ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE

January 1, 1996 - December 31, 1996

PROJECT TITLE: Protection of rice from invertebrate pests.

PROJECT LEADER AND PRINCIPAL UC INVESTIGATOR:
L. D. Godfrey, Extension Entomologist/ Associate Entomologist;
T. D. Cuneo, Post-Graduate Researcher;
Department of Entomology, University of California, Davis.

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OBJECTIVES AND EXPERIMENTS CONDUCTED BY LOCATION:

Objective 1: Evaluate the most effective control of rice water weevil with three insecticides that are proceeding toward registration (compared with Furadan 5G which is being removed from the market) while maintaining environmental quality compatible with the needs of society.

1.1) Rice water weevil chemical control - Ring plots.

1.1.1) Evaluation of the efficacy of Furadan, Regent, Dimilin, and Karate for controlling the rice water weevil.

1.1.2) Evaluation of the influence of application method and timing on the efficacy of various compounds for rice water weevil control.

1.1.3) Compare efficacy of various formulations of target products for controlling rice water weevil.

1.2) Rice water chemical control - Basin plots.

1.2.1) Evaluation of the efficacy of Dimilin 25W, Regent 1.67SC, Furadan 5G, and Karate 1E for controlling a natural infestation of rice water weevil.

1.3) Rice water weevil chemical control - Grower field plots/ EUPs.

1.3.1) Evaluation of the efficacy of Dimlin 25W and Dimilin 2L compared with Furadan 5G for controlling a natural infestation of rice water weevil in grower fields.

1.3.2) Evaluation of the efficacy of Regent 80WDG compared with Furadan 5G for controlling a natural infestation of rice water weevil in a grower field.

1.4) Rice water weevil chemical control with Dimilin - Greenhouse studies

1.4.1) Evaluate the influence of Dimilin 25W on rice water weevil adults with the product placed in water versus on the foliage.

1.4.2) Determine the persistence of a single application of Dimilin 25W with both application methods.

Objective 2: To evaluate a revised economic-injury level of rice water weevil on the most common commercial variety, and to appraise rice water weevil sampling methods.

2.1) Study the influence of rice water weevil on the growth, development, physiology and yield M-202.

2.2) Examine the relationship between rice water weevil scar incidence, larval density, plant growth and grain yield under grower conditions.

Objective 3: Monitor the movement of RWW populations that result in economic injury to rice plants.

3.1) Monitor seasonal trends (timing and magnitude) in the flight activity of the rice water weevil at the Rice Experiment Station near Biggs.

SUMMARY OF 1996 RESEARCH BY OBJECTIVE:

Objective 1:

1.1) Chemical Control of Rice Water Weevil - Ring Plots

1.1.1, 1.1.2 & 1.1.3) The efficacy of 4 chemical insecticide active ingredients and a total of 24 treatments was evaluated in a replicated field study. Each treatment was replicated four times. Numerous formulations and application timings were used. Several of these treatments were a continuation of the testing we did in 1995. The following treatments were evaluated:

Treatment	Rate (lbs. AI/A)	Timing	Treatment Date
1. Regent 70FS	0.0325	Seed treatment	16 May
2. Regent 70FS	0.0325	Pre, incorporated	15 May
3. Regent 70FS	0.025	Pre, incorporated	15 May
4. Regent 70FS	0.0125	Pre, incorporated	15 May
5. Regent 80WDG	0.0325	Pre, incorporated	15 May
6. Regent 1.5G	0.0325	Pre, incorporated	15 May
7. Regent 70FS	0.025	Post, 3 leaf stage	3 June
8. Furadan 5G	0.5	Pre, incorporated	15 May
9. Furadan 4F	1.0	Pre, incorporated	15 May
10. Furadan 5G	0.5	Post, 3 leaf stage	3 June
11. Dimilin 25W	0.25	5 d after 50% emerg.	5 June
12. Dimilin 2L	0.25	5 d after 50% emerg.	5 June
13. Dimilin 2L	0.25 + oil	5 d after 50% emerg.	5 June
14. Dimilin 2L	0.125	5 d after 50% emerg.	5 June
15. Dimilin 2L	0.125 x 2	3+7d after 50% emerg.	3 & 7 June
16. Dimilin 2L	0.063 x 2	3+7d after 50% emerg.	3 & 7 June
17. Karate 1E	0.03	Post, 3 leaf stage	3 June
18. Karate 1E	0.03	Post, 5 leaf stage	7 June
19. Regent 70FS	0.0325	5 days before flood	9 May
20. Reg 0.12GRw/fert.	0.0325	Pre, incorporated	15 May
21. Fertilizer Blank	-------	Pre, incorporated	15 May
22. Regent 1.67SC	0.038	Post, 3 leaf stage	3 June
23. Dimilin 2L	0.063 x 3	3+7+11d aft. 50% emer.	3 & 7 & 11 June
24. Untreated	-------	-------	-------

Testing was conducted with the cultivar 'M-202' in 8 ft² aluminum rings at the Rice Experiment Station. The plots were flooded on 15 May (pm) and seeded on16 May, 1996. The pre-flood applications were made on 15 May, the seed treatment was made on 16 May, the 3-leaf stage applications on 3 June, and the 5-leaf stage applications on 7 June. The Dimilin applications were made on 3 June, 7 June, and 11 June for the 3, 7, and 11 days after 50% rice emergence timings, respectively. The following application methods were used: a hand-held pump-up sprayer at 100 GPA for the liquid treatments, a "salt-shaker" granular applicator for the granular treatments, and for seed treatments, the appropriate amounts of pre-soaked seed, polymer, and AI product were placed into a plastic bag, shaken vigorously and allowed to dry before planting. Rice stand was evaluated and adjusted to 96 plants per 8 ft² aluminum ring from 10-12 June. The natural rice water weevil infestation was supplemented with 6 adults placed into each ring on 3 June and 3 adults per ring on 6 June.

The following sample dates and methods were used for this study:

Sample Dates:

Seedling Vigor/ Emergence: 10, 12 June
Adult Leaf Scar Counts: 10 June
Larval Counts: 3 July, 17 July
Plant Growth Characteristics: 3 July, 17 July
Rice Yield: 14-15 October

Sample Methods:

Seeding Vigor/ Emergence: stands rated before manual thinning on a 1- 5 scale with:
1 = very poor stand (<20 plants)
3 = good stand (~100 plants)
5 = very good stand (>150 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)
Plant Growth Characteristics: plant height, root length, number of leaves, number of tillers, and leaf/root dry weights were recorded from plants which had been sampled for larvae.
Rice Yield: entire plots were hand-cut and grain recovered with a "Vogel" mini-thrasher.

Results:

The Rice Water Weevil (RWW) flight at the Rice Experiment Station (RES) in 1996 was greater than that in 1995. The RWW flight at the RES was 40% higher in 1996 than it was in 1995 and 30 times more than that caught 5 years ago. However, we only had a moderate natural infestation in the rings. Therefore, we supplemented the natural infestation by adding additional weevils into the rings. Larval population density was similar in 1995 and 1996.

Emergence/Phytotoxicity

Based on a visual rating, stand establishment was on average delayed the most in the Dimilin 2L (0.0125 AI/A) 5 days after 50% rice emergence treatment. In the past studies, it is not uncommon for Crustacean pests such as crayfish and tadpole shrimp to infest a few rings and inhibit stand establishment. Symptoms for Crustacean invasion include cloudy water and floating seedlings. Even though many of these potential pests were observed around the ring plots, they were not recorded as being found in the rings themselves (therefore, the treatment may have had some effect on the stand establishment).

