United States Department of Agriculture
Bureau of Entomology and Plant QuarantineBIOLOGY OF THE WHITE-FRINGED BEETLE (*NAUPACTUS LEUCOLOMA* BOH.)¹By H. C. Young and B. A. App,²
Division of Cereal and Forage Insect Investigations

Introduction

The first report of the appearance of the white-fringed beetle in the United States was made by the Division of Insect Identification in the Bureau News Letter dated September 1, 1936, when it was reported that L. L. Buchanan had identified as *Naupactus leucoloma* Boh. two specimens received from A. N. Tissot, of the Florida Agricultural Experiment Station. These beetles came from the area around Svea, Okaloosa County, Fla., and at that time were reported to be injuring peanuts. In the October 1, 1936, issue of the Insect Pest Survey Bulletin J. R. Watson reported that this insect had appeared during the summer in the northern part of Walton County in western Florida, and in adjacent areas in Alabama, where it was causing much damage to peanuts and some injury to cotton and other plants.

J. R. Watson, of the Florida Agricultural Experiment Station, and U. C. Loftin, of the Bureau of Entomology and Plant Quarantine, made a brief survey of the infested area in Walton and Okaloosa Counties, Fla., on May 14, 1937, and an account of their observations is given in the Bureau News Letter dated June 1, 1937. At that time the larvae were reported attacking cotton, corn, peanuts, and velvetbeans.

This insect is native in Argentina, Chile, and Uruguay, in South America, and has recently been discovered in New South Wales, Australia

¹ Order Coleoptera, family Curculionidae, subfamily Otiorhynchinae, tribe Epicaerini.

This circular supersedes mimeographed circular E-420, The White-fringed Beetle, *Naupactus leucoloma* Boh., which was issued in January 1938.

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(Rev. App. Ent., vol. 21, p. 303, 1933), where it was "attacking the roots of lucerne."

The research upon which this paper is based was started at Florala, Ala., on June 23, 1937. This work has been under way for too short a period to cover all phases of the life history, but a brief summary of the data secured prior to January 1, 1939, is presented herein.

Present Known Distribution in the United States

The area known to be infested by the white-fringed beetle was greatly enlarged by intensive scouting during 1938. At present this insect has been found in 23 counties in 4 States. The infested counties and States are as follows: Covington, Geneva, Conecuh, Monroe, Wilcox, and Mobile Counties in Alabama; Escambia, Okaloosa, and Walton Counties in Florida; Jackson, Harrison, Pearl River, Jones, Smith, Covington, and Hinds Counties in Mississippi; and Orleans, Saint Bernard, Jefferson, Saint Tammany, Plaquemines, East Baton Rouge, and Jefferson Davis Parishes in Louisiana.

The larger infested areas are around Florala, Ala., and New Orleans, La. In the Florala area parts of four counties lying in two States are infested and the beetle is known to occur on approximately 16,000 acres. At New Orleans parts of four parishes are infested and the infested acreage is approximately 21,000 acres. The infested area in the other counties is less extensive, comprising slightly more than 6,000 acres in the 15 counties. The infestation at Glendale, Walton County, Fla., about 16 miles southeast of Florala, is the farthest east of any known infestation; the northernmost known infestation occurs at Bolton, in Hinds County, Miss.; and the westernmost known infestation occurs at Lake Arthur, in Jefferson Davis Parish, La.

Another very similar species, which has been identified as Naupactus sp. and tentatively as a new species, was found in southern Mississippi during 1937. Infestations of this species have been found at Gulfport, Landon, and Saucier in Harrison County, and at McHenry in Stone County. The area now known to be infested by this species is approximately 6,600 acres. Both species have been found occurring simultaneously in a limited area at Gulfport, Miss. A study of this new species has been under way at Gulfport, Miss., since April 21, 1938, and its biology and habits are very similar in many respects to those of the white-fringed beetle.

Stages of the White-Fringed Beetle

The adult

Description.--The adult beetle (fig. 1, A and B) is seven-sixteenths of an inch in length and about five thirty-seconds of an inch across the abdomen. The color is dark gray, with a lighter band along the margins of the elytra, and two paler longitudinal lines on each side of the thorax and head (one above and one below the eye, fig. 1, A). The body is densely covered with pale hairs, which are especially long on the elytra. The

underwings are present but very rudimentary and vary greatly in size with the individual beetles. The elytra are fused together, and the adults are incapable of flight. The newly formed adults are equipped with a pair of cusps (fig. 1, F), one attached to the anterior face of each mandible. These cusps are used for cutting their way through and out of the soil. Shortly after emergence the adults lose these cusps, sometimes one at a time or both at once, usually after they have fed more or less extensively upon plant foliage. After these cusps are lost there remains a scar on the anterior face of each mandible indicating the place from which the appendage has fallen.

Emergence of the adults.--In 1938 information on the dates and rate of emergence was obtained by the use of 138 cages, which covered 1 square yard each. A portion of these cages were located near Svea, Fla., and the remainder near Lockhart, Ala. Daily rainfall records were kept in each locality. The first adult was observed in the field on May 25, but it is highly probable that a few emerged as much as a week prior to this date, as a few pupae were found on May 6.

The emergence as determined by means of these cages extended from June 5 to August 15. The peak of emergence was reached on different dates in the two localities. At Svea the peak was during the period June 21-30, when 44.3 percent of the total emergence occurred. At Lockhart the peak was reached during the period July 11-20, when 53 percent of the total emergence occurred. A study of the combined records of emergence for the two localities shows that 7.8 percent of the total occurred prior to June 21, 87 percent occurred during the 30-day period June 21 to July 20, and only 5.2 percent occurred during the remainder of the season.

The length of time this insect remains in the pupal cell after transformation to the adult depends upon the amount of moisture in the soil. When the upper soil becomes dry only a small number of the beetles transforming to adults cut their way out; most of them remain in the soil until rain occurs. Under laboratory conditions beetles have remained in their pupal cells within the soil for periods ranging from 8 to 80 days, emerging whenever moisture was applied.

