number in untreated tubs, while the number in tubs treated at the 5 lsr was significantly lower. Feeding marks in Dimilin and Intrepid treatments were not significantly different form the untreated tubs.

Conclusions

The data suggests that Coragen applied pre-flood can have an effect on early instar armyworms a month later (26 days after application in this study). The results with Dimilin and Intrepid were not conclusive; repeating the study is necessary.

OBJECTIVE 2. To evaluate the physical and biological factors that result in fluctuation and movement of populations of key rice invertebrate pests.

2.1 Rice water weevil flight monitoring

The RWW is native of the southern US, where it is considered the most damaging insect pest of rice. It was first identified in California in 1958. Since then, research has focused on many aspects of its biology and management. One aspect that has been studied for many years, almost since its discovery in California, is the timing of its spring flight.

The insect is in an overwintering (hibernation) state during the late fall, winter, and early spring hidden in the soil and under debris. As RWW emerge from overwintering sites in the spring, the adults feed on grasses on levees and other areas. These nutrients cause the flight muscles to develop and the RWW adults to be able to fly. They fly only on evenings that have warm (70-80 F) temperatures with calm winds. The flight appears to be more on a local scale (field-to-field, within farm) than long-range flight. The flight monitoring allows us to assess population level and flight timing. 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.

Considering that RWW adults are very small (aproximately 1/8 inch long) and nondescript, and that on some nights two to three gallons full of insects are collected, sorting samples for RWW can be time consuming, preventing us from providing RWW flight numbers to the industry in real time.

Methods

A light trap is maintained at the RES. The trap has an 18 watt black light bulb and readily attracts nocturnal insects. When in flight, the insects hit metal baffles and fall into a collection bucket. The nightly capture is collected every few days from mid-March to mid-June and stored in a freezer. The samples are later sorted and RWW adults counted.

Results

Trapping was delayed in 2018 due to problems with the light trap. Typically, the trap is started mid March or early April, and quite a few RWW can be collected during those months. This year, the trap was started in early May.

Only 20 adults were caught in the trap (fig. 3). This is the lowest number of RWW adults caught in the light traps since 1969 (not sure if trapping was conducted before). As a comparison, more than 15,000 weevils were found in 1969, 1981, and 1989. Similar levels to 2018 had been found when light traps were set up in locations other than the RES.

Historical data (38 year average) suggests that 90% of RWW catches are completed by mid May. In some years (1990, 1996, 1998), 90% of the flight was completed by late April. This may explain the low levels found this year. However, numbers caught during May even in these early flight years have been much higher than what was found this year.

A general trend of the past decade (or more) is the lessening of severity of RWW as a pest. While there are certain areas where RWW can cause problems if left unchecked, most growers and pest control advisers do not consider the RWW a key pest. Some of the scientists that worked on RWW during the early years after its introduction into California are suprised by the fact that RWW is no longer a key pest. This may be due to the use of improved varieties that can withstand injury better, changes in agronomic practices such as the reduction in burning and improved straw management, weather patterns, or the increase use of pyrethroid insecticides early in the season.

2.2 Armyworm flight monitoring using pheromone traps

Armyworms have been considered a secondary pest in California rice. Outbreaks have occurred, but they have not been severe according to those working in the industry for more than 25 years. In late June 2015, an armyworm outbreak caught the industry by surprise. Growers and PCAs tried to control infestations with available insecticides such as pyerthorids, carbaryl, even malathion, with very poor results. The industry was able to obtain a Section 18 registration for the insecticide Intrepid (methoxyfenozide). However, the registration was approved in late August, when the outbreak had passed. Several fields suffered yield losses. In 2016, armyworm infestations were not as bad as in 2015. Again, Intrepid received a Section 18 registration in June 30, allowing for more use than in 2015. In 2017, infestations appeared to be more widespread and severe than in 2015. Once Again, Intrepid received a Section 18 registration on June 30. Yields losses were reported, especially in fields where defoliation occurred before Intrepid was available.

The reason for this sudden resurgence of armyworms as pests is unknown. The efficacy of currently registered insecticides against armyworms is not adequate. The rice industry has been able to obtain a Section 18 registration for Intrepid for all years of the armyworm outbreak, and field reports have been very positive. Additionally, Dimilin was granted a 2EE label in 2017, and its use in rice has increased, with good results. The problem with Dimilin is its long pre-harvest interval, 80 days, which only allows for applications very early in the season. Nevertheless, outbreaks seem to occur early (last week of June, first week in July), therefore, Dimilin use has been possible.

One problem when managing armyworms is that their scouting is based on defoliation. Small armyworms are difficult to find. When defoliation is noticeable, armyworms are already on the 5th, or 6th instar, and they are much more difficult to control using insecticides. To improve on armyworm monitoring, pheromone traps were established in the Sacramento Valley in seven locations in 2017. Additionally, traps were also established near rice fields in the Delta.

There are very effective pheromones for both species of armyworms that infest rice fields. The two species of concern are true armyworm, *Mythimna unipuncta*, and western yellowstriped armyworm, *Spodoptera praefica*. These lures attract the male of both species.

Methods

Pheromone traps were placed in rice field levees in 16 locations all across the rice production area of the Sacramento Valley (fig. 4). Each trap consisted of a bucket, a lure, and a killing agent inside the bucket. Lures were changed every two weeks and killing agent every four weeks. In each location, three traps were placed per species, for a total of six traps per location. Moths were counted weekly from May until fields were drained, when rice is not at risk of armyworm injury.

Weekly updates were sent via e-mail to growers and PCAs. The updates were also distributed by the California Rice Commission electronically to their members.

Results

In 2018, armyworm infestations were not as severe as in 2017. Intrepid received a Section 18 registration on June 22, a week earlier than in 2017. This was helpful for growers and PCAs in that they had an effective product available before the infestations occurred. At this point, is not clear if armyworm populations were lower, or growers and PCAs did a better job of monitoring and timing treatments, avoiding yield losses. Most likely, a combination of both factors may have occurred.

The number of moths trapped peaked on 25 June, 10 days later than in 2017 (fig. 5). The number of moths trapped during the peak was similar to the peak in 2017. A second peak was detected mid August, reaching almost as high levels as the late June peak. True armyworm was the dominant species caught. In the field, only true armyworm larvae were found while monitoring fields and setting up trials.

Pheromone monitoring of armyworms was conducted by this project from 2003 to 2005 in Butte and Colusa counties. In those years, trapping was started in mid to late July. The western yellowstriped armyworm was more commonly trapped in 2003 and 2004, and the numbers trapped reached a maximum of 12 to 30 moths per day.

In 2018, trap data was sent weekly via email to growers and PCAs. A degree-day model available in the literature was used to predict when infestation of large worms would be expected in the field, so that monitoring efforts could be increased during those times.

OBJECTIVE 3. To evaluate the response of rice plants to injury by arthropod pests and determine the potential for yield losses and varietal tolerance.

3.1 Susceptibility of rice varieties to RWW injury

3.1.1 Ring plots

Methods

Seven rice varieties were grown in 10.7 ft^2 aluminum rings. For each variety, two treatments were established; uninfested rings protected with Warrior II at 2.56 oz/a applied pre-flood on 28 May to make sure no RWW infested the rings, and infested, unprotected rings. The basin was flooded and seeded on 6 June at a rate of 150 lbs/a. Before seeding, seed was treated with sodium hypochlorite as in objective 1.1. The rings were infested with five and three RWW adults on 20 and 28 June, respectively (2 and 3 weeks after seeding). Adult scarring, larval populations, and yields were assessed as described in objective 1.1.

Sampling Dates
Adult Leaf Scar Counts: 5 July and 12 July (4 and 5 weeks after seeding)
Larval Counts: 23 July and 2 Aug (7 and 9 weeks after seeding)
Rice Yield: 5 October

Statistics
Plot design: Randomized complete block, four replications, two factors (variety and treatment).
Data analysis: Analysis of variance, mean separation using LSD test ($\alpha = 0.05$).

Results

The levels of RWW scarring was very low to non-existent in the treated plots (table 9). Within treated plots, no significant differences in percentage of scarred leaves was observed. The number of RWW larvae/core in treated rings was very low. In untreated rings, M401 and S102 had significantly higher RWW populations than other varieties, and A201, L206, and M209 had significantly lower populations.

Overall, yields were low because this study was conducted in rings, which are not conducive to good yields. The interaction between treatment and variety was significant, indicating that for each variety, differences in yield between treated and untreated plots existed. Differences among varieties were expected, since we are comparing short, medium, and long grains, and different maturity groups. The only variety where a significant difference between treated and untreated plots was observed was M401, where yield loss attributable to RWW was 61.5% (table 10). Even though for other varieties no significant reduction in yield was detected, some of the varieties numerically had a lower yield when untreated (S102, M105, M206, A201). Other varieties had higher yields when untreated (M209, L206), however, the difference was not statistically significant.

