18. Risse, L. A., W. R. Miller, and D. Chun. 1985. Effect of film wrapping, waxing and imazalil on weight loss and decay of Florida cucumbers. Proc. Fla. State Hort. Soc. 98:189-191.
19. Risse, L. A., T. Moffitt, and A. Dow. 1980. Effect of storage temperature on color and incidence of decay of tomatoes under simulated export conditions. Proc. Fla. State Hort. Soc. 93:310-313.
20. Segall, R. H. and A. Dow. 1976. Soft rot of tomatoes resulting from dump-tank and washer-water contamination and its control by chlorination. Proc. Fla. State Hort. Soc. 89:204-205.
21. Segall, R. H., A. Dow, and P. L. Davis. 1974. Effect of waxing on decay, weight loss, and volatile pattern of cucumbers. Proc. Fla. State Hort. Soc. 87:250-251.
22. Segall, R. H., C. M. Geraldson, and P. H. Everett. 1973. The effects of cultural and postharvest practices on postharvest decay and ripening of two tomato cultivars. Proc. Fla. State Hort. Soc. 86:246-249.
23. Sherman, M., R. K. Showalter, J. R. Bartz, and G. W. Simone. Tomato packinghouse dump tank sanitation. Fla. Coop. Extn. Serv., Univ. Fla. Vegetable Crops Fact Sheet VC-31.
24. United States Department of Agriculture. 1976. United States standards for grades of fresh tomatoes. US Dept. Agr. Agr. Mktng. Serv. Washington, DC.

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FOOD BAITS FOR PRE-PLANT SAMPLING OF WIREWORMS (COLEOPTERA:ELATERIDAE) IN POTATO FIELDS IN SOUTHERN FLORIDA

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Abstract. **Wireworms [*Melanotus communis* (Gyllenhal) and *Conoderus* spp.] are the most important insect pests of Irish potato (*Solanum tuberosum tuberosum* L.) in southern Florida. Studies were conducted during 3 consecutive growing seasons to develop a pre-plant sampling plan for wireworm larvae in the Perrine marl soils of southern Dade county. Eight food baits were tested for attractiveness to wireworm larvae: hybrid sweet corn seed, hybrid sorghum-sudangrass seed, a 1:1 mixture of sweet corn and sorghum-sudangrass seed, a whole sweet corn ear, potato seed pieces, a 1:1 mixture of oatmeal and corn flake, carrots, and rolled oats. Oatmeal:corn flake and rolled oat baits were most attractive to wireworm larvae. More *M. communis* larvae. More *M. communis* larvae were consistently found in these baits than in other food baits. Numbers of *Conoderus* spp. larvae did not consistently differ among food baits. Further studies determined spatial patterns of wireworm larvae using rolled oat baits. Wireworm larvae were clumped in potato fields. An excessive number of samples was needed to reliably estimate wireworm density within 10% of the mean; however, a reasonable number of samples was needed to reliably estimate density within 40% of the mean. Rolled oat baits are currently being used for pre-plant sampling of wireworms in potato fields in southern Florida.**

Irish potato is the fifth most economically important vegetable crop in Dade county Florida with a crop value of $12.8 million (1). In southern Florida, potatoes are planted between mid-Oct. and late Dec. and harvested between mid-Feb. and late Apr.. After harvest, fields are usually planted with a summer cover crop, a sorghum-sudangrass hybrid to improve the tilth of the soil, increase the organic matter, and reduce weed populations in the following potato crop. Unfortunately, the sorghum-sudangrass cover crop is also very attractive to adult wireworms (click beetles). Adults fly into fields planted with the cover crop, mate, and lay eggs in the cracks and crevices of soil at the base of plants. Wireworm larvae that hatch out of eggs eventually attack tubers in the following potato crop (5).

Currently, a pre-plant sampling plan for estimating wireworm larval densities in potato fields in southern Florida is lacking. Historically, growers have sampled for wireworms before planting by removing several soil samples (ca. 3,540 cm^3) from each field. This method is time consuming and its reliability is unknown. For this reason, alternative methods for sampling wireworms in potato fields are needed.

Several reports showed that several food baits, such as wheat seed, wheat:corn seed, sorghum seed, oatmeal, wheat flour, and whole wheat:corn seed mixtures, were effective at attracting and collecting wireworm larvae in soil (2,3,4,6,9,12). The present studies were conducted to (1) evaluate the effectiveness of various food baits for sampling wireworms before planting, (2) compare the effectiveness of food baits with soil samples for sampling wireworms, and (3) assess the reliability of food bait sampling methods (i.e., would the number of food bait samples needed to reliably estimate wireworm densities be realistic?).