Adult Leaf Scar Counts

Adult leaf-scar damage normally is insignificant in terms of rice plant growth and development. Although, feeding scars are evaluated as a means to determine the effects of the treatments on adult density. In 1996, the feeding scar data were collected after the majority of the treatments were applied. The Regent 70 FS- 0.025 lb. AI/A (post 3-leaf), Furadan 5G- 0.5 lb. AI/A (PPI & post 3-leaf), Karate 1E, and Regent 1.67SC- .038 lb. AI/A (post 3-leaf) were the most effective treatments (Table 1). Adult mortality from the post-flood treatments is expected since the insecticide is sprayed on to the exposed RWW adults. In fact, adult mortality is the mode of action for Karate. The excellent activity from the Furadan 5G PPI was unexpected.

<u>Larval Counts</u>

RWW larval counts were made twice during the season. Most individuals were second-third instars and third instar-pupae at the first count and second counts, respectively. The population decreased in the untreated and less effective treatments from the first to second sample dates probably due to larval feeding to the extent that some larvae starved to death (Table 2). Densities ranged from 0.0 to 5.05 larvae per plant in 3 July samples. The pre-flood Regent 70FS (0.025 and 0.125 lb. AI/A), Furadan 4F, post-flood Dimilin 2L (0.25 lb. AI/A) and Karate 1E (post, 5-leaf) treatments were the most effective on this date (Table 2). Although the above treatments had the fewest larvae, the majority (74%) of the remaining treatments also provided good to excellent control with larval densities less than 1 larva per plant. On 17 July, the RWW immature density ranged from 0.0 to 2.20 per plant. The control seen with the treatments was better (88%) on this date. These results are in contrast with the 1995 studies which showed the control of RWW immatures to be less on the second sampling date. The increased control by the treatments in the 1996 study could be indicative of a refining of treatment rates and timings, i.e. the less effective treatments were eliminated. The Furadan (4F and 5G), Karate (post, 5-leaf), and Regent 0.12GR (with fertilizer) treatments provided the best control (numerically).

Table 1. Stand rating evaluation and RWW adult leaf feeding scar data, 1996.

Treatment	Rate (lbs. AI/A)	Timing	Stand Rating(1-5)	% Scarred Plants
1. Regent 70FS	0.0325	Seed Trt.	4.5	35.0 abcde
2. Regent 70FS	0.0325	Pre, incor	4.0	21.5 cdefghij
3. Regent 70FS	0.025	Pre, incor	3.0	11.0 ijk
4. Regent 70FS	0.0125	Pre, incor	4.0	23.5 efghijk
5. Regent 80WDG	0.0325	Pre, incor	3.1	19.5 efghijk
6. Regent 1.5G	0.0325	Pre, incor	4.2	15.0 fghijk
7. Regent 70FS	0.025	Post, 3 leaf	4.1	6.0 ijk
8. Furadan 5G	0.5	Pre, incor	3.9	2.5 jk
9. Furadan 4F	1.0	Pre, incor	3.1	11.5 fghijk

Table 1. cont.

10. Furadan 5G	0.5	Post, 3 leaf	4.2	4.0 ijk
11. Dimilin 25W	0.25	5 days*	3.9	20.0 defghijk
12. Dimilin 2L	0.25	5 days*	3.1	28.5 cdef
13. Dimilin 2L	0.25+oil	5 days*	4.1	31.5 bcde
14. Dimilin 2L	0.125	5 days*	2.9	50.5 ab
15. Dimilin 2L	0.125 x 2	3+7days*	3.5	12.5 ghijk
16. Dimilin 2L	0.063 x 2	3+7days*	4.0	51.5 a
17. Karate 1E	0.03	Post, 3 leaf	4.0	1.5 k
18. Karate 1E	0.03	Post, 5 leaf	3.8	23.0 defghi
19. Regent 70FS	0.0325	5 d before flood	3.2	17.5 efghijk
20. Reg 0.12Gw/frt	0.0325	Pre, incor	4.0	27.5 cdefg
21. Fertilizer Blk	-----	Pre, incor	4.0	39.5 abcd
22. Regent 1.67SC	0.038	Post, 3 leaf	3.8	7.5 hijk
23. Dimilin 2L	0.063 x 3	3+7+11days*	4.5	36.0 cdefg
24. Untreated	-----	-----	4.0	40.0 abc

* days after 50% rice emergence
Means within columns followed by the same letter are not significantly different; least significant differences test ($p < 0.05$).

Table 2. RWW immature density data from ring plots, 1996.

			RWW Immatures/Plant		
Treatment	Rate (lbs. AI/A)	Timing	3 July	17 July	Avg.
1. Regent 70FS	0.0325	Seed Trt.	2.10 bc	2.15 a	2.13
2. Regent 70FS	0.0325	Pre, incor	1.55 cd	0.40 cde	0.98
3. Regent 70FS	0.025	Pre, incor	0 e	0.20 cde	0.10
4. Regent 70FS	0.0125	Pre, incor	0.05 e	0.35 cde	0.20
5. Regent 80WDG	0.0325	Pre, incor	0.30 de	0.35 cde	0.33
6. Regent 1.5G	0.0325	Pre, incor	0.35 de	0.05 de	0.20
7. Regent 70FS	0.025	Post, 3 leaf	0.15 e	0.30 cde	0.23
8. Furadan 5G	0.5	Pre, incor	0.10 e	0 e	0.05
9. Furadan 4F	1.0	Pre, incor	0.05 e	0.05 de	0.05
10. Furadan 5G	0.5	Post, 3 leaf	0.15 e	0.65 bcde	0.40
11. Dimilin 25W	0.25	5 days*	0.30 de	0.80 bc	0.55
12. Dimilin 2L	0.25	5 days*	0.05 e	0.75 bc	0.40
13. Dimilin 2L	0.25+oil	5 days*	0.25 de	0.55 bcde	0.40
14. Dimilin 2L	0.125	5 days*	0.10 e	0.30 cde	0.20
15. Dimilin 2L	0.125 x 2	3+7days*	0.35 de	0.35 cde	0.35
16. Dimilin 2L	0.063 x 2	3+7days*	0.30 de	0.80 bc	0.55
17. Karate 1E	0.03	Post, 3 leaf	0.30 de	0.05 de	0.18

Table 2. cont.

18. Karate 1E	0.03	Post, 5 leaf	0 e	0.15 cde	0.08
19. Regent 70FS	0.0325	5 d before flood	0.25 de	0.60 bcde	0.43
20. Reg 0.12GRw/frt	0.0325	Pre, incor	0.05 e	0.20 cde	0.13
21. Fertilizer Blank	-----	Pre, incor	3.05 b	2.20 a	2.63
22. Regent 1.67SC	0.038	Post, 3 leaf	0.20 e	0.70 bcd	0.45
23. Dimilin 2L	0.063 x 3	3+7+11days*	0.15 e	0.25 cde	0.20
24. Untreated	-----	-----	5.05 a	1.15 b	3.10

* days after 50% rice emergence
Means within columns followed by the same letter are not significantly different; least significant difference test ($p < 0.05$).

Plant Growth Characteristics

Plant growth is a good measure of the immediate impact of RWW feeding. Quantification of plant growth characteristics is still ongoing in the laboratory from stored samples.

Rice Yield

Rice yield was evaluated on 14-15 October. Grain yields were increased in comparison with the 1995 results. The yields in the untreated fields were 510.8 g/plot in 1995, and 528.8 g/plot in 1996. In the Furadan 5G (0.5 lb. AI/A pre-flood) treatment, the yields were 519.8 and 725.8 g/plot in 1995 and 1996, respectively (Table 3). In 1996, yields ranged from 528.8 to 756.8 g/plot. Yield was lowest in the untreated plots and highest in the Regent 1.67SC (0.038 lb. AI/A, post, 3-leaf) and Regent 0.12GR (with fertilizer)treatments.