Conclusions

- Overall, RWW populations were low.
- Differences in the number of RWW/core were found. M401 and S102 hand significantly higher populations than other varieties.
- Yield reduction due to lack of treatment was found only in M401. For this variety, yield reduction was 61.5%.

3.1.2 Open plots

Methods

The same study as in 3.1.1 was conducted in open plots. Plots 10x20 ft were treated in the same manner as mentioned above, the same parameters were evaluated, and dates of activities were the same. The plots were not infested with RWW adults, but relied on natural populations. The statistical analysis method was the same as 3.1.1.

Results

No adult RWW feeding scars were observed during the first sampling date. On the second sampling date, only 1% of leaves showed signs of RWW feeding on L206 and A201. All other varieties did not have any adult RWW feeding scars.

Larvae were found at very low levels, mostly on the first core sampling date. Interestingly, a few larvae were found in treated S102 and L206 plots; however, the level of RWW larvae/core was very low, even in the untreated plots (from 0.05 to 0.18 larvae/core). During the second sampling date, larvae were only found in untreated S102 and M206 plots, at very low levels (0.06 and 0.1 larave/core, respectively). When analyzing the total number of RWW/core, the interaction between variety and protection was not significant, and only the effect of treatement was slightly significant (P=0.079). On average, untreated plots had more RWW larvae/core than treated plots (0.09 versus 0.03). The number of RWW/core across varieties was highly variable and not significantly different from one another.

When analyzing yield, only variety had a significant effect. On average, M401 had the lowest yields, most likely because being a late maturing variety, it did not have enough time to fill grain. Other varieties yielded between 4,874 and 6,393 lbs/a.

In conclusion, this study did not show if any of the varieties was preferred by the RWW or was able to sustain more RWW damage because of the low RWW pressure.

3.2 Effect of levels of RWW infestation on rice growth and yield

A study was initiated in 2014 to examine the effect of increasing RWW population levels on the most important rice varieties. Initially, M202 and M206 were used. With the face out of M202, the study was repeated with M206 and M209, two varieties that dominate the acreage in California. This is the third year the study is conducted with these two varieties.

Methods

M206 and M209 rice were used. These were planted in ring plots (10.7 ft^2 aluminum rings) at a seeding rate of 150 lbs/a on 6 June. For each variety, four RWW infestation regimes were used – 0, 1, 2, and 3 RWW adults per ring. These densities correspond to 0, 0.01, 0.02, and 0.03 RWW adults per plant (100 plants per ring). RWW adults were introduced on 28 June. The rings with 0 RWW received a pre-flood treatment as in 3.1. Measurements collected included RWW leaf scarring (twice), RWW larval levels (twice), and biweekly measurements of number of tillers, root length (cm), stem length (cm), length of the newest fully developed leaf (cm) and of the next newest leaf (cm), total above ground dry weight (g), and root dry weight (g), and grain yield.

Because plants were sampled biweekly to determine the effect of RWW infestation on plant development, two rings per each RWW level was established. One of the rings was used to sample plans, the other to obtain grain yield at the end of the season. This procedure was also used last year.

Sampling Dates
Adult leaf scar counts: 12 July and 19 July (5 and 6 weeks after seeding)
Larval samples: 30 July and 13 August (8 and 10 weeks after seeding)
Plant samples: 20 July, 3, 17, and 31 August (6, 8, 10 and 12 weeks after seeding)
Rice yield: 12 October

Statistics
Plot design: Randomized complete block, 4 replicates for RWW and plant sampling and 4 replicates for yield.
Data analysis: Analysis of variance, mean separation using Tukey or LSD test ($\alpha = 0.05$). To relate RWW larval densities and yield, yield was converted to relative values by dividing the yield from each ring infested with adult RWWs by the yield from the ring not infested with RWW for each replication. These data was analyzed using analysis of covariance ($\alpha = 0.05$), with relative yield as dependent variable, variety as factor, and RWW larval density as covariate. Simple linear regression was used to relate relative yield to its corresponding RWW total larval density.

Results

The levels of RWW infestation this year were very low. Unfortunately, not enough RWW were found to infest the rings at the same level as in 2017 (which was 20 times higher than this year).

Percentage of plants showing feeding scars was not affected by variety, but was affected by RWW level. Plants in rings that were not infested did not have any feeding scars (fig. 6). The percentage of feeding scars on the three RWW infestation levels were not significantly different. On average, only 1.5% of plants showed adult RWW feeding scars when weevils were introduced to the rings. The number of RWW larvae/core was not affected by variety either. However, it was affected by RWW infestation level. The highest infestation level resulted in significantly more RWW larvae/core than the lowest infestation level and the not infested (fig. 7).

For all plant parameters evaluated, the interaction between RWW level and variety was not significant in most cases, indicating that both varieties responded similarly to RWW infestation. In the discussion, we will concentrate on the effect of RWW level.

The number of tillers per plant was affected by RWW level 6 and 12 weeks after seeding (fig. 8). In both dates, the number of tillers per plant was significantly lower in rings not infested and rings infested with 3 RWW/ring.

Root length was affected by RWW level 12 weeks after seeding. Rings infested with 1 RWW/ring had significantly longer roots than all other infestation levels. Stem length was affected by RWW infestation level 10 weeks after seeding. Stems were significantly longer on plants infested with 3 RWW/ring (18 cm) than all other infestation levels. The newest and second newest leaf length was affected by RWW level 6, 10, and 12 weeks after seeding, with a tendency of lower infestation levels to have longer leaves (fig. 9).

Total plant mass and root mass were highly variable. RWW levels significantly affected total plant mass 6 and 12 weeks after seeding. Plants infested with 1 or 2 RWW/ring tended to have higher weight than plants not infested or infested with 3 RWW/ring. Root mass was not significantly affected. Grain yield was not affected by RWW infestation level, variety, or their interaction. On average, yield was 7,380 lbs/a.

The analysis of covariance showed that for both varieties, the slope and intercept of the line relating relative yield and RWW larval density were not significantly different. However, when regressing relative yield and RWW with a single line, the relationship was not significant.

Conclusions

- This year, RWW levels were much lower than desired.
- The percentage of plants with feeding scars and the number of RWW larvae per core showed differences between uninfested and infested treatments. The highest level of RWW obtained was a total of 1 RWW larvae/core.
- None of the parameters evaluated responded to RWW infestation level. In fact, some plant parameters evaluated were significantly higher when the RWW infestation was low. Only leaf length seemed to decrease as the RWW infestation increased.
- No relationship was found between RWW level and yield.

3.3 Effect of artificial defoliation on rice growth and yield

The current thresholds used for armyworm monitoring are derived from research conducted in California in 1978 and 1979 in varieties no longer in use. The recent armyworm outbreak has brought the issue of thresholds again to the forefront. This study was conducted as a first step in trying to determine the effect of defoliation on the yield of rice.

Methods

Two rice varieties, M206 and M209, were seeded at a density of 150 lbs/a on 4 June in 10x10 ft plots at the RES. Each variety was subjected to four defoliation treatments: 0, 25, 50, or 100% of foliage above the water. When plants reached the second tiller stage on 10 July (36 days after seeding), the defoliation treatments were started. To defoliate plants, 25% of foliage in the whole plot was cut per day using hedge shears. Leaf residue was raked outside of the plots. Water depth during the time defoliation treatments were applied was 4 inches.

Sampling methods
Plant height was measured at different times during plant growth and before harvest. Plots were harvested with a small plot combine.

Statistics
Plot design: Randomized complete block, four replications.
Data analysis: Analysis of variance with two factors, variety and defoliation level. Mean separation using Tukey's test ($\alpha = 0.05$).

Results

The plots had a suboptimal seedling stand. In some plots the stand was 60% or lower than what would be expected. Those plots were dropped from the analysis.

Plant height was measured 10, 17, 31 and 41 days after the defoliation was started, and before harvest. For all sampling dates, no significant interaction between the variety and defoliation level was found, meaning that the effect of defoliation on plant height was similar for both varieties. In all dates, the plots defoliated 100% were significantly shorter than other plots. Plant height in plots defoliated 25 and 50% were not significantly different than plant height in control plots (fig. 10). Initially, plots 100% defoliated were 25% shorter than not defoliated plots. In later sampling dates, the difference was 10%, and before harvest the difference was 6%.

Defoliation did not have a significant effect on yield. Variety had a significant effect, with M206 plots yielding on average 8,132 lbs/a and M209 yielding 7,160 lbs/a. These yields are low for what would be expected in plots this size; most likely because of the poor stand. Grain moisture content at harvest was not affected by defoliation or variety.

Conclusions

- Plant height was significantly affected by defoliation, with 100% defoliated plots resulting in shorter plants.
- Recovery from the 25 and 50% defoliation levels was fast, and no significant differences in plant height with the control was detected.
- None of the defoliation levels resulted in a reduction in yield. However, yields were suboptimal due to stand establishment problems. The experiment should be repeated.

