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Life History and Control of the Cowpea Curculio

By

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AGRICULTURAL EXPERIMENT STATION

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By

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INTRODUCTION

THE COWPEA CURCULIO (*Chalcodermus aeneus* Boheman; Order Coleoptera, Family Curculionidae) is one of the major insect pests in Alabama and other Gulf Coast States. It causes injury to cowpeas, string beans, lima beans, strawberries, young cotton plants, and other crops. The principal damage caused by this insect results from the larvae developing in the seed of peas and beans. The edible varieties of cowpeas are frequently so "wormy" as to be unfit for table use. The damage to other crops is of less importance, although a majority of the references to the cowpea curculio in the literature of economic entomology deal with its injury to young cotton plants.

Investigations directed at the control of the cowpea curculio were conducted at the Alabama Agricultural Experiment Station during the period 1930-36. These investigations included life-history studies, laboratory and field experiments with insecticides, and other control practices.

Historical Account

The cowpea curculio was originally described in 1837 by the Swedish entomologist, C. H. Boheman, who obtained data regarding the habitat of the insect from Dejean (13) and A. Chevrolat. Dejean gave the habitat as Boreal America and Chevrolat as Mexico. Boheman's description was published in a book by C. J. Schoenherr (22) who described the genus.

In 1873 Horn (16) reported *Chalcodermus aeneus* Boh. as occurring in Georgia and Florida and in 1878 Schwarz (23) reported it as "not rare" around Tampa, Enterprise, and New Smyrna, Florida. The first reference to the cowpea curculio in the literature of American economic entomology was apparently by Chittenden (11) in 1903. In 1904, however, Chittenden (12) stated that the Division of Entomology received reports of injury to string beans in Polk County, Florida, as early as 1888. Several articles on the cowpea curculio appeared during the six-year period following Chittenden's publications. The most comprehensive of these papers was by Ainslie (2) who reviewed and summarized the work previous to 1910. The principal references

*This paper is taken from a thesis presented in August, 1937, to the graduate faculty of Iowa State College in partial fulfillment of requirements for the Doctor of Philosophy degree. The original copy of the thesis is on file in the Iowa State College library.

to the insect since 1910 are as follows: Sanborn (21) in 1912 discussed the insect as a garden pest often mistaken for the boll weevil and recommended lead arsenate as a control; Pierce (20) in 1917 reported adults injuring young cotton by feeding in the buds; Watson (27) in 1917 described larval injury to cowpeas and recommended lead arsenate as a control; and Brooks, Watson, and Mowry (10) in 1929 reported adult injury to strawberries.

Distribution and Economic Importance

Data on the distribution of the cowpea curculio were obtained from Dr. J. A. Hyslop (18) and from entomologists in various states. It is apparent from the data collected (Fig. 1) that the insect is confined in this country largely to the Atlantic and Gulf Coast States from North Carolina to Texas. It also occurs in Mexico.

The cowpea curculio damages cowpeas principally by feeding in the seeds within the pod. Both adults and larvae feed in the peas, causing them to be dwarfed and distorted. A study was made in 1930 to determine the extent of curculio injury to cowpeas. The results of the study are presented in Table 1 and Figure 2. Larval injury caused a greater loss in weight and volume than feeding punctures of adults. When both adult and

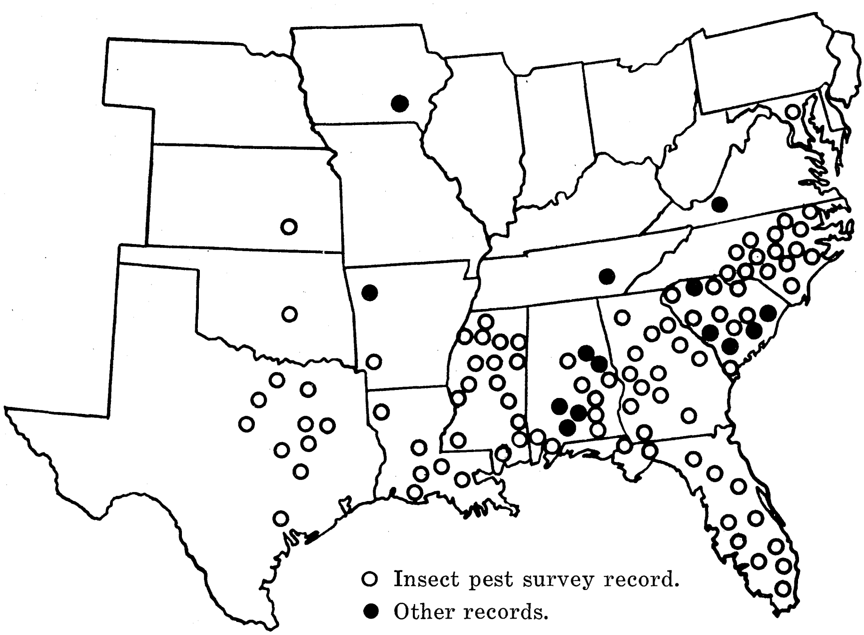

FIGURE 1.—Distribution of the Cowpea Curculio.

larval feeding were present, the loss was no greater than from larval injury. The mean percentage decrease in the weight of all damaged peas was 37.6 per cent.

TABLE 1.—Decrease in the Weight and Volume of White Crowder Peas Caused by Cowpea Curculio Injury, 1930.

Injury	Number of peas	Weight of peas: grams	Volume of peas: cc.
None	300	75.5	101
Adult	300	55.2	75
Larval	300	42.7	70
Adult and larval	300	43.5	86
Mean of all injured peas	300	47.1	77
Mean per cent decrease due to injury		37.6	23.9

Experiments conducted during 1930-32 and reported elsewhere in this paper showed that in 14 leading varieties of peas the average infestation was 36.0 per cent. Assuming the peas containing the various types of injury to be equal in number, the mean loss in the weight of all peas was 13.5 per cent. Actually the loss on the farm would be considerably more as many of the infested peas, which were weighed in figuring loss in weight, would ordinarily be winnowed out in thrashing and thereby be lost entirely.

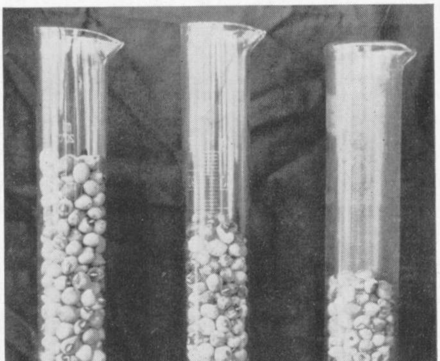

FIGURE 2.—Loss in Volume Due to Cowpea Curculio Damage to Peas. Left, uninjured peas; center, peas injured by adults; right, peas injured by larvae.

Estimates from the Bureau of Agricultural Economics placed the farm value of cowpeas harvested in Alabama at $1,269,000 in 1935 and $1,703,000 in 1936. These figures do not include peas cut for hay, grazed, or "hogged". Figures from the United States Yearbook of Agriculture showed the average annual value of cowpeas to be $3,230,100 in Alabama and $18,454,860 in eight southern states during the five-year period, 1926-30. All peas except those cut for hay are included in the estimate. If it is assumed that the 13.5 per cent reduction in yield of peas caused by the cowpea curculio at Auburn, is typical of the damage through the range of the insect, the annual loss in the yield of peas may be evaluated at approximately $400,000 in Alabama and over $2,000,000 in the eight southern states. The most serious type of injury, however, is that to the fresh-vegetable crop of peas and it cannot be readily evaluated in terms of reduced yields. Since "wormy" peas are unfit for table use, and since the average infestation over a three-year period was 36 per cent, approximately one-third of the peas intended for table use must be discarded. When it is considered that cowpeas rank among the half-dozen most important vegetables in Alabama, it is evident that the loss from this insect is very great, although exact figures are not available. Painstaking labor is required to remove the infested peas and there is always the possibility of a "worm" being found after the peas are served for dinner. Hence, in addition to the financial loss from this insect, there is also an aesthetic consideration.

