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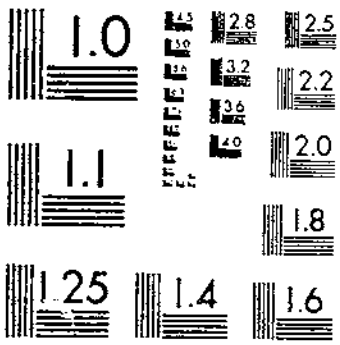


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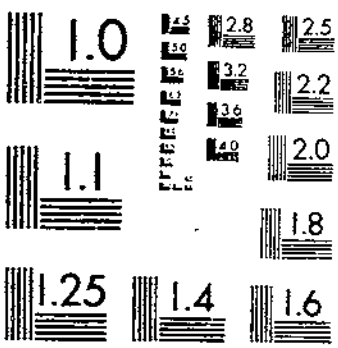


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# THE SOUTHERN POTATO WIREWORM

## Its Biology and Economic Importance in Coastal South Carolina



Technical Bulletin No. 1443

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE
in cooperation with
South Carolina Agricultural Experiment Station

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Many local vegetable growers for allowing us the use of their land, crops, farm equipment, and labor.

## CONTENTS



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# THE SOUTHERN POTATO WIREWORM

## Its Biology and Economic Importance in Coastal South Carolina

By AUGUSTINE DAY, F. P. CUTHBERT, JR., and W. J. REID, JR.,[1] *entomologists*, Entomology Research Division, Agricultural Research Service

Wireworms (Coleoptera: Elateridae) damaged potatoes in coastal South Carolina as early as 1927. At that time the Gulf wireworm (*Conoderus amplicollis* (Gyllenhal)) was considered the major pest. The wireworm problem in the area intensified about 1952, partly because it became a general practice to wash the tubers before they were marketed and this made the injury easier to detect.

The insect now known as the southern potato wireworm (*Conoderus falli* Lane) was found to be the wireworm most injurious to potato tubers in the Charleston, S.C., area in 1952 and 1953 (Lane *10*).[2] It was also reported as injurious to potato tubers near Hastings, Fla., during the same period (Dobrovsky *8*).

Studies of the biology of this insect in coastal South Carolina were undertaken in 1953 and intensified in 1956 after it became resistant to chlordane and certain other previously effective soil insecticides (Norris *13*, Reid and Cuthbert *15*). Results of these studies through 1967 are reported here. Previous information on the biology or control of the southern potato wireworm was published by Cuthbert et al. (*5*), Dobrovsky (*9*), and Norris (*12*).

## SYNONYMY AND DISTRIBUTION

According to Lane (*11*), synonyms of *Conoderus falli* include *Monocrepidius difformis* Fall and probably *Heteroderes vagus* Candèze. He also listed the literature in which other designations, especially *Conoderus vagus* (Candèze), have been used.

The southern potato wireworm (fig. 1) probably was introduced into the United States from South America. It was collected in 1927 near Savannah, Ga., and Chadbourn, N.C., and in 1930 at

[1] Retired Apr. 27, 1968.

[2] Italic numbers in parentheses refer to Literature Cited, p. 32.

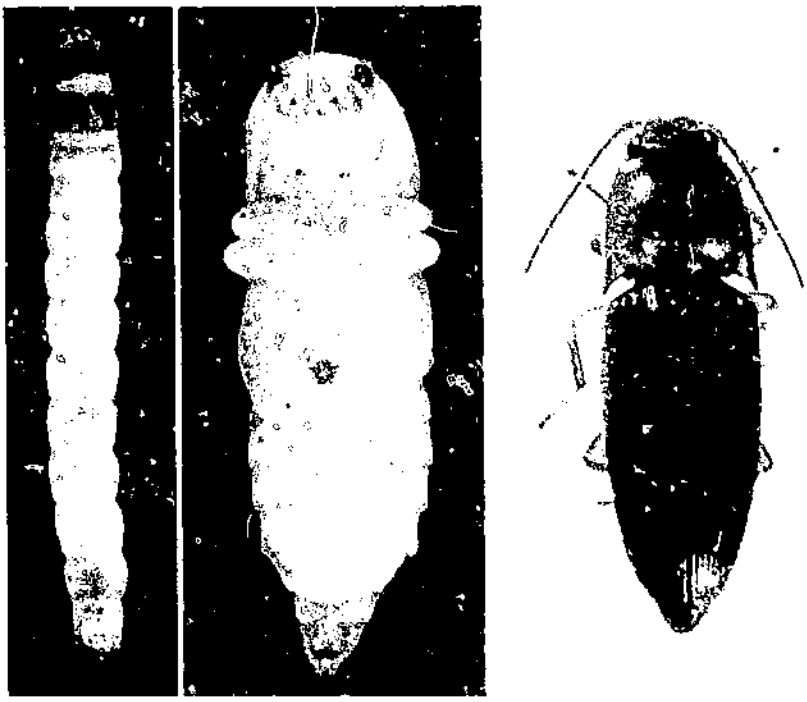

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FIGURE 1.—Southern potato wireworm: *Left*, larva (dorsal view); *center*, pupa (ventral view); *right*, adult (dorsal view).

Florence, S.C. Deen and Cuthbert (*7*) in 1955 reported it along the South Atlantic and gulf coasts from North Carolina to Louisiana, which include several areas where early potatoes are grown. Damaging populations appear confined to the Coastal Plain, but adults are not uncommon as far inland as Clemson, S.C.

## ECONOMIC IMPORTANCE

The southern potato wireworm extensively damages potato tubers (fig. 2, *A*) in the Southeast and seriously injures newly transplanted tobacco (Creighton et al. *2*) and sweetpotato roots (fig. 2, *B*) (Cuthbert *3*). The authors of this bulletin observed occasional serious injury to the stems of tomato transplants (fig. 2, *C*) and the roots of carrots (fig. 2, *D*) and of corn seedlings. Less frequently injury has been observed on melons, the roots of beets, and the fruits of strawberries and tomatoes that touched the soil surface.

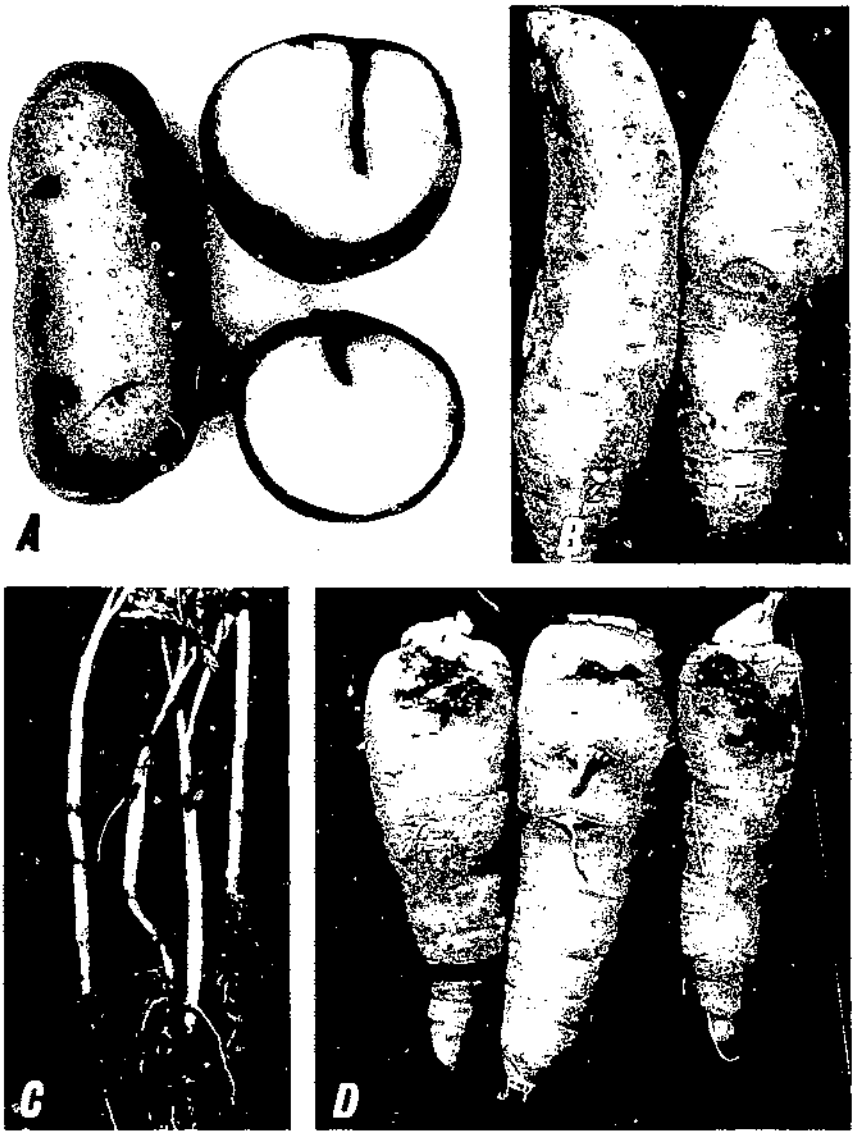


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FIGURE 2.—Injury by larvae of southern potato wireworm to potatoes (*A*), sweetpotatoes (*B*), newly transplanted tomato plants (*C*), and carrots (*D*).

E. G. Kelsheimer [3] reported severe injury to gladiolus in Florida, and he also observed occasional damage to strawberry fruits in

[3] Personal communication.

Plant City, Fla. F. S. Chamberlin [3] reported serious injury to recently transplanted tobacco under shade at Quincy, Fla., and J. W. Wilson [3] to *Gerbera* sp. daisies near Sanford, Fla.