OBJECTIVE 4. Develop a database on the effects of registered and experimental insecticides used in rice on populations of nontarget invertebrates in the rice system to enhance development of best management practices in rice.

Methods

Treatments showed in table 11 were applied at different times during the development of the crop when typical insecticide applications occur in rice. Basins were flooded on 5 June and seeded 6 June with M206 at 150 lbs/a.

Sample Methods
Quadrant samples – confines a 0.55-ft^2 area with animals collected with an aquarium net, collections made weekly, four areas sampled per plot
Mosquito dip samples - used to estimate populations of mosquito larvae, 25 dips in each of five locations per plot, data were collected weekly from June to September

Results

Collecting the samples for this study during the growing season is done weekly. However, the largest effort for this project is separating, counting, and identifying the specimens in the laboratory which occurs during the "off-season". This quantification often takes 12 months and therefore the data for the 2018 season will be presented in 2019 report.

OBJECTIVE 5. To maintain awareness of new and emerging rice invertebrate pests in California including those present in the other rice production areas of United States.

Two invasive stink bug species are on the radar of the entomology project, the browm marmorated stink bug and bagrada bug. Both species occur in California and in some of the rice producing counties. Research by this project has shown that the brown marmorated stink bug can feed on rice and cause peck. None of these stink bugs have been found feeding on rice.

During 2018, no new arthropod pests were found affecting rice in California. However, there are a few organisms of concern in other areas of the US. In Louisiana, the channeled apple snail has been found in rice-crayfish fields, clogging crawfish traps. This fresh-water snail is present in California (Contra Costa, Riverside, San Diego, Los Angeles, and Kern counties). In Texas, the rice planthopper (*Tagosodes orizicolus*) was found damaging ratoon rice in 2015 and then again in 2018. This planthopper can transmit the "hoja blanca" virus, and is therefore an insect of concern. The planthopper was found in Texas in the late 50s and early 60s, but then disappeared until 2015. During there years Texas entomologists searched for the insect, without finding it until now. A Section 18 registration for a premix of lambda cyhalothrin and thiomethoxam was issued.

CONCISE GENERAL SUMMARY OF CURRENT YEARS (2018) RESULTS:

Research activities during 2018 focused on rice water weevil, tadpole shrimp, and armyworms. RWW natural populations were very low, and not enough RWW adults could be collected to infest RWW plots at levels done in the past. Because of this, several of the RWW trials conducted were deficient.

Testing of insecticides for RWW control showed that Dimillin worked best at the 16 oz/a rate. Belay worked well at the 3 lsr and as a rescue treatment. Its performance as pre-flood treatment was not bad, however, in previous years Belay has not worked well pre-flood. This year, Belay may have worked better due to the low level of RWW infestation. Coragen worked well pre-flood and at the 3 lsr, but its performance as rescue treatment was poor. Intrepid worked well when applied at the 3 lsr. This treatment needs to be explored further with higher RWW infestation levels.

For TPS, complete control was found 2 days after post-flood treatments with Warrior at 2.56 oz/a, Dimilin at 8 oz/a, Coragen pre-flood at 3 oz/a, Belay at 2 oz/a, and Sevin at 1.5 qt /a. The low rates of Dimilin killed TPS more slowly than other insecticides tested. A rate of 8 oz/a seems to be effective. Reduced label rates of Coragen and Belay were tested and proved to be effective.

Insecticide trials for armyworm control confirmed that Warrior does not provide good control. Intrepid, Dimilin, Coragen and Prevathon reduced the number of armyworm finds. In a greenhouse trial using western yewllowstriped armyworm, Coragen applied pre-flood had an effect on early instar armyworms introduced to plants 26 days after application. More testing is needed.

The RWW light trap at the RES caught the lowest numbers of RWW in record. This combined with the difficulty finding RWWs to infest plots, indicates that 2018 was a very low RWW pressure year. This trend has been observed for the past 10 years.

Armyworms were monitored using pheromone traps in 16 locations across the Sacramento Valley. Weekly updates were sent to growers and PCAs to keep them informed about armyworm levels. This year, the peak during the June-July infestation occurred 10 days later than in 2017, and was of the same magnitude. A peak was also observed during mid August.

Variety testing against RWW showed that M401 and S102 had higher RWW levels than other varieties. Only M401 showed a yield reduction due to RWW. In plots that relied on natural RWW levels to produce an infestation, levels were too low to show any effects.

An artificial defoliation study conducted to assess the effect of armyworm infestations on modern rice varieties did not find effects on yield, only effects on plant height. However, problems with stand establishment may have resulted in low yields, skewing the data.

Table 1. Treatment list for RWW chemical management ring study.

Treatment	Rate/a	Timing	Chemical Group
1. Untreated	--	--	--
2. Dimilin 2L	16 oz	3 leaf	Insect growth regulator
3. Dimilin 2L	8 oz	3 leaf	Insect growth regulator
4. Warrior II	2.56 oz	Preflood	Pyrethroid insecticide
5. Warrior II	2.56 oz	3 leaf	Pyrethroid insecticide
6. Belay 2.13 SC	4.5 oz	Preflood	Neonicotinoid insecticide
7. Belay 2.13 SC	4.5 oz	3 leaf	Neonicotinoid insecticide
8. Belay 2.13 SC	5.5 oz	5-6 leaf	Neonicotinoid insecticide
9. Mustang	4.3 oz	3 leaf	Pyrethroid insecticide
10. Coragen	6.1 oz	Preflood	Anthranilic diamide insecticide
11. Coragen	6.1 oz	3 leaf	Anthranilic diamide insecticide
12. Coragen	7.6 oz	5-6 leaf	Anthranilic diamide insecticide
13. Sevin XLR	32 oz	3 leaf	Carbamate
14. Intrepid	10 oz	3 leaf	Insect growth regulator
15. Pyganic	8 oz	3 leaf	Organic pyrethrum
16. Pyganic	16 oz	3 leaf	Organic pyrethrum
17. Grandevo	2 lb	3 leaf	Microbial
18. Venerate	2 qt	3 leaf	Microbial

Table 2. Percentage of plants showing feeding scars from RWW adults in chemical ring study.

Treatment	**% scarred plants 4 WkAS**	**% scarred plants 5 WkAS**	**Average % scarred plants**
1. Untreated	13.50 ab	14.50	14.00
2. Dimilin 2L 16 oz	9.50 ab	14.00	11.75
3. Dimilin 2L 8 oz	5.00 ab	14.00	9.50
4. Warrior II PF	13.50 ab	19.50	16.50
5. Warrior II 3 leaf	11.00 ab	14.00	12.50
6. Belay 2.13 SC PF	4.50 ab	11.50	8.00
7. Belay 2.13 SC 3 leaf	23.00 a	18.00	20.50
8. Belay 2.13 SC 5-6 leaf	5.00 ab	11.00	8.00
9. Mustang	7.50 ab	17.00	12.25
10. Coragen PF	14.00 ab	19.00	16.50
11. Coragen 3 leaf	4.00 ab	21.50	12.75
12. Coragen 5-6 leaf	11.00 ab	8.00	9.50
13. Sevin XLR	15.00 ab	12.50	13.75
14. Intrepid	10.00 ab	22.50	16.25
15. Pyganic 8 oz	8.50 ab	16.50	12.50
16. Pyganic 16 oz	7.50 ab	21.50	14.50
17. Grandevo	7.50 ab	17.00	12.25
18. Venerate	2.00 b	21.00	11.50

WkAS: Weeks after seeding
Means within columns followed by different letters are significantly different; Tukey's test ($P < 0.05$).

Table 3. Average immature RWW/core and % reduction in immature population in chemical ring study.

Treatment	RWW/Core 6 WkAS	RWW/Core 8 WkAS	Total RWW/core	% reduction
1. Untreated	0.65	0.60	1.25 a	--
2. Dimilin 2L 16 oz	0	0	0 b	100.00
3. Dimilin 2L 8 oz	0.10	0.25	0.35 b	72.00
4. Warrior II PF	0	0	0 b	100.00
5. Warrior II 3 leaf	0.05	0.05	0.10 b	92.00
6. Belay 2.13 SC PF	0.13	0.05	0.13 b	89.34
7. Belay 2.13 SC 3 leaf	0.06	0	0 b	100.00
8. Belay 2.13 SC 5-6 leaf	0	0.10	0.10 b	92.00
9. Mustang	0.10	0.05	0.15 b	88.00
10. Coragen PF	0.20	0	0.21 b	83.16
11. Coragen 3 leaf	0	0.29	0.29 b	76.47
12. Coragen 5-6 leaf	0.11	0.20	0.40 b	68.00
13. Sevin XLR	0	0	0 b	100.00
14. Intrepid	0.06	0.07	0.13 b	89.34
15. Pyganic 8 oz	0.07	0.09	0.18 b	85.46
16. Pyganic 16 oz	0	0	0 b	100.00
17. Grandevo	0	0.07	0.07 b	94.66
18. Venerate	0.05	0.06	0.13 b	90.00

WkAS: Weeks after seeding
Means within columns followed by different letters are significantly different; Tukey's test ($P < 0.05$).

