# Wireworm (Coleoptera: Elateridae) Effects on Sugarcane Emergence after Short-Duration Flood Applied at Planting[1]

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**Abstract** The purpose of this study was to analyze sugarcane, interspecific hybrids of *Saccharum* spp., emergence under severe wireworm, *Melanotus communis* Gyllenhal, pressure after floods of 7, 14, and 21 d applied at planting, as well as following a conventional application of an organophosphate insecticide at planting without flooding. In three experiments, wireworms were applied at the rate of 13 larvae per m of row in plastic containers filled with Pahokee muck soil. In the first experiment, sugarcane bud emergence percentages under the flood treatments were lower than under the insecticide treatment, probably due to lower than normal air and soil temperatures. Emergence percentages in the 14- and 21-d flood treatments and the insecticide treatment were similar in the final two experiments, except that the 14-d flood resulted in greater emergence than the insecticide treatment in the second experiment. Reductions in plant weight were associated with some flood treatments. Previous work reported that wireworms damaged growing plants in containers, but damage was primarily limited to reduced emergence in field studies. This study identified short-term flooding in sugarcane as a potential measure to control wireworm damage with environmental and economic benefits. Temperature-response and field studies are needed to verify results.

**Key Words** Sugarcane, wireworm, Everglades, integrated pest management, Histosol, flooding

The Everglades Agricultural Area (EAA) is a 280,000 ha basin of Histosols that cover limestone rock in the northern region of the Everglades in Florida. Sugarcane is grown on about 144,000 ha in the EAA (Glaz 1999). Sugarcane farmers typically apply an organophosphate soil insecticide at time of planting to control wireworm, *Melanotus communis* Gyllenhal, damage to newly-planted sugarcane stalk sections (Hall 1985). Samol and Johnson (1973) and Coale and Sosa (1991) reported increased sugarcane yields in Florida by controlling wireworms through the use of soil insecticides at planting. Hall (1985) reported that if confined to pots, and introduced at heavy densities, wireworms not only damaged buds on the planted stalk sections, but also reduced root and shoot weight. However, in field studies, at densities of up

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to 3.3 wireworms per m of row, Hall (1985) reported that damage was due only to reduced emergence from planted stalk sections.

Prior to planting sugarcane in Florida, fields can be flooded continuously for at least 6 wks during warm weather, and longer during cool weather, to control wireworms (Hall and Cherry 1993). Glaz (2001) reported that flooding sugarcane at planting for up to 12 d enhanced its emergence rate and its ultimate emergence. In that research, it was not known if 12 d was the maximum beneficial flood duration, rather it was the longest flood duration attempted. The research of Glaz (2001) was conducted to find a cycle for Florida sugarcane growers to maintain a flood on their organic soils to improve their conservation. From the early 1900's until 1978, these soils subsided at a rate of about 2.5 cm per yr (Shih et al. 1978). This soil subsidence is due primarily to aerobic microbial activity (Tate 1980). Therefore, the most logical means of reducing subsidence is progressively higher water tables, with flood providing the most control. Since 1978, this subsidence rate was reduced to 1.4 cm per yr, probably due mostly to grower efforts to maintain crop yields while raising water tables (Shih et al. 1998).

Control of wireworm damage might provide an economic incentive to attempt the new strategy of flooding sugarcane fields at time of planting. The cost of phorate to control wireworms in sugarcane in Florida is approximately $87 per ha. This is only the cost of the product; it is generally applied as stalk sections planted in the furrow are covered with soil so other application costs are minimal. Alvarez (1992) estimated the cost at $40 per ha to maintain a flood on rice, *Oryza sativa* L., for 80 d.

We hypothesized that a short-duration flood timed immediately after planting would control the damage caused by wireworms without killing the wireworms. One reason for this hypothesis was the new knowledge that flooding sugarcane at planting for 2 to 12 d improved bud emergence (Glaz 2001). This improved emergence was due to more rapid and increased emergence. A second basis was the possibility that wireworms would become inactive during a flood. The purpose of this study was to examine sugarcane emergence under severe wireworm pressure after floods of 7, 14, and 21 d applied at planting, as well as following a conventional application of an organophosphate insecticide at planting without flooding.