Table 3. Effects of RWW damage on rice grain yield from ring plots, 1996

Treatment	Rate (lbs. AI/A)	Timing	Grain Yield (g/ring)	Estimated Grain yield (lbs./acre)
1. Regent 70FS	0.0325	Seed Trt.	616.00 cdef	7360
2. Regent 70FS	0.0325	Pre, incor	666.50 abcde	7948
3. Regent 70FS	0.025	Pre, incor	621.50 cdef	7509
4. Regent 70FS	0.0125	Pre, incor	711.75 abcd	8532
5. Regent 80WDG	0.0325	Pre, incor	607.50 def	7324
6. Regent 1.5G	0.0325	Pre, incor	676.50 abcde	8131
7. Regent 70FS	0.025	Post, 3 leaf	704.00 abcd	8453
8. Furadan 5G	0.5	Pre, incor	725.75 abc	8684
9. Furadan 4F	1.0	Pre, incor	724.75 abc	8630
10. Furadan 5G	0.5	Post, 3 leaf	726.00 abc	8683
11. Dimilin 25W	0.25	5 days*	696.75 abcde	8359

Table 3. cont.

12. Dimilin 2L	0.25	5 days*	708.25 abcd	8413
13. Dimilin 2L	0.25 + oil	5 days*	668.75 abcde	7999
14. Dimilin 2L	0.125	5 days*	675.00 abcde	8055
15. Dimilin 2L	0.125 x 2	3+7days*	663.25 abcde	7936
16. Dimilin 2L	0.063 x 2	3+7days*	648.00 bcde	7782
17. Karate 1E	0.03	Post, 3 leaf	700.25 abcde	8379
18. Karate 1E	0.03	Post, 5 leaf	709.75 abcd	8502
19. Regent 70FS	0.0325	5 d before flood	588.75 ef	7109
20. Reg 0.12GRw/frt	0.0325	Pre, incor	770.50 a	9218
21. Fertilizer Blank	-----	Pre, incor	652.50 bcde	7828
22. Regent 1.67SC	0.038	Post, 3 leaf	756.75 ab	8995
23. Dimilin 2L	0.063 x 3	3+7+11days*	704.75 abcd	8445
24. Untreated	-----	-----	528.75 f	6342

* days after 50% rice emergence

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

1.2) Rice Water Weevil Chemical Control - Basin Plots

1.2.1) The efficacy of Dimilin 25W , Regent 1.67SC, Furadan 5G, and Karate 1E for controlling a natural infestation of RWW was evaluated in small basins. This study was a continuation of the 1995 study, designed to evaluate treatments that indicated assurance for RWW control under more realistic grower situations. These small basin studies were larger plots, using more commercial application methods and natural RWW infestations. We did not augment the basins with more RWW adults as we did in the smaller ring plot studies. The ring studies are always useful for screening numerous treatments. The following treatments were used in the small basin studies:

Treatment	Rate (lbs. AI/A)	Timing
1. Regent 1.67SC	0.038	Pre, incor.
2. Regent 1.67SC	0.038	7 days post-flood
3. Regent 1.67SC	0.038	14 days post-flood
4. Furadan 5G	0.50	Pre, incor.
5. Furadan 5G	0.50	Post, 3-leaf
6. Dimilin 25W	0.25	5 days*
7. Dimilin 25W	0.25 x 2	3 + 7 days*
8. Karate 1E	0.03	Post, 3-leaf
9. Untreated	-----	----------
10. Untreated	-----	-------

* days after 50% rice emergence

Testing was conducted within a 0.25 acre check in 10 feet x 20 feet basins of 'M-202' at the Rice Experiment Station. The plots were flooded 15 May (p.m.) and seeded 16 May, 1996. The pre-flood applications were made 15 May, the 3-leaf stage on 3 June and 5 days after 50% rice emergence on 5 June. The liquid treatments were applied with a CO_2 sprayer at 31 GPA and the granular treatments were applied by hand with a grass seeder. A natural rice water weevil infestation was used in this test.

The following sample dates and methods were used for this study:

Sample Dates:

Adult Leaf Scar Count: 13 June
Larval Counts: 4 July, 18 July
Plant Growth Characteristics: 4 July, 18 July
Rice Yield: 16, 23 October

Sample Methods:

The sample methods used were identical to those described under 1.1 with this exception. Rice yield was estimated by harvesting four 10.8 ft^2 areas and recovering the grain with a "Vogel" mini-thrasher.

Results:

Initially seedling establishment was poor in the east-end basins; however, at the end of the season, the grain yield data showed no difference across the basins. A seed midge infestation was suspected to have caused the poor stand seed germination and establishment was slow which favor seed midge damage. This study exemplifies the unpredictable and variable nature of RWW infestations. Although the seasonal RWW flight was high in 1996 at the RES, these plots were infested to a low-moderate degree. Apparently, when the plots were most conducive for infestation a flight was not in progress.

Adult Leaf Scar Counts

The Furadan 5G and Regent 1.67SC treatments had the lowest scar counts, but in comparison, the other treatment scar counts were also low. The infestation, as indicated by scar counts, was low in this test (Table 4).

Larval Counts

RWW larval counts were made twice during the season. Most individuals were third instars and third instar-pupae at the first count and second counts, respectively. The population of larvae per plant decreased in the untreated basins from the first to the second evaluation from an average of 1.9 to 0.4. This population would be classified as low to moderate. There were no significant differences among the 8 chemical treatments and all of these were better than the untreated (some numerically better and some statistically better) on the first date (Table 5). Numerically, Dimilin (0.25 + 0.25 lbs.AI/I, 3 + 7days), Karate, and Regent (0.038 lbs. AI/A, pre-flood & 7 days post-flood) gave the best controls. On 17 July, all treatments were significantly better than the untreated.

Plant Growth Characteristics

Plant growth is a good measure of the immediate impact of RWW feeding . During the mid-season of 1996, there were no obvious differences in plant growth across the treatments. Treatments providing excellent larval control did not have noticeably larger plants than the poorer performing treatments. The RWW infestation level was not high enough to substantially effect plant growth.

Rice Yield

There were no significant differences in rice grain yield (Table 6). The best yielding treatment yielded ~ 845 lbs./A more than the untreated. Furadan 5G was the lowest yielding treatment.

Table 4. RWW adult leaf feeding scar data, 1996, basin tests.

Treatment	Rate (lbs. AI/A)	Timing	% Scarred Plants 13 June
1. Regent 1.67SC	0.038	PPI	4.5 ab
2. Regent 1.67SC	0.038	7 d post	0.5 b
3. Regent 1.67SC	0.038	14 d post	8.5 ab
4. Furadan 5G	0.50	PPI	0.0 b
5. Furadan 5G	0.50	3-leaf	4.0 ab
6. Dimilin 25W	0.25	5 days*	8.0 ab
7. Dimilin 25W	0.25 x 2	3 + 7 d*	15.5 a
8. Karate 1E	0.03	3-leaf	8.0 ab
9. Untreated	-----	----------	11.0 ab
10. Untreated	-----	----------	13.5 ab

* days after 50% rice emergence
Means within columns followed by the same letter are not significantly different; least significant differences test (p<0.05).

Table 5. RWW immature density data, 1996, basin tests.

Treatment	Rate (lbs. AI/A)	Timing	RWW per Plant 4 July	18 July	Avg.
1. Regent 1.67SC	0.038	PPI	0.00 c	0.00 b	0.0
2. Regent 1.67SC	0.038	7 d post	0.00 c	0.00 b	0.0
3. Regent 1.67SC	0.038	14 d post	0.25 bc	0.00 b	0.125

Table 5. cont.

