# Insects of Wild Rice in Minnesota

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## INTRODUCTION

Little information is available concerning the insect pests of wild rice. Jenks (1901) stated that caterpillars were serious pests of wild rice in the Rainy River area, and he referred also to the rice water weevil *(Lissorhoptrus simplex)*. Moyle (1944) reported that "armyworms (*Agrotis* sp.)" occasionally injured wild rice by feeding on the kernels. Authors of this publication* have never observed armyworms causing this type injury, and believe that Moyle was referring to the wild riceworm, *Apamea apamiformis* (Guenee), which, currently, is the most important insect pest of wild rice. In the late 1950s, the riceworm was reported to be a pest of wild rice in Canada (Hammond, 1957, 1958, 1959). MacKay and Rockburne (1958) described the life history of the riceworm on wild rice in Canada and reported extensive injury to the seeds by the larvae. In 1960, the riceworm was reported to be a serious pest of wild rice in commercial paddies near Zim, Minnesota. Young larvae ate out the kernels and older larvae bored in the plants. Furthermore, the riceworm was a nuisance because larvae were flailed out with the rice at harvest (personal communication from Richard Swartz, October 4, 1960). Melvin (1966) published observations on insects attacking wild rice in Manitoba, and he concluded that the two most common pests were the riceworm and the rice stalk borer, *Chilo plejadellus* Zincken. He outlined the life history of the rice stalk borer and recovered the parasite, *Chelonus knabi* Vier. from the stalk borer larvae. However, he believed that parasites were not important in controlling stalk borers.

As a result of recent increased acreages of wild rice grown in commercial paddies, there was a demand for additional knowledge concerning insect pests and how to control them. The present studies were begun in 1970, funded by the Minnesota Agricultural Experiment Station in cooperation with the Departments of Agronomy and Plant Genetics, Plant Pathology, Soil Science, and Agricultural Engineering.

## The Riceworm (*Apamea apamiformis* [Guenee]: Family Noctuidae)

The riceworm, *Apamea apamiformis* Guenee, is the most important insect pest of wild rice in Minnesota. Its life cycle is coordinated remarkably well with the seasonal development of the wild rice plant. Adult moths (figure 1) begin to emerge at about the same time that the first wild rice panicles appear. According to light trap catches, the first emergence of adults is usually in late June or early July (table 1), and the flight period lasts until early August. Panicles of wild rice continue to emerge on new tillers during July and early August. Young panicles of wild rice are suitable for oviposition, and they are present during the entire oviposition period, which lasts from soon after moths begin to emerge until about the second week of August. The long oviposition period results in the presence of larvae of different ages at the same time. Thus, riceworms use the host plant effectively from the time the panicles appear until harvest.

**Table 1. Dates of first and last collections of adult riceworms in light traps and first appearance of eggs and milkweed blossoms**

| YEAR | COLLECTIONS OF ADULTS FIRST | COLLECTIONS OF ADULTS LAST | FIRST BLOSSOMS OF MILKWEED | EGGS FIRST OBSERVED |
|---|---|---|---|---|
| 1972 | July 12 | Aug. 9 | — | July 12 |
| 1973 | July 9 | Aug. 14 | — | July 9 |
| 1974 | — | — | July 8 | July 8 |
| 1975 | July 8 | Aug. 2 | July 2 | — |
| 1976 | June 24 | Aug. 1 | June 25 | July 2 |
| 1977 | June 19 | Aug. 3 | June 15 | June 28 |
| 1978 | June 26 | Aug. 7 | June 29 | July 1 |

Riceworm adults are particularly attracted to flowers of the common milkweed (*Asclepias syriaca* L.) which blooms at about the same time as the moths begin to emerge. The authors watched the moths visit flowers of common milkweed on several occasions. On August 3, 1973, the moths first appeared at 9:20 p.m. (Central Daylight Time) just as it was getting dark. During the next 25 minutes, 6 riceworm moths flew directly to milkweed flowers where they collected nectar. They did not visit any other flowers although, close by, there were numerous blossoms of fireweed (*Epilobium angustifolium* L.), Canada thistle (*Cirsium arvense* [L.] Scop.), swamp milkweed (*Asclepias incarnata* L.), and sweetclover (*Melilotus alba* [Desrl]). On July 19, 1974, the authors again observed riceworm moths visiting milkweed flowers between 9:30 p.m. and 9:50 p.m. (C.D.T.). They visited only common milkweed and did not visit flowers of sweetclover, fireweed, or swamp milkweed.

*Authors are identified inside the front cover and subsequent text reference to the authors is to them.

As indicated by MacKay and Rockburne (1958), eggs of the riceworm are deposited inside the florets when the stigma of the floret protrudes through an opening between the lemma and palea. Johnson (1975) found freshly laid eggs in florets in which the stigmas were either exposed or recently retracted. From 2 to 152 eggs were deposited in a single floret. The average number of eggs per floret during 1972 ranged from 23 at the peak of the oviposition period in mid-July to 12 near the end of the oviposition period July 31. The eggs are pearly white when first laid (figure 2) and gradually darken with age and become yellow. They turn dark gray just before hatching. The egg stage lasts 8 or 9 days.

Newly hatched larvae can be seen crawling about inside the florets (figure 3). They consume the ovary. When there are a dozen or more larvae in a single floret there must not be enough food to go around. Within a day or so the tiny larvae bore out of the floret. On several occasions the authors watched them crawl about on the panicle. They frequently crawled to the tips of the florets where they spun fine silken threads and were carried away by the breeze. Some of the larvae were carried to nearby plants, and some fell on the water. After the larvae have emerged from the florets they are difficult to find. Many of them feed on the male floral parts during the first and second stages or instars (Soemawinata, 1976). Although the authors have observed larvae of about the third instar still feeding on the male floral parts, most of the larvae of the third instar occur among the developing grains on the heads. As the larvae feed in the heads, they mine out the kernels (figure 4). They continue to feed on kernels in the head and increase in size passing through the fourth, fifth, and sixth instars (figures 5, 6). The larvae not only consume the kernels of wild rice, but leave remnants of silk and starchy excrement (figure 7). Johnson (1975) concluded that there are 8 larval instars. Larvae of the third to seventh instar are present at harvest time, but most larvae are in the fifth to seventh instar by that time (Peterson, Johnson, and Noetzel, 1974). The larger larvae occur frequently under the leaf sheaths in the fall and may even find their way inside stalks. During September and October, larvae of the sixth and seventh instars move into the soil both within and outside the paddies, where they spend the winter. Larvae have been observed to enter cabins up to 300 feet from the closest rice. Overwintered larvae become active in May, feed for a time, molt to the eighth instar, and pupate during June. The pupal stage lasts about 3 weeks, and adult moths emerge in late June and early July.

## Evaluation of Injury by Riceworms

The riceworm probably causes greater losses than the combined losses of all the other insect pests of wild rice. Severely injured panicles are conspicuous with their matted silk, masses of white starchy frass, and ruined kernels (Dore, 1969). It has been difficult to evaluate injury accurately and in a quantitative manner. The authors observed one paddy in 1975 which had 3 to 4 riceworms per panicle, and the yield was practically negligible. There were other paddies with high populations of riceworms, but they were sprayed with malathion. It is important to know how much damage smaller populations can do and what the economic levels of injury are, so that growers can be provided with some guidelines as to when control measures are necessary.

Noetzel (unpublished) made field counts of riceworms and injured florets in 1970 and tentatively concluded that it would pay to control riceworms if the numbers exceeded 18 to 25 worms per 100 panicles. To evaluate injury further, in 1974 the authors placed fine-mesh dacron cloth bags over a series of wild rice panicles and confined riceworms at rates of 0, 1, and 2 larvae per panicle. When the authors harvested these panicles, there appeared to be no relationship between the numbers of larvae on the panicles at harvest and the initial numbers of larvae placed in the bags. Furthermore, the weights of individual panicles were so variable that there was no clear relationship between numbers of larvae and yields.

In a similar experiment in 1975, Soemawinata (1976) discovered that small riceworms were feeding on the male floral parts and moving to the kernels after the cloth bags were placed on the heads. He repeated the experiment and removed the male florets from the heads before putting on the cloth bags. This helped solve the problem, although there were still occasional panicles which had more larvae than had been originally placed in the bags. Results indicated that, with increased numbers of riceworm larvae, there were more damaged kernels per panicle and lower yields (table 2). Figure 8 indicates the relationship between numbers of fourth-instar larvae per head and subsequent yields. An infestation of one larva per panicle would be expected to cause a 10 percent yield loss.

