factors, such as increasing temperature, precipitation, and intensity of ultraviolet radiation, probably affected efficacy between experiments and between years, and more detailed studies on the effects of these factors on insecticide efficacy, especially that of biological insecticides, are warranted.

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DISTRIBUTION AND DENSITY OF WIREWORMS AND THEIR DAMAGE IN RELATION TO DIFFERENT CULTIVARS OF SWEETPOTATO

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Abstract. **In fields planted to 3 sweetpotato (*Ipomoea batatus* (L.) Lam.) cultivars, distribution and density of wireworms (*Conoderus* spp.) were estimated using baits of corn-wheat seed mixture (1:1). The number of wireworms per sample was significantly greater in 'Red Jewel' and 'Jewel' than in the rest of the cultivars in the 2 respective fields. Maximum number of wireworms were recorded within the bait in both fields. Wireworm population was the highest in July and decreased successively with the progression of growing period. Comparatively higher number of wireworms were recorded within 10 cm of the sweetpotato hill. Most larvae were in the upper 10 cm of the soil and then moved down beginning in Oct. with the highest number at a depth of 20 cm when damage to the root was highest. Maximum numbers of larvae was recorded from the rows near the edge of the field.**

Most known wireworm species change their vertical distribution seasonally. Populations generally peak in the

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upper soil stratum during spring and fall and move into the lower soil stratum during summer and winter (Burrage, 1963; Lafrance, 1968; Fisher et al., 1975). In Missouri, Fisher et al. (1975) observed a close relationship between vertical distribution of *Melanotus* and *Conoderus* spp. and soil temperature. They recorded more wireworms in the upper 15 cm of soil during spring and fall than in the soil below top 15 cm from the surface when soil temperature was 12.8-23.9C. The dryness of soil influenced the downward movement of wireworms, but when soil became wet, wireworms moved back toward the soil surface (Jones and Shirck, 1942). The type of crop also influenced the extent of vertical movement. Root damage was directly influenced by vertical distribution. Rawlins (1939) noted only 50% of *Limonius ectypus* (Say) larvae within 15 cm of potato tubers during August when the largest wireworm populations were found. Greenwood (1945) reported that only a small percentage of *Limonius agonus* Say. larvae in potato hills fed at any one time and noted a number of potato hills with at least 12 wireworms close to tubers showing no feeding damage. The number of larvae actively feeding may be related to the molting cycle (Kosmachevskii, 1959).

Little research on wireworm distribution and damage to sweetpotatoes has been reported although surveys by the authors in Georgia indicate it is a major economic pest of this crop. It is essential to know the distribution of wireworms in space and their preference for different crops to develop effective management practice. Accordingly, the following research was a study of the abundance and distribution of wireworms in relation to the 3 major cultivars of sweetpotato grown in Georgia conducted in 2 fields having 2 distinct wireworm populations (*Conoderus scissus* and *Conoderus rudis*). The extent of damage in relation to vertical migration and the density of wireworms around sweetpotato hill was also observed in different months of the sweetpotato growing season.

Materials and Methods

The experiment was conducted in two 0.6 ha fields (21.9 × 30.5 m) located at Gopher Ridge research farm in Tifton, Ga. The soil type of Field 1 was Tifton loamy sand and that of Field 2 was boanyfay clay. 'Jewel', 'Red Jewel', and 'Georgia Jet' sweetpotatoes were planted in the field from vine cuttings collected from Charleston, SC. Each field was divided into 16 uniform plots comprising three 30.5 m long rows. The experimental design was randomized complete block with four replications. Plant spacing was 46 cm in the row and 1.3 m between rows. Preliminary survey indicated that ca 90% of the wireworm population in Field 1 was *C. rudis* while Field 2 was infested predominantly with *C. scissus*.

Larval distribution and density from July to Nov. were determined using baits consisting of a mixture of 30 ml each of untreated corn and wheat seed planted in a mass within the row between the plants of each cultivar. Ten baits were placed randomly in each plot. The baits contained within a 20 cm diameter and 10 cm deep core of soil were removed after 7 to 14 days depending on germination. A second and third groups of transversely separated cores of equal dimension were removed immediately below the baits. The samples were placed in polyethylene bags, then removed to the laboratory for separating wireworms. To determine the wireworm distribution in relation to sweetpotato hills, concentric cores around the plants, 10 and 20 cm in diameter, were removed for examination. Each concentric core was divided into three 10 cm deep transversely separated subsamples. The subsamples were checked carefully for wireworms. The roots were left intact in the field.

To determine the seasonal damage caused by wireworms, roots from 5 randomly selected hills per plot were removed and examined. The feeding holes were characterized as deep (> 1 mm deep) and shallow (< 1 mm deep), representing recent injury, and healed scars, representing old damage.

Density of wireworms in relation to the edge of a field was conducted in a 0.6 ha field. The field consisted of sixteen 30.5 m long rows. 'Jewel', 'Red Jewel', and 'Georgia Jet' sweetpotato were planted in alternate 2 rows starting from edge toward the center of the field. Two rows were sampled for each cultivar by randomly placing twenty-five corn-wheat mixture baits in a row. Two weeks after planting, baits contained in a 10 cm diam and 20 cm deep soil cores were removed and checked for wireworms.

Statistical Analysis. Data were subjected to an analysis of variance (ANOVA) by using the GLM procedures of the Statistical Analysis System (SAS Institute, 1985) and Waller-Duncan *K*-ratio *t* test (Waller and Duncan, 1969). Data transformed to square roots before statistical analysis was done. Nontransformed means were presented in all tables.

Table 1. Mean number of wireworms per sample in two fields by month irrespective of cultivar and location.