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

Treatment	Grain Yield (lbs/a)	Biomass (Straw+Grain, t/a)
1. Untreated	4,775	4.33
2. Dimilin 2L 16 oz	4,520	4.44
3. Dimilin 2L 8 oz	4,894	5.17
4. Warrior II PF	5,548	5.67
5. Warrior II 3 leaf	5,560	5.06
6. Belay 2.13 SC PF	6,311	5.04
7. Belay 2.13 SC 3 leaf	5,843	4.58
8. Belay 2.13 SC 5-6 leaf	5,128	4.56
9. Mustang	5,311	4.89
10. Coragen PF	5,148	4.55
11. Coragen 3 leaf	5,206	5.01
12. Coragen 5-6 leaf	5,743	5.26
13. Sevin XLR	5,586	5.16
14. Intrepid	5,188	4.89
15. Pyganic 8 oz	6,174	4.92
16. Pyganic 16 oz	5,459	4.41
17. Grandevo	5,227	4.44
18. Venerate	5,816	4.74

Table 5. Number of TPS/ft^2 caught in 3 scoops with a small fish net from a 0.785 ft^2 PVC ring located randomly over each plot.

Treatment	Rate/a	Pre-treatment	1 DAT	2 DAT	3 DAT	% reduction from untreated
Untreated	--	10.19 a	9.24 ab	12.74 a	11.15 a	--
Warrior	2.56 oz	11.89 a	2.97 ab	0 b	0 c	100
Dimilin	2 oz	7.96 a	4.46 ab	1.27 b	0.96 bc	91.43
Dimilin	4 oz	12.31 a	2.12 b	0.42 b	0 c	100
Dimilin	8 oz	9.55 a	1.91 b	0 b	0 c	100
Coragen (pre-flood)	3 oz	0.96 b	0.32 b	0 b	0 c	100
Belay	2 oz	8.49 a	0.85 b	0 b	0 c	100
Sevin	1.5 qt	14.44 a	1.27 b	0 b	0 c	100
Grandevo	2 lbs	11.15 a	7.96 ab	11.78 a	10.83 a	2.86
Venerate	1 qt	9.77 a	11.46 a	8.92 a	11.46 a	-2.86
Saponins	15 lbs	11.46 a	8.92 ab	9.24 a	8.60 ab	22.86

DAT=days after treatment
Means within columns followed by different letters are significantly different; Tukey’s test ($P < 0.05$).

Table 6. Stand and yield from TPS trial in leveed plots.

Treatment	Rate/a	Stand (plants/ft^2)	Yield (lbs/a)
Untreated	--	16.00 b	9,188
Warrior	2.56 oz	23.17 ab	9,557
Dimilin	2 oz	27.63 ab	9,379
Dimilin	4 oz	17.33 ab	9,133
Dimilin	8 oz	30.62 ab	9,398
Coragen (pre-flood)	3 oz	32.50 a	9,688
Belay	2 oz	32.83 a	9,466
Sevin	1.5 qt	31.50 a	9,192
Grandevo	2 lbs	19.88 ab	9,448
Venerate	1 qt	20.50 ab	8,860
Saponins	15 lbs	24.13 ab	9,468

Means within columns followed by different letters are significantly different; Tukey's test ($P < 0.05$).

Table 7. Number of searches with armyworms present and percenage reduction with respect to the untreated at the end of the trial.

Trial 1 (Road 61, Glenn County)						
Treatment	**Rate/a**	**Pre-treatment**	**3 DAT**	**7 DAT**	**10 DAT**	**% reduction from untreated**
Untreated	--	2.25	3.00 a	3.25 a	3.50 a	--
Warrior	2.56 oz	2.25	2.50 ab	2.50 ab	2.50 a	28.57
Intrepid	10 oz	2.67	0 c	0 c	0.33 b	90.57
Dimilin	8 oz	2.50	2.00 ab	0 c	0.25 b	92.86
Coragen	3.5 oz	2.50	0.50 bc	1.00 bc	0 b	100
Trial 2 (Road 47, Glenn County)						
Treatment	**Rate/a**	**Pre-treatment**	**3 DAT**	**7 DAT**	**10 DAT**	**% reduction from untreated**
Untreated	--	3.50	2.50	3.00 a	2.25 a	--
Warrior	2.56 oz	4.00	2.75	3.25 a	1.00 ab	55.56
Intrepid	10 oz	3.50	2.00	1.25 bc	0.25 b	88.89
Dimilin	8 oz	3.75	2.50	2.25 ab	0.25 b	88.89
Coragen	3.5 oz	3.75	1.25	0.25 c	0.50 b	77.78
Prevathon	14 oz	3.25	1.50	0 c	0 b	100

DAT: week after treatment
Means within columns followed by different letters are significantly different; Tukey's test ($P < 0.05$).

Table 8. Average number of armyworms and armyworm chewing marks found per tub at different dates after infestation.

Treatment	**Rate/a**	**Timing**	**1 DAI**		**3 DAI**		**7 DAI**		**10 DAI**	
			Live	**Chew marks**	**Live**	**Chew marks**	**Live**	**Chew marks**	**Live**	**Chew marks**
Untreated	--	--	3.25 a	4.00 a	1.00	6.00 a	0.50 a	6.00 a	0	6.00 a
Coragen	7.6 oz	Pre-flood	0 b	0.25 b	0	0.50 bc	0 b	0.50 bc	0	0.50 bc
Coragen	6.1 oz	Pre-flood	0 b	0 b	0	0 c	0 b	0 c	0	0 c
Coragen	3 oz	Pre-flood	0 b	0 b	0	0 c	0 b	0 c	0	0 c
Coragen	0.005 ml/gr	Seed treatment	0 b	0 b	0	0 c	0 b	0 c	0	0 c
Dimilin	8 oz	3 lsr	1.50ab	2.00 ab	0.50	2.50 ab	0 b	2.50 ab	0	2.50 ab
Intrepid	10 oz	5 lsr	0 b	1.75 ab	0	2.75 ab	0 b	2.75 ab	0	2.75 ab
Dimilin	8 oz	5 lsr	0 b	2.00 ab	0	2.00 ab	0 b	2.00 ab	0	2.00 ab

DAI=days after infestation

Means within columns followed by different letters are significantly different; Tukey’s test ($P < 0.05$).

Table 9. Average percentage of plants with feeding scars and number of RWW/core in varietal response ring study.

Variety	Treatment	% scarred 4 WkAS	% scarred 5 WkAS	RWW/core 7 WkAS	RWW/core 9 WkAS	Total RWW/core
S102	Untreated	6.50	5.50 ab	0.18	0.40	0.70 ab
M105		9.00	10.50 a	0.25	0	0.28 c
M206		10.00	10.50 a	0.30	0.10	0.40 bc
M209		8.00	3.00 b	0.15	0	0.15 c
M401		10.00	6.50 ab	0.20	0.55	0.75 a
L206		7.00	3.00 b	0.10	0.13	0.25 c
A201		9.50	4.50 b	0	0.32	0.32 c
S102	Treated	0	0	0.10	0	0.11
M105		0	0	0	0	0
M206		0	0	0.05	0	0.05
M209		0	0	0.05	0	0.05
M401		0	0	0	0	0
L206		0	0	0	0	0
A201		0	0	0	0	0

WkAS: Weeks after seeding
Means within columns followed by different letters are significantly different; LSD test ($P < 0.05$).

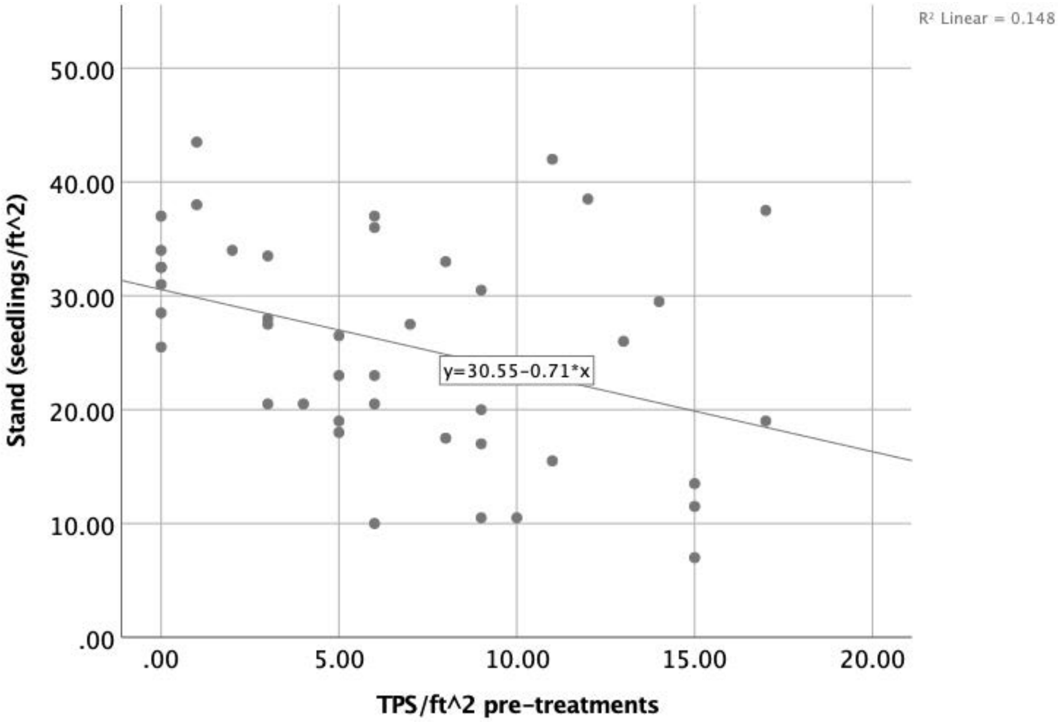
Table 10. Average grain yield, yield loss, and percentage yield loss due to RWW infestation between treated and untread rings.