STUDIES ON LIFE HISTORY AND HABITS

Life-history studies were made during the three-year period 1930-32, inclusive*. One of the primary aims of studying the life history was to determine vulnerable points in the cycle where control measures might be effectively applied. Previous reports by Chittenden (11) dealt mainly with the difficulties involved in rearing the insects. Ainslie (2) has reported observations on the life history of the insect made largely at Clemson College, S. C., although oviposition records included were of two females ob-

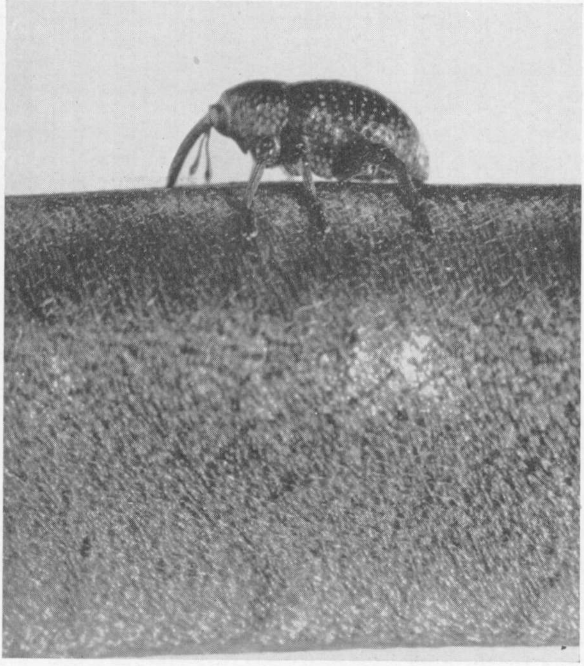

FIGURE 3.—Adult of the Cowpea Curculio Resting on a Pea Pod (Enlarged about 5 times).

*Summarized reports of these studies have been published by the Alabama Station (4, 5).

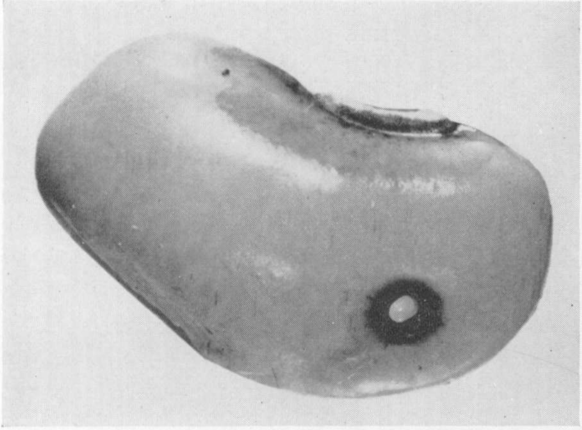

FIGURE 4.—Egg of the Cowpea Curculio in a Pea (Enlarged about 5 times).

served by H. M. Russel at Orlando, Florida. Observations on hibernation were on adults overwintering in a green house.

No attempt was made in this study to improve upon the published description of the cowpea curculio, but photographs of the adult, egg, larval, and pupal stages were made and are included in this report (Figs. 3, 4, 5, and 6). For the sake of convenience descriptions of the stages are also included. The description of the adult is from Blatchley (9) and descriptions of the egg, larva, and pupa are from Ainslie (2). These descriptions are as follows:

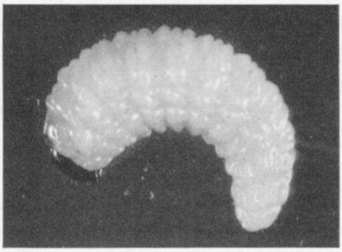

FIGURE 5.—Larva of the Cowpea Curculio (Enlarged about 5 times).

Adult: Oval, convex, robust. Black, finely alutaceous, usually with a bronze tinge. Beak nearly straight, slightly longer than thorax, sparsely punctulate, feebly carinate; eyes very narrowly separated. Thorax one-fourth wider at the base than long, suddenly narrowed in front, sides obtusely toothed behind the constriction, disc very coarsely and rather sparsely punctate. Elytra oval, convex, sides subparallel on basal half, then gradually narrowed at apex; disc with rows of large, deep, rather distinct punctures; intervals alutaceous, each with a row of very fine punctures, each puncture bearing a very minute scale. Beneath coarsely, abdomen more sparsely, last ventral more densely, punctured. Length 4.8-5.5 mm.

Egg: The egg is subelliptic, obtusely rounded on the ends, 0.9 mm. long, 0.6 mm. broad, white, translucent when first laid but gradually becoming more opaque. The shell is smooth and shining. Just before hatching the brown mandibles of the larva can be seen through the shell, which is very thin and delicate.

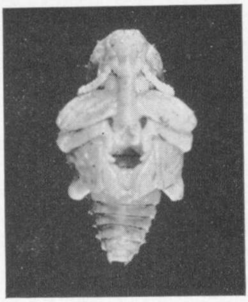

FIGURE 6. — Pupa of the Cowpea Curculio (Enlarged about 5 times).

Larva: Length, 7 mm.; width, 2.5 mm.; thickness (dorsoventral), 2 mm. Body footless, largest about one-third back from head, from there tapering to a rather acute cauda. Composed of 12 segments, 8 of which bear spiracles showing as yellowish or brown dots. Each segment also bears 8 minute brownish bristles, two on each side of the dorsal line and two on each lateral margin. Color pale yellow, dorsal plates on first segment brownish yellow. Head about one-third the greatest width of the body, vertical, dark amber-yellow with a white Y-shaped suture in front, the stem of the Y bordered with white.

Pupa: Length, 5 mm.; width, 3 mm. Of much the same shape as the adult except that the abdomen is longer and more acute.

Experimental Methods

Two methods of rearing the cowpea curculio were originally used, one a laboratory method, the other a field method.

The laboratory method was similar to the one used in rearing the southern corn root worm (3). Adults, confined in vials, deposited their eggs in fresh field peas which were removed daily. Infested seeds or pieces of pods were placed on moist cotton for incubation and larval development. The mature larvae were allowed to enter the soil to pupate. This method was soon discarded as it was found that the rate of development was considerably accelerated over field conditions.

In the field method, adults were confined in suitable screen-wire cages placed over groups of pea pods on the cowpea plant (Fig. 7). After remaining 24 hours on a group of peas, the beetles were transferred to a new unpunctured group. The peas from which the insects were removed were protected from further infestation by an empty cage.

Infested peas were dissected at intervals to determine the incubation period of the eggs. Peas containing punctures from 1 to 10 days old were used. Since the newer punctures contained only eggs and the older ones contained only larvae, the most recent punctures containing larvae were assumed to represent the hatching point of the eggs. In most instances when one egg in a pod had hatched the others had also, but upon a few occasions pods were found to

FIGURE 7.—Cages in Which Cowpea Curculio Adults Were Confined for Life-History Studies. The cages were constructed of 36-mesh copper screen wire with wooden bottoms and cloth tops.

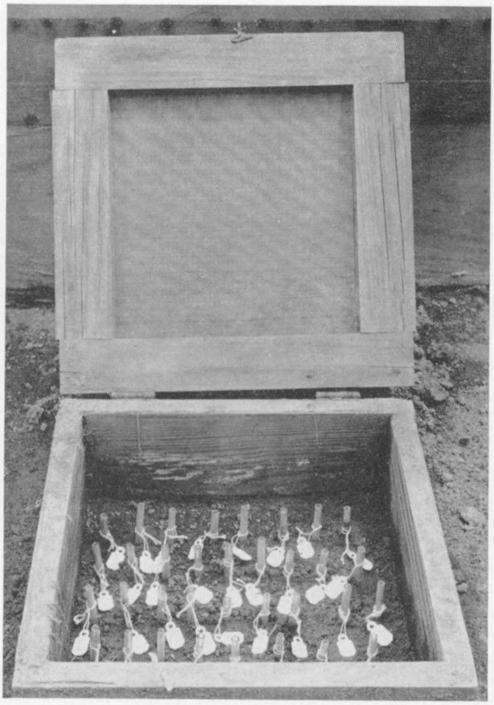

FIGURE 8.—Soil Box in Which Pre-pupae and Pupae of the Cowpea Curculio Developed.

contain both recently hatched larvae and unhatched eggs. In such instances, it was assumed that the eggs would have hatched within one day. An incubation record was made for them based upon this assumption.

Most of the infested peas were permitted to remain on the vine until ripe, so that the larvae might develop normally. At the time of ripening the pods were removed and placed in wooden boxes in a screen-wire insectary to collect emerging larvae. The emerged larvae, or pre-pupae, were placed in glass tubes 5 mm. in diameter and 4 to 5 inches long. These tubes were filled with moist sand. They were labelled and pushed down into the moist sand in a soil box (Fig. 8) to such a depth that the insects rested approximately two inches below the surface of the soil.

The soil boxes were constructed of wood and had 36-mesh copper screen-wire lids. The holes, provided in the bottom and sides of the boxes to admit moisture, and also all cracks in the boxes, were covered with screen wire of the type mentioned. The insects remained in these boxes during the prepupal, pupal, and resting adult stage, after which they were transferred to cages for adults.

All life-history data reported in this paper were obtained under outdoor conditions. In addition to the observations on insects in the rearing cages, observations were made on feeding, breeding, hibernation, and other habits in the field. For specific hibernation tests adults were collected and placed in suitable hibernation cages in an insectary with screen-wire top and sides. Observations were also made on immature stages which entered the soil late in the fall. For records on seasonal changes in infestation in the field, 200 newly ripe pea pods, selected at random, were harvested each week throughout the summer and placed on racks. Each rack had a platform of quarter-inch wire screen with a removable tray below the platform. The larvae emerged from the peas and dropped through the screen into the tray from which they were removed daily and placed in soil boxes for records on pupation and transformation to adults.