**Table 2. Results of confining different numbers of riceworm larvae on bagged panicles of wild rice: Grand Rapids, 1975**

| NUMBER OF INTRODUCED LARVAE/ PANICLE | NUMBER OF DAMAGED KERNELS/ PANICLE | NUMBER OF FILLED KERNELS/ PANICLE | PERCENT OF KERNELS FILLED | YIELD IN GRAMS PER PANICLE |
|---|---|---|---|---|
| 0 | 6.3 a[1] | 125.3 a[1] | 94.5 a[1] | 2.59 a[1] |
| 1 | 7.5 a | 113.6 a | 93.3 a | 2.55 a |
| 2 | 12.9 b | 104.0 ab | 87.6 a | 2.40 a |
| 3 | 24.6 c | 105.5 ab | 76.3 b | 2.09 a |
| 4 | 31.9 d | 97.0 ab | 69.4 b | 1.79 ab |
| 5 | 22.6 c | 58.0 b | 58.6 c | 1.05 b |

[1]Means in a column not followed by the same letter are significantly different at the 5 percent level as determined by Duncan's Multiple Range Test.

In 1977, individual panicles of wild rice were bagged with 0, 1, and 2 riceworm larvae of the third or fourth instar on July 28. There were 24 replications. Following harvest on August 24, the number and growth stage of riceworms in each bag were recorded, and rice kernels on each panicle were counted and classified as good, poorly filled, or damaged by riceworms. Cool weather during August resulted in less feeding than usual by the larvae perhaps because of the smaller-than-usual numbers of filled kernels per panicle. During the experiment each larva which developed beyond the fourth instar destroyed an average of 7.1 wild rice kernels (table 3). The authors calculated an average loss of 16.3 percent for a population of one larva per head as compared with 10 percent in Soemawinata's experiment in 1975.

In 1978 the authors again confined riceworm larvae on bagged panicles of wild rice at rates of 0, 1, and 2 larvae per head and used 26 replicates. The larvae were placed on the panicles August 9, and panicles were harvested September 1. During this experiment, each larva which developed beyond the fourth instar destroyed an average of 8.7 kernels of wild rice. The authors calculated an average loss of 10.9 percent for a population of 1 larva per panicle (table 3). The authors believe the 10.9 percent figure to be more realistic than the 16.3 percent

obtained in the 1977 experiment because the rice panicles in the 1978 experiment were allowed to mature longer and there was an average of 80 plump kernels per panicle in 1978 compared with only 43 plump kernels per panicle in the 1977 experiment. Table 4 gives the calculated losses in dollars per acre due to riceworms as based on (1) a loss of 10.9 percent per larva per panicle, (2) expected yields, and (3) a selling price of $1 per pound for green rice. Growers can use the table as a guide in making the decision whether to apply malathion, or not, to control riceworms.

**Table 3. Summary of results from confining 0, 1, and 2 riceworm larvae on bagged panicles: Grand Rapids, 1977**

| OBSERVATIONS | YEAR 1977 | 1978 |
|---|---|---|
| Total florets per panicle | 107.3 | 131.6 |
| Plump undamaged kernels per panicle | 41.7 | 72.1 |
| Weight (g) per plump kernel | .028 | .035 |
| Plump + damaged kernels per panicle | 43.40 | 80.05 |
| Kernels destroyed per larva | 7.09 | 8.70 |
| Average instar of larvae at harvest | 5.96 | 5.97 |
| Loss per larva per panicle | 16.34% | 10.87% |

**Table 4. Calculated losses in dollars per acre due to riceworms as based on expected yields, numbers of riceworms per 100 wild rice heads, and a selling price of $1 per pound for unprocessed wild rice**

| NO. RICE-WORMS PER 100 PANICLES | EXPECTED YIELD IN POUNDS PER ACRE 100 | 200 | 300 | 400 | 600 | 800 | 1,000 |
|---|---|---|---|---|---|---|---|
| 10 | $1.09 | $2.18 | $3.27 | $4.36 | $6.54 | $8.72 | $10.90 |
| 15 | 1.64 | 3.28 | 4.92 | 6.56 | 9.84 | 13.12 | 16.40 |
| 20 | 2.18 | 4.36 | 6.54 | 8.72 | 13.03 | 17.44 | 21.80 |
| 30 | 3.27 | 6.54 | 9.81 | 13.08 | 19.62 | 26.16 | 32.70 |
| 40 | 4.36 | 8.72 | 13.08 | 17.44 | 26.16 | 34.88 | 43.60 |
| 60 | 6.54 | 13.08 | 19.62 | 26.16 | 39.24 | 52.32 | 65.40 |
| 80 | 8.72 | 17.44 | 26.16 | 34.88 | 52.32 | 69.76 | 87.20 |
| 100 | 10.90 | 21.80 | 32.70 | 43.60 | 65.40 | 87.20 | 109.00 |

**Table 5. Counts of riceworm eggs and larvae in an advanced variety trial: Grand Rapids, 1978**

| VARIETY | NO. FLORETS WITH EGGS PER 25 PANICLES[1] AUG. 1 | LARVAE PER 25 PANICLES AUG. 1 | AUG. 10 |
|---|---|---|---|
| Netum | 3.2 bc[2] | 1.4 | 4.3 |
| Netum Short | 3.2 bc | 0.6 | 2.3 |
| K2 | 2.0 c | 0.6 | 3.5 |
| Johnson | 6.4 a | 0.6 | 2.3 |
| Johnson White | 8.4 a | 0.4 | 3.3 |
| M3 | 5.4 ab | 0.2 | 3.5 |

[1]Includes both eggs and eggs which have hatched.
[2]Figures with a letter in common do not differ significantly at the 5 percent level according to Duncan Multiple Range Test.

## Varietal Susceptibility to Riceworms

Under conditions of a low infestation, there appeared to be little, if any, difference in numbers of riceworms on Netum and K2 varieties in replicated plots of a fertilizer experiment at Grand Rapids. However, in an advanced trial of six varieties, there was significantly more oviposition in Johnson, Johnson White, and M3 than in the varieties Netum, Netum Short, and K2 (table 5). After the riceworm eggs had hatched and the larvae had dispersed on their silken threads, there appeared to be a relatively uniform infestation among the different varieties (see count made on August 10, table 5). Larval dispersal may not have been far, because in this experiment Replicate 2 had the most eggs on August 1 and also the most larvae on August 10. It seems likely that the variety Netum may escape some injury by riceworms because it is harvested a week or so earlier than the other varieties.

## Control of Riceworms

Replicated experiments in 1971 indicated that malathion (0,0-dimethyl phosphorodithionate of diethyl mercapto succinate) applied at rates of 0.5 to 1.0 pound actual insecticide per acre and carbaryl (1-napthyl methylcarbamate) applied at 1.5 pounds actual insecticide per acre gave excellent control of riceworms (Noetzel—unpublished data). In 1973 the authors observed one commercial paddy which averaged 200 riceworms per 100 panicles. An air application of malathion reduced riceworms to 17 per 100 panicles (92 percent control).

During 1973 several growers reported that malathion was not giving satisfactory control of riceworms. The authors hypothesized that perhaps chemical control might be more effective if insecticides were applied in the evening than in the morning because riceworms are nocturnal feeders and because malathion breaks down rather rapidly. The authors selected two 50-acre plots in a large field of wild rice north of Gully, Minnesota, to compare morning and evening applications of malathion in 1974. Treatments were assigned at random and the first plot was sprayed by airplane between 7:30 and 7:55 p.m. (Central Daylight Time) on August 6. One gallon of spray containing 1 pound actual malathion was applied per acre. The temperature at the time of application was 75° F., and the wind was 2 to 5 m.p.h. from the southwest. The second plot was sprayed between 7:40 and 8 a.m. on August 7. A misunderstanding with the flag man resulted in an application rate of 1.2 pounds actual malathion rather than the 1.0 pound rate which the authors had intended. The temperature during the morning application was 65° F., with 5 m.p.h. southwest winds. The plots were separated by a ditch and buffer strip of about 200 feet, so drift was not a problem. Pretreatment counts of riceworm larvae per 100 panicles and 24-hour post-treatment counts are in table 6. The authors concluded that the morning and evening applications were equally effective, even though the slightly higher rate of malathion was used for the morning application.