Variety	Treatment	Grain yield (lb/a)	Yield loss from RWW (lb/a)	% yield loss from RWW
S102	Untreated	5,171	973	15.84
	Treated	6,144	-	-
M105	Untreated	4,235	197	4.44
	Treated	4,432	-	-
M206	Untreated	3,958	793	16.69
	Treated	4,751	-	-
M209	Untreated	4,743	-629	-15.29
	Treated	4,114	-	-
M401	Untreated	998 a	1,594	61.50
	Treated	2,592 b	-	-
L206	Untreated	4,882	-692	-16.52
	Treated	4,190	-	-
A201	Untreated	4,775	130	2.65
	Treated	4,905	-	-

Means within columns followed by different letters are significantly different; LSD test ($P < 0.05$).

Table 11. Treatments applied in 2018 to study the effect of insecticides on nontarget organisms in rice fields.

Treatment	Rate/a	Timing	Date applied
Untreated	--	--	--
Warrior II	2.56 oz	Pre-flood	5 June
Warrior II	2.56 oz	3 lsr	22 June
Warrior II	2.56 oz	Mid tillering	27 July
Warrior II	2.56 oz	Heading	13 August
Coragen	7.6 oz	Pre-flood	5 June
Coragen	7.6 oz	3 lsr	22 June
Belay	4.5 oz	3 lsr	22 June
Intrepid	10 oz	Mid tillering	27 July
Intrepid	10 oz	Heading	13 August



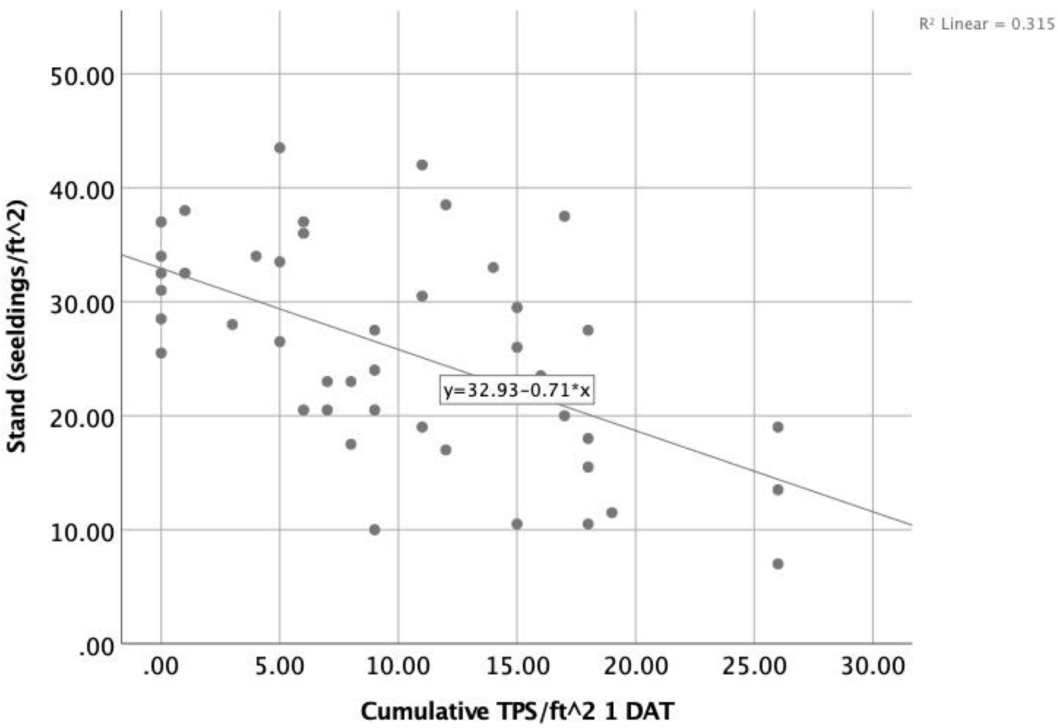


Fig. 1. Linear regression between seedling stand and number of TPS/ft^2 pre-treatments or number of TPS/ft^2 pre treatment plus one day after treatment.

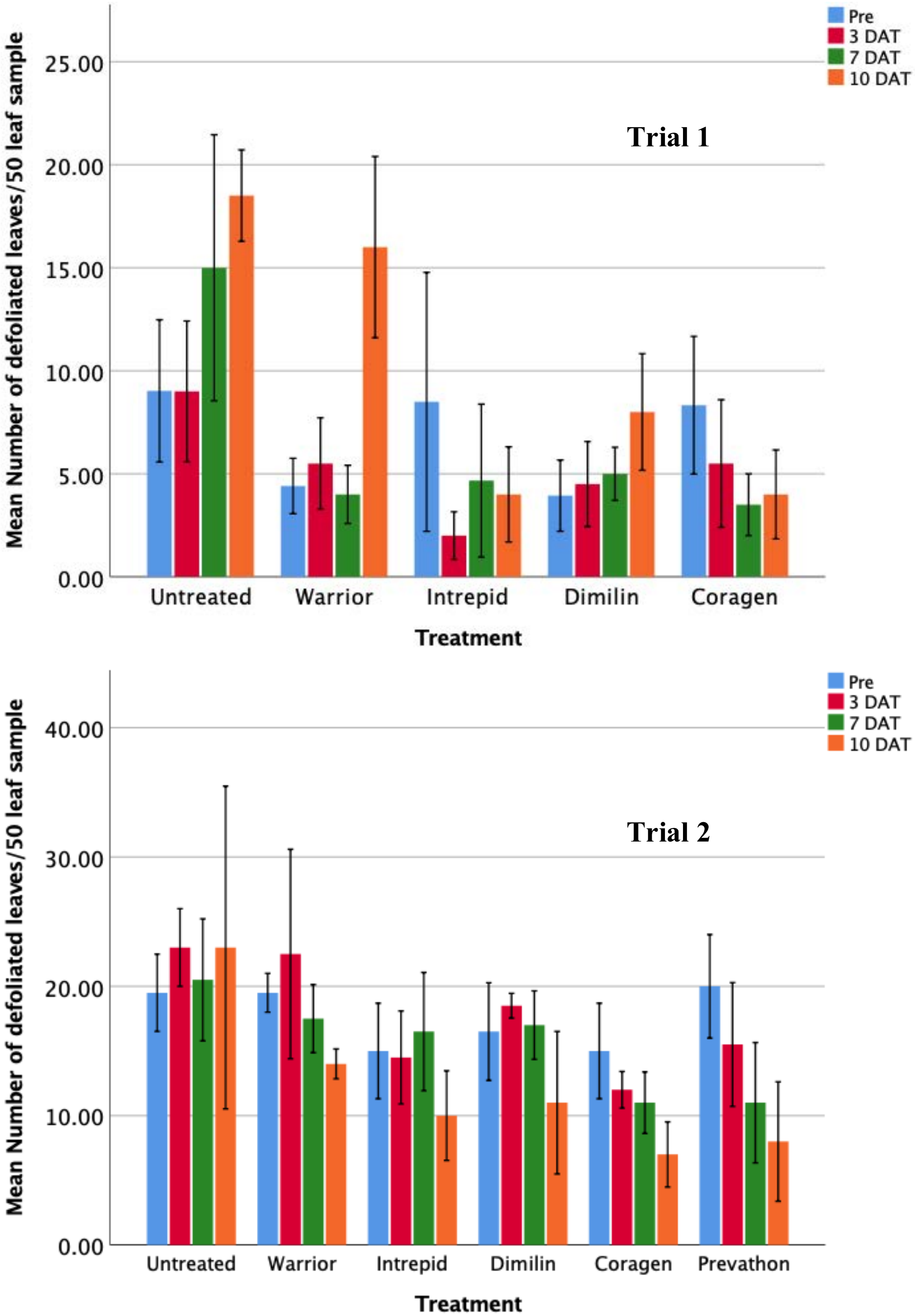


Fig. 2. Number of defoliated leaves per 50 leaf sample due to armyworm feeding in armyworm insecticide trials.