The emergence in 1938 at Svea and Lockhart reached the peak immediately following precipitation. At Svea the daily emergence in the cages from June 5 to June 20 never exceeded 39 beetles. A total of 1.43 inches of rain fell on June 19-21. The daily emergence increased from 6 on June 19 to 84 on June 21 and to 180 on June 22. During the 4-day period June 21-24, or immediately following this rain, a total of 424 beetles emerged. This was 19.2 percent of the total emergence. From June 29 to July 10 only one light shower occurred, this being 0.07 inch on July 6. A rain of 1.04 inches fell on July 11. Prior to this rain the emergence had slowed down, only 16 beetles emerging on July 10 and 3 on July 11. The emergence on July 12 was 128 beetles. Following this latter rain the emergence was 314 beetles for the 3-day period July 12-14. This constituted 14.3 percent of the total emergence.

In the cages located at Lockhart only 8 beetles emerged prior to June 19. The rainfall on June 19-20 was 1.27 inches, and immediately afterward the emergence increased. A total of 65 beetles emerged on June 22-24. From June 21 to July 9 inclusive there were only two light showers in this section and the total rainfall was only 0.25 inch. On July 10 a rain of 1.87 inches occurred. The emergence was only 21 beetles for the 3-day period July 9-11, but after the rain had softened the soil the emergence on July 12-14 was 360 beetles, or 45.2 percent of the total emergence. Frequent examinations of the soil in this section from June 21 to July 12 showed that the numbers of full-grown larvae and pupae were decreasing and the number of adults increasing, but that owing to the lack of moisture the adults were remaining within the pupal cells and not attempting to cut their way out.

Activities of the adults.--After emerging, the adults crawl to the nearest plant or other object protruding from the soil and remain there for several hours to allow the body to harden. After the body has hardened, those resting on objects other than plants move in search of plant foliage. A portion of the beetles spend a large part of their preoviposition period without migrating any appreciable distance, provided they find favorite host plants, but many do migrate considerable distances during the preoviposition period. Immediately after emergence the adults are found in clusters. On cotton plants they congregate near the terminal buds but usually on the underside of the leaves. In peanuts the beetles are usually found on the lower part of the vines near the surface of the soil. Beetles emerging in cornfields that are not intercropped with velvetbeans or peanuts usually migrate therefrom in search of other food soon after emerging. The beetles confine their feeding to the outer margin of the leaves, usually the portion of leaf nearest the petiole. They prefer the older leaves of all plants rather than the tender buds. They feed frequently but consume no great quantity of leaf surface. On cotton plants 30 inches in height, where 100 to 200 beetles fed for 6 to 10 days, less than 50 percent of the leaf surface was consumed. On velvetbeans 100 to 150 beetles have been observed to feed for several weeks without consuming more than 25 percent of the leaf surface. In a few instances where peanuts adjoined heavily infested cornfields the adjacent rows of peanuts have been totally stripped by the hordes of migrating beetles.

After the beetles have passed the preoviposition period they leave the plants to deposit eggs. At the end of each day's activity they usually come to rest on the ground beneath plant foliage, in crevices in the soil, or on the lower portion of plants. Observations made at various hours during the day and night showed virtually no activity on dark nights. The period of greatest activity is from 1 p. m. to 4:30 p. m.; however, there is considerable movement between 9:30 a. m. and 6 p. m. In a well-ventilated insectary open to natural light conditions at all hours, beetles deposited 62 percent of the total egg masses between 12 m. and 4:30 p. m., 31.8 percent between 4:30 p. m. and 8 a. m., and only 6.2 percent between 8 a. m. and 12 m. Although at certain periods most of the adults are found on the underside of the leaves, they are most active during the hours of most intense

light. Migrating beetles invariably check their rate of movement or come to a dead stop when a shadow from a cloud or other objects is cast over them. Examinations made in the early morning hours in lightly infested fields often fail to reveal a single beetle, but as the sunlight and temperature increase the beetles begin to move and are easily detected, many coming from the cracks and crevices in the soil and from around the base of the plants.

Migration of the adults.--The migration is more or less a general dissemination away from the areas where the adults emerged. The beetles do not move any great distance per day but keep moving in the same general direction day after day. The migration was studied during 1938 by placing trap holes along barriers around an infested field. The peak movement of the beetles occurred on July 13-14 and the peak of emergence on July 12-14 in this locality. The daily rate of travel was studied by releasing a number of marked beetles at a given point and recording their recovery in traps at various distances from the release point. The field utilized for these studies was cropped to cotton and corn and had a fair growth of grass and weeds when the beetles were released. It was found that the average daily rate of travel was 16.8 yards. The seasonal movement covered from one-fourth to three-fourths mile, depending on the type of vegetation in the path of the beetles. The movement is greatest over areas bearing scant vegetation and least over areas covered with dense vegetation. The beetle's habit of investigating practically every plant in its path prevents it from moving any great distance.

Parthenogenesis.--So far as is known there are no males. This insect reproduces parthenogenetically. L. L. Buchanan, of the Division of Insect Identification, dissected more than 2,300 adults collected on July 14, 1937, in the field in the Floral area and found that all individuals were females. A. N. Tissot, of the Florida Agricultural Experiment Station, examined about 200 adults collected during 1937 in the Floral area and reported (Fla. Ent., vol. XXI, pp. 20-27, 1938) that all individuals were females. During 1937 and 1938 more than 100 beetles were reared in individual containers or taken from their pupal cells within the soil and confined singly in the insectary in small jelly glasses with soil and foliage. Every one of these individuals deposited fertile eggs.

Abundance of adults.--In a heavily infested cotton field one man collected approximately 80,000 beetles from one-half acre in 4 hours on July 14, 1937. As the bag-and-hoop method was used for collecting the beetles shaken from the plants and only about two-thirds of the beetles were captured, they were present at the rate of about 240,000 per acre. The average population was 48 beetles per plant. Approximately 50 percent of the plants in this field had been destroyed by the larvae, and the stand was only 5,000 plants per acre.