Materials and Methods

The attractiveness of 8 food baits was assessed during 2 consecutive growing seasons in 1986 and 1987. Baits evaluated the first year included: 3 cups of corn seed, 3 cups of sorghum-sudangrass seed, 3 cups of corn and sorghum-sudangrass seed (1:1), one sweet corn ear, 6 potato seed pieces, and 3 cups of oatmeal and corn flake (1:1). Eight food baits were evaluated the second year: the 6 baits, and quantities, tested during the first year with the addition of 3 whole carrots and 3 cups of rolled oats. All seed baits were soaked overnight in water to enhance germination.

Four trials (1-4) were conducted (one in 1986 and three in 1987). Treatments were arranged in randomized complete block designs with 9 or 12 replications. Bait locations

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were separated by 10 to 40 m within replicates and 50 to 400 m between replicates. One soil sample (3,540 cm^3 [15.2 $cm]^3$) was removed from each bait location 1 day before baits were placed in fields. Baits were then placed in a hole (15.2 x 15.2 x 10.2 cm) dug within 1 to 3 m of each soil sample and covered with soil to a height of 10 cm above the soil surface. After 10 to 14 days, the bait and all the surrounding soil were dug, placed in plastic bags, and washed with water through a series of three progressively smaller screens. The numbers of *M. communis* and *Conoderus* spp. larvae found in each bait and soil sample were recorded.

Spatial patterns of *M. communis* larvae were determined during 1987-1989. Spatial patterns of *Conoderus* spp. were not determined since few *Conoderus* spp. larvae were found. In 1987 and 1988, wireworm larval populations were sampled using rolled oat baits in 32 treatment plots (0.2 ha in 1987 and 0.03 ha in 1988) in which the wireworm density was manipulated by varying the time after harvest that the cover crop was planted. Five baits were placed in each plot as previously described. Numbers of wireworm larvae were recorded in each sample. In 1989, five sections of a potato field were each subdivided into 16 subplots (each = 0.005 ha). Five rolled oat baits were placed in each subplot as previously described. The numbers of wireworms found in each rolled oat bait were recorded. The mean and variance for wireworm larvae per bait were determined for each treatment plot in 1987 and 1988. In 1989, means and variances were computed for each of 4 different subplot sizes (0.01, 0.03, 0.07, and 0.13 ha) by combining subplots into groups of 2, 4, 8, and 16. This approach was used to determine the effects of subplot size on sampling reliability. Analyses were conducted on each of 2 types of samples: rolled oat baits dug to 10 and 20 cm below the soil surface.

The spatial pattern of wireworm larvae was assessed in each year by using Taylor's power law (10, 11). Indices of dispersion were obtained by regressing $\log_{10}$– transformed variance, s^2, on $\log_{10}$–transformed mean, $\bar{x}$, numbers of wireworms found per rolled oat bait (10, 11). To determine the potential reliability of food baits for sampling wireworm larvae, minimum sample size requirements, in terms of the number of bait samples required at fixed levels of precision were determined using the equation:

$$n = (100/c)^2 t^2 a x^{b-2}$$

where c is the reliability as a percentage of the mean, t is the appropriate value of the t distribution (= 2.00) determined by n–1 degrees of freedom, and a and b are estimated from Taylor's power law (8). Minimum sample sizes were determined at densities of 0.2, 1.0, and 5.0 larvae per bait for c = 10, 20, and 40%.

Results and Discussion

Evaluation of food baits. Melanotus communis larvae were consistently more numerous than *Conoderus* spp. larvae in all trials. More wireworm larvae were found in food baits than in soil samples although results were not consistently significant (Table 1). Numbers of *M. communis* and *Conoderus* spp. larvae did not differ among most food baits, although they tended to be most numerous in oatmeal baits (oatmeal:corn flake and rolled oats). In trial 1, *M. communis* larvae were 3.2-4.6 times more numerous in oatmeal:corn flake and sorghum-sudangrass seed baits than in potato and corn seed baits. *Conoderus* spp. larvae were most numerous in sweet corn ear and sorghum-sudangrass seed baits. Overall, wireworm larvae were most numerous in sorghum-sudangrass seed baits and oatmeal:corn flake baits, followed in decreasing order by corn:sorghum-sudangrass seed, sweet corn ear, potato seed, and corn seed. In trial 2, *M. communis* larvae were 3.9 times more numerous in oatmeal:corn flake and rolled oat baits than in potato seed bait (Table 1). Numbers of *Conoderus* spp. larvae did not differ among food baits. In experiments 3 and 4, wireworm numbers did not differ among food baits, although trends in the data consistently indicated that wireworm larvae were most numerous in oatmeal:corn flake and rolled oat baits (Table 1).