4. Furadan 5G	0.50	PPI	0.50 abc	0.00 b	0.25
5. Furadan 5G	0.50	3-leaf	1.25 abc	0.00 b	0.625
6. Dimilin 25W	0.25	5 days*	0.75 abc	0.25 b	0.50
7. Dimilin 25W	0.25 x 2	3 + 7 d*	0.00 c	0.00 b	0.0
8. Karate 1E	0.03	3-leaf	0.00 c	0.00 b	0.0
9. Untreated	-----	----------	2.00 a	0.00 b	1.0
10. Untreated	-----	----------	1.75 ab	0.75 a	1.25

* days after 50% rice emergence
Means within columns followed by the same letter are not significantly different; least significant differences test (p<0.05).

Table 6. Effects of RWW damage on rice grain yield, 1996, basin tests.

Treatment	Rate (lbs. AI/A)	Timing	Grain Yield (g/plot)	Est. Yield (lbs./A)
1. Regent 1.67SC	0.038	PPI	877.93 a	7814
2. Regent 1.67SC	0.038	7 d post	876.55 a	7801
3. Regent 1.67SC	0.038	14 d post	794.61 a	7072
4. Furadan 5G	0.50	PPI	748.09 a	6658
5. Furadan 5G	0.50	3-leaf	886.35 a	7889
6. Dimilin 25W	0.25	5 days*	892.06 a	7939
7. Dimilin 25W	0.25 x 2	3 + 7 d*	883.61 a	7864
8. Karate 1E	0.03	3-leaf	846.90 a	7537
9. Untreated	-----	----------	815.93 a	7262
10. Untreated	-----	----------	778.16 a	6926

* days after 50% rice emergence
Means within columns followed by the same letter are not significantly different; least significant differences test (p<0.05).

1.3) Rice Water Weevil Chemical Control - Grower Field Plots/ EUPs.

In the grower field studies, the efficacy of Dimilin and Regent (fipronil) was studied in comparison with Furadan (and untreated plots) for controlling a natural infestation of RWW in 1996. In cooperation with Uniroyal Chemical Co. (Dimilin) and Rhone-Poulenc Ag. Products (Regent) personnel, seven field sites were set-up under a Research Authorization/crop destruct scenario. Two of the sites were in Butte Co., four were in Sutter Co., and one in Placer Co. The standard preplant Furadan 5G application was used for comparison. The percentage scarred plants was sampled as previously described in all fields in May and June. All 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 late June and throughout July at a time when populations should be mostly large larvae and possibly 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 and recovering the grain with a "Vogel" mini-thrasher. At all sites, some yields may have been confounded with water level on that particular portion of the field, proximity to rice water weevil overwintering sites, soils, etc. The field site locations and treatments were as follows:

County	Site	Treatment
Sutter	1	Untreated
		Dimilin 2L (16 oz/A) 2 applications
		Dimilin 2L (8 oz/A) 2 applications
		Dimilin 2L (8 oz/A + oil) 1 application
	2	Untreated
		Dimilin 2L (16 oz/A) 2 applications
		Dimilin 2L (8 oz/A) 2 Applications
	3	Untreated
		Dimilin 2L (8oz/A)
		Dimilin 2L (16oz/A)
		Dimilin 25W (1lb./A)
		Furadan 5G
	4	Untreated-1
		Dimilin 2L (8oz/A)
		Dimilin 2L (16oz/A)
		Furadan 5G
		Untreated-2
Butte	5	Untreated
		Dimilin 2L (8oz/A)
		Dimilin 2L (16oz/A)
		Dimilin 25W (1lb./A)
		Furadan 5G
	6	Untreated
		Dimilin 2L (16 oz/A + oil)
		Dimilin 2L (8oz/A)
		Dimilin 2L (16oz/A)
		Dimilin 25W (1lb./A)
		Furadan 5G
Placer	7	Untreated
		Regent 80WDG (PPI)
		Regent 80WDG (postflood)
		Furadan 5G

1.3.1) The efficacy of Dimilin 25W and Dimilin 2L was studied in comparison to Furadan 5G (and to untreated plots). The Dimilin application rates and timings differed slightly among the six sites. All Dimilin applications were made by air to 3 acre plots within individual leveed checks. The untreated areas were similarly sized.

The percentage scarred plants in the Dimilin tests ranged from 2.0 % to 62%. The percentage was considerably lower in both the Dimilin treatments (7.3 and 11.6) when compared to the untreated fields. Overall, the percentage in the Dimilin treatments were comparable to the Furadan treatment (Table 7). The 27.8% scarred plants in the untreated exceeded the threshold of 10-20%. Larval densities ranged 0 to 3.1, and averaged over the sites, the densities were lower in the Dimilin 25W treatments (Table 7). All chemical treatments had lower RWW per plant when compared with the untreated plots. This is in contrast with the 1995 field data which showed the untreated plots with fewer larvae per plant when compared to the chemical treatments. Therefore, the 1996 data are in concordance with the results we would have expected in these field studies. Thus, the larval densities were reduced by the toxicant. Grain yields were similar in the two Dimilin treatments (Table 7). The Dimilin treatment areas yielded about 1290 lbs./A more than the untreated areas.

Table 7. Influence of Dimilin in grower field tests on average leaf damage, RWW larval density and grain yield.

Treatment	% Scarred Plants	RWW Per Plant	Grain yield (g/plot)	Est. Yield (lbs./A)
1. Dimilin 25W*	7.3	0.15	942.7	8410
2. Dimilin 2L*	11.6	0.28	955.6	8505
3. Furadan 5G**	7.3	0.28	883.9	7885
4. Untreated	27.8	1.04	803.5	7168

* Averaged over rates and timings.
** Preplant incorporated at 0.5 lb. AI/A.

1.3.2) The Regent 80WDG treatments were applied with a ground sprayer to 3 acre checks. A preplant treatment and as postflood. The percentage scarred plants ranged from 28% to 79% (Table 8). The percentage scarred plants were comparable in the Regent and Furadan treated checks. Regent yields were higher in comparison with both the untreated area and the Furadan plot (Table 8). The Regent treatments yielded about 2700 lbs/A more grain than the untreated area.

Table 8. Influence of Regent in a grower field test on average leaf damage, RWW larval density and grain yield.

Treatment	% Scarred Plants	RWW Per Plant	Grain yield (g/plot)	Est. Yield (lbs./A)
1. Furadan 5G**	29.0	0.30	473.5	4214
2. Regent 80WDG	28.0	0.32	518.4	4614
3. Untreated	79.0	2.3	214.6	1910

* Averaged over rates and timings.
** Preplant incorporated at 0.5 lb. AI/A.

1.4) Greenhouse studies

Field performance of Dimilin treatments in 1994 and 1995 were erratic. Previous research had shown that the primary mode of action for Dimilin was ingestion. Upon consuming the active ingredient, female RWW were sterilized. A secondary mode of action was that the Dimilin would kills newly-deposited eggs. Once the eggs had hardened-off in the leaf sheaths, the Dimilin had no effect. Therefore, treatments were timed so the product would be placed on rice leaves and therefore consumed by the adults. However, the best results with Dimilin had been with applications at the 3 leaf stage. At this plant growth stage, the amount of plant tissue exposed above the water is minimal. Much of the product was undoubtedly going into the water. Therefore, we believe that there must be more activity of Dimilin in the water than was first believed.

A greenhouse study was setup to evaluate the activity of Dimilin. Three studies were conducted with the objectives to study,

1.) the influence of timing and placement of Dimilin treatment on efficacy
2.) the number of days after exposure that Dimilin exerts and effect on RWW
3.) the time of exposure to Dimilin needed before an effect is seen.

Rice plants were grown in a UC-Davis greenhouse in 32 oz. plastic cups within soil from the RES. Once the plants reached the 3 to 4-leaf stage, the appropriate Dimilin treatments were applied, the plants were caged, and field-collected RWW adults were introduced. The introduction and removal of the adults was manipulated so that the above objectives could be addressed.