## Materials and Methods

Sugarcane cultivar CP 89-2143 was planted in three experiments at Canal Point, FL, from December through February. Commercial sugarcane in Florida is planted from August through March, but primarily from September through December. The first experiment was planted 15 December 2000 and terminated 22 February 2001. The second experiment was planted 7 February 2001 and terminated 3 April 2001. The third experiment was planted 23 February 2001 and terminated 23 April 2001. Experimental units in each experiment were plastic containers placed on the soil surface in a field. In the first two experiments, containers were 69 cm long × 54 cm wide × 41 cm high. Because containers of this size were not available later, container size was changed to 53 cm long × 44 cm wide × 44 cm high in the third experiment. Containers were filled with Pahokee muck soil (Euic, hyperthermic Lithic Haplosaprist). In the first experiment, containers were filled with about 13 cm of soil. To better simulate natural conditions in the final two experiments, containers were filled with soil to about 10 cm from the top of each container. The sugarcane stalk sections planted in each container were cut in pieces 2 to 3 cm less than the length of the containers. Three stalk sections were planted in the center of each container.

Larvae of *M. communis* (= wireworms) were collected from commercial sugarcane fields during a 2-wk period prior to each experiment. This is an active feeding period of *M. communis* larvae in the Florida Everglades (Hall 1985; Hall 1990). Before application, wireworm larvae were provided carrots for food while held in the laboratory at about 22°C in pans filled with Pahokee muck soil. On the day that each experiment was planted, wireworms were placed into each container at the rate of 13 larvae per m of row. Hall (1985) reported a damage threshold of three *M. communis* larvae per m of planted sugarcane row. The wireworm infestation rate we used was substantially higher than the damage threshold reported by Hall (1985), and provided a stringent test for all treatments designed to control wireworm damage to sugarcane emergence.

Each experiment had five replications with five treatments arranged in a randomized complete block design. Treatments not involving flood were an untreated control and the soil insecticide Thimet® 20G[1] (American Cyanamid Company, Parsippany, NJ) (phorate) applied at the rate of 4.3 kg AI per ha. The phorate was sprinkled over the planted sugarcane stalk sections. After phorate application, the planted stalk sections in both the untreated control and the phorate treatments were covered with soil, as in conventional commercial planting. The three other treatments were continuous flood durations of 7, 14, and 21 d begun immediately after planting. Sugarcane stalk sections in the flood treatments were not covered with soil until drained. Only sufficient soil was used to completely cover the stalk sections when stalks in all treatments were covered. Phorate and flood treatments were applied after all wireworms had burrowed beneath the soil surface. Soil temperatures were monitored 6 cm below the soil surface with HOBO®[3] (Onset Computer Corporation, Pocasset, MA) data loggers in one replication of each experiment. For treatments that were not flooded and during non-flood periods of flood treatments, soil was monitored frequently and irrigated or drained so that inappropriate moisture would not limit emergence.

In the first experiment, the mean number of buds planted per container was 15 (±SE 0.04) (range 13 to 18). In the second experiment, the mean buds planted per container was 17 (±SE 0.06) (range 15 to 21). In the third experiment, the mean buds planted per container was 13 (±SE 0.05) (range 11 to 16). Only healthy, nondamaged buds were planted. Final emergence counts were determined by removing stalk sections from the soil and counting emerged primary stalks from individual buds 69, 55, and 59 d after planting Experiments 1, 2, and 3, respectively. After removing the sugarcane (planted stalk sections and growing above ground stalks), the soil from each container was spread out on a flat surface and visually examined for live wireworm larvae, pupae, and adults. These final insect counts as well as measurements of total sugarcane aboveground fresh weights were determined on the date each experiment was terminated.

Analyses of variance were calculated with MSTATC (Freed et al. 1991) using a randomized complete block design. Significant LSD values were sought at $P$ 0.05 to determine differences among treatments means. Since emergence was calculated as a percentage, its analyses were conducted with data weighted by number of buds, weighted data transformed by the arcsin transformation, and with data not weighted or transformed. Conclusions were similar for all analyses so all data and analyses presented are of data that were not weighted and not transformed.

## Results and Discussion

**Emergence.** The experiment × treatment term was significant ($F = 2.7$; df = 8/48; $P = 0.02$) in the analysis of variance for emergence combined across all three experiments. Therefore, the emphasis in this section is placed on analyses from the individual experiments. While keeping in mind that this interaction existed, comparisons of combined-experiment means are also noted to help emphasize differences among experiments. Flooding wireworms and stalk sections for 7 d resulted in an overall mean emergence percentage similar to that of the control treatment (Table 1). Flooding for 21 d resulted in an overall mean emergence percentage lower than that of the phorate treatment, but higher than that of the 7-d flood. Flooding for 14 d or treating with phorate resulted in similarly high emergence percentages.