## Extent of Injury and Damage to Potato Tubers

Wireworm larvae mar the appearance of potatoes (fig. 2) and cause waste when the tubers are prepared for cooking or making chips. If damage is sufficient, either potatoes are downgraded and sold at lower prices or damaged tubers are discarded until the requirements for premium grade are met.

Table 1 gives the extent of injury and damage by wireworms, chiefly the southern potato wireworm, to potato tubers grown in untreated plots in experimental and commercial plantings in Charleston County, S.C., between 1952 and 1963 and the larval population in these plots.

Wireworm feeding of any degree was termed "injury" during these studies. The "damaged" tubers were those injured as severely

TABLE 1.—*Injury and damage by wireworms to potato tubers in untreated soil and southern potato wireworm populations in soil, Charleston County, S.C.*

| Year | Plantings | Plots | Injured tubers | | Damaged tubers | | Average larvae per square foot per plot |
|---|---|---|---|---|---|---|---|
| | | | Range | Average per plot | Range | Average per plot | |
| | *Number* | *Number* | *Percent* | *Percent* | *Percent* | *Percent* | *Number* |
| 1952 | 6 | 29 | 16–52 | 32 | 4–13 | 8 | ---- |
| 1953 | 7 | 33 | 25–52 | 35 | 7–16 | 10 | ---- |
| 1954 | 7 | 36 | 9–36 | 21 | [1] 2–10 | [1] 6 | ---- |
| 1955 | 8 | 45 | 5–52 | 20 | 2–9 | 4 | [1] 2 |
| 1956 | 15 | 40 | 3–72 | 43 | 0–31 | 9 | 3 |
| 1957 | 17 | 59 | 9–82 | 50 | 1–43 | 15 | 6 |
| 1958 | 8 | 26 | 10–40 | 29 | 1–7 | 4 | 2 |
| 1959 | 5 | 22 | 18–30 | 23 | 3–6 | 4 | 4 |
| 1960 | 6 | 28 | 3–26 | 14 | 0–3 | 1 | 2 |
| 1961 | 1 | 6 | ---- | 22 | ---- | 3 | 5 |
| 1962 | 4 | 21 | 19–32 | 22 | 3–6 | 4 | 2 |
| 1963 | 1 | 6 | ---- | 18 | ---- | 5 | 1 |
| Total or average | 85 | 351 | 3–82 | 31 | 0–43 | 7 | 5 |

[1] Data from 4 plantings.

as described in Section 15.1554, Item (0), of the U.S. Market Standards for Potatoes.

The field plots varied in size, but usually were at least 15 feet wide (5 rows) by 50 feet long. Samples consisting of 50 to 75 pounds of tubers per plot were graded for wireworm injury between 1952 and 1954; 50 pounds per plot were graded thereafter. One square foot of soil 6 inches deep (four subsamples 6 by 6 by 6 inches) from each plot was screened to determine the wireworm population. The 1955 populations were sampled during the late fall and winter of 1954; in all other years the sampling was done after the crops were planted in late winter. Prior to 1961 the soil samples were screened with a portable sifter described by Shirck (*16*). A motor-driven sifter (fig. 3) constructed at the Charleston, S.C., station was used thereafter. In each sifter the sieve that retained the larvae had 16 or 18 meshes per inch.

The 12-year data in table 1 indicate that 31 percent of the potatoes harvested from untreated experimental field plots in a total of 351 plots in Charleston County showed wireworm injury and 7 percent had sufficient injury to be classed as "damaged," as defined in the U.S. Market Standards for Potatoes. The tolerance for all defects in U.S. grade 1 was 5 percent. Wireworm injury was greatest in the spring of 1957, when the southern potato

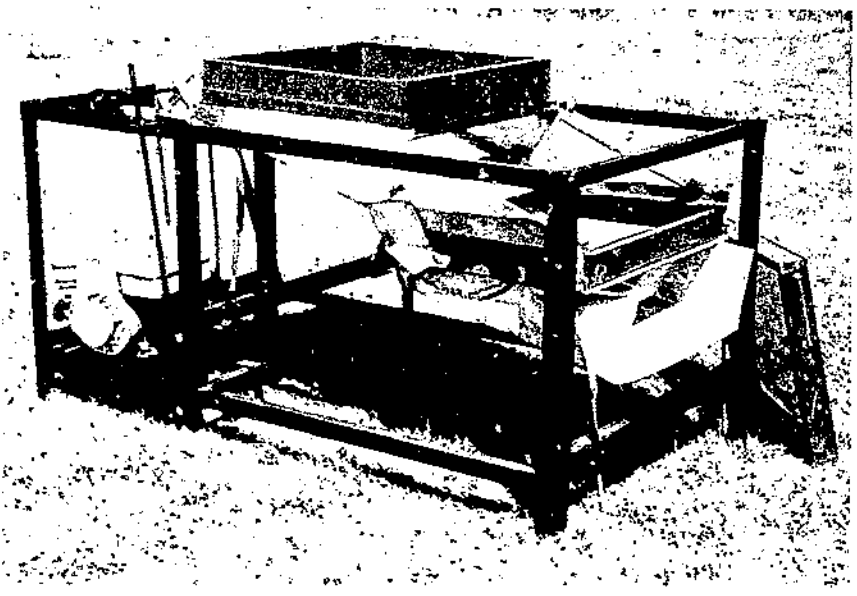

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FIGURE 3.—Motor-driven soil sifter used after 1960.

wireworm had developed resistance to insecticides then in common use. During that season the wireworm population averaged six larvae per square foot (to 6-inch soil depth); 50 percent of the tubers were injured and 15 percent were damaged.

There was a positive correlation coefficient (0.72 for injured tubers and 0.64 for damaged tubers) between the number of southern potato wireworms and the percent of tubers injured and damaged. These results are shown in figure 4.

The extent of wireworm damage to commercial potato plantings in Charleston County between 1955 and 1967 was estimated from the shipping-point inspection certificates issued to growers by the Federal-State Inspection Service. The greatest amount of wireworm damage occurred in 1956 (table 2), when in spite of control measures 36 percent of 1,035 lots of potatoes had 3- to 6-percent "damage" by weight, and 30 percent of the lots had more than 6-percent damage and therefore were ineligible for U.S. grade 1 because of that defect alone.

TABLE 2.—*Extent of southern potato wireworm damage to potatoes in Charleston County, S.C., as indicated by Federal-State shipping-point inspection certificates* [1]

| Year | Inspection certificates issued | Certificates showing indicated damage (percent) by wireworms | | |
|---|---|---|---|---|
| | | 1.5–2.9 | 3–6 | Above 6 |
| | *Number* | *Percent* | *Percent* | *Percent* |
| 1955 | 975 | -- | 4 | 14 |
| 1956 | 1,035 | | 36 | 30 |
| 1957 | 1,726 | [2]56 | 10 | 2 |
| 1958 | 959 | -- | 3 | 0 |
| 1959 | 900 | 13 | 2 | 0 |
| 1960 | 950 | 18 | 6 | 1 |
| 1961 | 1,066 | 25 | 4 | 0 |
| 1962 | 474 | 23 | 5 | 0 |
| 1963 | 607 | 39 | 12 | 1 |
| 1964 | 162 | 30 | 18 | 1 |
| 1965 | 290 | 36 | 6 | 0 |
| 1966 | 325 | 3 | 0 | 0 |
| 1967 | 233 | 11 | 0 | 0 |

[1] Each certificate gave results of inspector's examination of individual lot of potatoes, from 1 or more farms, intended to be 1 rail carlot or motor-truck shipment.

[2] 1–2.9 percent damaged tubers.