Table 1. Mean numbers of *Conoderus* spp. and *M. communis* larvae collected in various pre-plant food bait and soil samples in Homestead, Florida.[z]

	Conoderus		*M. communis*	
Food bait	Bait	Soil	Bait	Soil
			Trial 1	
Corn seed	0.1 ab	0.0	0.7 b	0.0
Oatmeal:corn flake	0.0 b	0.0	3.2 a	0.1
Sorghum-sudangrass seed	0.6 a	0.0	3.2 a	0.0
Corn:sorghum-sudangrass seed	0.0 b	0.2	2.5 ab	0.0
Sweet corn ear	0.8 a	0.0	1.4 ab	0.0
Potato seed pieces	0.1 ab	0.1	1.0 b	0.1
			Trial 2	
Corn seed	0.4	0.2	2.5 ab	0.0
Oatmeal:corn flake	0.2	0.0	5.4 a	0.1
Sorghum-sudangrass seed	0.6	0.0	2.5 ab	0.0
Corn:sorghum-sudangrass seed	0.1	0.0	2.3 ab	0.0
Sweet corn ear	0.0	0.0	2.7 ab	0.0
Potato seed pieces	0.1	0.1	1.4 b	0.0
Carrots	0.3	0.1	2.1 ab	0.0
Rolled oats	0.1	0.2	5.4 a	0.0
			Trial 3	
Corn seed	0.0	0.0	0.9	0.0
Oatmeal:corn flake	0.2	0.0	1.3	0.0
Sorghum-sudangrass seed	0.0	0.0	0.8	0.0
Corn:sorghum-sudangrass seed	0.0	0.1	0.7	0.0
Sweet corn ear	0.0	0.1	0.6	0.1
Potato seed pieces	0.0	0.1	0.8	0.1
Carrots	0.0	0.1	0.6	0.2
Rolled oats	0.1	0.0	1.8	0.0
			Trial 4	
Corn seed	0.0	0.0	0.1	0.0
Oatmeal:corn flake	0.0	0.0	0.4	0.0
Sorghum-sudangrass seed	0.0	0.0	0.1	0.0
Corn:sorghum-sudangrass seed	0.0	0.0	0.2	0.0
Sweet corn ear	0.0	0.0	0.1	0.0
Potato seed pieces	0.0	0.0	0.2	0.0
Carrots	0.0	0.0	0.1	0.0
Rolled oats	0.0	0.0	0.3	0.0

[z]Mean separation (in columns by trial) by Waller-Duncan *K*-ratio *t*-test (*K*-ratio = 100). Treatments with means and variances = 0 were separated by computing 95% confidence interval of all means > 0 (means differed if 0 was outside the range of the confidence interval).

Wireworm numbers varied among trials, and this was probably due, in part, to the time that the cover crop was planted in each sample field. Trials 1 and 2 were conducted in fields that had been routinely planted with the cover crop in April immediately after harvest. Trial 3 was conducted in a field that was fallowed for three months

Table 2. Parameter estimates from Taylor's power law regression of $\log_{10} s^2$ regressed on $\log_{10} \bar{x}$ number of *M. communis* larvae per rolled oat bait.

Year	Plot size (ha)	*n*	Taylor's power law[z] *a*	*b*	r^2
1987	0.20	26	1.22 b	1.30	0.92
1988	0.03	24	2.05 a	1.51	0.87
1987 + 1988	0.03-0.20	50	1.56 ab	1.35	0.87

[z]Parameter estimates followed by different letters are significantly different by the general linear test ($P = 0.05$).

after harvest and then planted with the cover crop in July. This field was also fallowed the previous summer. Trial 4 was conducted in a field that was routinely fallowed for three months after harvest and then planted with the cover crop in July. A previous study showed that wireworm larval density and concomitant tuber damage were positively correlated with the length of time that the cover crop was present in potato fields during the summer (7).

Results from these trials consistently showed that wireworm larvae were most attracted to oatmeal baits (oatmeal:corn flake or rolled oats). In addition to attracting the most wireworms, these baits can be processed (washed and visually examined for wireworm larvae) in less time (13-29 minutes per sample) than seed baits (13-62 minutes per sample) (6).