During the period immediately after emergence, July 7 to July 20, 1937, it was common to find from 50 to 100 beetles per plant in the infested cotton fields, and from 150 to 200 beetles were taken from individual plants in the heavily infested portions of cotton fields. On July 10, 1937, 250 beetles were taken from one cotton plant, 78 from one velvetbean plant, and

44 from one peanut plant. As late as September 6, 1937, 226 beetles were collected from one cocklebur, 188 from one velvetbean plant, and 30 from one cotton plant.

In July 1938 thousands of adults were collected for experimental purposes from cockleburs located around the borders of infested fields and during August from beneath velvetbean vines. It was common to find from 25 to 100 beetles per cocklebur and from 50 to 200 per velvetbean. In 1938 the number of adults emerging was determined in three fields by the use of cages. The average emergence in these fields was 22.2, 23.5, and 110.5 beetles per square yard.

The seasonal decrease in the abundance of adults was observed during the fall of 1937 and 1938 by making daily counts of the number trapped in designated sections of a barrier surrounding infested fields. The decrease was much more rapid in 1938 than in 1937. During the period of September 24-28, 1937, a total of 849 beetles were caught. The number captured decreased to 136 for the period of October 14-18, and to 87 for the period of November 3-7. During the period of July 16-20, 1938, a total of 12,866 beetles were caught. The number captured decreased to 1,600 for the period August 5-9, and to 9 for the period September 24-28. Only 3 beetles were captured during the period of October 14-18, and 5 during the period November 3-7. The last beetle captured in the sections of the barriers under observation in 1937 was taken on December 5 and in 1938 on November 21; however, living beetles were found as late as December 18, 1937, and December 7, 1938.

Life-history studies

The beetles used for life-history studies in 1937 were reared from pupae in the insectary or taken from pupal cells in the soil after transformation to adults, but those used in 1938 were secured from field emergence cages, outdoor rearing cylinders, or from their pupal cells in the ground after transformation to adults. Beetles reared under insectary conditions from egg to adult, or from the larval or pupal stage to adult, are not so vigorous as those reared under outside conditions. In 1938 beetles were taken on the date of their emergence and confined exclusively to a certain plant foliage so that the effect of the various foods on the length of the different periods in the life and on the fecundity of the beetle might be studied. The plants utilized in these studies in 1938 were peanut (Arachis hypogaea L.), upland cotton (Gossypium hirsutum L.), strawberry (Fragaria chiloensis (L.) Duchesne), blackberry (Rubus cuneifolius Pursh), pecan (Carya pecan (Marsh.) Engl. and Graebn.), and a grass (Paspalum paniculatum L.).

Preoviposition period.--The average preoviposition period for 32 individuals in 1937 was 11.4 days; the periods ranged from 4 to 37 days. During the preoviposition period three of these beetles were fed on peanut foliage and 29 on cotton foliage.

The preoviposition periods for beetles fed on various kinds of foliage in 1938 are shown in table 1. It is seen that different foods had some

effect on the length of the preoviposition period. The average preoviposition period was 4.9 days for beetles fed on peanut foliage and 16.4 days for those fed on grass.

Table 1.--The effect of different foods on the length of the preoviposition period of the white-fringed beetle, Florala, Ala., 1938.

Food	Number of beetles	Length of preoviposition period	
		Average (days)	Range (days)
Peanut	20	4.9	1-9
Cotton	17	6.6	1-13
Strawberry	7	8.4	3-18
Pecan	20	9.4	2-24
Blackberry	14	13.1	7-26
Grass	11	16.4	7-29

The preoviposition period as given here is the length of time elapsing between the emergence of the adult and the deposition of the first eggs. It does not take into consideration the period the beetle remained in the soil after becoming an adult.

Oviposition period.--The average length of the oviposition period for 32 individuals in 1937 was 71.9 days; the periods ranged from 9 to 122 days. Three of these beetles were fed on peanut foliage and 17 on cotton foliage during their entire life span, and 12 were fed on cotton foliage for a period and then on peanut foliage.

The oviposition periods for beetles fed on various kinds of foliage during 1938 are shown in table 2. The average length of the oviposition period for beetles fed on cotton foliage was 93.9 days and only 10.2 days for those fed on grass. One beetle fed on cotton deposited eggs during a period of 133 days. The average oviposition period for beetles fed on strawberry, blackberry, and pecan foliage did not vary greatly, being 52 days on strawberry, 50.1 days on blackberry, and 47.9 days on pecan.

Table 2.--The effect of different foods on the length of the oviposition period of the white-fringed beetle, Florala, Ala., 1938.

Food	Number of beetles	Length of oviposition period	
		Average (days)	Range (days)
Cotton	17	93.9	37-133
Peanut	20	66.1	40- 97
Strawberry	7	52.0	9- 88
Blackberry	14	50.1	18- 94
Pecan	20	47.9	1- 95
Grass	11	10.2	1- 22

Postoviposition period.--The average length of life for 32 beetles in 1937 after they had deposited their last eggs was 13.7 days.

The postoviposition periods for beetles fed on various kinds of foliage during 1938 are shown in table 3. The average postoviposition period ranged from 10.1 days for beetles fed on peanut foliage to 16.7 days for beetles fed on pecan foliage. A few beetles deposited eggs on the date they died, but the majority lived for a week or more after egg laying ceased.

Table 3.--The effect of different foods on the length of the postoviposition period of the white-fringed beetle, Florala, Ala., 1938.

Food	Number of beetles	Length of postoviposition period	
		Average (days)	Range (days)
Pecan	20	16.7	0-63
Cotton	17	14.8	2-44
Grass	11	12.4	1-22
Strawberry	6	12.3	3-22
Blackberry	14	10.9	2-24
Peanut	20	10.1	4-27

Length of life of adults.--The average length of life of 32 beetles in 1937 was 97 days. The maximum length of life was 147 days for a beetle which emerged on July 21 and died on December 15. Three of these beetles were fed on peanut foliage and 17 on cotton foliage throughout their life span and 12 on cotton foliage for a period and then on peanut foliage. The average longevity for 26 newly emerged beetles kept without food in 1937 was 13.8 days and the maximum was 46 days. The average longevity for 45 unfed beetles in 1938 was 19.8 days and the maximum was 62 days.