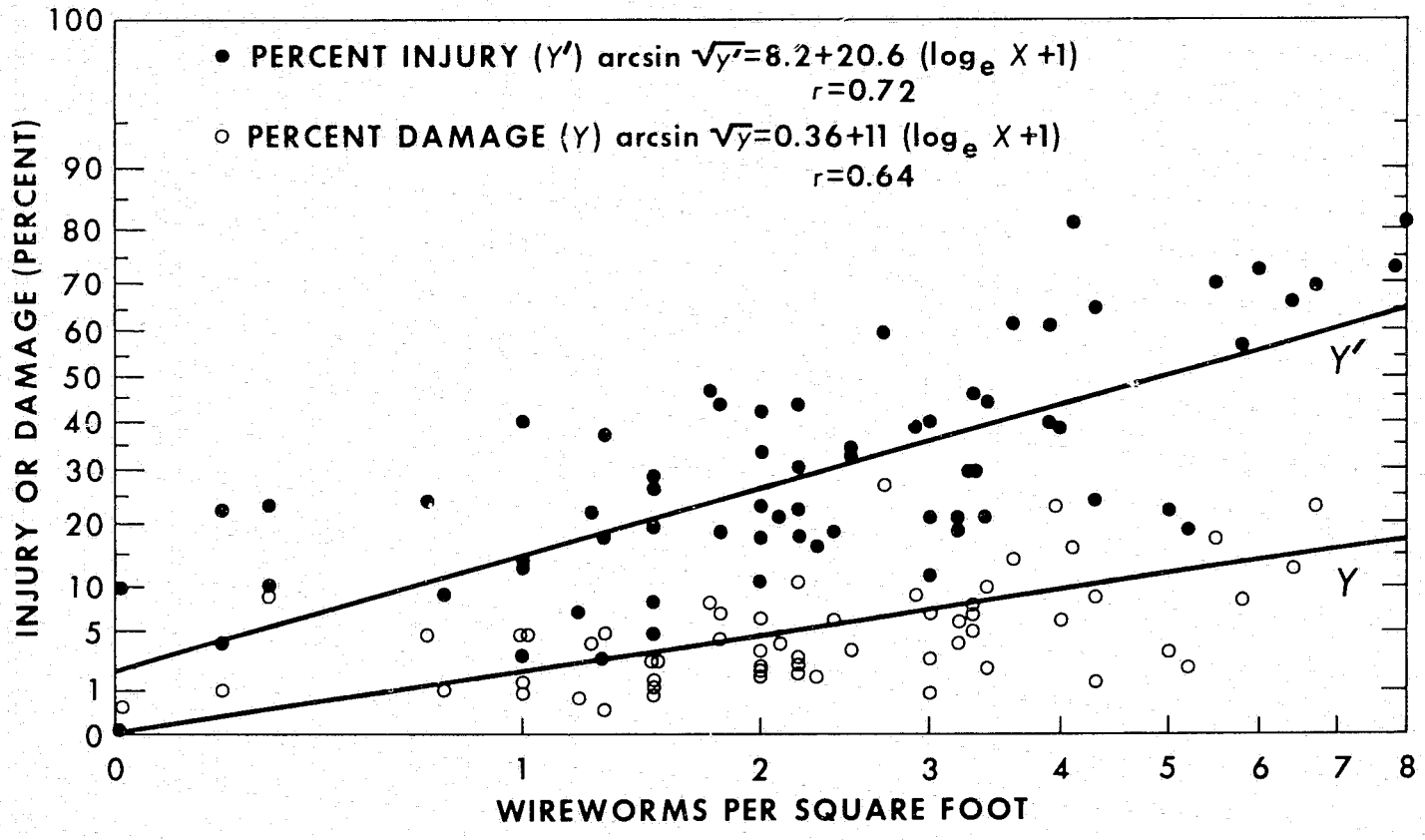


FIGURE 4.—Relationship between density of wireworms and percent of injury and damage to potatoes.

## Extent of Injury to Sweetpotatoes

In eight field-plot experiments conducted in Charleston County between 1962 and 1966, southern potato wireworm larvae ranged from 1.1 to 2.2 and averaged 1.6 per square foot in untreated plots of Centennial sweetpotatoes. From 13 to 75 percent of the roots from these plots showed some wireworm injury at harvest; the average was 32 percent.

# DESCRIPTION AND HABITS

## Adults

The adults (fig. 1) are oblong beetles, 2 to 3 mm. wide and 6 to 9 mm. long. Teneral forms are yellowish white, but they gradually become brown; some specimens appear almost black. The legs are light tan. Elytra are striate-punctate and usually have a distinctive pattern of light markings, which often are not visible to the unaided eye. The pronotum is wider than long, widest posteriorly, and slightly wedge shaped, with sides narrowing to the anterior margin. The surface is punctate with two sizes of punctures. The body is sparsely pubescent and the integument moderately shiny.

Adults occur in the field throughout the year. During the day they are usually found under trash, lumps of soil, or parts of plants resting on the soil surface. The adults remain motionless for a few seconds after being uncovered and then rapidly seek concealment. Piles of oat straw or sweetgum leaves are more attractive hiding places for the adults than piles of several other natural or artificial materials. The following numbers of southern potato wireworm adults were attracted to trap piles constructed of different materials:

| *Material* | *Adults (number)*[1] *found after—* |
|---|---|
| Test 1—Materials put in 5- by 18-inch piles on soil surface: | *4 days* |
| Oat straw (green) | 88 a |
| Oat straw (dry) | 87 a |
| Sweetgum (*Liquidambar styraciflua*) foliage (green) | 82 a |
| Pine (*Pinus taeda*) straw (green) | 68 ab |
| Dock (*Rumex* sp.) (green) | 35 b |
| Collard foliage (green) | 35 b |
| Test 2—Additives sprayed on burlap bags: | *1 day* |
| Oat straw | 69 |
| Burlap bags: | |
| Plus expressed juice of oat straw | 1 |
| Plus apple juice | 2 |

| | |
|---|---|
| Test 2—Additives sprayed on burlap bags:—Continued | |
| Burlap bags:—Continued | *1 day* |
| Plus 10-percent honey solution | 0 |
| Wet with water | 0 |
| Dry under field conditions | 0 |
| Test 3—Additives sprayed on excelsior: | *2 days* |
| Oat straw | 74 |
| Excelsior: | |
| Plus expressed juice of oat straw | 2 |
| Plus apple juice | 1 |
| Plus 10-percent honey solution | 0 |
| Wet with water | 3 |
| Dry under field conditions | 3 |

[1] Values followed by same letters are not significantly different at 5-percent level as determined by Duncan's multiple range test.

The adults are attracted to lights at night and their response to various types of electric-light traps has been described (Day and Reid *6*). They are particularly active within 48 to 72 hours after a rain on warm, damp nights. For example, after two such nights in 1960 approximately 8,000 and 9,800 adults were found in a fluorescent, 15-watt blacklight insect trap on July 17 and July 31, respectively. These were the highest numbers caught during a single night. The highest weekly catch, approximately 14,378, was taken during the week ending July 13, 1960. An occasional specimen was taken in midwinter, but only on nights when it was about 60° F. or above at 8 p.m. Males and females seemed to be attracted in equal numbers.

Dobrovsky (*9*) reported that oviposition can be maintained at a satisfactory rate only if the beetles receive a proteinaceous food. However, in our studies, laboratory-reared beetles survived for several months and laid viable eggs when furnished flowers of several plants or slices of apples. The association of large numbers of adults with deposits of honeydew on plants in the field indicates that this substance may be one of their natural foods.

Little is known about the mating habits of adults in the field. However, the preoviposition period in laboratory cages ranged from 12 to 17 days at average temperatures of 78.2° to 78.5° F. between August 26 and September 16, 1957, and 9 to 27 days at 71° to 79.8° between May 22 and September 21, 1958. There was little correlation between the length of the preoviposition period and temperatures during that period.

Dissection of adults taken at Charleston County in a light trap during 3 years showed that 65 to 74 percent of the females were gravid from March through September, 42 percent during October,

and 6 percent from November through February. These data indicate that most adults emerging in late fall do not lay eggs until the following spring. In 1959, overwintered adults began laying eggs in field cages on March 17 and continued until June 12. Eighty percent of the eggs were laid by May 5.

## Eggs

The eggs (fig. 5) are spherical, smooth, translucent white, and from 0.3 to 0.4 mm. in diameter. The chorin is tough and not easily ruptured. The eggs are deposited with a sticky coating. It hardens to a brittle white shell, which loosely encloses the egg. Particles of earth or debris adhere to the coating and make it difficult to see the eggs in the soil.

The few eggs found in the field were in the upper one-half inch of soil. In field-cage studies in 1959, 93.4 percent of the 454 eggs found were within one-half inch of the soil surface, 6.4 percent were in the next one-half inch, and only one egg was deeper than 1 inch.

The maximum number of eggs found in one female was 61. Specimens in field cages laid from 22 to 63 eggs, with an average of 36.

The incubation period in the field has not been determined. Table 3 gives the results of laboratory studies in which eggs were kept on moist blotting paper in 3- or 4-ounce salve cans. It is evident that the incubation period is dependent on temperature. During 1958, temperatures in the laboratory (attic) were comparable to temperatures at depths of 2 to 4 inches in the field. It therefore appears that eggs laid in the field may hatch in as few as 5 days in midsummer and may require as many as 30 days in early spring and late fall.

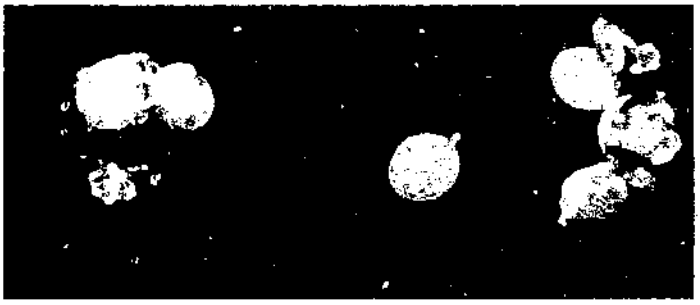

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FIGURE 5.—Eggs of southern potato wireworm.

TABLE 3.—*Incubation period of southern potato wireworm eggs in laboratory cages*

| Location of cages and period | Average temperature | Eggs | Incubation period | |
|---|---|---|---|---|
| | | | Range | Average |
| *Basement* | *° F.* | *Number* | *Days* | *Days* |
| July 29–Aug. 12, 1957 | 79 | 608 | 7–13 | 8 |
| Apr. 24–May 24, 1958 | 73 | 471 | 12–30 | 20 |
| *Attic* | | | | |
| June 29–July 14, 1958 | 84 | 450 | 5–12 | 8 |
| Aug. 5–29, 1958 | 86 | 713 | 5–14 | 7 |
| Aug. 27–Sept. 24, 1958 | 82 | 642 | 6–13 | 9 |
| Sept. 28–Oct. 21, 1958 | 73 | 300 | 10–23 | 15 |
| *Incubator (constant temperature)* | | | | |
| Apr. 24–May 24, 1958 | 83 | 375 | 6–12 | 8 |

## Larvae

Newly hatched larvae are white and later become cream colored or yellowish gray, with the head, pronotum, and outer extremities of the ninth abdominal segment a reddish orange. The surface of the body is smooth and sparsely hairy. Full-grown specimens (fig. 1) may be up to 2 mm. wide and 17 mm. long.