**Table 6. Comparison of morning and evening applications of malathion to control riceworms: Gully, Minn., 1974**

| TIME OF APPLICATION | RATE A.I./ACRE | AVERAGE RICEWORMS PER 100 PANICLES PRETREATMENT AUG. 6 | 24 HR. COUNT AUG. 7-8 | 30 DAYS SEPT. 4 | % CONTROL 24 HOURS |
|---|---|---|---|---|---|
| 7:30 p.m., Aug. 6 | 1.0 lbs. | 140 | 18 | 10 | 87 |
| 7:40 a.m., Aug. 7 | 1.2 | 233 | 29 | 12 | 88 |

Spore suspensions of *Bacillus thuringiensis* (Bt) were compared with malathion and a combination of malathion and *Bacillus* for control of the riceworms in 1975 at the Grand Rapids Experiment Station. Bt is a commercial preparation derived from cultures of a bacterium which has good activity against some insects. It kills by paralyzing the gut and/or infecting the target insect. The malathion was applied at 1 pound actual insecticide in 40 gallons of water per acre with a backpack sprayer equipped with a 3-nozzle boom. *Bacillus thuringiensis* (Dipel brand, 16,000 International Units of potency per milligram (mg) and 25 billion spores per gram (g)) was applied at rates of 0.5 pound and 1.0 pound spore powder in 40 gallons of water per acre. A fourth treatment consisted of a combination of 0.5 pound malathion and 0.5 pound of *Bacillus* spores per acre. Plot size was 88 by 32 feet. Sprays were applied the afternoon of August 12. Light showers totaling approximately 0.1 inch began about 10 minutes after the application of malathion, the last treatment to be applied. Results indicated that *Bacillus thuringiensis* is not very effective for controlling riceworms (table 7).

**Table 7. Comparison of *Bacillus thuringiensis* and malathion for control of riceworms: Grand Rapids, 1975 (sprays applied August 12)**

| TREATMENT | RICEWORMS PER 100 PANICLES | | |
|---|---|---|---|
| | AUG. 12 | AUG. 14 | AUG. 19 |
| Control (before treatments) | 312 | | |
| Dipel 1 lb/a.i./acre | | 145 | 87 |
| Dipel 0.5 lb/a.i./acre | | | |
| Dipel 0.5 lb + Malathion 0.5 lb/a.i./acre | | 90 | 94 |
| | | 0 | 4 |
| Malathion 1 lb/a.i./acre | | 0 | 2 |

Diflubenzuron (1-[4-chlorophenyl]-3-[2,6-difluorobenzoyl]urea), *Bacillus thuringiensis*, and malathion were compared for control of riceworms at Grand Rapids in 1976. Plots measured 20 by 40 feet, and a randomized block design was used with 4 replicates. The materials were applied in 40 gallons of water per acre on August 5. *Bacillus thuringiensis* gave poor control as it did in 1975. Diflubenzuron was nearly as effective as malathion in a count made 8 days after spraying (table 8). Populations of riceworms were rather low and variable in the plots, and control of riceworms did not result in any significant yield differences.

Preliminary observations in the Manomin and Jacobson paddies in Aitkin County in 1976 indicated that methiocarb, (4-[methylthio]3,5-xylyl methylcarbamate) (Mesurol®), which was applied by air as a blackbird repellent, controlled riceworms almost as effectively as malathion (table 9).

**Table 9. Effect of methiocarb (Mesurol) on riceworms: Aitkin, 1976 (methiocarb was applied as a blackbird repellent at 1.5 lbs actual insecticide per acre on July 30)**

| TIME OF COUNT | RICEWORMS PER 50 PANICLES | |
|---|---|---|
| | MANOMIN PADDY | JACOBSON PADDY |
| Before treatment July 29 | 27 | 39 |
| After treatment August 1 | 7 | 1 |

An experiment to compare the effectiveness of methiocarb and malathion for controlling riceworms was located in one of the Kosbau paddies north of Aitkin in 1977. The three treatments included malathion at 1 pound actual insecticide per acre, methiocarb at 1.5 pounds, and an untreated check. Plots were each 24 by 30 feet with 4 replicates. Insecticides were applied with a backpack sprayer in 40 gallons of water per acre. Sprays were applied from 5 to 6 p.m. on July 26 while a very slight breeze blew lengthwise of the plots and temperature was 70° F. It rained during early afternoon of the following day. In a pretreatment count on July 26, riceworm larvae averaged 124 per 100 panicles, and most larvae were in the 3rd and 4th instar. The authors counted riceworms per 100 panicles in each plot 1 day, 2 days, and 6 days following application of insecticides. The riceworm counts in the malathion and methiocarb treatments did not differ significantly, but both had fewer riceworms than the check (table 10).

**Table 10. Comparison of malathion and methiocarb for control of riceworms at 1, 2, and 6 days after spraying: Aitkin, 1977**

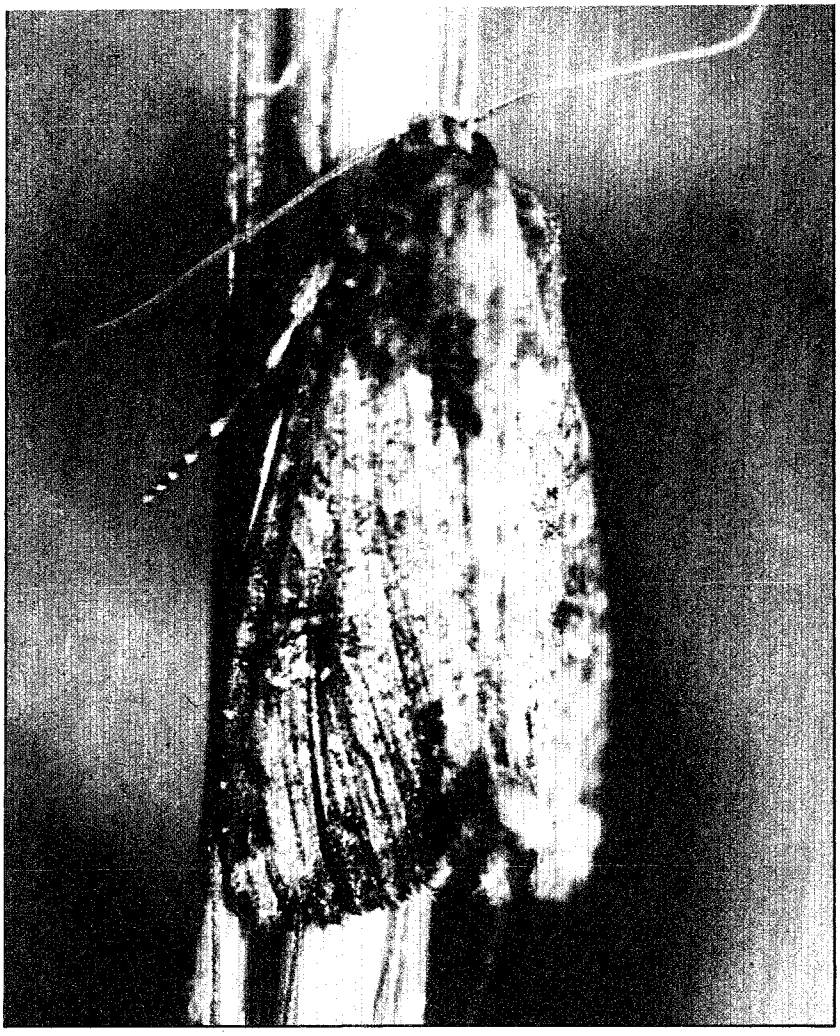
| TREATMENT AND RATE/A.I./ACRE | AVERAGE RICEWORMS PER 100 PANICLES | | |
|---|---|---|---|
| | 1 DAY | 2 DAYS | 6 DAYS |
| Malathion 1 lb | 32 | 17 | 10 |
| Methiocarb 1.5 lb | 51 | 29 | 28 |
| Check | 112 | 101 | 106 |

Methiocarb was applied by helicopter at 2 pounds actual insecticide per acre to one of two plots at Grand Rapids for evaluation as a repellent against blackbirds. Two days after spraying, the authors counted 13 riceworms per 100 heads in the sprayed plot compared with 58 riceworms per 100 heads in the untreated plot. This would amount to 78 percent control, compared with 74 percent control for the 6-day count in the Aitkin experiment.

**Table 8. Results of an experiment on control of riceworms: Grand Rapids, 1976 (insecticides applied August 5)**

| TREATMENT | RATE A.I./ACRE | AVG. RICEWORMS/50 PANICLES | | | YIELD IN GRAMS PER 10 SQUARE YARDS |
|---|---|---|---|---|---|
| | | JULY 26 | AUG. 6 | AUG. 13 | |
| *B. thuringiensis* | 1.0 lb | 9.0 | 13.8 | 9.3 | 1,323 |
| Diflubenzuron (Dimilin) | 0.25 lb | 4.5 | 6.3 | 1.5[1] | 1,416 |
| Malathion | 1.0 lb | 10.0 | 0.8[1] | 0.5[1] | 1,284 |
| Check | | 9.0 | 13.3 | 17.3 | 1,365 |

[1]Significantly lower than check at 5 percent level.



▲ Figure 1. Adult riceworm.