The longevity for beetles fed on different kinds of foliage and for beetles kept without food in 1938 is shown in table 4. The maximum longevity was 171 days for a beetle which emerged on June 12 and was fed on cotton foliage.

Table 4.--The effect of no food and of different foods on the longevity of the white-fringed beetle, Florala, Ala., 1938.

Food	Number of beetles	Length of life	
		Average (days)	Range (days)
Cotton	17	115.3	55-171
Peanut	20	81.0	53-112
Pecan	20	73.9	8-125
Strawberry	6	67.2	27- 99
Blackberry	17	65.0	17-122
Grass	36	30.6	9- 53
No food	45	19.8	1- 62

Fecundity.--Complete oviposition records were secured from 32 beetles in 1937. A total of 25,302 eggs were deposited by these 32 beetles, ranging from 83 to 1,847 eggs per beetle, with an average of 790.7. These beetles emerged from July 10 to July 31, and the egg-deposition period ranged from July 15 to November 29. Ten of the 32 beetles deposited more than 1,000 eggs each. Three of these beetles were fed on peanut foliage and 17 on cotton foliage throughout their life span and 12 were fed on cotton foliage for a period and then on peanut foliage.

The oviposition records for beetles fed on different kinds of foliage in 1938 are shown in table 5. These records are based on a limited number of individuals and cover only one season, but they do indicate that the food plant has considerable influence on the fecundity of the beetle.

Table 5.--The effect of different foods on the fecundity of the white-fringed beetle, Florala, Ala., 1938.

Food	Number of beetles	Average number Range in number	
		of eggs per beetle	of eggs per beetle
Peanut	20	1,531.7	923-2,418
Cotton	17	1,449.5	537-2,030
Strawberry	7	1,122.6	72-2,170
Blackberry	14	538.2	169-1,100
Pecan	20	349.3	2- 909
Grass	11	21.5	2- 50

Rate of egg deposition.--The rate of egg deposition is also influenced by the food upon which beetles feed. The average daily oviposition for 32 beetles in 1937 was 11 eggs, and the range for the individual beetles was from 5.7 to 25.8. The average daily oviposition for 3 beetles fed on peanut foliage was 19.6 eggs; for 17 beetles fed on cotton foliage, 9.6 eggs, and

for 12 beetles fed on cotton foliage for a period and then on peanut foliage, 10.8 eggs.

The records for 1938 on the rate of egg deposition are shown in table 6. The beetles fed on peanut foliage deposited eggs most rapidly. One beetle which emerged on June 11 was fed on peanut foliage and deposited 1,567 eggs during its oviposition period of 40 days, or at a daily rate of 39.2. This beetle deposited 86 eggs on July 18, 33 on the preceding day, and 48 on the following day. Eggs were deposited on 35 of the 40 days covered by the oviposition period. Another beetle which emerged on June 11 was fed on peanut foliage and deposited 2,418 eggs during its life. The oviposition period was 83 days and eggs were deposited on 61 days. The average daily oviposition was 29.1 eggs. This beetle deposited eggs on 15 consecutive days, June 30 through July 14, and during this period it deposited 804 eggs, 169 being deposited on July 5.

The beetles fed on cotton foliage lived the longest and had the longest oviposition period, but, as shown in table 6, they deposited eggs at a slower rate than those fed on peanut and strawberry foliage.

Table 6.--The effect of different foods on the rate of egg deposition of the white-fringed beetle, Florala, Ala., 1938.

Food	Number of beetles	Number of eggs per day		Maximum number of eggs on any day (range for series)
		Average per beetle	Range for series	
Peanut	20	23.2	14.2-39.2	50-169
Strawberry	7	21.6	8.0-28.0	40- 87
Cotton	17	15.4	9.1-23.0	33- 95
Blackberry	14	10.7	6.1-14.2	18-134
Pecan	20	7.3	2.0-14.1	2- 77
Grass	11	2.1	0.7- 8.0	2- 23

The egg

The egg (fig. 1, C) is approximately 0.9 mm long and 0.6 mm wide, and is oval in shape. The color when freshly deposited is milky white, but it changes to dull light yellow after 4 or 5 days.

The eggs are deposited in masses, ranging in number from a few to as high as 60 or more, but the usual number is from 15 to 25. The individual eggs and the masses are covered with a gelatinous substance which makes them adhere to one another and to objects or the soil.

Place of deposition.--The eggs are deposited at the point of contact between soil and objects such as sticks, gravel, plant stems, and

other things lying on or protruding from the ground. In some instances, where the soil is easily penetrated by the ovipositor, eggs are deposited directly in the soil. The depth of the eggs in the soil ranged from one-sixteenth to five-sixteenths inch. In a few instances egg masses have been found on plants as much as $1\frac{1}{2}$ inches above the surface of the soil. Egg masses have been found on cotton bolls, seed cotton, pecans, maypops, velvetbean pods, unshelled peanuts, corn husks, firewood, and farm tools and implements where they were in contact with the soil. In fields cropped to cotton the previous year, the parts of the old stalks that are partially covered with soil seem to be favorite places for egg deposition. In peanuts and Mexican-clover the egg masses are often found attached to the underside of the stems where they are in contact with the soil. The beetle prefers to deposit eggs in shaded places beneath plants, but the greatest egg-laying activity occurs between 12 m. and 4:30 p. m., i. e., usually during the brightest and warmest hours of the day.

Duration of the egg stage.---The eggs kept for incubation records were removed from the oviposition jars daily, placed in metal salve boxes on blotting paper which was kept moist throughout the incubation period, and stored in an unheated room. The data on the duration of the egg stage are for eggs deposited during 1937, as information concerning eggs deposited during 1938 is not complete at the time this is written.

The incubation period for eggs deposited from July 21 to August 29 averaged 14.7 days, and 81 percent of the eggs hatched on the 12th to the 15th day, inclusive. Many eggs deposited during October and November did not hatch until January and February and a few did not hatch until March. The hatching of eggs deposited after September 18 was a long-drawn-out process. For instance, eggs deposited on October 11 began hatching on October 22 but hatching was not complete until February 1, a few larvae hatching during each of the months of October, November, December, January, and February. After August 28 the incubation period increased, as shown in table 7.