The median caudal notch on the dorsal plate of the ninth abdominal segment (fig. 6, *left*) is short and almost closed at the

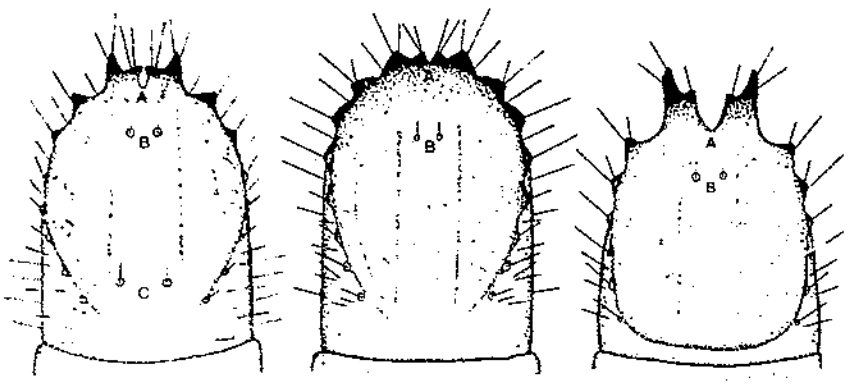


FIGURE 6.—Dorsal plate of ninth abdominal segment of larvae of southern potato wireworm (*left*), Gulf wireworm (*center*), and tobacco wireworm (*right*): *A*, Median caudal notch; *B*, posterior pair of setae; *C*, anterior pair of setae. Pairs of setae within parallel grooves.

tips of the V. One pair of setae is in front of the median caudal notch and another pair near the anterior margin of the plate; both are within the parallel grooves.

### *Habitats and Abundance*

Larvae were found in soil in cultivated fields, lawns, pastures, orchards, and in such weedy or grassy areas as unplanted fields, roadsides, and ditchbanks. No infestations were seen in woodlands. In a 10-acre wooded tract under observation, no wireworms were found in the soil immediately after clearing in November; however, a moderate infestation had developed by the following July.

Samples consisting of 4 square feet of soil (16 subsamples 6 by 6 by 6 inches) from each of three habitats on each of three farms were screened in mid-April and during August 4–5 and November 23–28 in 1960. The results of these screenings showed average larval populations as follows: Cultivated fields 3.4, grass sod 1.7, and woodlands 0.

Populations of overwintering larvae in cultivated fields following various summer and fall crops are shown in table 4. These records were obtained between 1957 and 1959 by screening at least 2 but usually 4 or more square feet of soil to the 6-inch depth from each field during October, November, or December.

No field in table 4 received insecticides that would appreciably affect the wireworm population. In fields of fall vegetables, including cabbage, snap beans, cucumbers, and tomatoes, insecticides were applied to control foliage-feeding pests. Although some adults and larvae of the southern potato wireworm may have been killed

TABLE 4.—*Effect of various kinds of vegetation during late summer and fall on overwintering larval populations of southern potato wireworm in cultivated fields, 1957–59*

| Vegetation | Fields | Larvae per square foot | |
|---|---|---|---|
| | | Range | Average |
| | *Number* | *Number* | *Number* |
| Weeds (mostly grasses) | 13 | 1–19 | 10 |
| Weeds (mostly cocklebur[1]) | 6 | 3–9 | 6 |
| Cattail millet | 3 | 8–9 | 9 |
| Grain sorghums | 22 | 0–13 | 5 |
| Soybeans | 7 | 1–9 | 4 |
| Cowpeas | 1 | -- | 2 |
| Fall vegetables | 5 | 0–2 | 1 |

[1] *Xanthium pensylvanicum* Wallroth.

incidentally, the low larval population in vegetable fields was primarily due to the lack of vegetation in the field during most of the period when eggs of the fall brood are laid. Cuthbert et al. (4) found 79 percent fewer larvae in plots kept relatively bare by frequent disking or harrowing in July, August, and September than in plots allowed to grow up in native grasses and broadleaf weeds. Two reasons account for this finding. Adults avoid fields in which there is insufficient cover to hide under during the day, and soil temperatures in such fields often become too high for newly hatched larvae to survive.

Larvae of all readily seen sizes occur in cultivated fields each season of the year. Most of them remain near the soil surface unless they are buried by plowing operations. When the soil is wet, many can be found on top of the soil under leaves, trash, or other cover. The vertical distribution of larvae in 10 fields during 3 years was as follows:

| *Inch layer* | *Percent* |
|---|---|
| 0–2 | 72.5 |
| 2–4 | 22.7 |
| 4–6 | 4.7 |
| 6–8 | Less than .1 |

Seasons of the year and soil temperature appear to have little effect on the location of the larvae. Those near the surface under average soil-moisture conditions move downward during dry spells, but very few apparently go deeper than about 4 inches. The high percent of larvae that remain close to the soil surface, even during the winter, probably accounts for the high mortality during cold spells when the soil is frozen to a depth of 2 inches. Larvae in soil plowed during the fall in preparation for early-spring crops, such as potatoes, are especially vulnerable. The extent of larval mortality under such conditions is discussed under Natural Control.

The density of larvae in cultivated fields in Charleston County varied greatly between fields, farms, seasons, and years. The highest population in a single field, 22 larvae per square foot of soil 6 inches deep, was found in December 1958. A single square-foot sample of soil (four subsamples 6 by 6 by 6 inches) from a localized area in one field in the fall of 1958 contained 41 larvae.

Populations in untreated cultivated fields during 1955–67 (table 5) were determined by screening from each field at least 2 but usually 4 to 6 square feet of soil to a depth of 6 inches (four subsamples, 6 by 6 by 6 inches, per square foot). Spring records were obtained during February and May and fall samples during Sep-

TABLE 5.—*Larval populations of southern potato wireworm in cultivated fields in Charleston County, S.C.*

| Year and season | Fields | Farms | Larvae per square foot of soil 6 inches deep | |
|---|---|---|---|---|
| | | | Range | Average per field |
| 1955: | *Number* | *Number* | *Number* | *Number* |
| Spring | 3 | 3 | 1.9–2.2 | 2.0 |
| Fall | 20 | 12 | .5–15.0 | 5.7 |
| 1956: | | | | |
| Spring | 14 | 13 | .3–12.0 | 4.1 |
| Fall | 11 | 7 | 2.5–18.5 | 8.7 |
| 1957: | | | | |
| Spring | 16 | 11 | 1.5–13.8 | 5.7 |
| Fall | 13 | 10 | 4.0–16.0 | 6.8 |
| 1958: | | | | |
| Spring | 7 | 5 | .8–4.2 | 2.6 |
| Fall | 9 | 8 | 3.2–12.0 | 6.3 |
| 1959: | | | | |
| Spring | 14 | 8 | .6–8.5 | 4.3 |
| Fall | 19 | 15 | .2–19.0 | 4.5 |
| 1960: | | | | |
| Spring | 7 | 6 | 1.0–5.5 | 2.4 |
| Fall | 19 | 9 | 1.2–12.6 | 3.9 |
| 1961: | | | | |
| Spring | 4 | 4 | 2.6–8.5 | 4.8 |
| Fall | 18 | 8 | 1.0–11.8 | 4.4 |
| 1962: | | | | |
| Spring | 5 | 4 | 1.6–5.0 | 2.7 |
| Fall | 19 | 9 | 0–8.5 | 1.9 |
| 1963: | | | | |
| Spring | 2 | 1 | 1.3–1.9 | 1.6 |
| Fall | 20 | 8 | .7–11.0 | 3.6 |
| 1964: | | | | |
| Spring | 2 | 2 | 2.0–3.6 | 2.7 |
| Fall | 19 | 13 | 0–10.7 | 2.7 |
| 1965: | | | | |
| Spring | 1 | 1 | | 4.7 |
| Fall | 18 | 10 | 0–6.5 | 2.2 |
| 1966: | | | | |
| Spring | 1 | 1 | | 3.3 |
| Fall | 21 | 12 | .25–6.2 | 3.0 |
| 1967: | | | | |
| Spring | 1 | 1 | | 3.1 |
| Fall | 22 | 17 | 0–5.0 | 1.6 |
| Total or average: | | | | |
| Spring | 77 | | | 3.8 |
| Fall | 228 | | | 3.9 |

tember through December. During the 13 years the populations in cultivated fields during the spring were chiefly larvae that hatched during the preceding fall, survived the winter, and did not pupate before the soil was screened. These were the larvae that injured the spring potato tubers in coastal South Carolina. Populations during the spring were highest in 1957 (5.7), lowest in 1963 (1.6), and averaged 3.8 per square foot. Populations during the fall were highest in 1956 (8.7), lowest in 1967 (1.6), and averaged 3.9 per square foot.

These averages do not reflect the full extent of winter mortality of larvae because in most years the soil screenings during the spring were made only in fields having highest populations during the preceding fall and therefore were selected for spring insecticide tests.

### *Larval Food*

The principal food of larvae appears to be the seeds, roots, stems, tubers, and fruits of certain plants, especially those parts with a high starch content. The larvae are cannibalistic when several are together. They have been observed feeding on southern corn rootworms and probably are predaceous on other soil-inhabiting insects.

The suitability of certain materials as food for larvae was studied in the laboratory during 1959 and 1960 in cage tests. Each food tested was supplied to at least 10 larvae in each of three tests from the time they hatched until they pupated or died. The larvae were caged individually in 4-ounce salve cans within 5 days after hatching. Prior to being isolated some cannibalism may have occurred; otherwise, the larvae had access only to the foods tested. Test 1 was started in June and July and the cages were kept in the attic of an office building until October. They then were placed in a controlled temperature cabinet at 83° F. Test 2 and 3 cages were kept in the cabinet at 83° from the outset. The cages were examined at approximately weekly intervals and fresh food was supplied when needed. Results of the food comparisons are summarized in table 6.