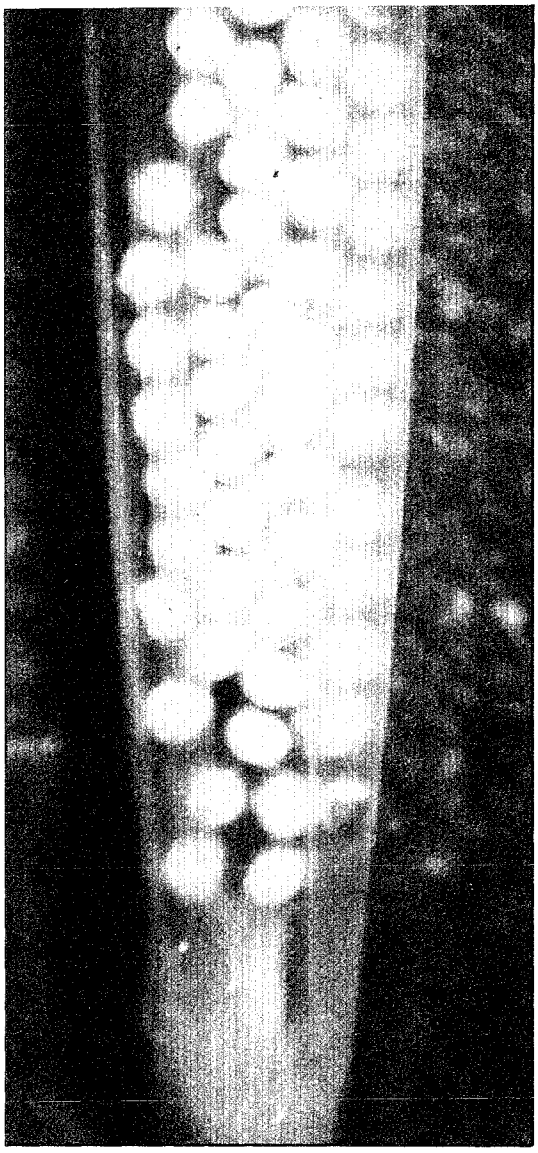


Figure 2. Eggs of the riceworm inside a floret of wild rice. ▶

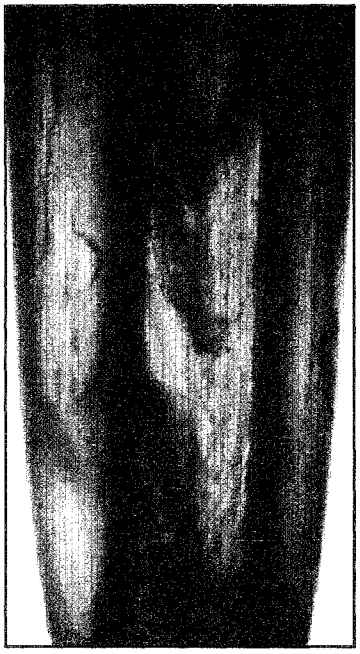


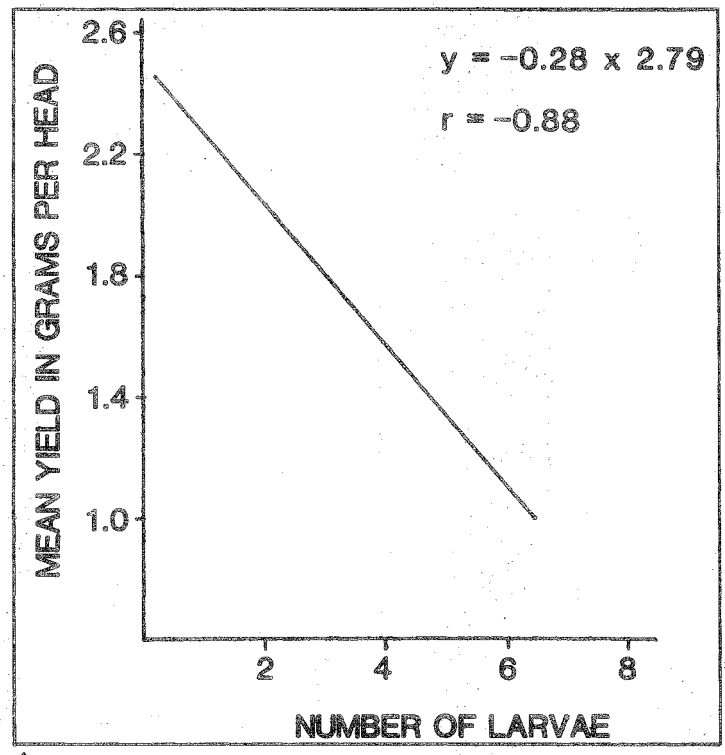
Figure 3. Newly hatched larvae of the riceworm inside a floret of wild rice. ▶

Figure 4. Injury to kernels of wild rice by small larvae of the riceworm. ▶

Figure 5. Half-grown larva of the riceworm in a panicle of wild rice.

◀ Figure 6. Late instar larva of the riceworm in a panicle of wild rice.

Figure 7. Panicle of wild rice injured by riceworms. Note damaged kernels, remnants of silk, and starchy excrement.




▲ Figure 8. Regression of yield per panicle on number of 4th instar riceworm larvae on bagged heads, 1975.

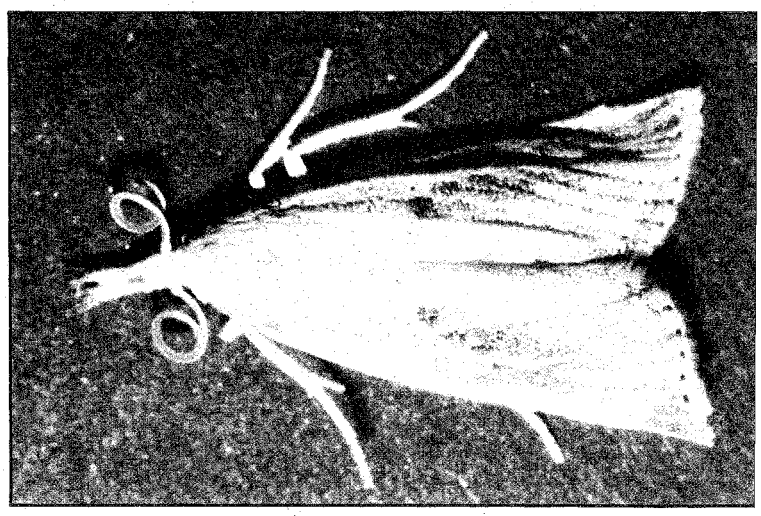


Figure 9. Adult of the rice stalk borer.

Figure 10. Eggs and newly hatched larva of the rice stalk ▶ borer.

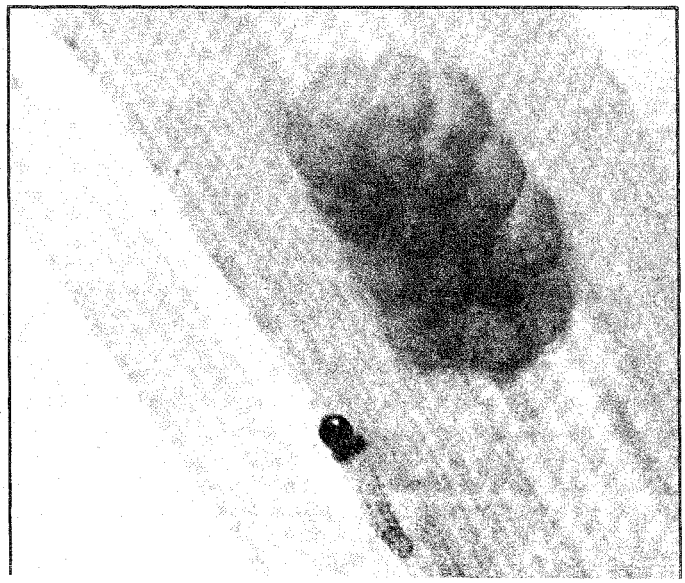


Figure 11. Larvae of the rice stalk borer in stem of wild rice.