In the first experiment, emergence was low for all treatments. However, the use of phorate resulted in significantly higher emergence than any other treatment. The three flood treatments and the control all had similarly low emergence percentages. Thus, in the first experiment, flooding for 7 through 21 d did not control wireworm damage to sugarcane emergence.

Air and soil temperatures were the lowest of the three experiments during the first experiment and were probably the cause of the low emergence. Minimum soil temperatures during December 2000 and January 2001 averaged 10.1°C in the phorate containers, 9°C in the untreated control, and 7.1°C in the flooded containers. These temperature differences may have been partially responsible for the increased emergence associated with the phorate treatment. In the second and third experiments, wireworm treatment did not affect soil temperature. The minimum soil temperatures averaged 17.6°C in the second experiment and 18.8°C in the third experiment. Minimum air temperatures averaged about 5°C lower in the first experiment than in the final two experiments.

**Table 1. Mean percent emergence of sugarcane buds in three experiments for each of five wireworm-control treatments***

| Treatment | Experiment 1 | Experiment 2 | Experiment 3 | Overall mean |
|---|---|---|---|---|
| | % emergence | | | |
| Control | 23.0b | 62.1b | 43.2b | 45.6cd |
| Phorate | 44.5a | 70.1ab | 74.9a | 63.1a |
| 7-d flood | 29.8b | 66.0ab | 42.7b | 44.8d |
| 14-d flood | 27.3b | 79.8a | 71.4a | 59.0ab |
| 21-d flood | 20.7b | 69.7ab | 68.4a | 53.6bc |
| Mean | 29.1 | 69.5 | 60.2 | 52.9 |
| LSD ($P = 0.05$) | 14.3 | 15.0 | 19.2 | 8.6 |

* Within columns, means followed by the same letter are not significantly different according to LSD (0.05).

In the second experiment, the mean emergence percentage was more than double that of the first experiment (Table 1). Romero et al. (2001) reported that emergence percentage increased as air temperature increased from 20 to 28°C. Thus, the greater emergence percentages in Experiment 2 were presumably due to the higher soil temperatures recorded in Experiment 2 compared with Experiment 1. Emergence was low in the control, but not significantly lower than that of the phorate treatment in Experiment 2. There were no differences among any treatments in the second experiment except that emergence from the 14-d flood treatment was higher than that of the control and almost significantly higher than that of the 7-d flood ($P = 0.07$). In the third experiment, flooding for 14 or 21 d resulted in emergence similar to that of phorate, and all three treatments had higher emergence than flooding for 7 d or the control (Table 1).

At the minimum soil temperatures recorded in Experiment 1 (7.1°C), flood durations of 7 to 21 d did not provide acceptable control of wireworms. However, results of Experiments 2 and 3 suggest that floods of 14 and 21 d would control wireworm damage at least as well as the conventional phorate treatment when minimum soil temperature is at least 17.6°C. Hall and Cherry (1993) reported that wireworm mortality due to flood increased as temperature increased from 18 to 27°C. The results of Hall and Cherry (1993) combined with results reported here suggest that the success of flooding at planting to control wireworms will be temperature dependent. Further research is needed to more precisely quantify the effects of soil temperature and flooding at planting on wireworm control and sugarcane emergence.

These experiments began in December and ended in April. Cherry and Hall (1986) reported that seasonal flight activity in *M. communis* in Florida occurs primarily during May and June. Therefore, wireworm larvae, pupae, and adults recovered in the containers were probably from our original larvae. The experiment × treatment interaction was highly significant ($F = 2.9$; df = 8/48; $P = 0.01$) in the analysis of variance for number of wireworms recovered combined across the three experiments. In Experiment 1, the 21-d flood resulted in a reduced number of live wireworms recovered at the end of the experiment compared with the control and 14-d flood (Table 2). Otherwise, in all three experiments, the total number of live wireworms recovered was similar in the control and all three flood treatments (Table 2). Significantly less wireworms were recovered from the phorate treatment than from floods of 7 and 14 d in Experiment 1 and floods of 14 and 21 d in Experiment 3. Number of wireworms recovered after phorate application was similar with the five other flood treatments of Experiments 1 to 3. These results are consistent with efficacy of phorate against *M. communis* recently reported by Cherry and Raid (1999).