Table 7.--Average length, in days, of the incubation period for eggs of the white-fringed beetle deposited on dates given, Florala, Ala., 1937.

Date eggs were deposited	Number of eggs	Average incubation period (days)
July 11-20	729	16.0
July 21-30	3,379	13.5
July 31-Aug. 9	2,396	13.9
Aug. 10-19	804	15.2
Aug. 20-29	828	16.2
Aug. 30-Sept. 8	1,610	17.3
Sept. 9-18	1,264	20.2
Sept. 19-28	1,300	20.9
Sept. 29-Oct. 8	1,372	33.4
Oct. 9-18	423	63.7
Oct. 19-28	169	73.7
Oct. 29-Nov. 7	143	78.7
Nov. 8-17	47	80.3
Nov. 18-27	23	62.4
Total	14,487	

Although larvae complete their embryonic development within the eggs under dry conditions, they will not emerge except under moist conditions. Eggs collected in the field on July 23, 1937, and kept under dry conditions remained viable through March 10, 1938, or for more than 7.5 months. Eggs collected in the field on September 24, 1937, December 10, 1937, and January 21, 1938, were viable when collected and remained so through April 11, 1938. Eggs collected in the field at intervals from February 5 through April 14, 1938, were not viable when collected. Eggs deposited in the insectary during 1937 and kept under dry conditions remained viable through April 11, 1938. The moist conditions that are necessary for the emergence of the larvae from the eggs also cool and soften the soil, making it favorable for the newly emerged larvae.

The larva

Description.--The full-grown larva (fig. 1, D) ^{3/} averages approximately one-half inch in length. The body is yellowish white, fleshy,

^{3/} The illustration, lateral view, of the larva (fig. 1, D) was made from a specimen preserved in fluid and is an accurate representation of that specimen. The foregoing description was made from living larvae, and any discrepancies between it and the drawing are due to distortion in the preserved material.

more or less curved, legless, and sparsely covered with hair. It consists of 12 much-folded segments, which are interrupted by two sublateral longitudinal grooves running the length of the body. The dorsal portions of the segments are bulging; the ventral portions are flat. On the sides, above the longitudinal separating grooves, small spiracles are present on all segments except the second, third, and twelfth (last).

Feeding habits of the larvae and the injury they cause.--The principal damage is caused by the larvae feeding on the roots of the young plants in the spring. The lower part of the stem and taproot are chewed away, but apparently the smaller lateral roots are not damaged to any appreciable extent. In many instances the larvae burrow into large seeds and devour the contents before the young plants have had sufficient time to appear above the ground.

On most plants such as cotton, velvetbeans, peanuts, field peas, and sweetpotatoes the larvae consume the fleshy portion of the underground stem and taproot, usually leaving the tougher central portion. Only occasionally is the stem or root completely severed and then only in the case of young plants. On larger plants the larvae may feed on one side of the root for several inches.

The feeding on corn and sugarcane is somewhat different from that on other plants. On these plants the larva cuts a small hole one-fourth to one-half inch in diameter into the main stem, usually burrowing one-fourth to one-half inch into the stem, but rarely tunneling along the root for any great distance.

The major portion of the feeding on roots during the spring extends from the surface of the ground to a depth of 6 inches. Where the feeding is severe the plants turn yellow, wilt, and die. Where only a small section of the cambium layer is eaten away the plants survive but produce very little or no crop.

The larvae are very general feeders and caused serious injury to field and garden crops in the Florala area during 1937 and 1938. The infestations are still localized on many farms, but the yields were materially reduced in many fields. In some fields as high as 90 percent of the plants were killed in areas ranging from a few square yards to as much as 10 acres. In many instances, after the larvae had destroyed the stand, the fields were replanted and the larvae then destroyed the second planting. In heavily infested spots the larvae not only killed the cultivated crops but also the grass and weeds. Late in June and early in July these spots were barren and could easily be detected at great distances (figs. 2 and 3). After the greater number of the larvae matured and emerged as adults, a heavy growth of grass developed on the former barren areas.

The larval injury to peanuts occurs at two distinct periods. At planting time and shortly thereafter the larvae feed on the planted seed and on the roots of the young plants, thereby damaging the stand. The

adults after emerging concentrate on the remaining plants and deposit eggs in the area immediately surrounding the plants. Later in the season the newly emerged and older larvae attack the developing nuts, chewing away portions of the hulls, and often boring through the hull and destroying the kernel. The nuts of the chufa are injured in the same manner as are those of peanuts.

Irish potatoes are very susceptible to larval injury and serious damage has been observed to this crop at Florala, Ala., and Gulfport and Laurel, Miss. The larvae feed upon the tubers planted, the underground stems of the plants, and the crop of tubers produced. In this instance the larvae feed primarily upon that portion of the plant which is being grown for market or consumption. In many gardens 80 percent of the tubers were damaged to some extent and 50 percent were damaged so seriously that they were unfit for home consumption. In one instance the larvae killed 11 percent of the plants and damaged 91 percent of the tubers. Larvae burrow into and throughout the tubers, and it is very common to find several larvae in the same tuber. Where the larval population is great the major part of the contents of many tubers is consumed or destroyed. Strawberry plants are also seriously damaged by the larvae.

Plants such as oats which have a fibrous root system and can be sown by broadcasting or drilling during the fall or winter can withstand high larval populations without any appreciable damage. The grasses also appear able to withstand high larval populations. The larvae are not voracious feeders during the cooler parts of the year, consequently plants which grow and develop late in the fall and during the winter are not damaged to the same extent as spring crops.

During the fall larvae have been observed feeding on the underground stems and taproots of cowpeas and peanuts after these plants had matured and died or had been killed by frost. Evidently the decaying roots furnish a desirable food for the larvae. In one field the soil from around 96 cowpea plants was examined in November 1937, and an average of 16.6 larvae per plant was found. An area 4 inches in diameter around each plant was examined to a depth of 6 inches.

Larval development.—The average length of the larval period as determined for 19 specimens was 320.5 days, or 10.7 months. These larvae hatched from eggs between August 4 and September 12, 1937, and became adults between May 24 and September 6, 1938.