Spatial statistics and reliability. Rolled oat baits were selected for further study since there was no difference in attractiveness between rolled oat and oatmeal:corn flake baits. Spatial statistics indicated that $\log_{10} s^2$ and $\log_{10} \bar{x}$ were linearly related in both 1987 and 1988 (Table 2). Slope values were significantly greater than 1.0, indicating an aggregated wireworm larvae population.

The minimum numbers of samples needed to reliably estimate *M. communis* larval populations at different levels of precision are presented in Table 3. In general, if high levels of precision are desired (e.g., estimates within 10% of the actual mean), an excessive number of samples would be needed. If less precise estimates are desired (e.g., within 40% of the actual mean), the number of samples needed decreased considerably and was more practical. For example, based on data from 1987 and 1988 combined, if wireworm populations average 1.0 larvae/bait, 624, 156, and 39 rolled oat bait samples would be needed to reliably

Table 3. Minimum sample sizes needed to reliably estimate pre-plant *M. communis* larval population densities with rolled oat baits at three levels of precision.

	Wireworm population density								
	0.2 larvae/bait			1.0 larvae/bait			5.0 larvae/bait		
	Level of precision								
Year	10%	20%	40%	10%	20%	40%	10%	20%	40%
	Sample size (no.)								
1987	1,503	376	94	488	122	30	158	39	10
1988	1,804	451	113	820	205	51	372	93	23
Both	1,778	445	111	624	156	39	218	55	12

Table 4. Parameter estimates from Taylor's power law regression of $\log_{10} s^2$ regressed on $\log_{10} \bar{x}$ number of *M. communis* larvae per rolled oat bait in each of four subplot sizes and two bait sample depths.

Depth (cm)	Plot size (ha)	n	Taylor's power law[z] a	b	r^2
0-10	0.01	27	1.65	1.39	0.84
	0.03	13	1.81	1.23	0.91
	0.07	9	1.99	1.21	0.94
	0.13	5	2.76	1.29	0.99
0-20	0.01	27	1.10 b	1.73	0.59
	0.03	13	2.13 ab	1.39	0.92
	0.07	9	2.58 a	1.41	0.96
	0.13	5	3.51 a	1.53	0.99

[z]Parameter estimates (in columns by depth) followed by different letters are significantly different by the general linear test ($P = 0.05$).

estimate wireworm populations at 10, 20, and 40% levels of precision. If wireworm populations average 5.0/bait, 218, 55, and 14 bait samples would be needed to reliably estimate wireworm populations at these same levels of precision. From a practical perspective, a 40% level of precision is probably adequate considering the concomitantly large decrease in effort needed to sample wireworms.

In 1989, results concurred with those from 1987 and 1988. $\log_{10} s^2$ and $\log_{10} \bar{x}$ were linearly related for all possible subplot grouping combinations within both sampling depths (0-10 and 0-20 cm depth) (Table 4). Parameter estimates did not differ among most subplot grouping combinations, indicating that the spatial pattern of *M. communis* larvae was consistent among all subplot sizes tested.

Minimum numbers of rolled oat bait samples needed to reliably estimate wireworm populations are presented in Table 5. Data concur closely with those from 1987 and 1988. Numbers of samples needed decreased with a decrease in precision, and increased with an increase in subplot size and soil depth. Interestingly, although more wireworm larvae were found in bait samples between 0-20 cm than between 0-10 cm below the surface (Seal et al., unpubl. data), considerably more samples were needed to reliably estimate wireworm density using a 0-20 cm depth sample. Thus, larger-volume food bait samples were less precise than smaller-volume food bait samples. An obvious advantage for using a smaller-volume sample would be a decrease in effort by the sampler, which may save both time and money.

To reliably estimate wireworm densities of 1.0 or 5.0 larvae/bait, 69 and 22 samples would be needed per 0.13 ha, respectively, at a 40% level of precision (Table 5). These numbers differ slightly from those of 1987 and 1988 combined (39 and 14 samples at densities of 1.0 and 5.0, respectively). From a practical perspective, 40 rolled oat bait samples per 0.2 ha area is probably an adequate sample size. This number of samples may seem excessive, considering that most fields are 8-32 ha in size. However, entire fields do not need to be sampled. Several sections (0.2 ha) of each field should be sampled with rolled oat baits (40 baits per section). This method would provide a reliable estimate of wireworm densities if densities were moderate to high (1.0-5.0 larvae/bait). Current studies are examining methods to simplify this method for growers.

Table 5. Minimum sample sizes needed to reliably estimate pre-plant *M. communis* larval population densities with rolled oat baits at three levels of *precision* for each of four subplot sizes and two bait sample depths.