Results

Habits of Adults

General.—Cowpea curculio adults were found to be most active in the early morning and late afternoon or early evening. During these periods they were easily found upon the pea pods and tips of the fruiting stems. Most of the major activities such as feeding, mating, and oviposition, were quite evident at this time. The slightest disturbance caused these activities to cease and the adults to drop from the vines to the ground where they sulled or feigned death. They often sulled at the mere approach of the observer, even though the cowpea plants were not disturbed.

During the hot part of the day the beetles became less active and were much less likely to sull. They crawled into the shaded crotches formed by the branches of the plant or hid in other protected places among the foliage or at the base of the plants. They were dislodged from these protected places only with difficulty.

These insects are not active fliers. In fact, the writer has never observed one in flight. Adults have been collected, however, in situations which could have been reached only by flight. Upon one occasion several specimens were collected, along with specimens of the closely related species, *Chalcodermus collaris* Horn, around a light on the porch of a cottage located in a wooded area about 100 yards from a field of old cowpeas which had ceased fruiting. This was the only time *C. aeneus* was found near a light.

Feeding.—The preferred host plant of the cowpea curculio is the cowpea (*Vigna sinensis* Hassk.) but when driven by hunger the adult will feed on a variety of plants. Other than the cowpea, plants upon which the writer has observed the insect feeding include the following: string bean (*Phaseolus vulgaris* Linn.), lima bean (*P. limensis* Macf.), soy bean (*Glycine hispida* Maxim.), English pea (*Pisum sativum* Linn.), common vetch (*Vicia sativa* Linn.), cotton (*Gossypium herbaceum* Linn.), and wild bean (*Strophostyles umbellata* Muhl.). Brooks, Watson, and Mowry (10) reported the insect feeding on strawberries. The writer has collected adults from sheep sorrel (*Rumex acetacella* Linn.), sow thistle (*Sonchus* sp.), and evening primrose (*Oenothera* sp.). The insects fed sparingly on sheep sorrel and evening primrose but the plants could hardly be considered a suitable source of food, except possibly in the early spring.

Leaves, fruiting stems, flowers, pods, and seeds may be attacked by the cowpea curculio. Leaves and stems serve more generally as food before pods of the leguminous host plants are available. Injury to cotton and to string beans usually occurs early in the season before cowpeas are available. At this time feeding may also occur on common vetch, sheep sorrel, and other plants.

Males and females of the cowpea curculio were observed feeding on cowpeas at intervals throughout the growing season. Early in the season the lower epidermis of the leaves was attacked. When pods developed, the weevils fed upon the pods (Fig. 9) and also the peas within them. Small cavities were formed within the peas; upon many occasions several cavities were observed in a single seed. The only parts of the fruiting stems attacked were the terminal points in the vicinity of the nectar glands. This was a favorite feeding place even when an abundance of fruit was available, but it was not determined whether the insect actually obtained nectar. Only upon a few occasions were adults observed feeding on the petals. Recently emerged adults often fed on the surface of the pods, eating out furrows 5 to 10 mm. in length.

Breeding.—The cowpea curculio was observed developing only in cowpeas and string beans, although it is possible that breeding may occur to a considerable extent in other plants. Bissell (8) reported the rearing of a curculio from the seed pod of a wild legume (*Strophostyles umbellata* Muhl.) in Georgia. Hinds (15) reported the rearing of a specimen from a cotton square. The writer and others have been unsuccessful in getting the insect to breed in cotton. Thus it seems highly probable that development ordinarily occurs only in legumes; however, additional study is needed regarding the possibility in wild plants.

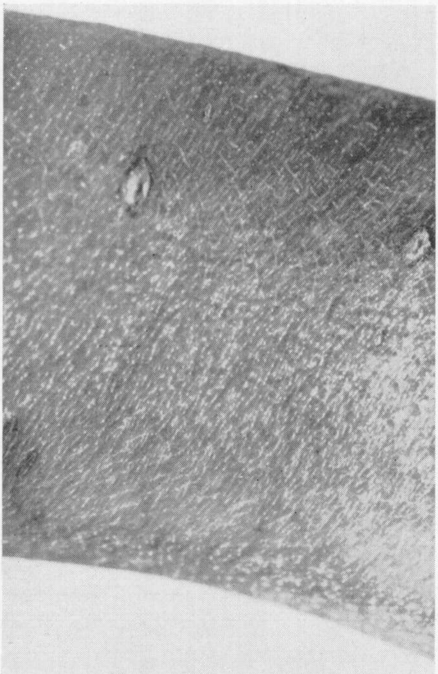

FIGURE 9.—Cowpea Pod Showing Punctures Made by the Cowpea Curculio (Enlarged about 5 times).

Oviposition

Method of Oviposition.—Eggs were deposited in the cowpea pod or in the seed within (Fig. 4, p. 7). In preparing to deposit an egg the female punctured the green pod by chewing through the hull and frequently into the seed. This required from 20 to 30 minutes or longer. After completing a puncture the female turned around, placed the tip of the abdomen over the opening for one or two minutes, and deposited an egg. Only one egg was deposited in a puncture, although several eggs were sometimes deposited in a single seed when adults were numerous. The female sometimes made a short examination of the puncture with the end of the snout after the deposition was made; at other times the examination was omitted. Oviposition occurred most frequently during the cooler part of the day or when the weather was cloudy. Green pods, half-grown to mature, were preferred by the females for oviposition.

Oviposition Period.—Oviposition continued in cowpeas from about June 15 to the first of October in 1930 and 1932. In 1930 a few females, collected in the field under conditions which indicated they had overwintered, deposited eggs throughout the entire period and entered hibernation in the fall. In 1932, however, a majority of the overwintered females deposited their eggs and died before August 1; one lived until September 9; the last oviposition occurred the previous day.

The oviposition period as determined from eight overwintered and six first generation females is given in Table 2. The maximum number of days in the oviposition period was 86, the minimum was 22, and the mean 45.6.

TABLE 2.—The Oviposition Period of Overwintered and First Generation Females, 1932.

Generation	Days in oviposition period			No. of females
	Maximum	Minimum	Mean	
Overwintered	86	35	45.2	8
First	76	22	46.2	6
Both	86	22	45.6	14

Number of Eggs.—The number of eggs deposited daily by each of the 16 females under observation varied from 0 to 10 (Table 3); the mean was 2.6. The total number of eggs deposited by each female varied from 40 to 164 for overwintered adults and from 29 to 281 for first generation females (Table 4). The mean number per female for both generations was 112.7 eggs.

TABLE 3.—The Number of Eggs Per Day Deposited by Overwintered and First Generation Females, 1932.

Generation	Number eggs per day per female			No. of females
	Maximum	Minimum	Mean	
Overwintered	7	0	2.5	8
First	10	0	2.6	8
Both	10	0	2.6	16

TABLE 4.—The Total Number of Eggs Deposited by Overwintered and First Generation Females, 1932.

Generation	Number of eggs per female			No. of females
	Maximum	Minimum	Mean	
Overwintered	164	40	91.0	8
First	281	29	141.7	6
Both	281	29	112.7	14

Development

Development Within the Pea.—The developmental period within the pea included the incubation and active larval stages. The length of this period varied considerably not only with the temperature but also with the rainfall. Observations in 1930 indicated that rains or heavy dews were conducive to the emergence of the larvae from the pods. During a period of extremely hot dry weather, when daily maximum temperatures were 100° F. or above, examinations were made of pods in which the emergence of larvae was overdue according to previous records. Most of the larvae had matured and left the pea (seed) but had not left the pod; approximately 85 per cent of them were dead, having apparently been killed by the heat. At maturity, under favorable conditions, the larvae gnawed holes through the dry pod and crawled out to enter the soil. The length of the total developmental period within the pea varied from 8 to 27 days (Table 5). The mean was 13.2 days.

TABLE 5.—The Maximum, Minimum, and Mean Developmental Periods of Cowpea Curculio in the Field, 1930.

Period of development	Duration of period (days)			No. of individuals
	Maximum	Minimum	Mean	
Incubation	6	3	3.8	82*
Total in pea; incubation and active larval	27	8	13.2	398
Prepupal	14	3	6.2	264
Pupal	19	5	9.7	232
Resting adult	16	1	2.6	200
Total in soil	44	12	18.3	200
Total period; egg to emergence of adult	53	23	30.8	200

The incubation period varied in length from 3 to 6 days (Table 5), with a mean of 3.8 days. The length of the larval period could not be determined directly, since insects in the peas shelled to determine hatching were of necessity discarded. However, the larval period can be calculated by subtracting the mean incubation period from the total period within the pea. Hence, 9.4 days may be assumed to represent the mean larval period within the pea.