A total of 143 beetles were reared from egg to adult in outdoor rearing cylinders. The larvae in these cylinders hatched from the eggs from August 7 to December 23, 1937. The adults emerged from the cylinders from June 4 to August 16, 1938. The adults from larvae hatched during August emerged somewhat earlier than those from larvae hatched later in the season. The average date of emergence for beetles from larvae hatched during August was July 4 and the average date of emergence for beetles from larvae hatched in November was July 24. Some larvae which hatched during 1937, although apparently full-grown in 1938, did not pupate during the latter year. These rearing cylinders from which 143 adults emerged were examined in September 1938 and 7 pupae and 7 larvae were found. Most of the larvae that failed

to pupate in the summer of 1938 were from eggs that hatched in November 1937.

These full-grown larvae which fail to pupate during the summer have been termed "carry-over" larvae. No reason is known for this carry-over of apparently mature larvae, nor is it known whether they develop to adults the following year or die as larvae. The number of carry-over larvae in the rearing cylinders was very small. Under field conditions in cropped areas the carry-over in 1938 was found to be 0.8 larva per square yard, and the emergence in the same fields was 23.5 beetles per square yard. The carry-over is apparently greater in noncultivated land than in cultivated fields.

The newly emerged larvae are capable of living for a long period without food. On August 13, 1937, newly emerged larvae were confined in salve boxes without food, soil, or moisture. The average length of life for these larvae was 24.2 days. On September 1, or 19 days after hatching, 49.7 percent were alive. One month after hatching 29.4 percent were alive. The last larvae lived through October 24, or 73 days.

Thus far it has not been definitely determined how important fresh plant roots are to the development of the larvae. Large well-developed larvae deprived of plant roots but kept in moistened soil after February 16, 1938, completed development to adults as well as those given fresh plant roots. A few medium-sized but no small larvae receiving similar treatment matured to adults without feeding on plant roots. In a limited number of rearing tests newly hatched larvae were placed in sifted soil devoid of plant roots, but all died before reaching maturity.

Vertical distribution of larvae in the soil.--In order to determine the distribution of the larvae in the soil, diggings are being made in infested fields at intervals. The larvae are removed from the soil by a combination process involving washing through a series of screens and flotation in a heavy solution. It is realized that soil type, soil moisture, available food material, and possibly soil temperature affect the vertical distribution of the larvae. Usually the distribution is the result of a combination of these factors. Because it is impossible, in the preliminary work, to separate the results of the diggings and to group them satisfactorily according to the factors involved, the vertical distribution of the larvae for all diggings made on or near a definite date are grouped together in table 8.

Table 8.--Vertical distribution of white-fringed beetle larvae in the soil, Florala, Ala.

Depth (inches)	Accumulated percentages of white-fringed beetle larvae found at different depths in the soil														
	1937						1938								
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
0 - 3	25.8	50.0	43.0	56.0	39.8	53.6	49.1	36.6	10.9	35.0	23.1	15.1	24.0	46.5	29.5
0 - 6	66.5	80.6	79.8	83.4	76.5	85.0	85.2	71.0	52.8	55.0	69.4	65.2	63.2	68.8	61.6
0 - 9	83.5	90.8	92.1	91.1	89.8	97.4	94.5	86.0	89.2	85.0	92.0	87.4	82.9	85.8	80.8
0 - 12	90.4	94.8	97.4	94.3	95.3	100.0	98.2	95.6	92.8	90.0	95.2	99.1	91.6	91.6	89.8
0 - 15	94.0	98.8	99.1	96.9	97.6		99.1	97.8	96.4	100.0	96.8	99.7	97.8	94.3	94.3
0 - 18	97.6	98.8	99.1	98.8	98.4		99.1	100.0	100.0		100.0	100.0	99.7	95.6	97.5
0 - 21	99.6	99.4	100.0	99.4	99.2		100.0						100.0	98.7	99.0
0 - 24	100.0	100.0		100.0	100.0									100.0	100.0
Mean depth	5.78	4.09	4.18	3.91	4.59	3.42	3.75	4.89	6.25	5.55	5.19	5.51	5.73	5.08	5.92
(inches)															
Number of larvae in sample	248	176	114	157	128	153	108	93	55	20	190	325	309	224	156

The mean depth during October 1937 and October 1938 was approximately the same, but during November and December 1938 the mean depth was greater than in the same months of 1937. This additional depth in 1938 is thought to have been due to the lack of rainfall which prevented eggs from hatching, thus making fewer small larvae to be found in the upper part of the soil. The larvae move nearer the surface during March and April to feed on plant roots and complete their development. The mean depth was greatest during June, because many of the larvae in the upper part of the soil pupated and none hatched at that time. During the 15-month period October 1937 to December 1938 from 55 to 85 percent of the larvae have been found in the upper 6 inches of soil. The percentage of the total number of larvae in the upper 12 inches during this same period ranged from 89.8 to 100 percent. In only one month, March, were all the larvae found in the upper 12 inches. Although diggings have been made to much greater depths, larvae have not been found beyond the layer of soil 21 to 24 inches below the surface.

Larval population.--During November and December 1937 and in November 1938 larval-population counts were made in a number of fields throughout the Florala area. In the fall of 1937 three cores, approximately 4 inches in diameter and 12 inches deep, were taken with a soil sampler in each of 5 places in each field, and in the fall of 1938 three cores of approximately the same size were taken in each of 9 places in each field. The washing method described above was used for determining the number of larvae present in these samples. The results have been grouped according to the crop grown each year and are presented in table 9.

Table 9.--Larval populations of the white-fringed beetle in the fall of 1937 and 1938 in fields planted to various crops, Florala, Ala.

Crop	Number of fields		Average number of larvae per square yard	
	1937	1938	1937	1938
Cotton	13	12	147	44
Corn	5	8	41	171
Peanuts	12	7	283	166
Cotton (intercropped)	1		44	
Corn (intercropped)	10	18	198	45
Average			184	86

Forty-one fields were sampled in 1937, and 5 of these showed no infestation. The number of larvae per square yard in the infested fields ranged from 8 to 1,041, or from 38,720 to 5,038,440 per acre. The intercrops in cornfields were velvetbeans or peanuts.