Results showed that Dimilin does have significant activity with the material being placed in the water (Fig. 1). In fact, Dimilin placed in the water provided greater RWW control than when the material was placed on the foliage. Additionally, if Dimilin was applied 5 days before oviposition to 1 day after oviposition, the control was 95+%. The activity was still significant, although declining in effectiveness, with applications at 3 and 5 days after oviposition.

Therefore, the window of application with Dimilin is longer and the applications should be timed earlier than previously thought. In additional greenhouse studies, it was shown that once exposed to Dimilin, RWW are effected for 3 days. At 5 days after exposure, the effect is minimal. Data between 3 and 5 days were inconclusive. Finally, as little as 4 hours of exposure to Dimilin are needed to exert an effect.

In other studies, RWW oviposition was studied. The timing of RWW egg deposition in relation to plant growth stage, days after flooding, etc. has always been important, but is now taking on increased importance. The reason for this is possible registration of post flood insecticides for RWW management. Two of the three possible replacements for Furadan would be applied postflood. These products have no to minimal effects on RWW larvae. Thus, it is imperative that the treatment be properly timed in order to achieve RWW control and more information is needed to describe this timing.

Rice seedlings were sampled from the 3-leaf stage to the 8-leaf stage from field plots at the RES. Seedlings were taken from basins treated with Dimilin 25W (0.25 lbs. AI/A at the 3-leaf stage), Regent 1.67 SC (0.38 lbs. AI/A PPI), and untreated. These seedlings were taken to the laboratory and suspended with the roots in water. RWW eggs, deposited within the leaf sheaths, hatched and the resulting larvae were recovered from the water and counted.

At the first sample date which corresponded with the 3-leaf stage, a significant number of RWW eggs was found (Fig. 2). This was surprising because the common belief is that the migrating RWW adults move into rice fields at the time of plant emergence through the water. A 3-4 day period is needed for the females to mature eggs before egg deposition. Therefore, we would not expect to find eggs in the field until the ~5 leaf stage. It appears, based on this one year study, that RWW move into field and oviposit earlier than we thought.

Significantly fewer eggs were found in the Dimilin treated areas than the untreated plots. This is consistent with our understanding of the manner in which Dimilin works. This product sterilizes RWW females upon exposure. Regent had no significant influence on RWW egg-laying or egg survival. The primary activity of Regent is on RWW larvae; therefore, these results were expected.

Objective 2: To evaluate a revised economic-injury level of rice water weevil on the most common commercial variety, and to appraise rice water weevil sampling methods.

2.1) Study the influence of rice water weevil on the growth, development, physiology and yield 'M-202'.

Larval survival under high RWW densities is one possible confounding effect from our earlier studies. In many cases, larval density decreases from one sample date to the next at a time when pupation is not involved. A logical reason for this is that the RWW larvae damage the roots to the extent that they are lacking for food. Starvation is therefore the probable reason for the decline in populations. A study was designed to test this idea. Plots were assembled in 8 ft^2 aluminum rings with either 96 or 150 plants (4 replications or each). At 17 days after seeding, each plot was infested with 58 RWW adults which were collected from nearby fields. This number of adults had been shown in previous studies to lay an excessive number of eggs. Core samples for RWW larvae were taken once per week from 18 June to 30 July. Results are shown in Fig. 3. RWW larval densities were indeed greater in the plots with the higher plant density compared with the lower plant density. This result occurred from 18 June to 2 July. Apparently, the lower incidence of roots associated with the lower plant density inhibited larval survival.

Studies continued in 1996 to examine the relationship between scar counts, larval density, and grain yield. These studies were in an abbreviated format compared with past years. The objective in 1996 was to develop additional data on year-to-year variation in yield losses from RWW injury. Three densities of RWW were evaluated in ring plots at the RES. These densities were achieved by infesting field-collected RWW adults in plots at 17 days after seeding. Densities used were 0 RWW adults per plant (uninfested), 0.4 RWW adults per plant (moderate infestation, and 0.6 RWW adults per plant (high infestation). Studies were conducted in a rice ('M-202') check planted on 16 May.

Analyses of results (Table 9) showed a ~425 lb./A yield loss per RWW larva (4.7% per larva). This is greater than in previous years (1992-95). Other analyses of the data are ongoing.

Table 9. Relationship among scar incidence, larval density, and rice grain yield, 1996.

Infestation Level	RWW Scar Incidence	RWW Larval Density/Plant 4 July	17 July	Rice Grain Yield (g/ring)	lbs./A
0 adults/plant	3.0 c	0.6	0.5	753.7	8409
0.4 adults/plant	29.3 b	8.8	4.9	573.4	6397
0.6 adults/plant	42.7 a	11.6	5.5	369.6	4124

2.2) Examine the relationship between rice water weevil scar incidence, larval density, plant growth and grain yield under grower conditions.

Research was conducted in 1996 to evaluate yield losses from RWW under grower field conditions. These studies were done to supplement the 3 years of research in this area conducted in ring plots at the RES. The data collected from ring plots are useful; however, similar data from field plots are also needed. The elevated yield from ring plots and the controlled RWW infestation introduce some uncertainty in these data. Information on yield losses from RWW has several uses such as, 1.) to support Section 18 and 24c registrations, 2.) by agrichemical companies investigating possible product development, 3.) by EPA regarding the need for registrations, 4.) by growers concerned about possible yield losses from RWW, and 5.) for investigating thresholds needed for possible postflood applications.

Studies are conducted in 9 grower fields. In each field, the incidence of plants with RWW scars, RWW larval density (2 times), and grain yield were determined. These factors were examined at 5 areas, namely 5, 15, 25, 35, and 45 feet from the levee, in each field. Previous research by Grigarick had shown that the RWW larvae density generally decreases within the first 50 feet from the levee. Areas more than 50 feet from the levee generally have very low RWW populations.

Several interesting results came from this study. Averaged over the 9 fields, % scarred plants declined from 33.2 to 5.1% over the range of distance away from the levee (5 to 45 feet). Similarly, larval densities declined from 1.9 to 0.9 per plant over these same treatments. Larval density at the second sample time was lower but the same trends persisted (Table 10).

Several growers in 1996, under the severe RWW pressure, reported damage from this pest outside of the ~50 feet adjacent to the levee. In 3 of the 9 fields we sampled, damaging larval populations (1.2+ larvae per plant) were found in the 45 feet sample. In this case, losses would still result with a perimeter insecticide treatment. In fact, in 2 of the 9 fields, there was not a decline in larval populations from the 5 to 45 feet sample areas. The RWW larval density was relatively constant across these samples.

Table 10. Average percentage scarred plants and RWW larvae density at various distances from levee in grower field threshold test, 1996.

Distance from Levee	% Scarred Plants	RWW Density 6/26 to 7/12	RWW Density 7/15 to 7/25
5 feet	33.2	1.9	0.8
15	13.0	1.4	0.7
25	11.0	1.1	0.2
35	6.8	0.9	0.4
45	5.1	0.9	0.2

Analyses of the data from grower fields showed a 8.1% yield loss per RWW larva. This compares with a 1.9% yield loss per RWW larva from the ring studies conducted from 1992-95. Although the relationship between larval density and yield was statistically significant, there was considerable variability and therefore a poor equation fit. The objective of this study was to determine how the yield loss from RWW compared in ring plots and in grower fields. From this first year's data, it appears that the significant losses found in ring plots are even more magnified in grower fields.

Objective 3:

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

The timing of RWW adult flight in the spring has been monitored for several years with a black light trap. Monitoring weevil flights is important to determine the levels and intervals of peak flight periods which provides important baseline data on the timing and intensity of the spring weevil flight.