Larvae that were fed wheat all survived, and they had the shortest average larval period in the tests. Sorghum and oat seeds were the next best foods included in at least two tests. Boiled corn was fairly good, but sprouted corn seed was poor. Moderate to good survival resulted when larvae were fed seeds of several lawn and pasture grasses and *Amaranthus* sp., a common weed in cultivated fields. Cowpeas and lima beans were relatively poor foods and no

TABLE 6.—*Survival to adult stage and rate of development of southern potato wireworm larvae when furnished various foods in laboratory cages*

| Food | Survival [1] | | | Period from oviposition to adult emergence | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Test 1 | | Test 2 | | Test 3 | |
| | Test 1 | Test 2 | Test 3 | Range | Average | Range | Average | Range | Average |
| | *Percent* | *Percent* | *Percent* | *Days* | *Days* | *Days* | *Days* | *Days* | *Days* |
| Wheat seed | 100 | 100 | --- | 46–52 | 47 | 47–65 | 56 | --- | --- |
| Sorghum seed | 90 | 90 | 100 | 47–75 | 55 | 51–103 | 72 | 48–94 | 69 |
| Oat seed | 90 | 80 | --- | 39–83 | 59 | 47–66 | 60 | --- | --- |
| Sorghum seed and potato tuber | --- | --- | 100 | --- | --- | --- | --- | 49–83 | 65 |
| Soybean seed and potato tuber | --- | --- | 100 | --- | --- | --- | --- | 58–120 | 88 |
| Carrot and boiled corn seed | 95 | --- | --- | 60–88 | 71 | --- | --- | --- | --- |
| Carrot | 70 | --- | --- | 56–94 | 77 | --- | --- | --- | --- |
| *Amaranthus* sp. seed | 80 | 50 | --- | 60–82 | 70 | 97–160 | 116 | --- | --- |
| Dallisgrass seed | 90 | 60 | --- | 77–188 | 110 | 93–109 | 100 | --- | --- |
| Bermudagrass seed and potato tuber | --- | --- | 70 | --- | --- | --- | --- | 60–96 | 79 |
| Cowpea seed and potato tuber | --- | --- | 70 | --- | --- | --- | --- | 53–105 | 81 |
| Carpetgrass seed and potato tuber | --- | --- | 70 | --- | --- | --- | --- | 75–113 | 96 |
| Potato tuber | 0 | 50 | 60 | --- | --- | 69–151 | 104 | 79–126 | 106 |
| Carpetgrass | 50 | 30 | 40 | 73–203 | 128 | 100–159 | 125 | 107–145 | 125 |
| Boiled corn | 80 | --- | --- | 56–94 | 72 | --- | --- | --- | --- |
| Sprouted corn seed | --- | 40 | --- | --- | --- | 101–135 | 125 | --- | --- |
| Bermudagrass seed | --- | --- | 70 | --- | --- | --- | --- | 63–99 | 79 |
| Cowpea seed | --- | --- | 60 | --- | --- | --- | --- | 59–86 | 75 |
| Lima bean seed | 50 | --- | --- | 84–125 | 92 | --- | --- | --- | --- |
| Poultry laying mash (20-percent plant protein) | 10 | --- | --- | 65 | --- | --- | --- | --- | --- |
| Soybean seed | --- | --- | 0 | --- | --- | --- | --- | --- | --- |
| Fish food (38-percent animal protein) | 0 | --- | --- | --- | --- | --- | --- | --- | --- |
| Sweetpotato | 0 | --- | --- | --- | --- | --- | --- | --- | --- |
| Field soil with plant roots | 0 | --- | --- | --- | --- | --- | --- | --- | --- |
| No food | 0 | 0 | --- | --- | --- | --- | --- | --- | --- |

[1] Most of mortality occurred during larval stage.

larvae fed soybeans reached pupation. Carrots were fair, but potato tubers were poor and sweetpotatoes very poor. Combinations of carrots or potatoes with one of the seeds resulted in better survival or growth or both than either food alone. Slices of potato tubers and of carrot root usually molded or decayed within a few weeks and this may have affected the results obtained with them.

### *Duration of Larval Stage*

High mortality of newly hatched larvae, cannibalism, and difficulty in maintaining proper moisture and a constant food supply prevented effective larvae rearing in field cages. Larvae were successfully reared in soil in 3- and 4-ounce metal salve cans containing sandy loam and whole grains of corn. Corn heated in water just enough to prevent sprouting proved more satisfactory than unheated seed that soon sprouted and rapidly depleted the moisture in the cages.

The salve cans were kept in an unheated basement of a concrete-block building prior to May 9, 1958, and in an unheated attic of the building thereafter. The location of the cages was changed so as to have them where temperatures were more comparable to those at 2- to 4-inch soil depths, the location of most larvae in the field. Before 1958 many of the larvae hatching during June and July did not pupate until the following spring or summer, whereas most field specimens of that age pupated within 2 or 3 months. Therefore larval development in the attic was more nearly like that observed in the field. Average monthly temperatures at the location of these cages and at various soil depths are shown in table 7.

All laboratory-reared larvae hatching during April, May, and June, most of those hatching in July, and about 25 percent of those hatching in August pupated the same year (table 8). These specimens had larval periods of 27 to 92 days, with group averages of 41 to 69 days. These will be termed the "short-cycle" or "summer" larval brood. Average monthly temperatures at their locations during most of their larval periods ranged from approximately 75° to 85° F. and usually 80° or above for those reared in the attic (table 7). Comparable temperatures prevailed at the 2-inch soil depth in the field.

A few of the laboratory-reared larvae that hatched in July, most of those hatching in August, and all of those hatching in September and October did not pupate until the following spring or summer. Their larval periods ranged from 191 to 340 days, with group averages of 239 to 318 days. These specimens will be termed the "long-cycle" or "overwintering" larval brood. Average monthly temperatures at their locations ranged from approximately 55°

TABLE 7.—*Comparison of average monthly temperatures in soil and in 2 insect-rearing locations*

| Month | 1957 | | 1958 | | | 1959 | | |
|---|---|---|---|---|---|---|---|---|
| | Basement | 6-in. soil depth | Attic | 2-in. soil depth | 4-in. soil depth | Attic | 2-in. soil depth | 4-in. soil depth |
| | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. |
| January | | --- | 57.6 | | 43.1 | 56.5 | 46.4 | 47.4 |
| February | | 56.3 | 57.3 | | 44.3 | 61.3 | 54.2 | 53.9 |
| March | | 58.1 | 62.0 | | 54.2 | 62.1 | 56.6 | 56.2 |
| April | | 69.6 | 67.8 | | 67.0 | 71.2 | 72.7 | 68.6 |
| May | 73.4 | 75.3 | 77.4 | | 78.9 | 79.9 | 79.1 | 77.1 |
| June | 78.0 | 80.0 | 82.2 | | 81.0 | 84.2 | 82.7 | 80.9 |
| July | 79.0 | 76.6 | 85.9 | | 85.0 | 84.0 | 84.9 | 83.9 |
| August | 78.5 | 78.8 | 86.0 | [1]81.2 | 83.3 | 83.8 | 83.0 | 81.1 |
| September | 78.2 | 75.8 | 83.3 | 77.1 | 77.4 | 78.4 | 75.3 | 75.2 |
| October | 68.0 | 64.0 | 69.7 | 61.9 | 67.0 | 74.3 | 71.4 | 69.4 |
| November | 65.6 | 57.9 | 66.0 | 61.3 | 62.7 | 59.6 | 59.0 | 59.8 |
| December | 60.6 | 47.9 | 56.5 | 48.5 | 50.5 | 54.5 | 52.3 | 51.7 |

[1] Records not taken until Aug. 14.

TABLE 8.—*Duration of larval stage of southern potato wireworm in laboratory cages*

| Month hatched | Specimens | Larvae hatched and pupated in same year | | | Larvae overwintered before pupating | | |
|---|---|---|---|---|---|---|---|
| | | Proportion | Larval period | | Proportion | Larval period | |
| | | | Range | Average | | Range | Average |
| *1957* | *Number* | *Percent* | *Days* | *Days* | *Percent* | *Days* | *Days* |
| May | 6 | 100 | 46–82 | 61 | 0 | | |
| July | 19 | 74 | 42–73 | 64 | 26 | 311–323 | 318 |
| August | 24 | 38 | 36–78 | 59 | 62 | 253–340 | 308 |
| September | 44 | 0 | | | 100 | 257–330 | 282 |
| October | 8 | 0 | | | 100 | 256–279 | 266 |
| *1958* | | | | | | | |
| May | 23 | 100 | 55–92 | 65 | 0 | | |
| June | 9 | 100 | 31–50 | 42 | 0 | | |
| July | 41 | 98 | 27–52 | 41 | 2 | | 299 |
| August | 34 | 15 | 50–81 | 69 | 85 | 191–325 | 275 |
| September | 27 | 0 | | | 100 | 224–329 | 255 |
| October | 24 | 0 | | | 100 | 192–264 | 239 |
| *1959* | | | | | | | |
| April | 18 | 100 | 54–82 | 68 | 0 | | |

to 75° F. during the greater part of their development, reaching approximately 75° to 80° during pupation the following April and May. A few did not pupate until June, when average temperatures were 78° to 84° at the location of the cages.

The overwintering larval brood causes most, if not all, of the injury to spring potato tubers in coastal South Carolina. Few adults overwinter and the small number of larvae hatching from eggs laid in late March and April cause little injury since the crop is harvested in late May or early June. Summer-fall crops, such as sweetpotatoes, are subject to injury by both summer and fall broods.