*Observations were actually made on several hundred eggs from one to ten days old; the exact date of hatching was determined for only 82.

During the development within the pea, the larva of the cowpea curculio fed in the pea or seed proper. The nature of the feeding injury is shown in Figure 10. This picture shows a larva in a nearly full-grown seed.

Frequently the larvae developed in immature peas which failed to approach normal size. Unless the pea attacked was very immature, however, it continued to grow after the young larva began feeding. Ordinarily a larva completed its development in a single pea, but occasional exceptions were noted. Ainslie (2) found that not more than two larvae could develop to maturity in one pea.

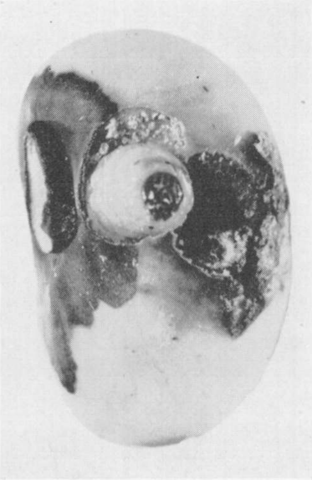

FIGURE 10.—Larva of the Cowpea Curculio in the Pea Where it Developed (Enlarged about 5 times).

Development Within the Soil.—Upon emergence from the pea pod, the larvae ordinarily penetrate the soil to a depth of one to three inches and pupate. In these studies the larvae were placed in glass tubes in soil boxes (Fig. 8, p. 9) for observation as previously explained.

The developmental period within the soil included prepupal, pupal, and resting adult stages. During the prepupal period the larva became thick and short. It was not very active but moved enough to wallow out a cell in the soil for the pupa. The prepupal stage varied in length from 3 to 14 days, with a mean period of 6.2 days (Table 5). At the end of this period the insect moulted and became a pupa. The pupal period varied from 5 to 19 days with a mean of 9.7. After transformation from the pupa, the adult remained in the pupal cell for a short time. This period varied from 1 to 16 days. The mean period was 2.6 days. The total time passed in the soil varied from 12 to 44 days, with a mean period of 18.3 days.

Total Developmental Period.—The total developmental period included all stages from oviposition to the emergence of the new adults. This period varied from 23 to 53 days with a mean of 30.8 days (Table 5). A larger number of insects completed their development in 27 days than in any other period.

Seasonal History

Hibernation.—The cowpea curculio passed the winter only in the adult stage at Auburn, Alabama, during the two years observations were made on immature stages. The females continued to deposit eggs in the fall until green cowpeas were no longer available. The eggs hatched and the larvae usually matured, emerged from the pods, and entered the soil in apparently good condition. The latest record of a larva entering the soil was December 2, 1930. None of the immature forms survived the winter of 1930-31 or 1931-32; very few pupated.

As food became scarce and the weather cool in the fall, many of the cowpea curculio adults crawled down to the base of the host plant and became quiescent under clods of soil, fallen leaves, weeds, or other rubbish. On warm days or during the warmer part of the day, they returned to the host plants. Insects for hibernation experiments were collected from beneath the fallen leaves in old cowpea fields during late October and early November. The beetles were placed with leaves and old cowpea vines in hibernating cages in the screen-wire insectary.

In the fall of 1930, 860 adult curculios were placed in the hibernation cages. This number included 43 old beetles caught in the early summer. All insects in the cages were inactive under rubbish or in the soil during most of December and January. A few hibernating adults were also found in an old pea field January 31. During February, March, and April some of the insects became intermittently active and inactive. On warm days they were observed crawling on the cage; on cool days they disappeared from view. Sixty active beetles were observed March 1, but the number decreased to 13 March 13 when the minimum temperature was 31° F. No active beetles were to be found March 17 when the temperature again dropped to 31 degrees. Only 12 living beetles were recovered from the cages when they were opened May 6. This represents a survival of 1.8 per cent. None of the 43 old beetles survived.

Similar experiments were conducted during the winters of 1931-32 and 1932-33. In the fall of 1931, 410 adults were placed in the hibernation cages. A survival record was not obtained for one cage containing 126 beetles, due to the escape of some of the insects through a hole accidentally torn in the cage. Of the remaining 284 adults, 14, or 4.9 per cent survived the winter. Of the 1,263 beetles placed in the hibernation cages in the fall of 1932, not one was alive when the cage was opened April 22, 1933.

Starvation and a fungous disease appeared to be important factors in reducing the winter survival. Since adults sometimes became intermittently active as early as February or March, it is logical to suppose that starvation was an important factor. Most of the dead insects, however, were covered by a fungus, *Metarrhizium anisopliae* Metch.* It is possible that the fungus attacked the insect after death, but Chittenden (12) referred to a fungous disease destroying the immature stages being reared in the laboratory and Swingle and Seal (26) found *Metarrhizium anisopliae* to be highly fatal to the larva of the pecan weevil (*Curculio caryae* Horn).

The time of emergence of adults from hibernation in the field necessarily varies with variation in climatic conditions. In

*Identified by Dr. J. L. Seal, Ala. Agr. Expt. Sta.

these studies adults were collected as early as April 22 from sheep sorrel and May 8 from dwarf string beans. They were found to be more numerous during the latter part of May.

These observations on hibernation differ considerably from those of Ainslie (2) in South Carolina, particularly concerning the intermittent activity of the insect during periods of warm weather. Ainslie made observations on hibernating insects that remained continuously inactive from late November until March 15 in a greenhouse kept at summer temperature.

Longevity of Adults.—Exact records of the longevity of adults are not available, but overwintering forms are known to live through a period of six to nine months. In one instance a few insects appeared to have lived at least 12 months. These beetles were collected early in June from young cowpeas just coming into fruiting in a field containing no other legumes. Adults were numerous and it seemed highly probable that they had overwintered, since cowpeas grew on the same area the previous year. These insects lived throughout the summer and entered hibernation in November, but failed to survive the winter. Most adults live for a much shorter period. Field records show that curculios emerging in July usually die before November, although two insects which emerged from the pupal cell July 20, 1932, entered hibernation about November 1. They did not survive the winter.

Number of Generations.—Breeding was continuous in cowpeas throughout the fruiting period of the plants in 1930 and 1932. Although there was considerable overlapping, two rather distinct generations occurred in 1932 (Fig. 11). First generation eggs were deposited over a period extending from June 16 to September 8 and second generation eggs from July 21 to October 3. The records were from eight females of each generation. The larval and adult emergence records shown in the figure are from peas taken from the field at weekly intervals without regard to generations.

Vulnerable Points in the Life Cycle

The adult of the cowpea curculio feeds largely within the pods of legumes and is therefore very difficult to poison. Likewise, the eggs and larvae are protected within the pod. The apparent invulnerability of the insect is further enhanced by the fact it passes the winter in the adult form which is a hard-bodied, resistant stage. Several vulnerable points were discovered and are discussed briefly in the following statements:

1. Adults frequently feed on cowpea leaves previous to the formation of seed pods. Recently emerged adults also feed on the surface of the pods, devouring areas of considerable size. If the plant is covered with an effective insecticide at the time these two types of feeding occur, partial control might reasonably be expected.

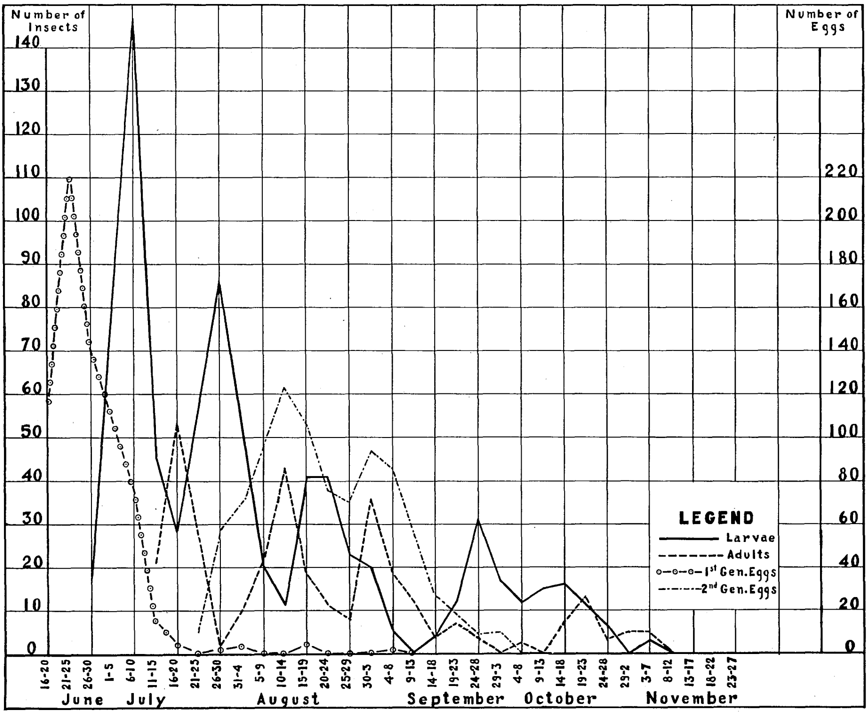

FIGURE 11.—Seasonal Distribution of Oviposition and Emergence of Larvae and Adults, 1932. The number of eggs is from eight females of each generation. The number of insects is from 200 cowpea pods picked at random each week in the field.