Forty-five fields were sampled in 1938, and 3 of these showed no infestation. The number of larvae per square yard in the infested fields ranged from 4 to 768, or from 19,360 to 3,717,120 per acre. The intercrops

in cornfields were velvetbeans or peanuts. The high average population for cornfields was due to heavy growth of cockleburrs in early corn.

The smaller larval population in the fall of 1938 was due to several factors, namely, the retirement from crops and the maintenance of a fallow during 1938 in practically all the heavily infested fields in the Florala area, the scant rainfall after August 8, and probably others not known at the present time.

Larval mortality.--The mortality of larvae from the fall of 1937 to June 1938 was great. The decrease in larval population, as shown by the soil samples from 41 fields in the Florala area from November-December 1937 to June 6-7, 1938, was 88.8 percent. In one field which received normal farm practices the larval population was determined on November 1, 1937, and March 1 and June 1, 1938. The adult emergence was also determined in this field. The larval population on November 1, 1937, was 301.2 per square yard. The population had decreased to 167.4 per square yard on March 1 and to 68 per square yard on June 1, 1938. The larval population had decreased 44.4 percent by March 1 and 77.4 percent by June 1. The exact cause of this high mortality has not been definitely determined, although the larvae bite one another when they come into contact, thus causing some of it. The adult emergence in the field was 23.5 per square yard, or 7.8 percent of the November larval population. The larval population in this field in November 1938 was 390.7 per square yard.

Construction of the pupal cell.--After the larvae have completed their growth and stopped feeding they retire from immediate contact with plant roots and construct pupal cells in the soil. The cell is made by movements of the larva which gradually pack the soil until a smooth cavity of sufficient size for the activities of pupation and emergence is formed and glazed with a secretion from the insect's body. Although these cells are practically waterproof, moisture must penetrate them slowly to a certain degree, since the adults within cells react to outside moisture conditions. The longitudinal axis of the pupal chamber is on an inclined plane.

The prepupa.--The average length of the prepupal period as determined from 9 specimens was 11.2 days; the periods ranged from 9 to 15 days. In this stage the insect is semi-inactive, and the body becomes somewhat straightened, losing its former much-curved shape.

The pupa

The pupa (fig. 1, E) is approximately seven-sixteenths inch in length, and when first formed is white. Parts of the body and appendages darken somewhat before transformation.

The average length of the pupal period for 135 specimens was 12.5 days; the periods ranged from 8 to 15 days.

The average depth of pupation as determined in 1938 was 3.8 inches. An average of 93.7 percent of the pupae were found from 2 to 6 inches below

the surface. Only 3.6 percent of the pupae were found in the upper 2 inches of soil and only 2.7 percent below the 6-inch level. No pupae have been found more than 8 inches below the surface.

Pupation under field conditions in 1938 in the Floral area began as early as May 6, but it was May 27 before any appreciable number of pupae could be found. Diggings were made at frequent intervals from June 1 through August 11 to determine the abundance of pupae in the soil. On June 1-3, 88 percent of the stages found were larvae and 12 percent were pupae, but on June 14-15, 56 percent of the stages were larvae, 40.7 percent were pupae, and 3.3 percent were unemerged adults. Records made on June 28-29 showed the distribution of the stages as follows: 38 percent larvae, 30.5 percent pupae, and 31.5 percent unemerged adults. On July 12-13, only 13 percent of the stages were pupae, 69 percent were unemerged adults, and 18 percent were larvae. No pupae were encountered in these field diggings after July 28 and no unemerged adults were found after August 4. No doubt a limited amount of pupation occurred in the field during August. A few adults emerged from field cages as late as August 15 and a few pupae were found in outside rearing cylinders as late as September 7.

Host Plants

The host plants received a limited amount of study during 1937, but they have been the subject of a special study during 1938, conducted jointly by the Bureau of Entomology and Plant Quarantine and the State Plant Board of Florida. Both the larvae and adults are general feeders and feed upon a wide range of plants. The combined list of larval and adult host plants observed in the field now includes 234 species. The host-plant studies have been confined to the Floral area, and observations in the other infested areas will doubtless greatly enlarge this list. Many of these host plants are numerous and widely distributed throughout the Southeastern States. Some of them and many close relatives are generally distributed over a much larger area. Both the larva and adult feed upon such a diversity of plants that host plants apparently will not be an important factor in the spread of this insect. The complete list of host plants is too large to be included in this publication.

Host plants of the adults.--Under field conditions the adults have been observed to feed upon 132 species of plants. These include field, garden, and truck crops; grasses and weeds; ornamental flowers and shrubs; wild bushes, trees, and vines. Some of the most common host plants in the Floral area are as follows: Beautyberry, beggarweed, blackberry, button-weed, Caesar's-weed, camphor, cocklebur, coffeeweed, cotton, dahlia, dewberry, dollar-weed, false-indigo, four-o'clock, gallberry, honeysuckle, hoary-pea, horseweed, kudzu, lespedeza, lima bean, maypop, Mexican-clover, okra, peanut, pitcher-pea, ragweed, sickle-pod, smartweed, soybean, strawberry, and velvetbean.

Under laboratory conditions adults have fed upon 215 species of plants and have deposited fertile eggs when confined exclusively on 184

species. Beetles also deposited fertile eggs when confined exclusively on moistened peanut hay and moistened tissue paper. Unfed beetles have not deposited fertile eggs. Under laboratory conditions adults have fed upon every kind of foliage tested that they were physically able to cut with their mandibles. Apparently the adult cannot feed upon such foliage as bear grass which has hard fibrous margins, and they also have much difficulty in feeding upon such plants as sugarcane. The beetles are unable to cut the hard margin of the older leaves of American holly but feed readily on the young tender leaves. In the field adults prefer to feed on plants of medium pilosity rather than on plants with glabrous stems and foliage or plants that are extremely pilose; they also prefer broad-leaved plants to small-leaved plants.