Apparently larvae do not pupate in the spring until the soil reaches about 75° F. during the day. Pupation evidently ceases in the fall when the temperature averages below 65°. The pupae and adults of summer-brood larvae tend to be smaller than those of overwintering brood, possibly because high temperature accelerates maturation.

During the prepupal period, usually of 2- to 3-day duration, the larvae form a pupal cell in the soil by twisting or rolling. The cell is usually in the upper 4 inches of soil.

## Pupae

The pupae (fig. 1) are slightly larger than the adults. They are white when first formed, but soon change to a creamy yellow. The thorax and abdomen show some light tan just before eclosion. Dark eyespots are visible on all except newly formed pupae. One pair of sharp spines is present near the anterior margin of the pronotum and another pair at the posterior angle. A pair of long spines between two much shorter ones occurs at the tip of the abdomen.

Pupae can be sexed by examining the genital buds on the last abdominal sternite. Males have three protruding buds on the same horizontal plane; females have two buds on the same plane and a smaller one located anteriorly.

Pupae were found in the field in the Charleston area from April through November and were most abundant in May and August. They are fragile, easily crushed, and not often seen during soil-screening operations.

The duration of the pupal stage of reared specimens during 1957–59 (table 9) was inversely proportional to the average monthly temperatures (fig. 7). The minimum average duration was 6.1 days at about 84° F. and the maximum was 18 days at about 66°.

No caged specimens overwintered as pupae and no pupae were found in the field during the winter.

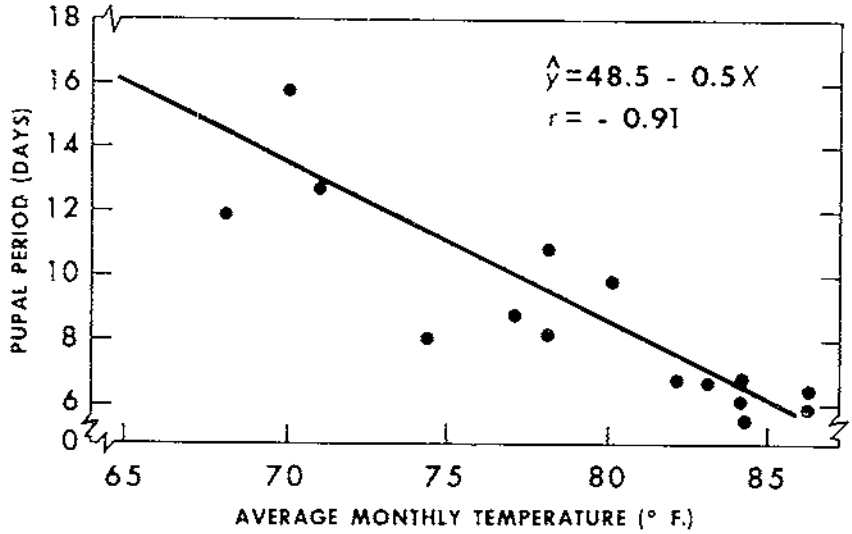


FIGURE 7.—Duration of pupal stage of southern potato wireworm as affected by average monthly temperature.

TABLE 9.—*Duration of pupal stage of southern potato wireworm in laboratory cages*

| Month [1] | Specimens | Pupal period | |
|---|---|---|---|
| | | Range | Average |
| | *Number* | *Days* | *Days* |
| *1957* | | | |
| September | 5 | 8–21 | 11.4 |
| October | 6 | 11–14 | 12.3 |
| *1958* | | | |
| May | 11 | 8–10 | 9.1 |
| June | 60 | 6–9 | 7.4 |
| July | 49 | 5–9 | 6.2 |
| August | 40 | 4–8 | 6.7 |
| September | 13 | 6–9 | 7.6 |
| October | 2 | 16–17 | 16.5 |
| November | 3 | 17–19 | 18.0 |
| *1959* | | | |
| April | 3 | 12–14 | 13.0 |
| May | 34 | 8–11 | 9.6 |
| June | 55 | 5–11 | 7.4 |
| July | 19 | 5–9 | 6.5 |
| August | 17 | 5–8 | 6.1 |
| September | 27 | 5–11 | 8.5 |
| October | 4 | 8–9 | 8.5 |

[1] In 1957, cages kept in unheated basement and after May 9, 1958, in unheated attic of building.

## Length of Life Cycle

Data on the duration of the egg-to-adult stage are summarized in table 10. The egg-to-adult rearings were in sandy loam in 3- and 4-ounce metal salve cans, which were stored until May 9, 1958, in a basement and thereafter in the attic of the building as described for the larval and pupal rearings. Average temperatures at these locations are given in table 7. The larvae were furnished raw or heated corn and occasionally a slice of potato or carrot.

Practically all the specimens hatching from eggs laid during April through July and from 15 to 70 percent of those from eggs deposited in August reached the adult stage the same year (table 10). The duration of the egg-to-adult stages of these short-cycle broods ranged from 42 to 109 days; group averages were from 54.4 to 94.2 days. Specimens developing from most of the eggs laid in August of 1957 and 1958 and from all eggs laid in September and October of 1957–59 overwintered as larvae and reached the

TABLE 10.—*Duration of egg-to-adult stage of southern potato wireworm in laboratory cages*

| Oviposition Specimens | | Became adults in same year they hatched | | | Overwintered before becoming adults | | |
|---|---|---|---|---|---|---|---|
| | | Proportion | Egg-to-adult period | | Proportion | Egg-to-adult period | |
| | | | Range | Average | | Range | Average |
| | *Number* | *Percent* | *Days* | *Days* | *Percent* | *Days* | *Days* |
| *1957* | | | | | | | |
| May | 4 | 100 | 90–100 | 93.2 | 0 | --- | --- |
| July | 13 | 100 | 55–95 | 82.7 | 0 | --- | --- |
| August | 23 | 39 | 55–106 | 82.1 | 61 | 294–348 | 324.7 |
| September | 50 | 0 | --- | --- | 100 | 274–410 | 299.5 |
| *1958* | | | | | | | |
| May | 23 | 100 | 55–108 | 80.3 | 0 | --- | --- |
| June | 9 | 100 | 45–65 | 54.4 | 0 | --- | --- |
| July | 40 | 98 | 42–75 | 56.8 | 2 | 299 | --- |
| August | 34 | 15 | 73–106 | 89.2 | 85 | 255–341 | 292.1 |
| September | 27 | 0 | --- | --- | 100 | 242–345 | 273.4 |
| October | 23 | 0 | --- | --- | 100 | 236–293 | 263.6 |
| *1959* | | | | | | | |
| April | 18 | 100 | 82–109 | 94.2 | 0 | --- | --- |
| July | 28 | 100 | 56–94 | 72.1 | 0 | --- | --- |
| August | 10 | [1] 70 | 56–68 | 68.0 | --- | --- | --- |
| September | | 0 | --- | --- | 100 | 244–298 | 274.5 |
| October | | 0 | --- | --- | 100 | 238–284 | 265.8 |

[1] Remainder died as larvae in 1960.

adult stage the following year. Their egg-to-adult cycles ranged from 236 to 410 days; group averages were from 263.6 to 324.7 days.

Laboratory-reared adults laid few fertile eggs and conclusive data regarding the preoviposition period were not obtained.

## SEASONAL OCCURRENCE

The relative seasonal abundance of adults in the field (fig. 8) was determined from the average monthly catch in a 15-watt fluorescent blacklight insect trap (table 11). It was furnished by the Agricultural Engineering Research Division, Agricultural Research Service, and operated continuously between 1956 and 1967 at the Clemson University Truck Experiment Station, Charleston County, S.C. The light-trap catches are not an entirely accurate index of seasonal abundance of the adults since low temperatures limit the catch during the winter. Occasional observations in the winter and early spring indicate that the adults are only slightly more abundant during the winter than shown in figure 8. Data on the abundance of gravid females are shown in figure 8 and table 12.

Figure 8 shows the seasonal abundance of larvae based on the average number of larvae (table 13) found in cultivated sandy loam in Charleston County between March 1956 and December 1959. Different fields were planted to potatoes in late winter and usually to a cover crop after the potatoes were harvested by the middle of June. Samples of soil, usually totaling 3 to 6 square feet to a depth of 6 inches (12 to 24 subsamples 6 by 6 by 6 inches), were taken at random from untreated plots or other untreated parts of each field at approximately bimonthly intervals.

Since the insect remains in the pupal stage for a relatively brief period and since the larval sampling method used was not suitable for recovering pupae, no data on pupal abundance were obtained. Only a few specimens were found during the screening of field soil.

A few adults survive the winter in coastal South Carolina, but most of the wireworms overwinter as larvae. They pupate in April, May, and early June, after which the earliest progeny of overwintered adults begin to pupate.