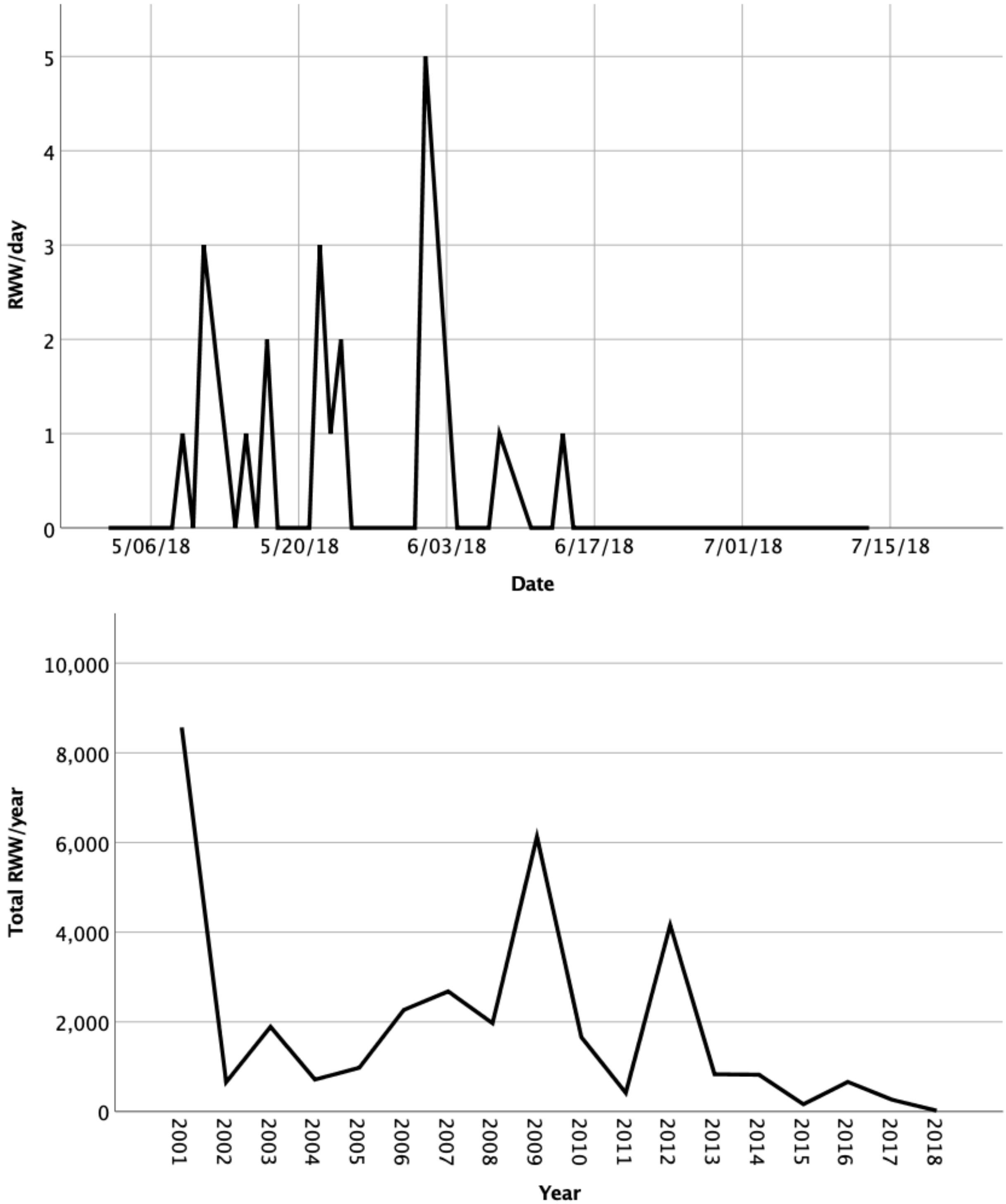


Fig. 3. Number of RWW caught per day during the spring of 2018 and per year in a light trap at the Rice Experiment Station in Biggs, CA.

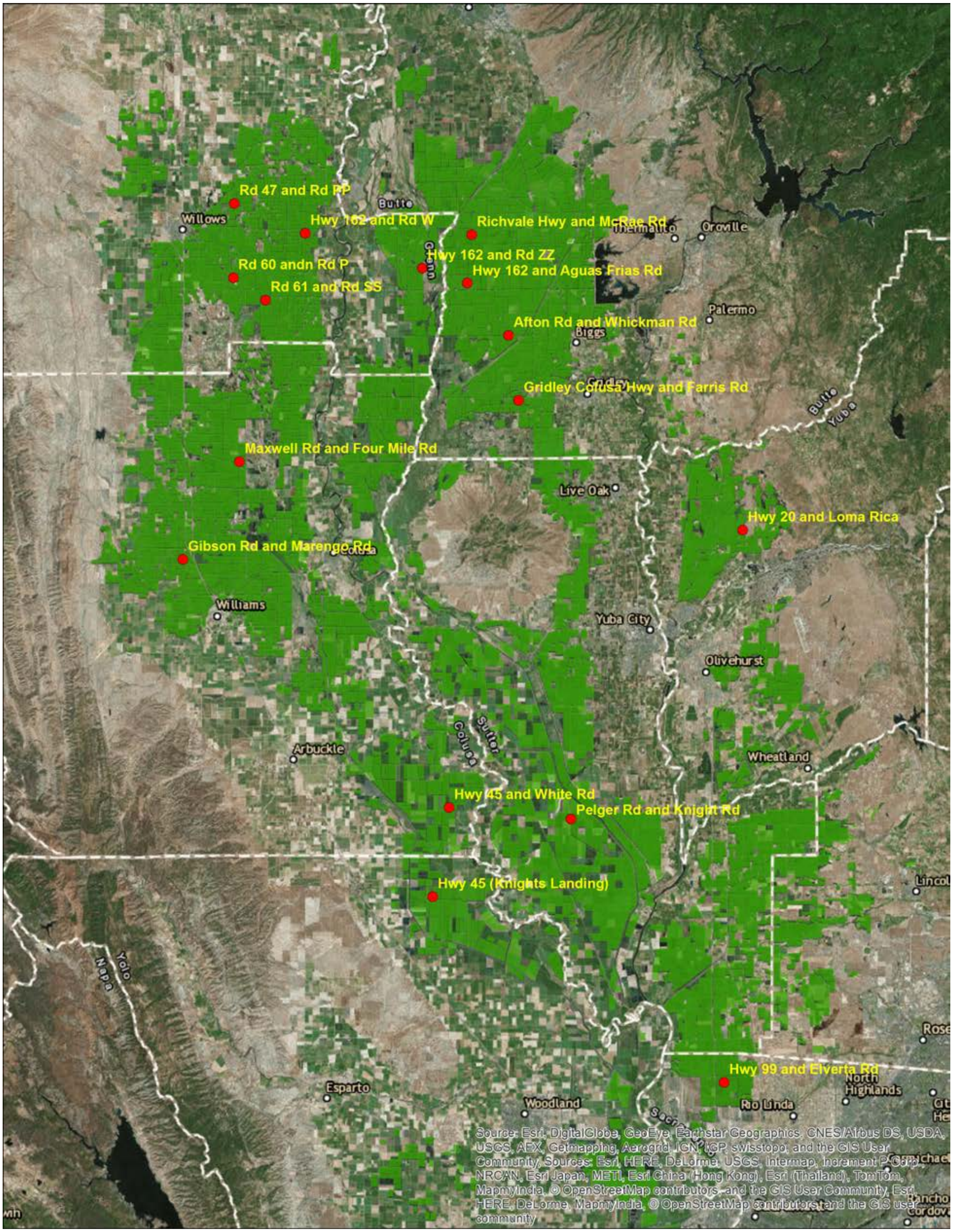


Fig. 4. Location of armyworm traps in the Sacramento Valley during 2018.