Except for the 21-d flood in Experiment 1, the three flood durations did not result in increased mortality of wireworm larvae relative to the untreated control. These results were consistent with the conclusion of Hall and Cherry (1993) that flood durations up to 21 d were not sufficient to kill wireworms. However, our data show that, under heavy wireworm pressure in containers, sugarcane emergence after a short-duration flood can equal that of sugarcane treated with insecticide. The success of this treatment is probably partially due to the enhanced and accelerated emergence from flooding uncovered sugarcane stalk sections (Glaz 2001). Also, it is likely that flooding for 14 to 21 d leaves wireworms inactive during the flood.

**Plant weight.** As with emergence percentage and number of wireworms recovered, the experiment × treatment term for fresh plant weight was significant in the combined analysis of variance ($F = 2.3$; df = 8/48; $P = 0.04$;). Thus, the analyses of

**Table 2. Total of larvae, pupae, plus adult *M. communis* recovered from containers during three experiments for each of five wireworm-control treatments***

| Treatment | Experiment 1 | Experiment 2 | Experiment 3 | Mean |
|---|---|---|---|---|
| | Wireworms recovered per container | | | |
| Control | 7.4a | 5.8a | 3.8a | 5.7a |
| Phorate | 1.2c | 2.0b | 1.2b | 1.5b |
| 7-d flood | 6.6ab | 3.8ab | 2.6ab | 4.3a |
| 14-d flood | 7.8a | 3.8ab | 3.0a | 4.9a |
| 21-d flood | 4.2bc | 4.8ab | 3.2a | 4.1a |
| Mean | 5.4 | 4.0 | 2.8 | 4.1 |
| LSD ($P = 0.05$) | 3.3 | 3.7 | 1.7 | 1.6 |

* Within columns, means followed by the same letter are not significantly different according to LSD (0.05).

individual experiments are of most interest, but comparisons among treatments from the analysis of combined experiments are also described here to emphasize differences among experiments. Among the overall treatment means of the three experiments, the plant weights were greatest after phorate application and lowest in the 21-d flood (Table 3). The plant weights of the control, and 7- and 14-d floods were not significantly different.

In the first experiment, the phorate treatment resulted in greater plant weight than

**Table 3. Fresh plant weight of sugarcane grown during three experiments for each of five wireworm-control treatments***

| Treatment | Experiment 1 | Experiment 2 | Experiment 3 | Mean |
|---|---|---|---|---|
| | g per container | | | |
| Control | 37.7bc | 51.4bc | 76.0ab | 55.0b |
| Phorate | 92.6a | 77.1a | 104.0a | 91.2a |
| 7-d flood | 60.6b | 76.3a | 53.7bc | 63.5b |
| 14-d flood | 47.8bc | 68.0ab | 60.0bc | 58.6b |
| 21-d flood | 36.4c | 37.6c | 32.8c | 35.6c |
| Mean | 55.0 | 62.1 | 60.8 | 59.3 |
| LSD ($P = 0.05$) | 23.3 | 21.2 | 31.6 | 14.1 |

* Fresh weights were measured 69, 55, and 59 d after planting Experiments 1, 2, and 3, respectively. Within columns, means followed by the same letter are not significantly different according to LSD (0.05).

any other treatment. All other treatments had similar plant weights except that the 7-day flood had greater plant weight than the 21-day flood. Relative results among treatments in the third experiment were generally similar to those of the first experiment. One minor difference was the relationship between the fresh weight of the control and phorate treatments, which differed at $P = 0.08$. Also, the plant weight resulting from the 21-d flood was less than that of the control, but similar to that of the 7-d flood.

Differences among treatment plant weights differed in the second experiment compared with those from the first and third experiments (Table 3). The weights from the phorate, 7-d flood, and 14-d flood treatments were similar in the second experiment. The plant weight of the control was less than the plant weights of the phorate and 7-d flood treatments. The plant weight resulting from the 21-d flood was less than the plant weight of all other treatments except the control.

Previous research concluded that wireworm damage was limited primarily to the buds of planted stalk sections in sugarcane growing in the field. This damage resulted in reduced rates of emergence. In pots, damage extended to roots and emerging shoots (Hall 1985). Based on Hall (1985), it is likely that the wireworms in our flooded treatments damaged plants after drainage. The floods in these confined containers were generally not effective in causing wireworm mortality, and the wireworms were introduced at the rate of 13 larvae per m of row compared with an economic threshold reported by Hall (1985) of 3 wireworm larvae per m of planted row.