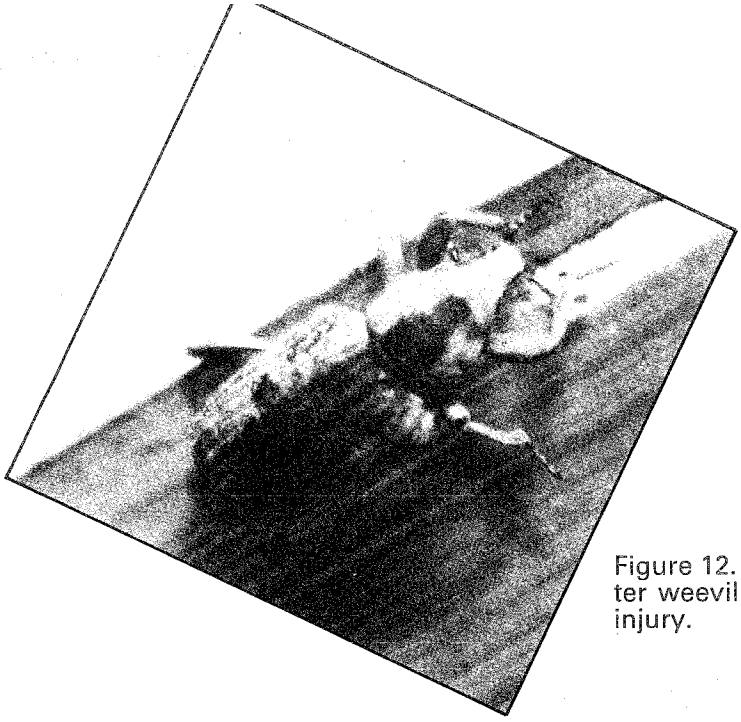
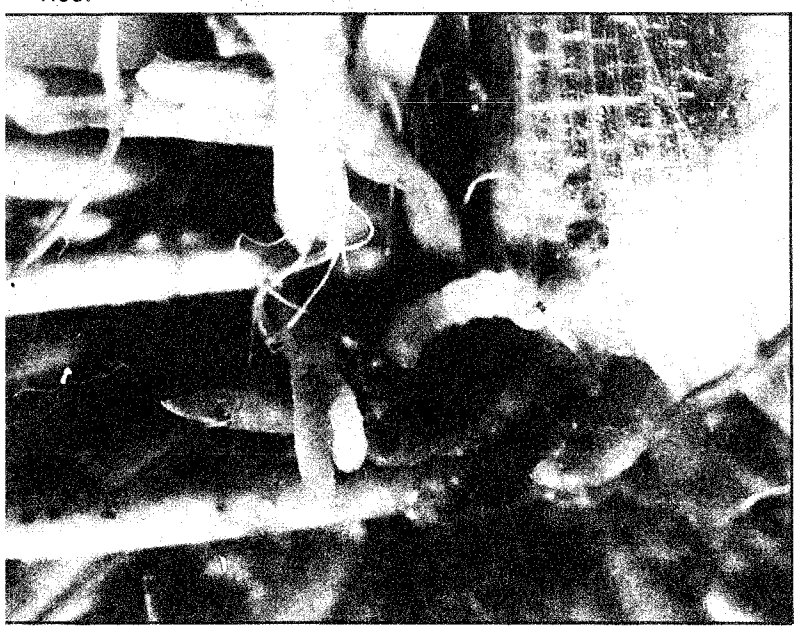


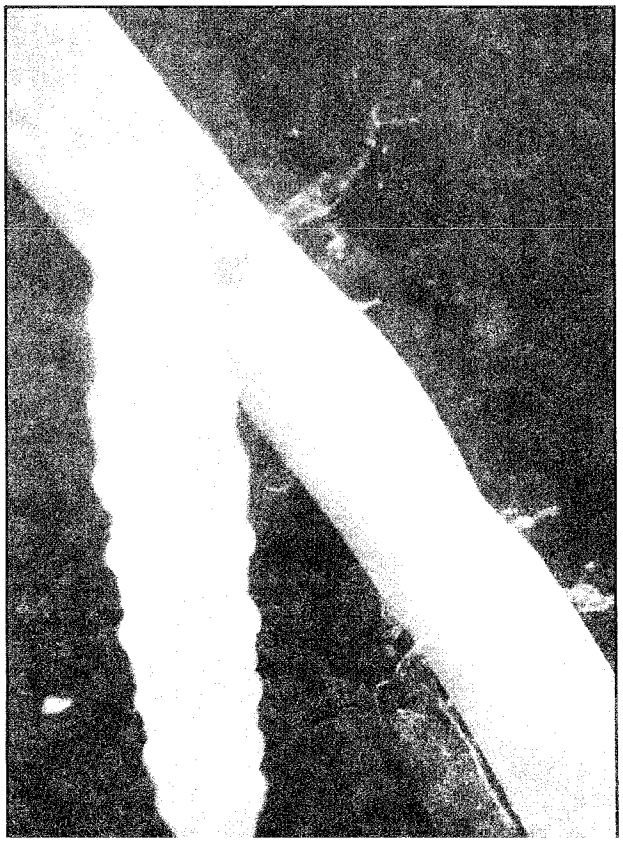
Figure 12. Adult of the rice water weevil and typical feeding injury.

Figure 13. Floating leaves of wild rice injured by adults of the rice water weevil.

Figure 14. Larvae of rice water weevil on roots of wild rice. They burrow into and cut off roots of the plant.

Figure 15. Larva of rice water weevil attached to root of wild rice.





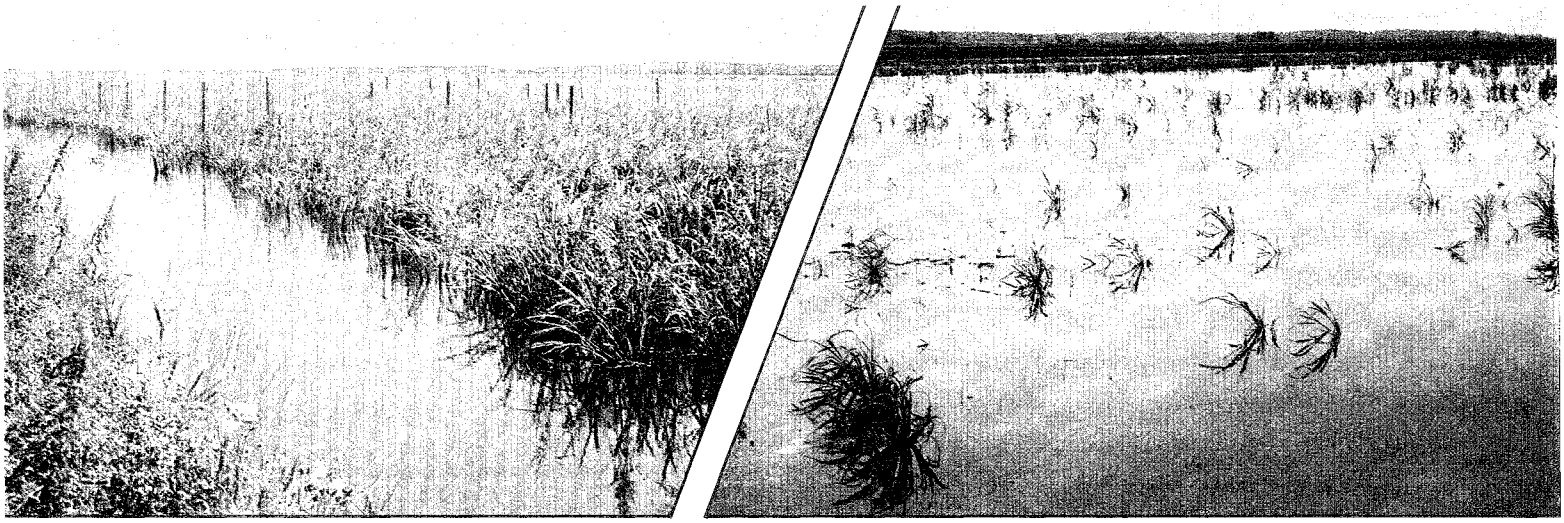
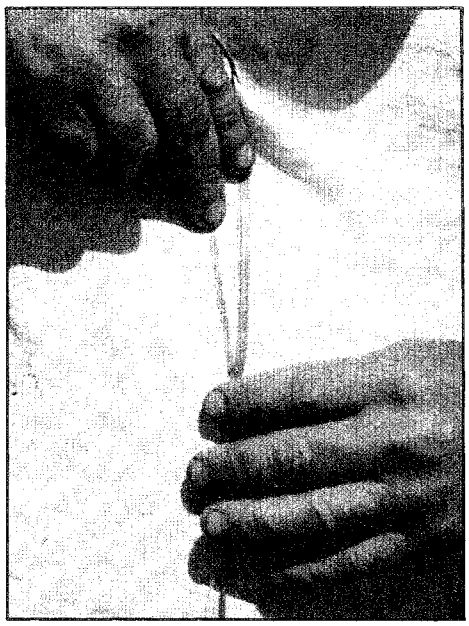


Figure 16a & b. Normal (a) and midge damaged (b) first year stands.



◀ Figure 17. Midge-damaged wild rice leaves.