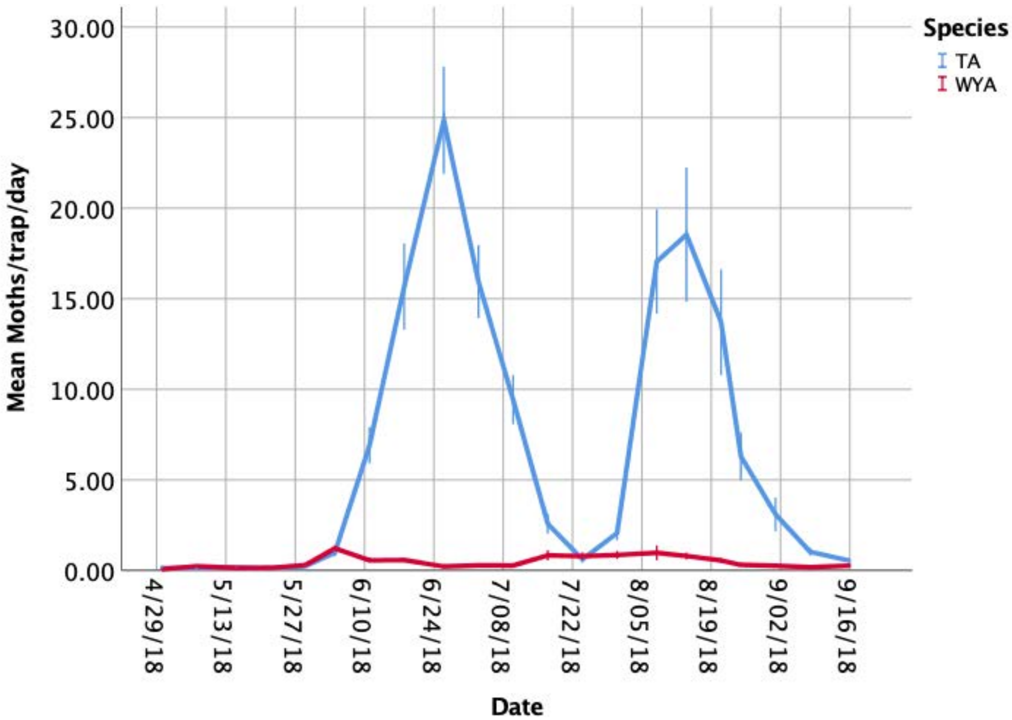


Fig. 5. Average number of moths caught per day in pheromone traps during 2018. TA = true armyworm, WYA = western yellowstriped armyworm.

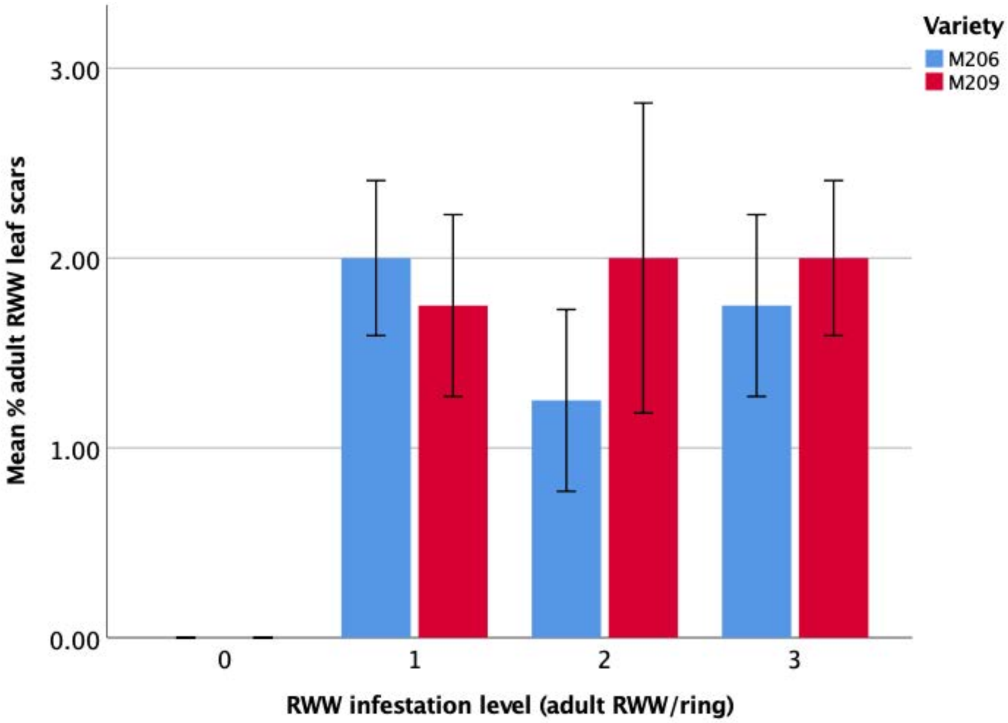


Fig. 6. Average percentage of plants with RWW feeding scars at different levels of RWW infestation.

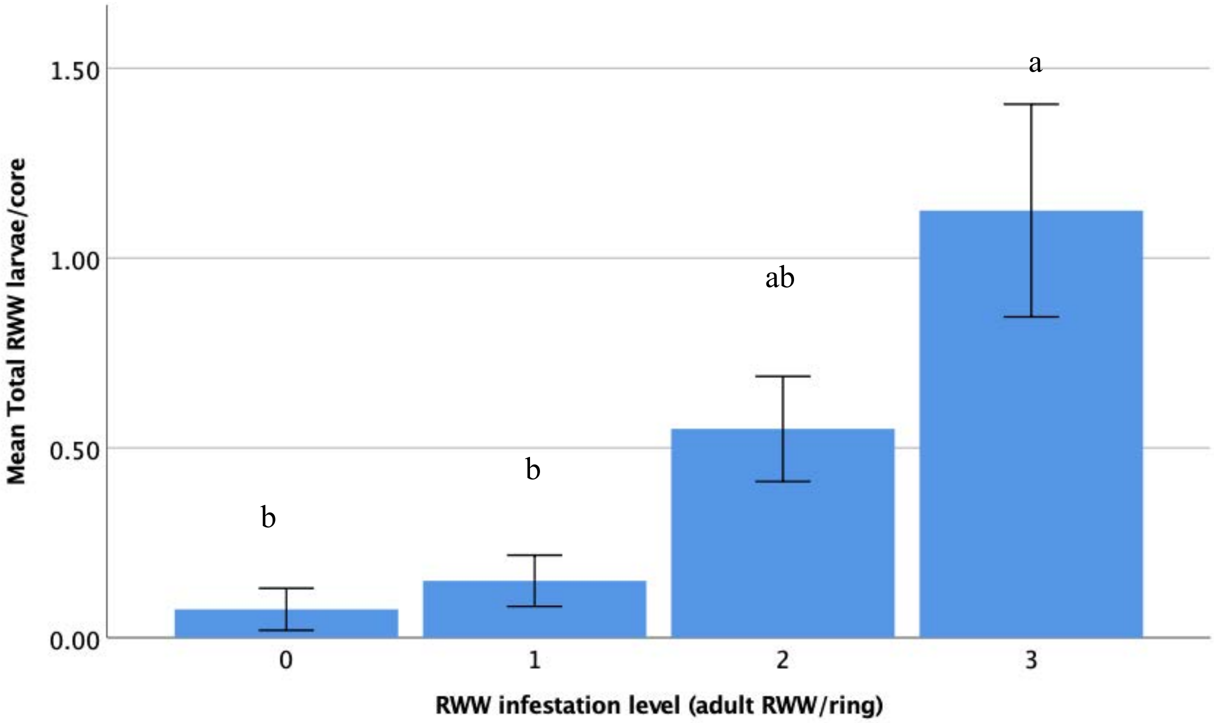


Fig. 7. Average number of RWW larvae/core obtained from rings infested with different levels of adult RWWs. Bars followed by different letters are significantly different; Tukey's test ($P < 0.05$).

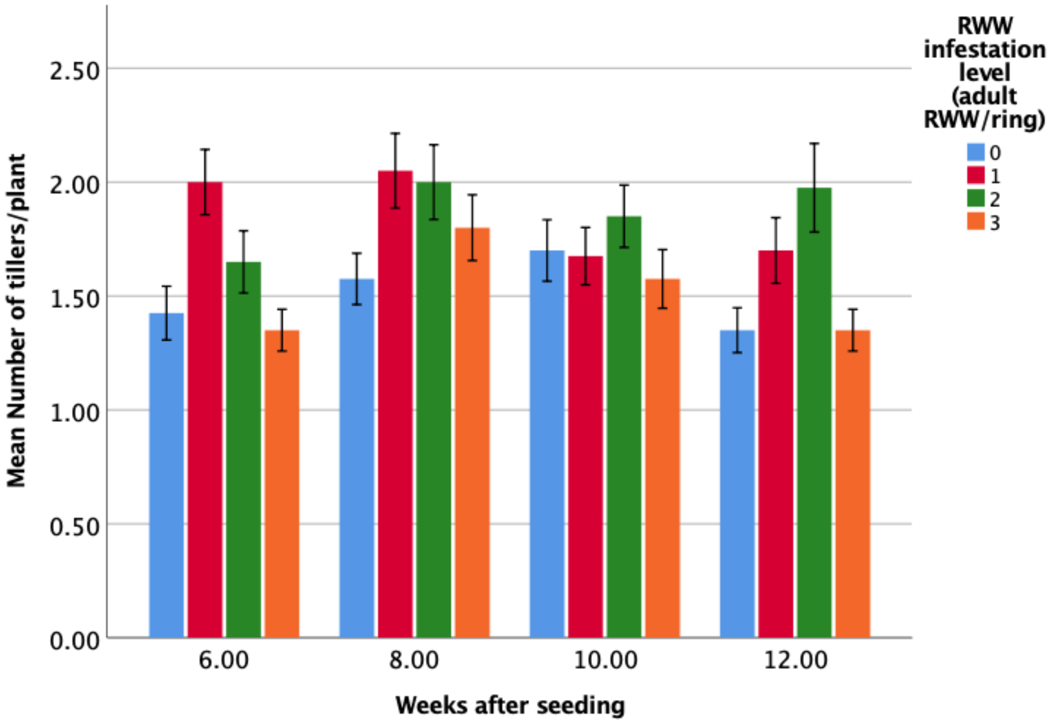


Fig. 8. Average number of tillers per plant at different times after seeding for four levels of adult RWW infestation.