In 1996, a light trap was placed at the Rice Experiment Station (RES) in Butte Co. This trap is used to provide a continuation of the light trap RWW record that began in 1962. Peak flights in 1996 occurred at the RES on 25 April and 29 April to 1 May. Secondary flights also occurred on 5 April, 22 April to 24 April, from 10 May to 12 May, 19 to 20 May, and from 24 May to 27 May. May 1 marked the completion of over 90% of the weevil flight at the RES. A total of 5420 weevils were captured in 1996 at the RES. This was about 40% greater than the number caught in 1995 and 30 times more than that caught 5 years ago. The location of the trap and protocol has been exactly the same over this period.

The flight timing in 1996 (date of 90% flight completion) was much earlier than in 1995, but this is somewhat misleading. In 1996, 1 May marked the date when 90% of the season's RWW had been captured. This compared with 24 May in 1995; however, this should be interpreted with caution. The extremely heavy flight in 1996 meant that the remaining 10% of the weevils still could create a significant infestation. The period of flight (capture of weevils) was very long in 1996 and ran from 5 April to 6 June. The cool, wet weather this spring delayed the emergence of RWW adults from overwintering and therefore the occurrence of the spring flight.

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Godfrey, L. D., A. T. Palrang, & A. A. Grigarick. 1996. 1995 Annual report comprehensive research on rice, RP-3, pp. 104-129.

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Influence of Timing of Dimilin Application on Efficacy on Rice Water Weevil

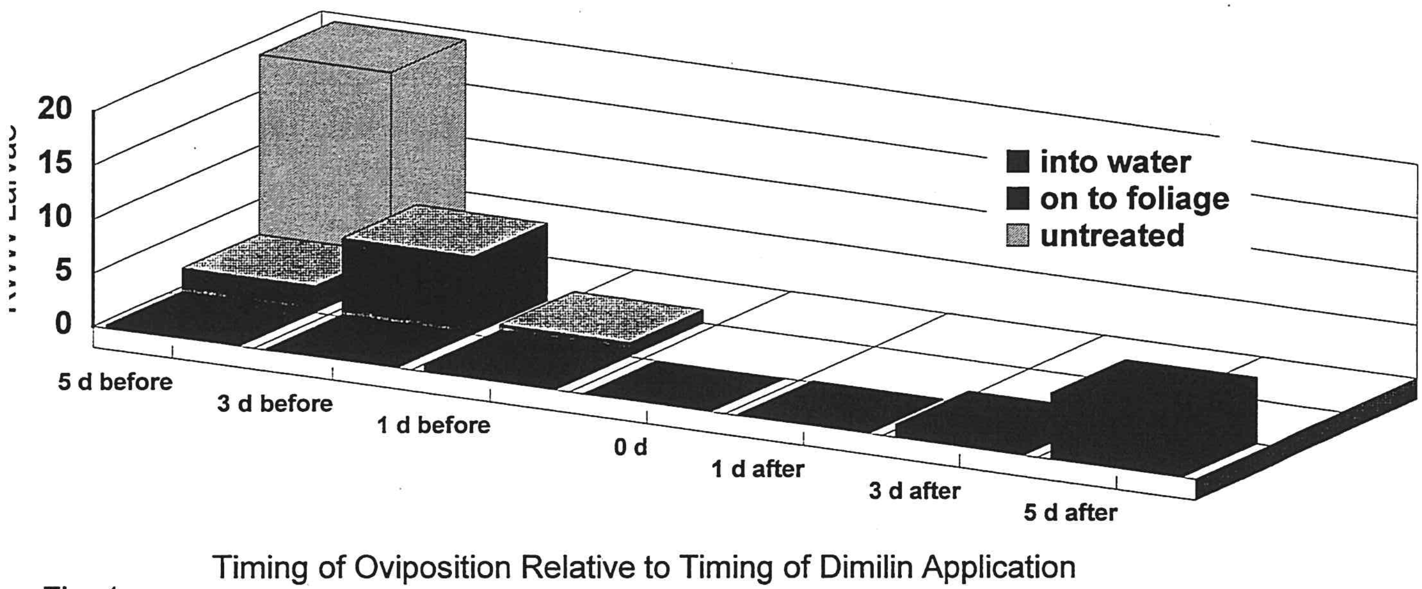
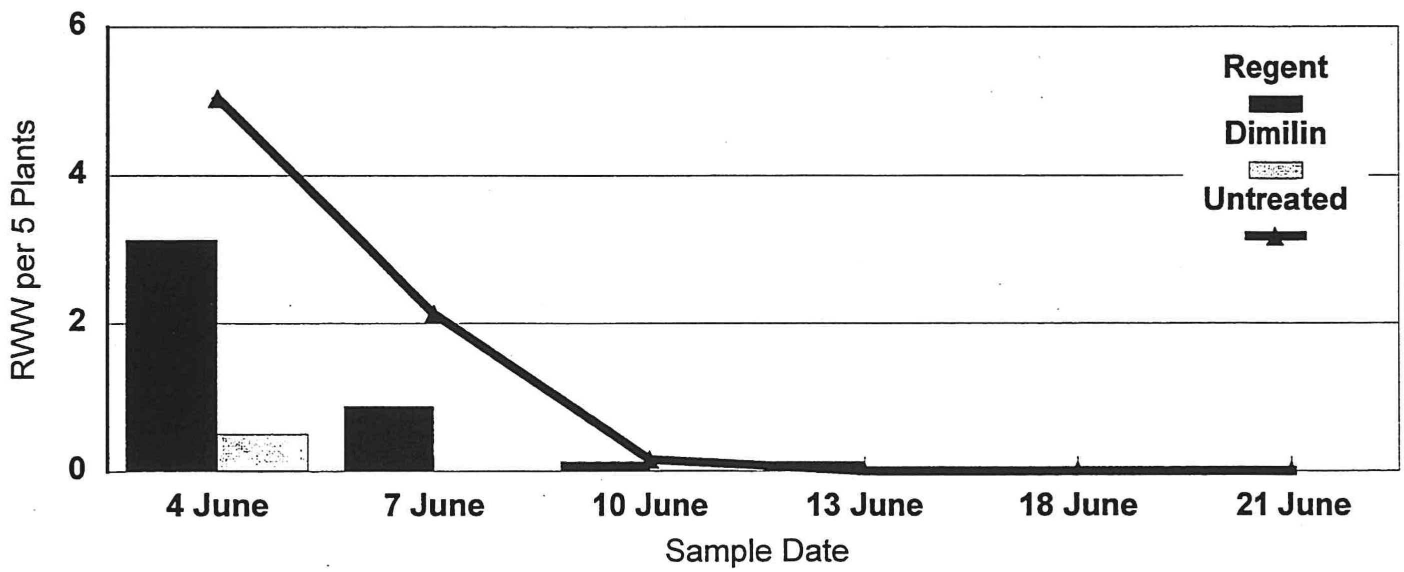