Adults from overwintered larvae begin appearing in appreciable numbers in May and reach a peak of abundance in June. These beetles and at least some of those from the first small, short-cycle larval brood that originated from the overwintered adults produce a large midsummer brood of larvae. These larvae grow rapidly from late June to early September and complete their develop-

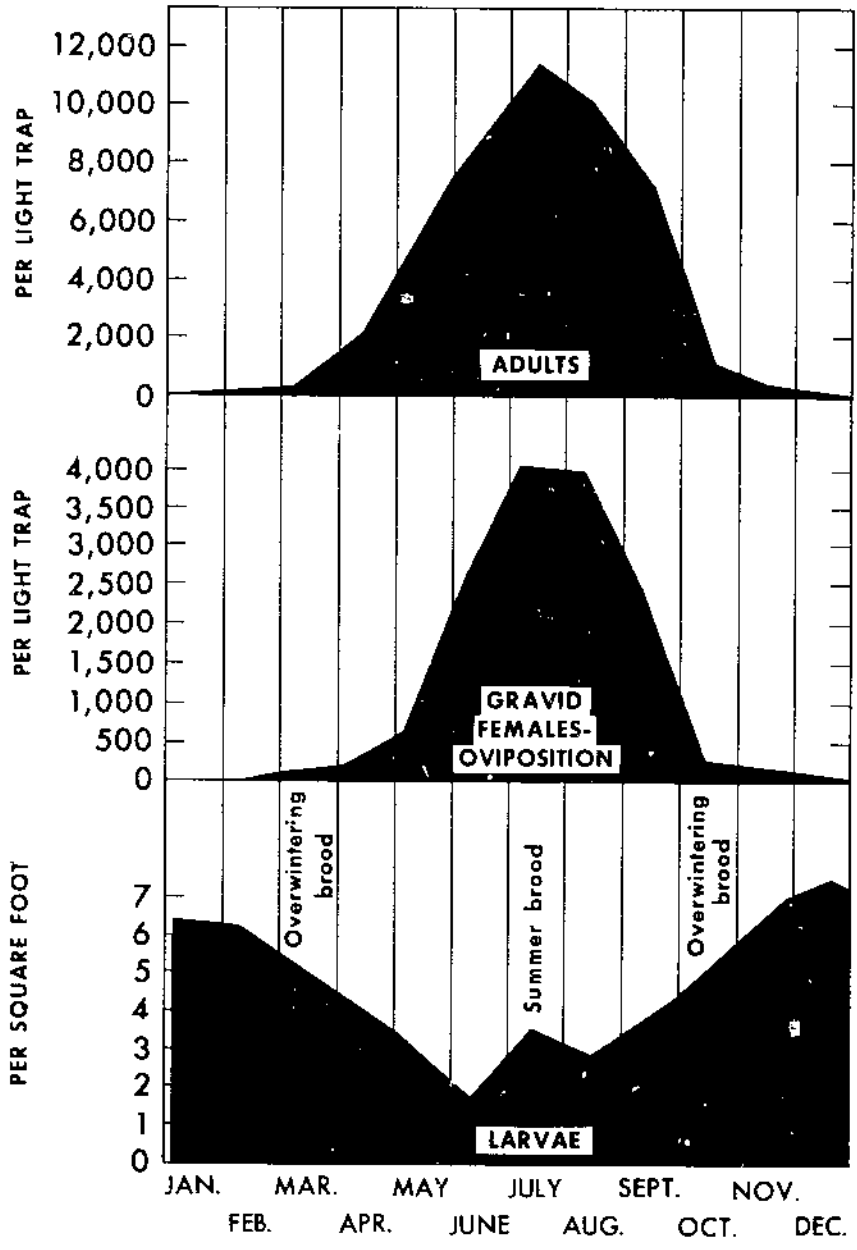


FIGURE 8.—Relative seasonal abundance of life stages of southern potato wireworm in Charleston County, S.C.

TABLE 11.—*Catches of southern potato wireworm adults in 15-watt fluorescent blacklight insect trap, Charleston County, S.C.*

| Year | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* |
| 1956 | --- | 7 | 121 | 246 | 3,009 | 10,420 | 9,072 | 19,381 | 9,956 | 3,247 | 362 | 119 | 55,940 |
| 1957 | --- | 6 | 78 | 442 | 6,181 | 16,399 | 14,564 | 10,295 | 12,469 | 86 | 43 | 1 | 60,564 |
| 1958 | --- | --- | --- | 271 | 823 | 5,315 | 3,566 | 8,119 | 7,535 | 1,523 | 807 | 1 | 27,960 |
| 1959 | --- | 6 | 4 | 353 | 2,085 | 13,428 | 20,640 | 13,756 | 10,633 | 2,725 | 2,127 | --- | 65,757 |
| 1960 | 5 | --- | --- | 400 | 1,853 | 18,047 | 47,195 | 16,416 | 18,600 | 3,086 | 226 | --- | 105,828 |
| 1961 | --- | --- | 105 | 9 | 353 | 5,758 | 8,315 | 6,615 | 4,885 | 1,106 | 1,036 | 39 | 28,221 |
| 1962 | 126 | 20 | --- | 29 | 2,661 | 3,657 | 3,003 | 10,761 | 8,908 | 1,996 | 12 | --- | 31,173 |
| 1963 | --- | --- | 17 | 183 | 2,881 | 12,088 | 5,821 | 3,914 | 5,933 | 813 | 121 | 1 | 31,772 |
| 1964 | --- | --- | 3 | 106 | 946 | 10,780 | 7,848 | 3,869 | 2,396 | 274 | 17 | 3 | 26,242 |
| 1965 | --- | --- | --- | 100 | 1,301 | 6,322 | 1,713 | 13,184 | 2,901 | 530 | 73 | --- | 26,124 |
| 1966 | --- | --- | --- | 260 | 661 | 3,433 | 7,917 | 6,232 | 3,095 | 759 | 255 | 6 | 22,618 |
| 1967 | --- | --- | 37 | 251 | 2,364 | 4,735 | 9,208 | 7,468 | 1,736 | 300 | 5 | 99 | 26,203 |
| Total | 131 | 39 | 365 | 2,650 | 25,118 | 110,382 | 138,862 | 120,010 | 89,047 | 16,445 | 5,084 | 269 | 508,402 |
| Average | 10.9 | 3.2 | 30.4 | 220.8 | 2,093.2 | 9,198.5 | 11,571.8 | 10,000.8 | 7,420.6 | 1,370.4 | 423.7 | 22.4 | 42,366.7 |

TABLE 12.—*Seasonal abundance of gravid females of southern potato wireworm, Charleston County, S.C.*

| Trap catch and year | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. |
|---|---|---|---|---|---|---|---|---|---|---|
| Females caught (percent):[1] | | | | | | | | | | |
| 1956 | -- | -- | -- | -- | -- | 53 | 51 | 51 | 44 | 41 |
| 1957 | -- | 43 | 39 | 61 | 47 | 49 | 53 | 38 | 33 | 39 |
| 1958 | -- | -- | 26 | 42 | 42 | 48 | 58 | 52 | 40 | 33 |
| 1959 | 29 | 48 | 41 | 35 | 43 | 40 | 52 | 52 | 36 | 57 |
| Average | 29 | 45 | 35 | 46 | 44 | 47 | 53 | 48 | 38 | 42 |
| Females examined (number): | | | | | | | | | | |
| 1956 | -- | -- | -- | -- | -- | 26 | 178 | 114 | 86 | 41 |
| 1957 | -- | 32 | 49 | 127 | 107 | 146 | 158 | 91 | 31 | 47 |
| 1958 | -- | -- | 25 | 100 | 201 | 271 | 278 | 218 | 116 | 59 |
| 1959 | 17 | 60 | 21 | 28 | 44 | 80 | 84 | 34 | 35 | 114 |
| Females gravid (percent of number examined): | | | | | | | | | | |
| 1956 | -- | -- | -- | -- | -- | 85 | 75 | 79 | 57 | 4 |
| 1957 | -- | 72 | 61 | 62 | 74 | 83 | 82 | 64 | 19 | 3 |
| 1958 | -- | -- | 80 | 63 | 65 | 69 | 66 | 70 | 40 | 2 |
| 1959 | 12 | 60 | 86 | 71 | 59 | 61 | 74 | 88 | 68 | 12 |
| Average | 12 | 66 | 76 | 65 | 66 | 74 | 74 | 75 | 46 | 5 |
| Females gravid (average number caught 1956–67)[2] | .11 | 9 | 59 | 626 | 2,671 | 4,025 | 3,922 | 2,671 | 240 | 89 |

[1] Based on table 11 totals.

[2] Estimated by applying average percent of gravid females (table 12) to average number of adults caught (table 11).

TABLE 13.—*Seasonal populations of southern potato wireworm larvae in untreated fields, Charleston County, S.C.*

| Year and field No. | Larvae per square foot in— | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
| 1956: | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* |
| 1 | - | -- | 2.5 | 2.2 | 0.6 | -- | 3.2 | 1.6 | 1.2 | 3.8 | 5.1 | 2.7 |
| 2 | -- | -- | 6.9 | 5.6 | 3.9 | 1.6 | 6.5 | 7.4 | 8.1 | 8.8 | 9.9 | 8.2 |
| 1957: | | | | | | | | | | | | |
| 1 | 4.8 | -- | 5.6 | 5.4 | 2.2 | .4 | 3.9 | 1.3 | 5.5 | 7.9 | 4.8 | 3.4 |
| 2 | 7.1 | -- | 6.7 | 3.5 | 4.4 | 1.1 | 6.7 | 2.5 | 2.3 | 2.4 | 3.7 | 1.0 |
| 3 | -- | 16.2 | 9.7 | 8.4 | 11.5 | 3.5 | -- | .6 | 3.4 | 2.7 | 3.7 | -- |
| 1958: | | | | | | | | | | | | |
| 1 | 1.8 | -- | 1.4 | .8 | 1.2 | .4 | 1.8 | 2.5 | 2.9 | 4.7 | 6.9 | 12.6 |
| 2 | -- | -- | 4.5 | 3.9 | 1.7 | 1.0 | 1.1 | 3.7 | 7.4 | 9.9 | 16.2 | 21.7 |
| 3 | 6.0 | 6.0 | 3.2 | -- | 2.0 | 2.6 | 1.4 | 3.3 | 2.1 | 6.1 | 8.4 | 9.0 |
| 1959: | | | | | | | | | | | | |
| 1 | 4.4 | 3.6 | 5.8 | 3.2 | .2 | 1.2 | 1.4 | 1.2 | .4 | 1.2 | .6 | 2.8 |
| Average | 4.8 | 8.6 | 5.1 | 4.1 | 3.4 | 1.5 | 3.2 | 2.7 | 3.7 | 5.3 | 6.6 | 7.7 |

ment in an average of 65 days. They are most numerous in July. Adults of this short-cycle midsummer brood are abundant in late August and in September. They oviposit soon after emergence. Most of the wireworms hatching from these eggs overwinter as larvae, but some hatching in early August become adults before winter. Most of the larvae hatching after mid-August do not pupate until the following year. Oviposition and pupation continue through October and to a limited extent during the first half of November, apparently ceasing when the temperature is below 65° F.