Host plants of the larvae.--Under field conditions the larvae have been observed to feed upon 175 species of plants. Some of the most common host plants in the Florala area are as follows: Blackberry, broomsedge, Caesar's-weed, careless-weed, carrot, chrysanthemum, chufa, cocklebur, corn, cotton, cowpea, cudweed, curled-dock, false-indigo, hair-grass, Johnson grass, Mexican-clover, mustard, oat, plantain, ragweed, peanut, sickle-pod, strawberry, sweetpotato, velvetbean, white clover, and Irish potato.

Larvae have been taken feeding on peach seeds and pecan and tung nuts after the seeds had swollen and burst the hard covering. Larvae feed to a certain extent on woody plants such as peach, pecan, and willow, but as yet no case of serious damage to other than seedlings has been observed.

The Effect of Topography and Soil Type on Infestations

In the Florala area infestations occur not only in the cultivated fields but also in the woodlands, pastures, fence rows, and abandoned farms. The host range of this insect is such that it is highly probable that it can subsist and develop on wild host plants in noncultivated areas. Thus far the highest populations found in the Florala area have been in cultivated fields. This may be due to the presence of certain host plants but no doubt is also due to some extent to the permeability of the soil. In noncultivated areas adjoining infested fields the larval population in November 1938 ranged as high as 31 per square yard in woodlands, 73 per square yard in pastures, 61 per square yard on fence rows, and 31 per square yard in bay-heads.

In the Florala area soil types seem to have had very little effect, since infestations of approximately equal intensity have occurred on clay, loam, and sandy soils. To date the greatest damage has occurred on the higher well-drained portions of the infested fields. The infestation in the vicinity of New Orleans, La., is widespread, but the beetle population is light when compared with the Florala area. The cause of this lighter infestation at New Orleans has not been determined. It is probable that the heavy soil at New Orleans is not so favorable for the insect's development as the lighter soils in other localities.

Biology and Habits of *Naupactus*, n. sp.

The adults of this species emerged over a longer period during 1938 than those of *Naupactus leucoloma*. Under field conditions emergence extended from May 26 to October 10. During the period June 21-30, 25 percent of the adults emerged, while during the period July 21-30, 36 percent of the total emergence occurred. During the 50-day period June 21 to August 9, 80.8 percent of the emergence occurred. The natural emergence of adults is quite definitely dependent on soil moisture. The adults do not attempt to leave their pupal cells unless the soil is moist. The average emergence in the cages was 58.3 per square yard, and 157 beetles emerged from one square yard.

As might be expected with a late emergence, the adults of this species continued to be fairly numerous throughout the fall. Living adults were taken in the field up to the time of this writing, February 2, 1939, even though freezing temperatures occurred as early as November 25.

The various periods in the life of the adult of this species are also affected to a certain degree by the food plant. The preoviposition period was longer and the oviposition period and longevity were shorter for the adults of the new species when fed on cotton and peanuts than for the adults of *Naupactus leucoloma*. The longevity without food and on blackberry foliage was greater for adults of the new species than for adults of *N. leucoloma*. There is a marked difference in the number of eggs deposited by the two species. The average numbers of eggs deposited by beetles of the new species when fed on peanut and blackberry foliage were 653 and 189.4, respectively. The average numbers of eggs deposited by adults of *N. leucoloma* when fed on peanut and blackberry foliage were 1,531.7 and 538.2, respectively. Only a very small percentage of the adults of this species deposited any eggs when confined exclusively on grass. This is also true for adults of *N. leucoloma*.

This species also reproduces parthenogenetically. During the season 73 adults reared in the insectary or taken from their pupal cells in the soil were caged singly and all of them deposited fertile eggs.

So far as has been determined, the place and manner of egg deposition, the feeding habits of the larvae and adults, and the larval injury to plants are the same for the two species.

The larvae and adults are general feeders and can subsist on a great variety of plants. During the past season the adults were observed feeding on 72 species of plants and the larvae on 36 species of plants. The indications are that in the larval and adult stages the new species will attack as wide a range of plants as *Naupactus leucoloma*. The larvae have caused serious damage to garden and field crops in the Gulfport area.

Economic Importance of the White-Fringed Beetle

Both the larvae and adults feed on a wide range of plants. As compared with the damage done by the larvae, the feeding of the adults on plant foliage is of minor importance. Where numerous, the adults may cause serious injury to garden and ornamental plants. The larvae have caused serious damage to numerous field and garden crops. The damage is exceedingly serious to such crops as potatoes and peanuts, where not only the stand is injured but the product is either destroyed or lowered in grade. It is reasonable to assume that the larvae and adults will attack many plants that are widely grown in other sections but are not grown in the area now known to be infested. If the amount of damage already done in the Florala area can be used as a valid criterion, it is apparent that the white-fringed beetle, if allowed to spread, may become a serious pest in many agricultural regions of the United States. Its large range of host plants renders control complicated.

Because of the habits of the beetle, it is easily disseminated through commerce and other artificial means. The eggs are deposited on many parts of plants and other objects that move in commerce, and they may remain viable for more than 7 months, hatching when favorable conditions occur. The larvae can be transported with products which carry small quantities of soil. The adults readily attach themselves to many objects that move in commerce. The importance of the parthenogenic reproduction of the white-fringed beetle should not be overlooked, since it is possible for an infestation to be started from only one specimen of any stage. Once the beetle has established itself in an area, an enormous population may build up within a short time, since the inability of the adult to fly reduces the possibility of immediate wide spread by natural dissemination.

Figure 1.--The white-fringed beetle: A, adult beetle, lateral view; B, adult, dorsal view; C, cluster of eggs; D, full-grown larva, lateral view; E, pupa, ventral view; F, temporary cusp borne on mandible of newly emerged adult, lateral view. All greatly enlarged. (Original.)

Figure 2.--View of a cornfield at Lockhart, Ala., June 19, 1938, showing where plants were killed by white-fringed beetle larvae. The area was planted to corn twice, once in March and again in April, and heavily fertilized. The larval population on June 3, 1938, in the damaged area was in excess of 100 per square yard.

Figure 3.--Cotton field at Svea, Fla., July 1937, showing a typical area damaged by larvae of the white-fringed beetle.

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