Fig. 1

Timing of Rice Water Weevil Oviposition: Influence of Treatments



16 May planting date
Fig. 2

Influence of Rice Plant Density on Rice Water Weevil Larval Survival

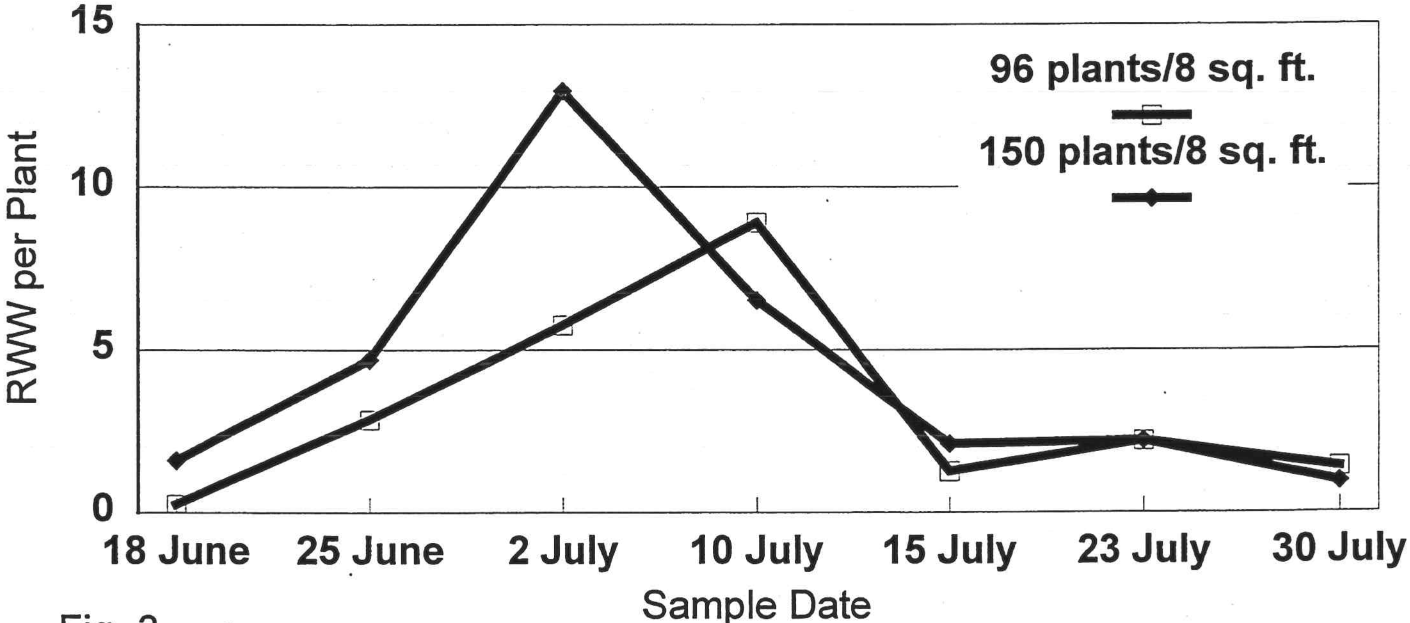
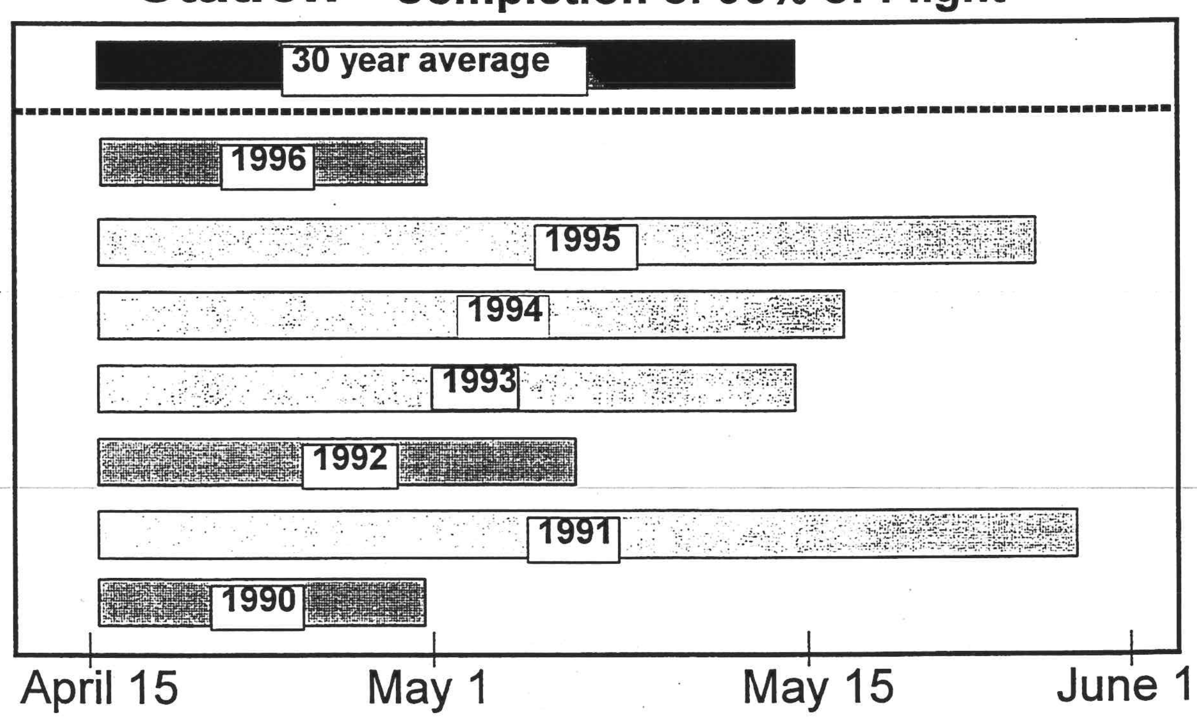


Fig. 3

Rice Water Weevil Flight Period - Rice Expt. Station - Completion of 90% of Flight *