2. The larva must leave the pod and enter the soil to pupate. It is not only susceptible to predators and unfavorable climatic conditions but also to man. This is the most vulnerable time in the life cycle.
3. Since the larvae very rarely leave the peas before the pods are ripe, frequent picking of ripe pods might be expected to be of value as a control measure.
4. Many adults crawl beneath the mulch of fallen cowpea leaves in the fall where they could be burned.
5. Although they are not essentially parts of the life cycle, certain habits of adults seem to render them susceptible to control measures. The habit of resting the end of the snout on pods and leaves of the host plant would theoretically render the beetles susceptible to a film of insecticidal dust on the plant. The fact that adults are not active fliers might also be of value in control. Other habits, such as sulling might be utilized but it is difficult to visualize feasible methods of control based on this habit.

FIELD EXPERIMENTS ON INSECTICIDAL CONTROL

Field experiments were conducted at the Alabama Station from 1931 to 1936, inclusive, in an effort to develop satisfactory insecticidal control for the cowpea curculio. Most of the insecticides used in the field had been tried in the laboratory (6). All materials were applied as dusts. Liquid sprays were not tried because control practices throughout the State are such that spraying of cowpeas would be entirely impracticable. Furthermore, dusting should be more effective since most of the poison ingested must be in a form which will adhere to the mouthparts when the beetle rests the end of its snout on the surface of the plant.

14 Rows - Dusted with Florote	14 Rows - Check
Buffer Rows	Buffer Rows
14 Rows - Dusted with Pyrethrum	14 Rows - Check
Buffer Rows	Buffer Rows
14 Rows - Dusted with Calcium Arsenate	14 Rows - Check
Buffer Rows	Buffer Rows
14 Rows - Dusted with Sodium Fluosilicate	14 Rows - Check

FIGURE 12.—Diagram of the Plots Used in Cowpea Curculio Control Experiments in 1933.

Experimental Methods

Arrangement of Plots

From 1931 to 1935 the experimental plots were arranged in two tiers (Fig. 12). The plots in one tier were dusted with insecticides, whereas those in the other tier were not dusted. The rows of cowpeas were continuous through both tiers so that one-half of each row was dusted. In this arrangement, not only each dusted plot but also each row had a corresponding check. The plots consisted of from 12 to 30 rows each and were separated from adjacent plots by at least two "buffer" rows. A strip approximately 10 feet wide between treated and check plots was also considered as a buffer and no infestation counts of peas were made from this area. This arrangement of plots seemed desirable in that a minimum of error would be expected from the drifting of dusts and migration of insects. It did not eliminate the possibilities of error due to localized infestations, but the proximity of checks to dusted plots provided a method of determining whether the infestation was "spotted".

A different arrangement of plots was tried in 1936. The experimental area, 286 feet long and 197 feet wide with 54 longitudinal rows, was divided into four tiers of four plots each (Fig. 13). Each plot consisted of 10 rows 60 feet long except that in tier two most of the rows were 70 feet long. It seemed desirable to make tier two longer than the others because of an excavation near the center. Each plot in a tier was separated from adjacent plots by four buffer rows. Each tier was separated from adjacent tiers by a 12-foot buffer strip. One-half of each buffer area received the same treatment as its adjoining plot. Treatments were replicated in such a manner that no check plot was completely surrounded by dusted plots. This arrangement permits an analysis of the data by the Latin square method and should minimize the error resulting from localized infestation.

Insecticides Used

The insecticides used during 1931-35 varied somewhat from year to year. An effort was made to test as many different materials as possible and at the same time to investigate thoroughly the more promising insecticides. When a material was proved to be ineffective, it was replaced by some other insecticide. During this period eleven combinations of insecticidal dusts were used (Table 6). These dusts included sodium fluosilicate, calcium arsenate, derris, barium fluosilicate, acid lead arsenate, magnesium arsenate, cryolite, pyrethrum, and florote*. The sodium fluosilicate used was a "light" brand containing 25 per cent colloidal silica (41.2 per cent F).

*A commercial dust, containing rotenone, 5 per cent; pyrethrins, 1 per cent; nicotine, 1 per cent; residual deposit of rotenone, 2.5 per cent; and inert materials, 90.5 per cent. Later samples contained a lower percentage of active ingredients.

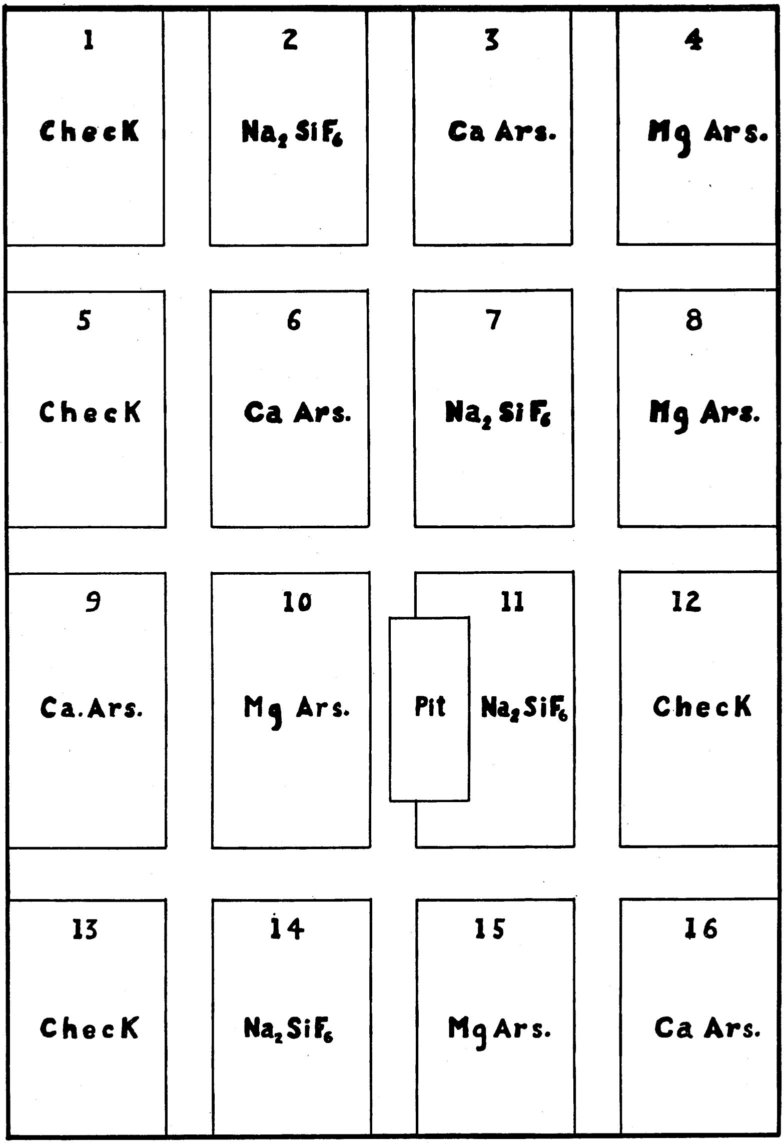

FIGURE 13.—Diagram of the Plots Used in Cowpea Curculio Control Experiments in 1936.

In the 1936 experiments, sodium fluosilicate, calcium arsenate, and magnesium arsenate were the only insecticides used. The sodium fluosilicate was an "extra light" brand, superior in both dusting and adhering qualities to the material previously used. It contained approximately 50 per cent colloidal silica (28.0 per cent F). The calcium arsenate was an autoclaved or "safened" brand especially treated by the manufacturer to prevent injury to plants. A standard commercial brand of magnesium arsenate was used. Each was replicated four times.

Application of Insecticides

All applications of insecticides were made with hand dust guns of the rotary type. With few exceptions, a separate gun was used for each insecticide throughout the season. The guns were adjusted to deliver a thin cloud of dust which completely enveloped the plants. The rate of application of all dusts was approximately eight pounds per acre. Applications of insecticides were made at any time during the day, provided the air was calm. The first application was made at the time the first blossoms appeared and additional dustings were made at intervals of 5 to 10 days throughout the fruiting season. Whenever heavy rainfall occurred within 24 hours after dusting, the application was repeated.