Evidently two generations of the southern potato wireworm usually occur each year in coastal South Carolina. One generation has a short-cycle summer brood of larvae and the other a long-cycle overwintering brood. However, adverse conditions could delay development of the summer brood, resulting in individuals that must overwinter as adults. Also under favorable conditions part of the population could complete two short-cycle broods, again resulting in individuals that must overwinter as adults. This could occur when overwintered adults begin to lay eggs in March and pupation continues into October.

## NATURAL CONTROL

The full extent to which natural agencies control southern potato wireworm populations is not known. The insect appears reasonably immune to normal weather variations in coastal South Carolina. However, larval populations in six cultivated fields on four potato-producing farms in Charleston County were reduced from 25 to 66 percent, with an average of 36 percent, by a sudden, severe freeze from December 11 to 14, 1957, when the minimum air temperature was 15.4° F. at the Charleston Municipal Airport. The soil was wet at the time and approximately 75 percent of the wireworms were in the top 2 inches, the depth to which the soil froze. Freezes during January and February of 1958 further reduced the larval populations, and by April the average population in the fields was only 1.8 larvae per square foot as compared with 4.3 in October and November 1957.

These fields were plowed during late fall or early winter of 1957. There were indications that the effects of the freezes were not so great in soils having heavy vegetative covering during the 1957–58 winter. Insect populations in certain fields at Hastings, Fla., also were reported to have been drastically reduced by freezes during the same winter.

Southern potato wireworm larvae survived a constant temperature of 38° F. for 3 days in laboratory cages, but 32 percent died after 4 weeks' exposure and 89 percent after 6 weeks' exposure to that temperature.

The larvae appear to be capable of surviving submergence in water for several days. During high temperatures in August 1958, seven larvae survived under water for 48 hours and three out of five were alive after 5 days.

Mortality of field-collected larvae from disease is sometimes high in laboratory cages. Two causative organisms have been isolated, a parasitic nematode and a fungus. When they were introduced into cages containing larvae, the nematode caused as high as 80-percent mortality and the fungus as high as 100 percent. Both pathogens kill slowly and their effects on the wireworms have not been consistent.

The fungus *Metarrhizium anisopliae* (Metchnikoff) Sorokin and schizogregarine protozoan, alone or in combination, were found in 59 percent of 100 dead or dying field-collected larvae of the southern potato wireworm (Bell et al. *1*).

No insect parasites or predators of this wireworm have been discovered, but the highly cannibalistic nature of the larvae probably limits the density of their population.

When potato fields are being prepared for planting during the winter, large flocks of sea gulls frequently follow the plows and pick up wireworms. Since they only get the ones left on top of the soil, little control is provided.

## ELATERIDAE ASSOCIATED WITH SOUTHERN POTATO WIREWORM

Several species of elaterids closely related to the southern potato wireworm occur in coastal South Carolina, and larvae of one or more of these species sometimes are found with this wireworm. The most common of the associated species are the Gulf wireworm, the tobacco wireworm (*Conoderus vespertinus* (F.)), *C. lividus* (DeGeer), and *C. bellus* (Say). The last two have no common name at present. Larvae of these five species can be distinguished by the characters in the key and the illustration given by Rabb (*14*). To supplement this information, distinguishing characters on the dorsal plate of the ninth abdominal segment of the larvae of these first three species are shown in figure 6.

Late-instar larvae of the southern potato wireworm (fig. 6) and *C. bellus* have an almost closed, oval, median caudal notch in the

dorsal plate of the ninth abdominal segment, whereas the Gulf and tobacco wireworms (fig. 6) and *C. lividus* have an open, V-shaped, median caudal notch. This notch in the last two species is deeper than that in the Gulf wireworm. The southern potato wireworm (fig. 6) and *C. lividus* have two pairs of setae (anterior and posterior) in front of the median caudal notch, but, as previously stated, this notch differs in the two species. The Gulf and tobacco wireworms (fig. 6) and *C. bellus* have only one pair of posterior setae in front of the median caudal notch. The average length of full-grown larvae of *C. bellus* is about 6.5 mm., of southern potato, Gulf, and tobacco wireworms about 13 mm., and of *C. lividus* about 24 mm.

Adults of the Gulf wireworm resemble those of the southern potato wireworm, but are more densely pubescent, usually larger, more uniformly dark brown or black, and do not appear shiny to the unaided eye. Tobacco wireworm adults have a clearly visible, characteristic pattern of light- and dark-brown markings on the thorax and elytra. Adults of *C. lividus* are a uniform tan and usually larger than southern potato wireworm adults. *C. bellus* adults are only two-thirds as large as those of the southern potato wireworm.

In addition to the five species described here, adults of *Conoderus scissus* Schaeffer, *C. perversus* (Brown), *C. auritus* (Herbst), *Melanotus* sp., and *Megapenthes* sp. were taken at times with the southern potato wireworm in a blacklight insect trap (table 11). However, in each of the 12 years of trap operation this last insect comprised at least 98.4 percent of the total elaterid catch.

Larvae of *Glyphonyx* sp., probably *G. bimarginatus* Schaeffer, which have a pointed "bullet-shaped" last abdominal segment, also were found with the southern potato wireworm in soil of cultivated fields.

## SUMMARY

The southern potato wireworm (*Conoderus falli* Lane) is widely distributed in agricultural areas in the Southeastern United States from North Carolina to Louisiana. In some of these areas the larvae seriously injure potato tubers, sweetpotato roots, and tobacco transplants. Occasional and usually less serious injury occurs on beets, carrots, melons, strawberries, tomatoes, *Gerbera* sp. daisies, and gladiolus. The insect was especially injurious in 1956 and 1957, shortly after it became resistant to several previously effective soil insecticides.

The adults are relatively small, brownish beetles that may be

found in fields throughout the year. They hide at or near the soil surface during the day and are most active during the early part of warm, humid nights. The beetles are attracted to lights at night when the air temperature at 8 p.m. is about 60° F. or higher. Approximately 9,800 were taken in a fluorescent blacklight trap during a single night in July 1960. Adults have been captured during each month of the year, but highest catches have occurred in midsummer and lowest in midwinter. Adults in laboratory cages fed on pollen and nectar of flowers and the flesh and juice of fruits.

Oviposition began from 9 to 27 days after the adults emerged. The maximum number of eggs found in a female was 61. Caged specimens laid from 22 to 63 eggs each, with an average of 36. Eggs laid within one-half inch of the soil surface hatched in 5 to 30 days depending on the temperature.

Larvae have smooth, shiny, yellowish-gray bodies, with reddish-orange extremities, and are up to 2 mm. wide and 17 mm. long when full grown. They were found throughout the year, usually in the top 4 inches of soil, in cultivated fields, pastures, lawns, ditchbanks, orchard sod, and grassy or weedy unplanted fields, but not in wooded areas. Populations of larvae in cultivated areas varied greatly between fields, farms, seasons, and years, but they were highest in December and lowest in June. The highest average population found was 22 per square foot. Larvae feed principally on the seed, roots, stalks, and tubers of a variety of plants. In laboratory cages they thrived best on wheat, sorghum, and oat seeds. The larval period of the summer brood was from 27 to 92 days and of the overwintering brood from 191 to 340 days. The prepupal period usually lasted 2 or 3 days.

Pupation occurs in an earthen cell in the upper 4 inches of soil. Pupae were found in the field from April through November and were most abundant in May and August. This stage lasted from 4 to 21 days in the laboratory.

The egg-to-adult period for the short-cycle generation in laboratory cages was from 42 to 109 days and for the long-cycle generation from 236 to 410 days. Few laboratory-reared adults deposited fertile eggs and conclusive data regarding the preoviposition period were not obtained.

Most of the wireworms in coastal South Carolina overwinter as larvae and pupate in April, May, and early June. They become adults in May and June (long-cycle generation). These adults plus some originating from eggs laid by overwintering adults produce a large midsummer brood of larvae, which are most numerous in July. They become pupae in about 65 days and adults about 6 to

10 days later (short-cycle generation). These adults are most abundant in August and September and oviposit soon after emergence. Some of the larvae that hatch from these eggs in early August become adults that overwinter and deposit eggs in the spring. However, most of the larvae hatching in August and all hatching thereafter overwinter as larvae.

Each year in coastal South Carolina one long-cycle generation overwinters as larvae and at least one short-cycle, spring-to-fall generation occurs. There may be a second short-cycle generation in part of the population.

A sudden cold spell that froze bare soil to a depth of at least 2 inches in December 1957 resulted in 36-percent mortality of larvae. A parasitic nematode, a fungus, and birds have caused some larval mortality, but no insect parasites or predators were observed. The cannibalistic nature of the larvae probably limits the density of their population.

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