Another plausible explanation for the low plant weights in the flood treatments is the reduced number of growing days for these treatments compared with treatments not flooded at planting. The reduction in growing days is a particularly likely explanation for the low plant weights in the 21-d flood treatment. These experiments were planted at a location with more moderate winter temperatures than much of the region in which sugarcane in Florida is planted. In most areas where sugarcane is grown in Florida, the crop grows slowly from November through January, and in many years is exposed to freezes that kills back young growth. Such freezes would probably neutralize any early growth disadvantages due to flooding sugarcane at planting.

This study identified short-duration flooding as a potential measure to control wireworm damage in sugarcane, and determined that further research should quantify effects of temperature on this treatment. Controlling wireworm damage by flooding at planting would allow EAA sugarcane farmers to lower costs and reduce pesticide residues by eliminating a soil insecticide application. In addition, it would allow them to add a flood cycle which would improve conservation of their organic soils. Along with the control of wireworm damage, reduced plant weights were generally associated with the short-duration floods. Similar yield losses may not occur in the field after these short-duration floods because previous work has reported that wireworms damaged growing plants in containers, but damage was primarily limited to reduced emergence in field studies. Nonetheless, both the beneficial and negative results of this study need to be verified in field studies.

## References Cited

**Alvarez, J. 1992.** Costs and returns for rice production on muck soils in Florida. Economic Information Report EI 92-2, Food and Resource Econ. Dept., Institute Food and Agricultural Sciences, Univ. Florida, Gainesville.

**Cherry, R. H. and D. G. Hall. 1986.** Flight activity of *Melanotus communis* (Coleoptera: Elateridae) in Florida sugarcane fields. J. Econ. Entomol. 79: 626-628.

**Cherry, R. and R. Raid. 1999.** Effect of flooding on efficacy of soil insecticides used for wireworm control in Florida sugarcane. J. Am. Soc. Sugar Cane Technol. 19: 18-23.

**Coale, F. and O. Sosa. 1991.** Sugarcane yield response to soil insecticides in the Everglades Agricultural Area. J. Am. Soc. Sugar Cane Technol. 11: 23-28.

**Freed, R., S. P. Eisensmith, S. Goetz, D. Reicosky, V. W. Smail and P. Wolberg. 1991.** Users guide to MSTAT-C: a software program for the design, management, and analysis of agronomic research experiments. Michigan State Univ., East Lansing, MI.

**Glaz, B. 1999.** Sugarcane variety census: Florida 1999. Sugar y Azucar 94: 30-36.

**Glaz, B. 2001.** Soaking sugarcane in water before planting. Sugar Cane Int. 11-16.

**Hall, D. G. 1985.** Damage by the corn wireworm, *Melanotus communis* (Gyll.) to plant cane during germination and early growth. J. Am. Soc. Sugar Cane Technol. 4: 13-17.

**Hall, D. G. 1990.** Stand and yield losses in sugarcane caused by the wireworm *Melanotus communis* (Coleoptera: Elateridae) infesting plant cane in Florida. Florida Entomol. 73: 298-302.

**Hall, D. G. and R. H. Cherry. 1993.** Effect of temperature in flooding to control the wireworm *Melanotus communis* (Coleoptera: Elateridae). Florida Entomol. 76: 155-160.

**Romero, E. R., J. Scandaliaris, M. Rufino and F. Perez Zamora. 2001.** Biothermal models to predict plant cane emergence, Pp. 95-100. *In* D. M. Hogarth [ed.], Int. Soc. Sugarcane Technol. Proc. XXIV Congress, 17-21 September 2001, vol. II. Brisbane, Australia.

**Samol, H. H. and S. R. Johnson. 1973.** Effect of some soil pesticides on sugarcane yields in Florida. Proc. Amer. Soc. Sugar Cane Technol. 2: 37-40.

**Shih, S. F., B. Glaz and R. E. Barnes, Jr. 1998.** Subsidence of organic soils in the Everglades Agricultural Area during the past 19 years. Soil Crop Sci. Soc. Fla. Proc. 57: 20-29.

**Shih, S. F., E. H. Stewart, L. H. Allen, Jr. and J. W. Hilliard. 1978.** Variability of depth to bedrock in Everglades organic soil. Soil Crop Sci. Soc. Fla. Proc. 38: 66-71.

**Tate, R. L. III. 1980.** Microbial oxidation of organic matter of Histosols. *In* M. Alexander [ed.], Adv. Microb. Ecol. 4: 169-201.