	Wireworm population density								
	0.2 larvae/bait			1.0 larvae/bait			5.0 larvae/bait		
	Level of precision								
Plot size (ha)	10%	20%	40%	10%	20%	40%	10%	20%	40%
	Sample size (no.)								
	0-10 cm								
0.01	1,762	440	110	660	165	41	110	41	15
0.03	2,498	624	156	724	181	45	210	52	13
0.07	2,842	710	178	796	199	50	223	56	14
0.13	3,455	864	216	1,104	276	69	353	88	22
	0-20 cm								
0.01	678	169	42	440	110	27	285	71	18
0.03	2,275	569	142	852	213	53	315	79	20
0.07	2,663	666	166	1,032	258	64	402	101	25
0.13	2,990	748	187	1,404	351	88	660	165	41

Literature Cited

1. Anonymous. 1988. Dade County agriculture. Dade County/Institute of Food and Agricultural Sciences. Cooperative Extension, Homestead, Florida.
2. Apablaza, J. U., A. J. Keaster, and R. H. Ward. 1977. Orientation of corn-infesting species of wireworms toward baits in the laboratory. Environ. Entomol. 6:715-718.
3. Doane, J. F. 1981. Evaluation of larval trap and baits for monitoring the seasonal activity of wireworms in Saskatchewan. Environ. Entomol. 10:335-342.
4. Foster, D. G., and C. R. Ward. 1976. Wireworm bait traps in grain sorghum. Texas Agr. Expt. Sta. PR-3425.
5. Jansson, R. K. 1987. The east glades: battling frost and wireworms to produce winter potatoes in south Florida. Spudman 25(3):18,37-38.
6. Jansson, R. K., and S. H. Lecrone. 1989. Evaluation of food baits for pre-plant sampling of wireworms (Coleoptera:Elateridae) in potato fields in southern Florida. Fla. Entomol. 72:503-510.
7. McSorley, R., J. L. Parrado, R. V. Tyson, V. H. Waddill, M. L. Lamberts, and J. S. Reynolds. 1987. Effects of sorghum cropping practices on winter potato production. Nematropica 17:45-60.
8. Ruesink, W. G., and M. Kogan. 1975. The quantitative basis of pest management: sampling and measuring, pp. 309-351. In: R. L. Metcalf and W. Luckmann (eds.). Introduction to insect pest management. Wiley, New York.
9. Seal, D. R. 1990. Biology and management of wireworms affecting. sweet potato in Georgia. Ph.D. Diss., University of Georgia, Athens.
10. Taylor, L. R. 1961. Aggregation, variance, and the mean. Nature (Lond.) 189:732-735.
11. Taylor, L. R. 1984. Assessing and interpreting the spatial distributions of insect populations. Annu. Rev. Entomol. 29:321-357.
12. Toba, H. H., and J. E. Turner. 1983. Evaluation of baiting techniques for sampling wireworms (Coleoptera:Elateridae) infesting wheat in Washington. J. Econ. Entomol. 76:850-855.

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BIOLOGY AND MANAGEMENT OF CORN-SILK FLY, *EUXESTA STIGMATIS* LOEW (DIPTERA: OTITIDAE), ON SWEET CORN IN SOUTHERN FLORIDA

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Abstract. **Research is reported concerning the biology, behavior, and management of corn-silk fly (CSF), *Euxesta stigmatis* Loew. CSF immigrated into the sweet corn (*Zea mays* var. *saccharata* (Sturt.) Bailey) fields when plants were 2-week old. At harvest, between 80-90% of all ears in a non-treated field were infested with at least one life stage of this fly, and yield losses due to CSF were > 60%. Fresh, new ears were the preferred substrate for oviposition. Females oviposited on silks within the tips of the ears. Peak oviposition occurred during daylight between 11:00-13:00 EST. Total developmental period from egg to adult was 28.3 ± 0.6 days at 30C. Adult longevity averaged 26.7 ± 8.0 days at 24 ± 2C. Contact toxicity of parathion, carbaryl, chlorpyrifos, and methomyl to adults was assessed in the laboratory. Parathion was most toxic to CSF adults.**

Sweet corn is one of the most important crops in the southern U. S. In southern Dade county, sweet corn is valued at $5.7 million (1). Because of high crop values and aesthetics, tolerance levels for insect damage to ears are very low. Corn-silk fly (CSF), *E. stigatis*, is one of the most important economic pests of corn in South, Central and North America (2). This fly has been reported to attack sweet and field corn in the West Indies, Central America,

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