Month	Observations (no.)	Wireworms (no./bait)[z] Field 1[y]	Field 2[x]
July	160	3.48a	2.08a
Aug.	160	2.00b	1.82ab
Sept.	160	1.33b	1.44b
Oct.	160	0.50c	0.82c
Nov.	160	0.33c	0.56c

[z]Mean separation (in columns) Waller-Duncan *K*-ratio *t*-test, 5% level.
[y]Mostly *C. rudis*.
[x]Mostly *C. scissus*.

Results and Discussion

The highest numbers of wireworms per bait sample were recorded in July in both fields (Table 1). Numbers decreased significantly in Nov. Most larvae were found inside the bait followed by the core below the bait (Table 2).

Table 2. Mean number of wireworms by location and cultivars in two fields.

Treatment	Observation (no.)	Wireworms (no./sample)[z] Field 1[y]	Field 2[x]
Location			
Inside baits	60	3.65a	3.42a
Below baits	60	0.61b	0.48b
Without baits	60	0.37b	0.13c
Cultivar			
Georgia Jet	100	1.44b	0.88c
Red Jewel	100	2.21a	1.40b
Jewel	100	0.92b	1.76a

[z]Mean separation (in columns) by Waller-Duncan *K*-ratio *t*-test, 5% level.
[y]Mostly *C. rudis*.
[x]Mostly *C. scissus*.

Table 3. Mean number of wireworms at different depths in different months irrespective of lateral distance from the plant.

Month	Mean number of wireworms at depth[z]		
	10 cm	20 cm	30 cm
Aug.	1.29a	0.57b	0.02c
Sept.	1.02a	0.57b	0.13c
Oct.	1.01a	0.76ab	0.48b
Nov.	0.51b	1.14a	0.80ab
Average	0.96	0.76	0.36

[z]Mean separation (in columns) by Waller-Duncan K-ratio t-test, 5% level.

Table 4. Mean number of holes per root in different months in different fields.

Month	Types of holes[z]			
	Deep	Shallow	Healed	Mean
		Field 1[y]		
Aug.	0.80b	0.29b	0.06b	1.17b
Sept.	1.13b	0.17b	0.25ab	1.69b
Oct.	1.55ab	0.22b	0.39ab	2.36ab
Nov.	3.20a	0.82a	0.75a	5.10a
		Field 2[x]		
Aug.	0.61c	0.21b	0.11c	0.97b
Sept.	0.94bc	0.70b	0.29ab	2.08ab
Oct.	1.64a	0.72b	0.26bc	2.94ab
Nov.	1.45ab	2.19a	0.48a	4.42a

[z]Mean separation (in columns) by Waller-Duncan K-ratio t-test, 5% level.
[y]Mostly *C. rudis*.
[x]Mostly *C. scissus*.

Table 5. Mean number holes per root in different cultivars in different fields, (four month average).

Cultivar	Types of injury (no./plant)[z]			
	Deep	Shallow	Heal	Total
		Field 1[y]		
Georgia Jet	2.83a	0.47a	0.57a	4.12a
Red Jewel	1.53b	0.46a	0.33ab	2.58a
Jewel	0.66b	0.11b	0.16b	0.99b
		Field 2[x]		
Georgia Jet	0.97b	0.68b	0.30a	2.14b
Red Jewel	1.96a	1.51a	0.43a	4.23a
Jewel	0.61b	0.51b	0.12b	1.38b

[z]Mean separation (in columns) by Waller-Duncan K-ratio t-test, 5% level.
[y]Mostly *C. rudis*.
[x]Mostly *C. scissus*.

In Field 2, dominated by *C. scissus*, more wireworms/bait were observed in 'Jewel' and 'Red Jewel' than in 'Georgia Jet' (Table 2). Averaged across both fields, more wireworms/bait were observed in 'Red Jewel' (1.31) than in 'Georgia Jet' (0.56) and 'Jewel' (0.25) ($P < 0.05$). Wireworms were more abundant within 10 cm (0.86) than within 20 cm (0.48) lateral distance from the sweetpotato hills ($P < 0.05$). Wireworm orientation to roots may be in response to CO_2 evolution by the root (Doane et al., 1975) which may explain the aggregation of the larvae within 10 cm of the root.

Table 6. Mean number of wireworms in different cultivars in different rows.

Row number	Distance from the edge (m)	Cultivar	Observations (no.)	Wireworms[z] (no./bait)
1	1.95	Jewel	15	10.80ab
3	4.55	Red Jewel	15	14.93a
5	7.15	Georgia Jet	15	12.87a
7	9.75	Jewel	15	7.53bc
8	11.05	Georgia Jet	15	5.33c
11	13.65	Red Jewel	15	3.93c

[z]Mean separation (in column) by Waller-Duncan K-ratio t-test, 5% level.

Vertical distribution and root damage changed with the progression of the season. From Aug. through Oct. most larvae were in the upper 10 cm of the soil. During Nov. larvae moved down to the 20-30 cm depths (Table 3). Feeding injury in both fields increased sharply at this time (Table 4). These results are supported by Jones and Shirck (1942) who reported that the vertical movement of wireworms was directly related to root damage. In Field 1, dominated by *C. rudis*, most feeding holes were in 'Georgia Jet' > 'Red Jewel' > 'Jewel'. In Field 2, dominated by *C. scissus*, most feeding holes were recorded in 'Red Jewel' > 'Georgia Jet' > 'Jewel' (Table 5). Numbers of wireworms were significantly more within 0-7 m of the edge of the field than within 8-14 m of the edge of the field (Table 6). More wireworms were observed in 'Jewel' planted within 2.0 m of the edge than in 'Jewel' planted near the center of the field. Similarly, more wireworms were observed in 'Red Jewel' planted near the edge than in the same cultivar planted away from the edge.

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