Figure 18a & b. Rice leafminer injury in field and container plots. ▼

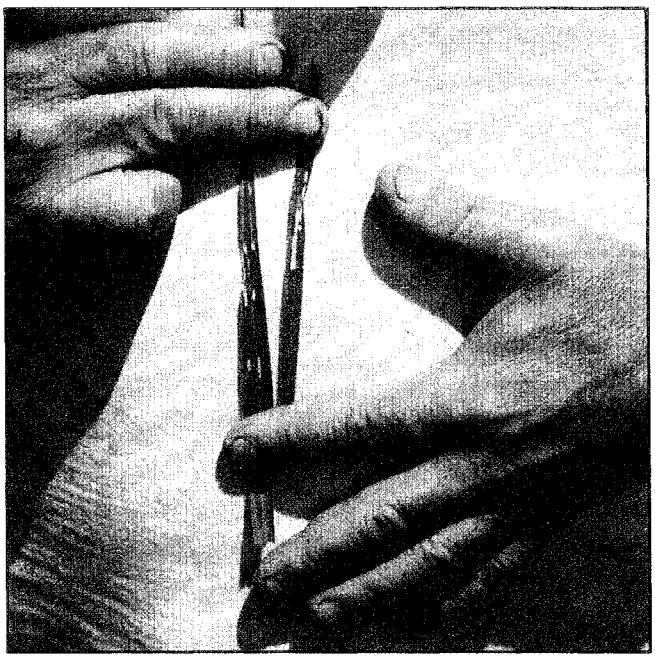
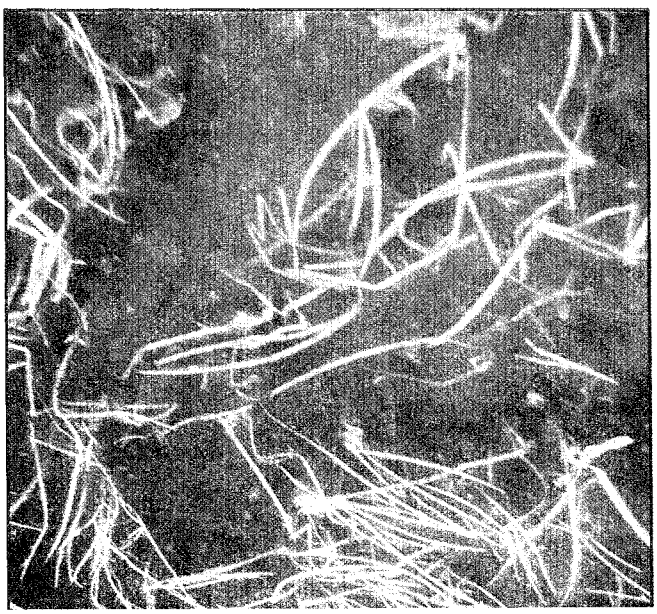


Figure 19. Rice stem maggot injury.



## The Rice Stalk Borer (*Chilo plejadellus* Zincken)

The rice stalk borer, *Chilo plejadellus* Zincken, was considered to be a minor pest during the early years of commercial production of wild rice (Oelke *et. al.*, 1973). However, it became very abundant in 1974. In parts of some paddies, 90 percent of the stems were infested. Occasional stems contained 8 to 15 borers. Growers became concerned about the effects of stalk borers on yields and were interested in possible methods of control. Surveys conducted in 1975 indicated that many commercial paddies were infested with stalk borers. Stalk borers were widely distributed also in natural stands of wild rice in Minnesota (Sargent, 1975, 1979).

It became obvious from the authors' observations in fall 1974 that stalk borers overwinter in the larval stage inside the stems of wild rice. Further observations in spring 1975 revealed that stalk borer larvae had overwintered in the stems of many species of weeds in the rice paddies and on the ditch banks. Nineteen species of plants contained overwintering larvae, but the larvae were found most commonly in wild rice stubble, cattails, and pigweed (Sargent, 1975). Most larvae were found in the rice paddies or within a few meters of the paddies. Larvae pupated in the stems during late May and early June, and the first emergence of adults occurred on June 12, 1975.

The adults of the rice stalk borer are light tan with a row of black dots along the distal margin of the fore wing (figure 9). Newly emerged specimens have an oblique diffused golden brown band across the forewing and scattered golden scales. According to light trap catches (Ellisco 12 volt, black light fluorescent lamp GE-F15T8/BL), the flight period lasted from June 12 to August 2, 1975, and the peak of flight activity occurred during the first week of July. Flight periods were about a week later in 1976 and 1977 (table 11). Eggs of the stalk borer are laid mostly on floating leaves. The eggs are circular, flat, cream colored, and laid in overlapping rows. Each egg mass contains a few to 100 or more eggs (Sargent, 1979). These become orange just before hatching (figure 10), and incubate in about 6 days. Newly hatched larvae feed on leaves and leaf sheaths and produce tiny elongated holes in the foliage. Later they bore into the plants, tunnel down the stem to a point just above the waterline, and enter the hollow part of the stem where they feed until October (Sargent, 1979). A single stem may harbor from 1 to 15 larvae (figure 11). During October the large larvae move about, apparently in search of dry overwintering quarters, and end up in the stems of many plants in the rice paddies and on the dikes.

**Table 11. Seasonal observation on rice stalk borers**

| OBSERVATIONS | YEAR | | | |
|---|---|---|---|---|
| | 1975 | 1976 | 1977 | 1978 |
| First emergence of adults | June 12 | June 4 | June 5 | June 11 |
| First eggs observed | June 12 | June 10 | June 7 | June 28 |
| Peak of moth flight | July 1-7 | June 14 | June 16 | June 28 & July 12 |
| Maximum catch per night in light trap | 113 | 195 | 15 | 8 |
| Flight period | June 12-August 2 | June 14-July 20 | June 5-July 11 | June 11-July 28 |

Stalk borer can be distinguished from riceworm by the cervical shield just posterior to the head (see figure 10, the dark band separate and to the rear of the head capsule). In some years a marked movement of riceworm larvae into the rice stems occurs and this is always after the fields are drained.

The rice stalk borer may cause several different types of injury. The most conspicuous is "white head" or "dead heart" which results when the stalk borer cuts off or girdles the inner part of the stem bearing the panicle. This is common on white rice, but not on wild rice. The authors observed occasional white panicles, but the incidence was always less than 1 percent, even in paddies where 50 percent of the stalks were infested with stalk borers. The authors' observations indicate that large borers in young tillers are most likely to cause white panicles in wild rice.

A second type of injury, called "dead heart," is characterized by wilting and death of young leaves near the growing point of the plant and failure of the stalk to produce a panicle. Although "dead heart" is common on white rice, it is rare on wild rice. Apparently wild rice's thicker stems make it much more tolerant than white rice to injury by the stalk borer.

A third type of injury is lodging. Stalk borers and rots associated with borer injury may weaken the stalks and make them subject to lodging following heavy rains or strong winds. The authors observed small areas in 1974 where nearly all of the stalks were lodged. However, there was a low incidence of stalk borers in all such areas the authors examined, and most of the lodging seemed to be associated with a root rot. No lodging due to stalk borers was observed by the authors in 1975.

A fourth type of injury is loss in yield. Accurate figures are difficult to obtain and require experiments over several years. The authors' experiments in 1975, 1976, and 1977 indicate that the rice stalk borer causes relatively little loss in yield even in paddies which have 30 to 50 percent stem infestation.

A fifth type of injury is loss in quality. The authors have some evidence that heads from borer-infested stems produce a higher proportion of poorly filled grains than heads from healthy stems.

## Evaluation of Injury by Rice Stalk Borers

To evaluate the effect of stalk borer infestions on yields and quality of wild rice, the authors collected heads from borer-infested and healthy plants. To achieve an unbiased sample, each head was selected at random and then the stem was dissected to determine whether it was borer-infested or healthy. Heads were segregated according to whether from borer-infested or healthy stems. Kernels from each head were weighed and classified as plump or poorly filled. In 1975, the authors compared 11 paired groups of heads from borer-infested and healthy stems (20 heads per group) at Clearbrook, and at Grand Rapids the authors compared the average yield of 94 heads from borer-infested stems with the average yield of 282 heads from healthy stems. In 1976, the average yield of 57 heads from borer-infested stems was compared with the average yield of 204 heads from healthy stems; and in 1977, the average yield of 132 heads from borer-infested stems was compared with the average yield of 173 panicles from healthy stems. Panicles from borer-infested stems yielded slightly, but consistently, less than panicles from healthy stems (table 12). The calculated loss for a 100 percent infestation of stalk borers ranged from 5.1 to 9.2 percent. The actual losses in yields in commercial fields would be less because infestations are always less than 100 percent.