Determination of Infestation

The cowpea curculio infestation was determined by examining samples of peas, taken from the experimental plots, for feeding and breeding punctures. In this work the peas on each row of each plot were harvested separately as soon as ripe, fumigated, and stored in an insect-free container. Samples of peas in the pod were obtained by saving each second or third handful of pods taken from a bag in which the peas from a row were stored. This gave a representative sample of pods from different parts of each row. The sample was then shelled, the seeds were mixed together, and a small beakerful of approximately 500 peas was taken for examination. This method gave a representative sample of peas from each row of each plot.

Results

Five-Year Period, 1931-1935

Infestation and Dusting Data.—The annual data on infestation for the five-year period are presented in Table 6. The infestation varied considerably from year to year. The highest infestations, as determined from the checks, occurred in 1934 and the lowest in 1932. The percentage of control by an insecticide was not as variable from year to year as was the infestation. In general an insecticide which gave a high percentage of control when the infestation was high also gave a high percentage of control when the infestation was low and vice versa. Variations which did occur in the percentage of control were apparently not related to the seasonal variation in abundance of insects nor were they closely related to the number of dustings.

Summarized data on the percentage of control are presented in Table 7. Although some variations result from the different methods of calculating control, these variations are not sufficient to affect the interpretation of results. The order of effectiveness of insecticides is the same when expressed by either of the means.

The number of dustings per season varied considerably with weather conditions during the fruiting period of the peas (Table 6). The maximum number was 9 in 1932 and the minimum 4 in 1935. The mean was 6.1. Observations were made in all experiments to determine burning of foliage by the insecticides. Very little or no burning resulted from the use of sodium fluosilicate, magnesium arsenate, derris, pyrethrum, cryolite, or florote.

TABLE 6.—Percentage Control of the Cowpea Curculio by Various Insecticides, 1931-35.

Year	No. pea samples	Insecticide used	No. of dustings	Mean per cent infestation		Per cent control
				Dusted	Undusted	
1931	32	Sodium fluosilicate & Lime: 1:1	5	10.93	19.61	44.26
1932	2	Sodium fluosilicate & Gypsum: 2:1	7	2.81	10.33	72.80
1932	52	Sodium fluosilicate	5	11.04	22.13	50.11
1932	24	Sodium fluosilicate & Gypsum: 2:1	9	1.73	3.25	46.77
	24	Sodium fluosilicate	9	0.78	4.26	81.69
	24	Barium fluosilicate	9	2.67	3.29	18.84
	24	Acid lead arsenate	9	1.68	2.65	36.60
1933	28	Sodium fluosilicate	8	9.08	29.19	68.89
	28	Calcium arsenate	8	6.75	30.87	78.13
	28	Pyrethrum	8	20.91	28.52	28.68
	28	Florote	8	30.32	31.49	3.71
1934	32	Calcium arsenate	6	8.96	36.00	75.11
	30	Calcium arsenate & Lime: 1:1	6	16.93	45.78	63.02
	30	Calcium arsenate & Talc: 1:1	6	24.20	40.51	40.26
	28	Calcium arsenate & Sulphur: 1:1	6	14.81	41.13	63.99
	30	Sodium fluosilicate	6	12.95	30.53	57.58
1934	60	Derris & Talc 2% Rotenone	5	36.68	35.43	–3.53
	60	Derris & Sulphur, 2% Rotenone	5	32.22	31.46	–2.41
1935	28	Calcium arsenate	4	3.48	11.74	70.36
	24	Magnesium arsenate	4	5.43	14.13	61.57
	28	Acid lead arsenate	4	3.80	10.94	65.26
	28	Sodium fluosilicate	4	2.30	10.13	77.29
	28	Barium fluosilicate	4	3.88	10.02	61.28
	28	Cryolite	4	6.50	8.81	26.22

TABLE 7.—Summary of Insecticidal Control of the Cowpea Curculio Based on Different Methods of Calculating, 1931-1935.

Insecticide used	No. of tests	No. peas examined	Per cent control*	
			Based on mean infestation	Mean based on control on each row
Sodium fluosilicate	5	87,831	67.11	61.85
Sodium fluosilicate diluted with other materials	3	14,731	54.61	43.71
Calcium arsenate	3	34,259	74.53	74.53
Calcium arsenate diluted with other materials	3	29,597	55.76	52.20
Acid lead arsenate	2	21,573	50.93	48.81
Barium fluosilicate	2	21,191	40.06	37.56
Derris: 2% rotenone	2	27,747	-2.97	-13.63
Magnesium arsenate	1	9,481	61.57	58.62
Pyrethrum	1	12,889	28.68	26.55
Florote	1	12,377	3.71	2.86
Cryolite	1	10,003	26.22	8.89

*Per Cent Control = $\frac{X - Y}{X} \times 100$, where X is the per cent infestation on the undusted area and Y is the per cent infestation on the dusted area (1).

Moderate burning was produced by barium fluosilicate and severe burning by lead arsenate and calcium arsenate. The burning resulting from lead arsenate and calcium arsenate was so severe that frequently the yield of peas on the plots treated with those materials was greatly reduced. The length of the pods and the number of peas within a pod were also reduced.

Analysis of Variance.—Some of the insecticides used in the experiments were effective in producing partial control of the insect. Other materials were unquestionably ineffective. There was considerable doubt whether differences between certain insecticides were sufficient to consider one significantly more efficient than the other. In order to determine if differences were statistically significant the data were analyzed.

In the analysis of variance of the field data for 1931-1935 an effort was made to use the actual percentages of infestation on the various plots. This seemed desirable since original data are preferable to ratios (percentages of control) derived from such data. It soon became evident that the data on infestation were not suitable for this type of analysis. In certain instances the differences were significant for each of a series of years, yet the infestation varied sufficiently from year to year to obscure the significant differences between treatments. These differences resulted from differences in the abundance of insects and were not related to the efficiency of the insecticides.

The results of the calculations made according to Snedecor's example 2 (25) are tabulated in Table 8. The value of F, calculated from the data in this table, was 9.04. For the degrees of freedom in the two mean squares, the significant value of F is

TABLE 8.—Analysis of Variance of Percentage Control of the Cowpea Curculio by Six Insecticidal Treatments, 1931-35.

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	248	214,537.5	865.1
Between treatments	5	33,650.3	6,730.1
Within treatments	243	180,887.2	744.4

2.26 and the highly significant value is 3.11 (25). Hence, some of the differences between means of the insecticidal treatments are highly significant. The variance 744.4 may be accepted as a proper estimate of experimental error. Its standard deviation, 27.284 per cent, may be used to test the significance of differences between the mean percentage control of any pair of insecticidal treatments.

The results of the tests for significant differences are shown in Table 9. With the exception of the last four treatments listed in the table, all means tested were significant. Calcium arsenate was the most effective material tested and sodium fluosilicate was second in efficiency. Analyses of variance were not made for magnesium arsenate, derris, florote, cryolite, and pyrethrum. Only one year's results were available for magnesium arsenate and it was omitted from the analysis for that reason. The other materials were tried only one year or were obviously ineffective.

One-Year Period, 1936

Infestation and Dusting Data.—The mean infestation and control data are presented in Table 10. The mean infestation was approximately 10 percent on the calcium arsenate, magnesium arsenate, and sodium fluosilicate plots as contrasted to 30.77 per cent on the checks. The percentage of control from each of the three insecticides was as follows: calcium arsenate, 70.72; magnesium arsenate, 64.28; sodium fluosilicate, 65.10. Data showing the variations in infestation on all plots are presented in Table 11.

Twelve applications of insecticidal dusts were made in 1936 between July 15 and September 8. Six of these applications were washed off by heavy rainfall within 24 hours after dusting; only two applications remained on the peas more than 72 hours unaffected by rain. This was the largest number of applications made during any year of the cowpea curculio experiments. No injury to cowpea foliage was produced by sodium fluosilicate or magnesium arsenate, but autoclaved calcium arsenate produced severe burning. The plants on the calcium arsenate plots were practically killed by the end of the dusting season and the yield of peas was only about 10 per cent of the yield on the other plots.

TABLE 9.—Results of Significance Tests of Percentage Mean Differences Between Various Insecticidal Treatments for the Control of the Cowpea Curculio.