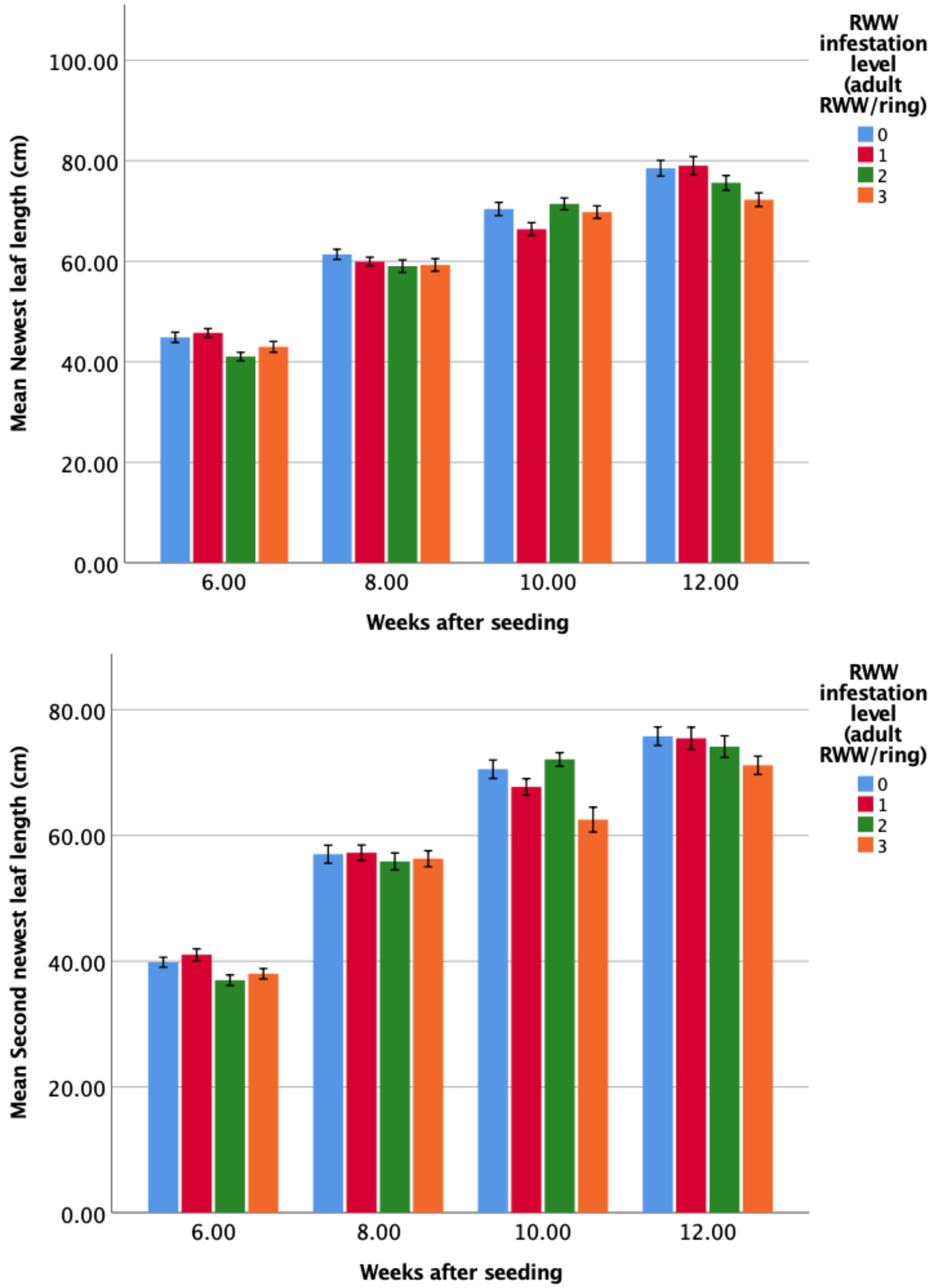


Fig. 9. Average leaf length at different time after seeding for four levels of adult RWW infestation.

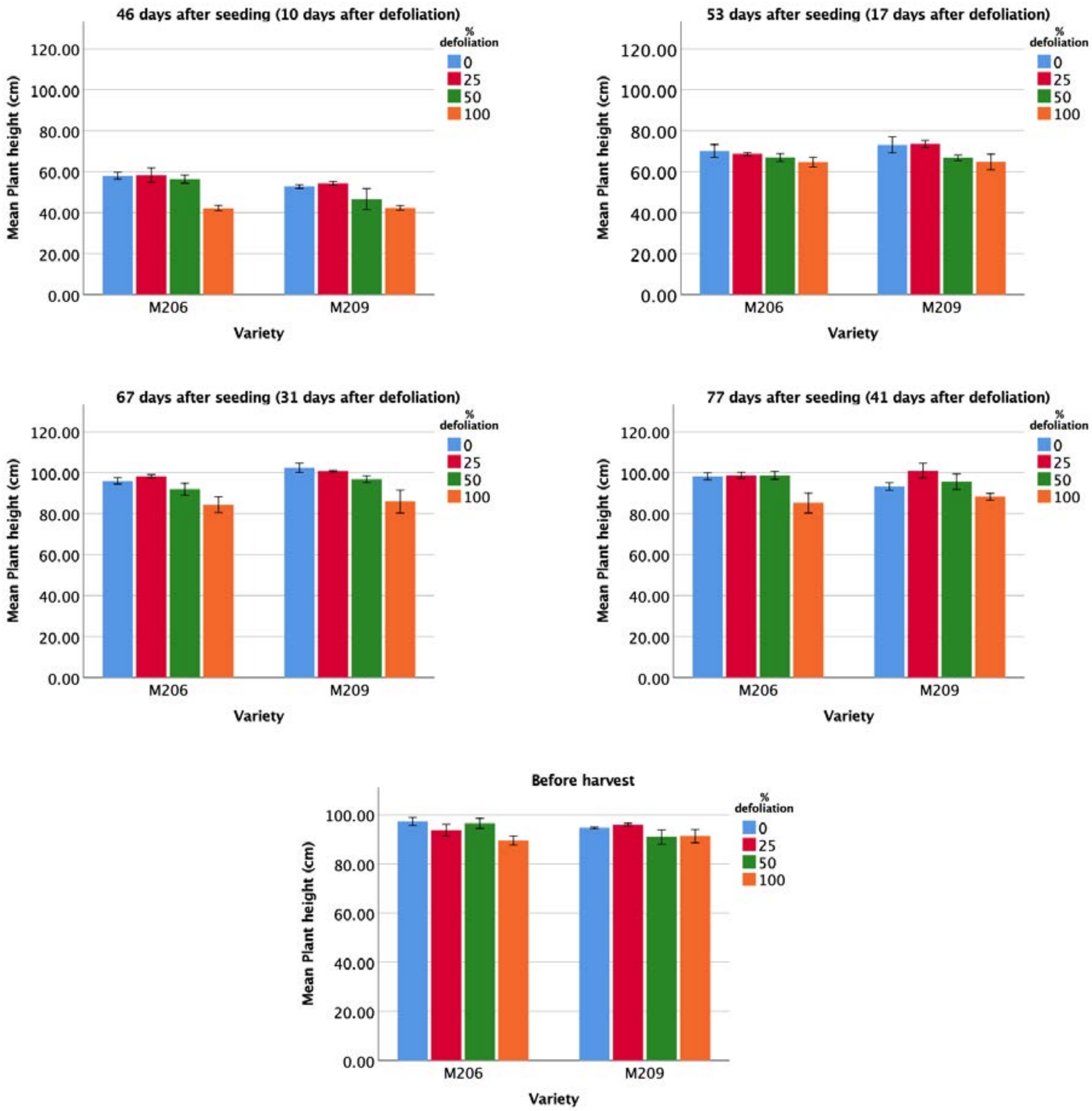


Fig. 10. Average plant height (cm) measured at different times after artificial defoliation to simulate armyworm defoliation.