* based on black light trap captures

Fig. 4

Timing and Magnitude of Rice Water Weevil Flight-Rice Experiment Station, 1996

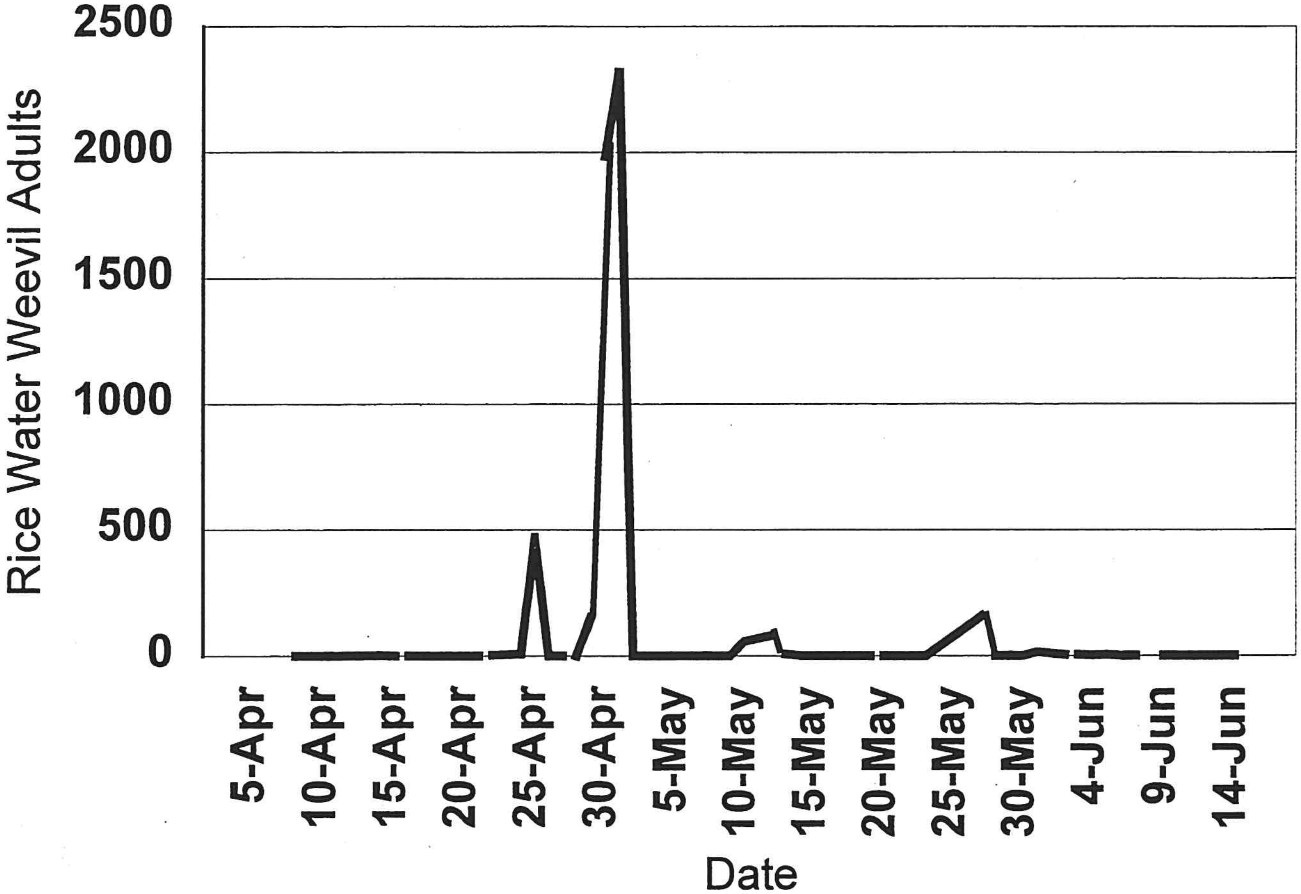


Fig. 5

CONCISE GENERAL SUMMARY OF CURRENT YEAR'S (1996) RESULTS:

Larry D. Godfrey and Terry Cuneo

Rice Water Weevil Control

Several studies were conducted to evaluate the efficacy of insecticides on Rice Water Weevil (RWW). With the scheduled cancellation of Furadan usage, there is a need for alternative management schemes for RWW. Three stages of testing were done, 1.) 8 sq. ft. ring studies, 2.) 200 sq. ft. small basin studies, and 3.) 3 acre plots in grower fields. The ring and small plot studies were conducted at the Rice Experiment Station. Grower field tests were done in Butte, Placer, and Sutter counties. The efficacy of 4 chemical insecticide active ingredients and a total of 24 treatments was evaluated in ring plots. Numerous formulations and application timings of Regent (fipronil), Dimilin (diflubenzuron), Karate (lambda-cyhalothrin), and Furadan (carbofuran) were compared. Regent, Dimilin, and Karate appear to be viable prospectives for managing RWW. Seedling vigor/emergence, percentage of plants with adult leaf scars, RWW larval density, rice plant growth characteristics (height, number of tillers), and rice grain yield were measured in each plot. RWW larval counts were made twice during the season. Densities ranged from 0.0 to 5.05 larvae per plant. The pre-flood Regent 70FS (0.025 lb. AI/A), Furadan 4F (1.0 lb. AI/A), Furadan 5G (0.5 lb. AI/A), and postflood Karate 1E (5-leaf) treatments were the most effective for reducing larval populations. Although the above treatments had the fewest larvae, a total of 21 of the 23 treatments provided good to excellent control with larval densities less than 1 larva per plant. The control seen with the treatments in the second sampling date was equal or only slightly poorer than that seen in the first sampling date. These results are in contrast with the 1995 studies which showed the control of RWW immatures to be less on the second sampling date. The increased control by the treatments in the 1996 study could be indicative of a refining of treatment rates and timings, i.e., the less effective treatments were eliminated. Grain yields ranged from an estimated ~9000 to ~6350 lbs./A. Yield was lowest in the untreated plots and highest in the Regent 1.67SC (0.038 lb. AI/A, post, 3-leaf) and Regent 0.12GR (with fertilizer)treatments.

In the small basin tests, RWW density (a natural infestation) was low. These studies were designed to evaluate viable treatments on a more "commercial" scale. Larval density ranged from an average of 1.1 (untreated) to 0.0 larvae per plant (Regent 1.67SC PPI, Regent 1.67SC 7 d post, 0.038 lbs. AI/A; Dimilin 25W, 0.25 lbs. AI/A at 3 and 7 d after 50% plant emergence; and Karate 1E, 0.03 lbs. AI/A at the 3 leaf stage).

Dimilin (a total of 17 treatments) efficacy was compared with Furadan 5G and an untreated in 6 grower fields in crop destruct testing. On the average, Dimilin performed equal to or better than Furadan in terms of larval control and yield. These results were more favorable than the 1995, in part as we have refined the use pattern for this product (rate, formulation, and timing). A portion of this refinement came from an accompanying greenhouse study that was done on the UC-Davis campus. In one grower field test with Regent, performance with this product was comparable to Furadan and there was substantial larval control and protection of yield compared with the untreated.

Rice Water Weevil Biology

The timing and incidence of RWW oviposition (egg-laying) was studied. This information may become more important as treatments go from pre-plant incorporated to post-flood timings. At the first sample timing (3-leaf stage), a significant number of RWW eggs was found. Oviposition at this time is earlier than previously thought. In another study, RWW larval density/survival was compared from plots with 96 and with 150 plants per 8 sq. ft. The plots were infested with the same number of RWW adults per plot. RWW larval densities were greater in the plots with the higher plant density compared with the lower plant density. Apparently, the lower incidence of roots associated with the lower plant density inhibited larval survival.

Rice Water Weevil Damage/Yield Losses

Studies continued in 1996 to examine the relationship among scar counts, larval density, and grain yield. The majority of this work was done in grower fields (untreated areas) with a limited number of ring plots at the Rice Experiment Station. Information on yield losses from RWW has several uses such as, 1.) to support Section 18 and 24c registrations, 2.) by agrichemical companies investigating possible product development, 3.) by EPA regarding the need for registrations, 4.) by growers concerned about possible yield losses from RWW, and 5.) for investigating thresholds needed for possible postflood applications. In the ring plots, RWW densities were achieved by infesting field-collected RWW adults in plots at 17 days after seeding. Densities used were 0 RWW adults per plant (uninfested), 0.4 RWW adults per plant (moderate infestation), and 0.6 RWW adults per plant (high infestation). Natural infestations were used in the grower fields. Analyses of results showed a ~425 lb./A yield loss per RWW larva (4.7% per larva) from the ring plots and ~650 lb./A yield loss per RWW larva (8.1% per larva) from the grower field tests. This compares with a 200 lb./A (1.9%) yield loss per RWW larva from the ring studies conducted from 1992-95. Reasons for these differences are uncertain at this time, but there appears to be significant year-to-year variation in rice plant response to RWW injury.

Rice Water Weevil Flight

The timing of RWW adult flight in the spring has been monitored for several years with a black light trap. Monitoring weevil flights is important to determine the levels and intervals of peak flight periods which provides important baseline data on the timing and intensity of the spring weevil flight. In 1996, a light trap was placed at the Rice Experiment Station in Butte Co. This trap is used to provide a continuation of the light trap RWW record that began in 1962. Peak flights in 1996 occurred at the RES on 25 April and 29 April to 1 May. Secondary flights also occurred on 5 April, 22 April to 24 April, from 10 May to 12 May, 19 to 20 May, and from 24 May to 27 May. May 1 marked the completion of over 90% of the weevil flight at the RES. A total of 5420 weevils were captured in 1996 at the RES. This was about 40% greater than the number caught in 1995 and 30 times more than that caught 5 years ago. The location of the trap and protocol has been exactly the same over this period. The flight timing in 1996 (date of 90% flight completion) was much earlier than in 1995, but this is somewhat misleading. In 1996, 1 May marked the date when 90% of the season's RWW had been captured. This compared with 24 May in 1995; however, this should be interpreted with caution. The extremely heavy flight in 1996 meant that the remaining 10% of the weevils still could create a significant infestation. The period of flight (capture of weevils) was very long in 1996 and ran from 5 April to 6 June. The cool, wet weather this spring delayed the emergence of RWW adults from overwintering and therefore the occurrence of a portion of the spring flight.