Table 12. Average yields of wild rice in grams per panicle from borer-infested and from healthy stems, and calculated loss from 100 percent infestation of borers

| SOURCE AND PERCENT LOSS | LOCATION AND YEAR | | | |
|---|---|---|---|---|
| | GRAND RAPIDS 1975 | CLEARBROOK 1975 | AITKIN 1976 | AITKIN 1977 |
| Borer-infested | 2.017 | 1.815 | 2.363 | 0.798 |
| Healthy | 2.126 | 1.996 | 2.535 | 0.872 |
| Percent loss | 5.1 | 9.1 | 6.8 | 8.5 |

To compare the percentages of plump and poorly filled kernels from panicles of borer-infested stems with those from healthy stems, the authors selected 10, 1-gram samples of kernels from panicles borne on healthy stems and comparable samples from panicles borne on borer-infested stems. An average of 32 percent of the kernels from healthy stems were classified as plump, compared with 24 percent plump kernels in panicles from borer-infested stems (table 13).

Table 13. Effect of stalk borers on the quality of grain

| SOURCE | PERCENT OF KERNELS | |
|---|---|---|
| | PLUMP | POORLY FILLED |
| Healthy | 32[1] | 68 |
| Borer-infested | 24 | 76 |

[1]Difference significant at the 5 percent level.

## Control of the Rice Stalk Borer

Cultural practices offer the most promising means of controlling the rice stalk borer. Rotovating paddies in the fall after harvest gave excellent control of the overwintering larvae. In Clearwater County on October 16 and 17, 1974, according to the authors counts of living and dead stalk borers, rotovating gave a 92 percent reduction in numbers of living larvae. Although burning the stubble gave 90 percent reduction in living larvae in areas actually burned, numerous unburned "islands" remained, and such unburned areas could provide sources of infestation in the spring. Sanitation of ditch banks is important because many stalk borer larvae overwinter in stems of weeds in areas adjacent to the rice paddies (Sargent, 1975, 1979).

A braconid wasp, *Chelonus knabi* Vier, is an important parasite of the rice stalk borer. Sargent (1975) observed that 50 percent of the overwintering stalk borer larvae which he collected at Clearbrook, Minnesota, were parasitized by this wasp. In spring 1976 Sargent found that 79 percent of the larvae were parasitized at Aitkin, 32 percent at Grand Rapids, and 34 percent at Clearbrook. The adult wasp oviposits in the eggs of the stalk borer. The parasitized stalk borer eggs hatch and larvae develop normally and overwinter until the following spring. The parasitized larvae die before pupation, and the adult wasps emerge and are present during the oviposition period of the stalk borer.

Sanitation of paddies and ditch banks in the fall to kill overwintering larvae and destruction of larvae by *Chelonus* parasites have apparently been responsible for decreased numbers of stalk borers beginning in 1976 and continuing through 1977 and 1978.

Several insecticides were evaluated for effectiveness in controlling rice stalk borers in 1975. Carbaryl, diazinon (0,0-diethyl 0-[2-isopropyl-4-methyl-6-pyrimidyl]phosphorothioate), and malathion were applied to 30 by 40 foot plots at Clearbrook. One application of each insecticide was applied to a series of plots July 15, and a second series of plots received applications of insecticides on July 10, 15, and 20. The same insecticides were applied to a series of plots at Grand Rapids on July 10, 15, and 20. A single application of diazinon or malathion did not reduce the incidence of stalk borers at Clearbrook, but carbaryl did result in some reduction. Three applications of the insecticides resulted in significant reductions in percent stems infested at both Clearbrook and Grand Rapids. Diazinon appeared to be most effective (table 14). Similar results occurred in numbers of rice stalk borer larvae per 100 stems (table 15). Although three applications of diazinon gave 90 percent control of rice stalk borers and carbaryl 73 percent control in the Clearbrook experiment, the insecticides did not result in increased yields (table 16). Yields seemed to increase at Grand Rapids (table 16), but the increases there may have resulted from the control of a moderately heavy infestation of riceworms.

Table 14. Effect of insecticides on percent stems infested by the rice stalk borer

| INSECTICIDE | RATE A.I./ACRE | LOCATION AND (NUMBER OF APPLICATIONS) | | |
|---|---|---|---|---|
| | | CLEARBROOK (1) | CLEARBROOK (3) | GRAND RAPIDS (3) |
| Check | — | 32.0[1] | 35.0 | 32.5 |
| Carbaryl | 1.5 lb | 14.0 | 9.5 | 10.0 |
| Diazinon | 0.5 lb | 31.5 | 3.5 | 3.5 |
| Malathion | 1.3 lb | 30.0 | 17.0 | 9.0 |

[1]Percent stems infested.

Table 15. Effects of insecticides on numbers of rice stalk borers per 100 stems

| INSECTICIDE | RATE A.I./ACRE | LOCATION AND (NUMBER OF APPLICATIONS) | | |
|---|---|---|---|---|
| | | CLEARBROOK (1) | CLEARBROOK (3) | GRAND RAPIDS (3) |
| Check | — | 28.5[1] | 44.0 | 27.5 |
| Carbaryl | 1.5 lb | 13.0 | 7.5 | 9.0 |
| Diazinon | 0.5 lb | 32.5 | 2.5 | 2.5 |
| Malathion | 1.3 lb | 31.5 | 16.5 | 9.0 |

[1]Average stalk borers per 100 stems.

Table 16. Effect of insecticides for rice stalk borer control on yields expressed as grams of cleaned seed per 100 square feet

| INSECTICIDE | RATE A.I./ACRE | LOCATION AND (NUMBER OF APPLICATIONS) | | |
|---|---|---|---|---|
| | | CLEARBROOK (1) | CLEARBROOK (3) | GRAND RAPIDS (3) |
| Check | — | 515[1] | 502 | 576 |
| Carbaryl | 1.5 lb | 520 | 486 | 675 |
| Diazinon | 0.5 lb | 495 | 444 | 628 |
| Malathion | 1.3 lb | 522 | 509 | 651 |

[1]Grams of cleaned seed per 100 square feet.

The correlation between yields and percent borer-infested stems for 16 individual sub-plots at Clearbrook was +0.36 which was not significant. A negative correlation was expected if the borers had any adverse effect on yields in this experiment. There was no relationship between percent infested stems and

number of panicles per plot. There was a correlation of –0.55 between yields and percent borer-infested stalks in the 8 subplots at Grand Rapids. This correlation may reflect the relationship of riceworms to yields rather than the effect of stalk borers.

Further evaluations of insecticides to control the stalk borer were continued in 1976. Chlordimeform (N'-[4 chloro-o-tolyl]-N, N-dimethylformamidine) (Galecron) applied July 1 and 9 at Aitkin and July 2 and 8 at Grand Rapids gave the best stalk borer control of any material the authors tested (tables 17 and 18). It has been reported to control rice stalk borers in Europe without harming fish, and it did not kill lady beetles in these experiments. Unfortunately, there is some question of cancer in mice, and the manufacturers withdrew all uses of chlordimeform until further tests can be made. At Aitkin both *Bacillus thuringiensis* (Dipel) and diflubenzuron were significantly less effective against stalk borers than chlordimeform, but significantly better than diazinon or the untreated check (table 17). At Grand Rapids only chlordimeform was significantly better than the check (table 18). Only 6 percent of the stalks were infested in the checks, and the differences in yields were not significant at either location.

**Table 17. Control of the rice stalk borer: Aitkin, 1976 (insecticides were applied July 1 and July 9)**

| TREATMENT | RATE A.I./ACRE | PERCENT STALKS INFESTED | YIELD IN GRAMS/ 12 SQUARE YARDS |
|---|---|---|---|
| *B. thuringiensis* | 1.0 lb | 2.5[1] | 621 |
| Diflubenzuron (Dimilin) | 0.5 lb | 2.0[1] | 601 |
| Diazinon | 0.5 lb | 4.2 | 434 |
| Chlordimeform | 1.0 lb | 0.5[1] | 520 |
| Check | — | 5.8 | 527 |

[1]Significantly lower than the check at the 5 percent level.

**Table 18. Control of the rice stalk borer: Grand Rapids, 1976 (insecticides were applied July 2 and July 8)**

| TREATMENT | RATE A.I./ACRE | PERCENT STALKS INFESTED | YIELD IN GRAMS/ 12 Square Yards |
|---|---|---|---|
| *B. thuringiensis* | 1.0 lb | 2.9 | 1,323 |
| Diflubenzuron (Dimilin) | 0.25 lb | 5.4 | 1,416 |
| Chlordimeform | 1.0 lb | 0.8[1] | 1,529 |
| Check | — | 5.5 | 1,365 |

[1]Significantly lower than check at the 5 percent level.

Rotovation of paddies soon after harvest and cleaning up ditch banks, together with natural control by parasites, appeared to make the use of insecticides unnecessary for control of the stalk borer. This is fortunate because no insecticides have been approved for their control.