More efficient material			Less efficient material			Difference in control	t Value	P Value
Insecticide	Degrees of freedom	Per cent control	Insecticide	Degrees of freedom	Per cent control			
Sodium fluosilicate (Undiluted)	80	61.9	Sodium fluosilicate (Diluted)	27	42.7	19.2	3.1	<.01
Sodium fluosilicate (Undiluted)	80	61.9	Calcium arsenate (Diluted)	43	52.2	9.7	1.9	.05
Sodium fluosilicate (Undiluted)	80	61.9	Barium fluosilicate	25	37.6	31.5	5.0	<.01
Sodium fluosilicate (Undiluted)	80	61.9	Lead arsenate	25	48.8	13.1	2.1	<.05
Calcium arsenate (Undiluted)	43	74.5	Sodium fluosilicate (Undiluted)	80	61.9	12.6	2.4	<.02
Calcium arsenate (Undiluted)	43	74.5	Calcium arsenate (Diluted)	43	52.2	22.3	3.8	<.01
Calcium arsenate (Undiluted)	43	74.5	Sodium fluosilicate (Diluted)	27	42.7	31.8	4.7	<.01
Calcium arsenate (Undiluted)	43	74.5	Barium fluosilicate	25	37.6	36.9	5.3	<.01
Calcium arsenate (Undiluted)	43	74.5	Lead arsenate	25	48.8	25.7	3.7	<.01
Calcium arsenate (Diluted)	43	52.2	Barium fluosilicate	25	37.6	14.6	2.1	.05
Calcium arsenate (Diluted)	43	52.2	Sodium fluosilicate (Diluted)	27	42.7	9.5	1.4	>.1
Calcium arsenate (Diluted)	43	52.2	Lead arsenate	25	48.8	3.4	0.5	.6
Sodium fluosilicate (Diluted)	27	42.7	Barium fluosilicate	25	37.6	5.1	0.7	>.4
Lead arsenate	25	48.8	Barium fluosilicate	25	37.6	11.2	1.4	>.1

TABLE 10.—Mean Percentage of Infestation on All Plots and the Percentage Control, 1936.

Insecticide used	No. peas examined	Mean per cent infestation	Per cent control
Calcium arsenate (autoclaved)	15,298	9.01	70.72
Magnesium arsenate	16,449	10.99	64.28
Sodium fluosilicate (50% colloidal silica)	16,703	10.74	65.10
None	15,958	30.77	

Analysis of Variance.—The method selected for analysis of variance was Snedecor's (25) example 5, the Latin Square Method. The data on the infestation of the cowpea curculio, arranged for analysis, are presented in Table 11. The results of the analysis of variance are presented in Table 12. The "remainder" is the variance representing experimental error in this analysis. Since the variance for treatments is high in relation to

TABLE 11.—Statistics on the Percentage of Cowpea Curculio Infestation on 16 Plots of Peas, 1936.*

Row	Column 1	Column 2	Column 3	Column 4	Sum
1	A 27.36 748.57	B 6.07 36.84	C 14.39 207.07	D 10.52 110.67	58.34
2	B 8.56 73.27	C 11.40 129.96	D 9.99 99.80	A 23.17 536.85	53.12
3	C 10.56 111.51	D 9.21 84.82	A 36.81 1,354.98	B 11.77 138.53	68.35
4	D 13.26 175.83	A 35.72 1,275.92	B 9.63 92.74	C 7.61 57.91	66.22
Sum	59.74	62.40	70.82	53.07	246.03

TABLE 12.—The Analysis of Variance of Cowpea Curculio Infestation on 16 Plots, 1936.

Sources of variance	Degrees of freedom	Sum of squares	Mean square
Total	15	1,452.10	96.81
Between Means of Columns	3	40.46	13.49
Between Means of Rows	3	37.36	12.45
Between Means of Treatments	3	1,272.25	424.08
Remainder (Error)	6	102.03	17.00

*The letters in the table represent the different treatments, namely: A, undusted; B, calcium arsenate; C, magnesium arsenate; D, sodium fluosilicate. The first figure below each letter is the percentage of infestation, the second is the square of the percentage (X^2).

that for error, F = 24.95, the differences between means of treatments are significant sources of variations. Should those variations result from random sampling even in one per cent of the trials, the value of F would be 9.78; the value could be as low as 4.76 and still be significant (25).

The value of t, when N = 6 and P = .05, is 2.447 (14). The standard error of the difference between means is 2.916. The mean difference is 7.135 for a standard error of 2.916 and a t value of 2.447. Hence, any difference between means of treatments must be 7.135 per cent or higher in order to be significant. It is obvious from the data in Table 10 that the only significant differences in mean infestation were those between the undusted and the dusted plots.

Discussion of Results

The experimental results of the one-year period, 1936, did not differ markedly from those of the five-year period, 1931-35. The most effective insecticides tried during the five-year period were calcium arsenate, sodium fluosilicate, and magnesium arsenate with 74.53, 67.11, 61.57 per cent control, respectively. The per cent control from essentially the same materials in 1936 was 70.72, 65.10, and 64.28, respectively. Statistical analysis of the data for the five-year period showed calcium arsenate to be significantly more efficient in controlling the insect than any other material; in 1936 there were no significant differences in efficiency. The failure of calcium arsenate to reduce infestation in 1936 significantly lower than the other materials may have been a result of the drifting of dusts between plots to a greater degree than formerly.

Data published elsewhere (7) show that an efficient insecticide applied to cowpeas on one plot reduced significantly the infestation on the adjoining check plot. If the infestation on check plots is so affected, then the infestation on dusted plots should likewise be affected by the treatment of their adjoining plots. Hence, it appears that the three insecticides used in 1936 are not necessarily of equal effectiveness. It appears also that all percentages of control reported herein are lower than those which would result from dusting all the peas in an area.

Practical Application

The cowpea curculio can be partly controlled by dusting the peas with sodium fluosilicate, but it is doubtful if control under farm conditions would exceed 75 per cent. Sodium fluosilicate is the only material tried that is suitable for commercial use. The toxicity of calcium arsenate to cowpea foliage and the high cost of magnesium arsenate render these materials unsuitable. A "light" brand of sodium fluosilicate should be applied to the foliage of the peas at the rate of eight pounds per acre. Dusting should begin just before the first pods appear and should be repeated at weekly intervals throughout the fruiting season of the peas.

Moderate profits may be expected from dusting cowpeas to be used as a fresh vegetable. Yields of table varieties grown at Auburn over a ten-year period varied from 1,500 to 6,000 pounds per acre of green peas in the hull*. Since green peas retail at five to ten cents a pound, the value of cowpeas grown as a vegetable may be estimated conservatively at $100 per acre. Thirty-six per cent of the undusted peas grown at Auburn over a three-year period were infested by the cowpea curculio (Fig. 14) and were unfit for food; sodium fluosilicate reduced the infestation approximately 70 per cent over a five-year period. Hence, the value of the peas saved by dusting may be estimated at $25.00 per acre. The cost of the dusting is approximately $6.00 per acre ($4.50 exclusive of labor).

STUDIES ON NATURAL AND AGRONOMIC CONTROL

Natural Control

The cowpea curculio is attacked by a number of parasites and predators. The only parasite observed in these studies was a tachinid fly identified† as *Myophasia globosa* Tns. Twenty of these flies were removed at intervals during the summer of 1932 from the fly-proof soil boxes in which 797 curculio larvae were placed for life-history records. The larvae of the flies were found to develop in the immature stages of the curculio. This parasite had been previously reported by Howard (17) in 1894, Ainslie (2) in 1910, and other workers. Howard also reported an unknown species of the genus *Sigalphus,* order Hymenoptera and Ainslie reported two unidentified species of hymenopterous insects parasitizing the cowpea curculio.

Larvae attempting to enter the soil are frequently attacked by ants. Upon numerous occasions during the summer of 1930 observations were made of larvae being killed and devoured by several common but unidentified species of field ants. Twenty-five larvae thus attacked were found in a field of cowpeas during 30 minute searches in the early morning of two consecutive days. All larvae observed were killed by the ants.

Attention has already been directed to the possibility of a fungus attacking adults in hibernation. Every dead beetle in the hibernation cages in the spring of 1932 was covered with the fungus. The fourteen apparently healthy beetles removed from the cages May 3 were placed in large vials stoppered with cotton and supplied with cowpea leaves while awaiting the fruiting of peas in the field. Within two weeks all adults were dead, having apparently succumbed to the disease.

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*Figures from unpublished data of Dr. C. L. Isbell, Horticulturist of the Ala. Agr. Expt. Sta.

†Identification by Dr. J. M. Aldrich, U. S. National Museum.

Hot dry weather appeared to be the most important climatic factor in controlling the cowpea curculio. Dry weather made it difficult for the larvae to gnaw through the pea pod and also to enter the soil once they escaped from the pea. High temperatures killed many of the larvae within the dry pods. Observations previously mentioned showed 85 per cent fatality of larvae in dry cowpea pods during a period when maximum temperatures were 100° F. or above on several successive days.