## Rice Water Weevil (*Lissorhoptrus oryzophilus* Kuschel)

During 1974 and 1975, the authors occasionally observed a small weevil feeding on the floating leaves of wild rice (figure 12). It caused characteristic linear holes (figure 13) in the leaves. When J. R. Gifford of the USDA Rice Insects Research Laboratory, Baton Rouge, Louisiana, visited Grand Rapids, Minnesota, in summer 1975, he found larval stages (figures 14 and 15) of weevils on the roots of an experimental planting of white rice. He recognized these as larvae of the rice water weevil, *Lissorhoptrus oryzophilus* Kuschel. Hanson (1979) found that there were actually two species of rice water weevils present on wild rice in Minnesota, *Lissorhoptrus oryzophilus* Kuschel and *L. buchanani* Kuschel. Both species are widely distributed in the state, and both occur in the same paddy of wild rice (Hanson, 1979).

The rice water weevil appeared to be increasing in abundance during 1976 and 1977, especially at Grand Rapids. Feeding injury on floating leaves was so prevalent in Grand Rapids plots during 1977 that all paddies except 1 untreated check were sprayed with diazinon during May. The diazinon resulted in a reduction in adult weevils but did not reduce the numbers of larvae which appeared later on the roots. The authors observed the weevils were spotted in distribution and less numerous in commercial paddies than in the experimental plots at Grand Rapids. The weevils continued to be abundant in the paddies at the Grand Rapids Experiment Station during 1978, but not a single commercial paddy was found in which they were abundant enough to cause economic damage.

Life history studies were conducted on *L. oryzophilus*, which is the more important species, but the life history of *L. buchanani* is probably similar. Adults overwinter primarily in sod along the ditch banks. On May 5, 1978, adult rice water weevils were found up to 8 per square foot in sod along the ditch banks at Grand Rapids. Some of the weevils were feeding to a limited extent on leaves of bluegrass, and some were mating. Dispersal from overwintering sites to wild rice occurred between May 19 and May 27. Adults feed on the floating leaves of wild rice and leave long narrow holes in the leaves. Larvae were quite abundant during late July and early August. Although they averaged less than 10 per plant, roots of some plants had from 20 to 47 larvae. Pruning of the roots was evident wherever the authors found larvae on the roots, but it was not observed to result in lodging of plants. Larvae pupated during late July and August. Pupation takes place in a cocoon resembling a tiny ball of mud which is attached to the roots of the plant. New adults began to emerge August 9. These newly emerged adults fed for a time and then migrated to overwintering sites along the ditch banks.

Although the rice water weevil is considered to be one of the most important pests of white rice in the United States, it has not become a major pest of wild rice in Minnesota. There are several possible reasons. In the southern states where white rice is grown, the weevil has two generations per year; in Minnesota it has only one. Commercial paddies of wild rice are usually drained about August 1 when most of the rice water weevils are in the larval stage, and then they die (Hanson, 1979). Drainage of paddies is one of the methods recommended for control of the rice water weevil on white rice. The experimental paddies at Grand Rapids are not usually drained until harvest time in late August or September, and this may explain why the weevil has become more abundant at Grand Rapids than in commercial wild rice paddies.

# OTHER INSECTS OCCURRING ON WILD RICE

## Wild Rice Midge (*Cricotopus* spp, Family: Chironomidae)

Severe damage to some first year stands of wild rice (figures 16a and b) continues to take place as a result of high populations of midge larvae. First year fields should normally have from 1 to 4 wild rice plants per square foot. Yield losses occur when stands are reduced below 4 plants per square foot. Larval midge numbers are significantly greater in second year and older fields, but plant population is so great that damage goes unnoticed.

The adult midge is commonly mistaken for a mosquito. However, they do not have the scales along the wing veins and margins. They also lack functional mouthparts. *Cricotopus* adults are comparatively small and dusky appearing so they will rarely be noticed by the grower.

Eggs are laid in a gelatinous mass in the soil and are present prior to seeding and flooding the field. It is probable that the conditions of the field (such as plant community, soil type), prior to preparation for seeding, contribute to midge egg deposition. Midge larvae build delicate silken tubes, both on and off the rice plant, within which larvae stages are passed. When these tubes are attached to the plant, the silken webbing itself interferes with leaf emergence from the whorl and leaf elongation. It is highly probable that wild rice plant photosynthesis is reduced as well. The silken webbing often becomes covered with mud and algae; thus the presence of midges can readily be seen by growers.

The larvae can also cause primary damage (figure 17) to the developing rice plant. They feed on the leaf tissue outside the silken tube, first severely abrading the leaf surface and edges, and then feed on the remaining pulpy tissue. This type of injury occurs before the floating leaf stage, causing the surface plant parts to lose their distinct structure.

The authors have not observed larval damage to the seed itself.

More severe damage seems to take place during warmer than normal springs. Greater damage occurs in fields where the water depth is less, again a function of temperature. However, within a single field the authors observed more midge damage where water depth is greater, such as in wheel tracks and borrow pits, probably because plants take longer to emerge from deeper water, thus allowing more time for the midge to injure the plants.

Fields showing midge damage also seem to have problems with excessive growth of algae. The algae may accentuate the damage by adhering to underwater leaves as well. Many fields with an excessive growth of algae, however, escape midge injury.

The authors have observed severe midge injury in fields with both peat and mineral soils so it is not known whether the midge has a soil preference.

Many first year stands suffer economic stand reduction due to midge feeding and occasional fields are totally destroyed. Thus some chemical control of midge larvae becomes necessary. Malathion, the only insecticide labeled for use on wild rice, provides some protection. However, it has some limitations and a more effective material would be desirable. The small market and legal limitations greatly limit such work.

## Wild Rice Leafminers (*Hydrellia griseola* [Fallin] and *Hydrellia ischiaca* Loew Family: Ephydridae)

Both species are widespread and abundant in Minnesota, but do not cause significant problems in cultivated fields. However, they can cause severe problems in small indoor and outdoor (figures 18a and b) experimental plots.

An excellent treatment of *H. griseola* has been done by Grigarick (1959) working in California with white rice as a host. Deonier (1971), while revising the genus *Hydrellia*, has included observations about the biology of *H. ischiaca* in Minnesota.

The general life cycle is as follows: egg stage, 2-7 days; larval period (3 instars), 9-18 days; pupal stage, 4-20 days. There are several generations during the growing season. Eggs are laid in masses either on the floating leaf or erect plant. Larvae mine the mesophyll layer of the leaf causing the leaf to lose its grassy structure. It is fairly common to observe several larvae in one leaf. Such infestations lead to disruption of movement of plant nutrient to the leaf tip and a subsequent chlorotic appearance. In both experimental plots (shallower water and warmer temperatures) and field situations, leafmining is most prevalent during the floating leaf stage. Once the plant becomes erect, mines can be observed but they are fewer and never economically important.

Grigarick (1959) lists forty-three Hymenoptera parasites of *H. griseola*. He indicates that the peak of parasitism occurs shortly after the seasonal population peak. Evidence available does not seem to support effective biological control, however.

Control of rice leafminer with malathion has not been effective either in field or experimental plots. Because the damage is rarely economic in the field in Minnesota little emphasis has been placed on seeking successful chemical controls.

## Wild Rice Stem Maggot (*Eribolus longulus* [Loew] Family: Chloropidae)

Perforated leaves due to larval feeding of this insect are not unusual in wild rice in Minnesota. Less common is damage to the tip of the stalk which bears the male and female florets. The head may not emerge from the whorl (figure 19), or if it does, the female and/or male florets may be broken off. Both types of damage were done while the head was in the "boot."

The rice stem maggot appears to have more than one generation per year. It is probably the second generation which is found in wild rice.

Additional information about the rice stem maggot biology is not available. Melvin (1966) has also reported very minor damage by this insect in Manitoba. The authors have observed noneconomic damage in most rice growing areas in the state. The most severe damage occurred in the corner of a small field surrounded by reed canarygrass. Stem maggot damage in the rice exceeded 50 percent of the stems while perforated leaves were common in the adjoining reed canarygrass. However, such injury is rare and the insect would have to be considered noneconomic.

## ADDITIONAL INSECTS

Wild rice, like many other grasses, harbors a rich and varied fauna of insect species; however, relatively few of these can be considered pests. Other insects, which may become abundant at times but are not known to be of economic significance, include the aster leafhopper, *Macrosteles fascifrons* (Stål); several species of aphids, *Macrosiphum avenae* (Fabr.) and *Rhopalosiphum padi* (L.); several unidentified species of thrips; leaf beetles, *Donacia* sp.; and several species of weevils. Many beneficial insects occur in the wild rice paddies, including several species of lady beetles, dragonflies, parasitic wasps, and many other parasites and predators.

## ACKNOWLEDGMENTS

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