Control By Agronomic Practices

Frequent Picking of Peas.—Since the larvae of *C. aeneus* rarely emerged from a cowpea pod before it was ripe, the practice of picking the ripe peas at frequent intervals and storing them in a clean dry place seemed feasible. To determine if such a scheme might work, several wagon loads of dry peas stored on a concrete floor were examined. The larvae had emerged and dropped to the floor but were unable to pupate. Many of the larvae were dead at the time and subsequent examinations revealed only shrivelled remains of the insects. It is evident from these observations that the insect could be controlled if all cowpeas were picked as soon as ripe and stored on a clean, tight, dry floor. The widespread use of cowpeas for hay and as a soil building crop, however, limits to some extent this method of control, since the insect can breed in the hay crop and then infest the garden varieties. Furthermore, peas from the varieties grown chiefly for hay are frequently used as food. Hence, frequent picking of ripe peas would be of most value in sections where fairly large areas of table varieties are grown for canneries or the fresh-vegetable market. It should be of value also in small gardens where peas are grown over a consecutive period of years on the same or closely adjoining areas.

Resistant Varieties.—Investigations to determine the resistance and susceptibility of the garden varieties of cowpeas were conducted in cooperation with the Horticulture Department of the Alabama Polytechnic Institute in 1930, 1931, and 1932. The cowpea curculio infestation was determined for each of four to five plantings annually of 14 varieties of cowpeas. The method of determining infestation was very similar to that previously described. Summarized data of these studies are presented in Figure 14. With the possible exception of Victor and Black Crowder, for which only one year's results were available, Taylor and Counch with mean infestations of 25.6 and 26.1 per cent, respectively, were attacked by the cowpea curculio the least of all varieties. California Black Eye and White Crowder were injured most of all varieties. The highest mean infestation for the three-year period was 52.8 per cent for California Black Eye, but the highest mean infestation in any one year was 65.0 per cent for the White Crowder in 1930. Although these data show unmistakable evidence of preference of the insect for certain varieties over others, all varieties were attacked sufficiently to indicate that any one might be heavily infested in the absence of others. However, some of the varieties which may be of value in resisting cowpea curculio attacks have other characteristics which render them desirable. The Counch variety, for example, in addition to possessing some resistance to the cowpea curculio, is also resistant to nematodes and adverse weather conditions.

Other Practices.—There are no data available bearing directly on the problem of control by means of trap crops. Adults of the cowpea curculio were found to be numerous on small areas of early peas growing on or near land previously in cowpeas. Infestation on these areas was sometimes extremely high. Later

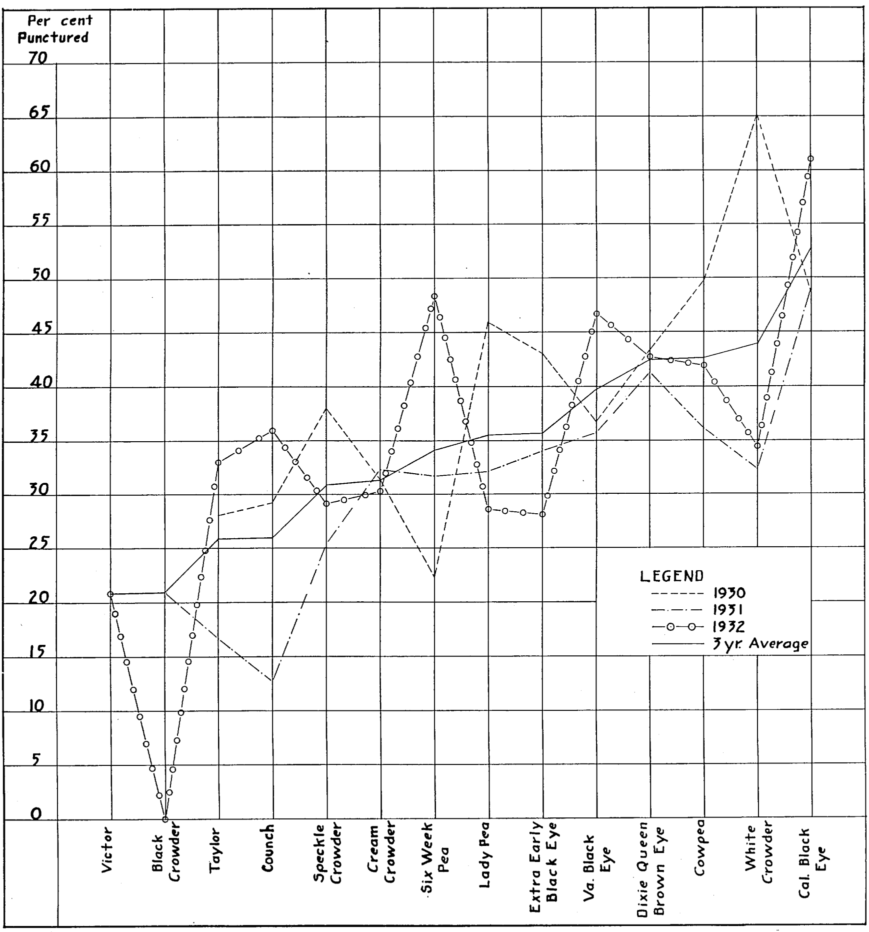

FIGURE 14.—Cowpea Curculio Infestation in 14 Table Varieties of Cowpeas, 1930-32.

in the season when large acreages of cowpeas came into fruiting the percentage of infestation was usually lower. The data presented in Figure 11 (page 17) indicate these facts. These data show the distribution of larval and adult emergence from a constant number of pea pods picked at random each week from the field throughout the season of 1932. Since the number of insects per pod was high early in the season and decreased as the season advanced, there is a possibility of control by destroying the insects on early trap crops of susceptible varieties.

In fields where the pea plants are not removed for hay, the fallen leaves form a mat or mulch over the surface of the ground during the fall. The adults of the cowpea curculio crawl under these leaves to hibernate and could be destroyed by burning the leaves during dry weather. This method of control would not be rendered ineffective by nearby hay crops of cowpeas. The hay crops are usually removed from the field early enough to force many of the insects to seek food elsewhere although specimens are sometimes found on young growth from old stubbles. Insects from nearby fields might actually invade the uncut peas and later hibernate beneath the fallen leaves. The chief disadvantages of burning are the loss of plant nutrients and the destruction of cover for game birds.

No experiments in crop rotation were conducted in these investigations and the extensive plantings of cowpeas over the Experiment Station farm prevented the making of very extensive observations of infestations in cowpeas grown in isolated areas. However, the habits of the insect are such that the writer feels certain a system of rotation would be helpful, provided the cowpeas were well removed from fields previously in peas or beans. Newell and Smith (19), Sherman (24), and others have reported serious injury to cotton in rotations where cowpeas were followed by cotton. Such occurrences, however, are not very common.

Conclusions

Natural enemies and unfavorable climatic conditions are of considerable value in controlling the cowpea curculio during certain seasons but they are too variable to be reliable controls. The agronomic practices are limited to vegetable gardens where peas are grown for human food. The frequent picking of ripe peas, and the growing of table varieties in isolated areas are the practices which should be of most value. The burning of dry leaves in the fall cannot be recommended as a general practice, but it might be helpful and justifiable under some conditions. In isolated garden areas where peas are grown each year, the combined practices of burning the cowpea leaves in the fall and the picking of all pea and bean pods as soon as ripe should be effective. There is need for definite experimental work to determine the value of some of the practices suggested.

SUMMARY AND CONCLUSIONS

1. The cowpea curculio (*Chalcodermus aeneus* Boh.) is distributed throughout the Gulf Coast region where it is a major pest of cowpeas. Experiments with 14 leading garden varieties of cowpeas showed a mean infestation of 36 per cent over a three-year period. Infestations of 65 per cent and above were recorded.

2. In addition to cowpeas, the adults feed on string beans, cotton, strawberries, and other crops, which serve as food principally before cowpeas are available. The insect breeds in the pods of cowpeas and string beans. The larvae developing in the seeds within the pods render infested peas and beans unfit for table use.

3. Two generations of the insect occur annually in cowpeas in Alabama. The female deposits her eggs in excavations in peas; there the larvae develop to maturity, emerge from the dry pod, and pupate in the soil. The time required for development from egg to adult varies with environmental conditions. Records on insects developing outdoors showed variations of from 23 to 53 days with a mean of 30.8 days. The maximum number of eggs deposited by one female was 281; the mean was 112.7.

4. Hibernation occurs in the adult stage. The insects pass the winter under leaves or other rubbish and in the soil. A fungous disease may be important in causing mortality during hibernation.

5. A tachinid fly and several species of ants are the most important insect enemies of the cowpea curculio. Hot dry weather is the most important climatic factor in the natural control of the insect.

6. Certain garden varieties of cowpeas are more resistant to attacks of the cowpea curculio than others. Of the 14 varieties tested, California Black Eye and White Crowder were the most susceptible, Counch and Taylor, the most resistant. It is doubtful, however, whether any variety is sufficiently resistant to escape serious injury in the absence of more susceptible varieties.

7. Larvae do not often emerge from the peas until after the pods are dry. If the pods are harvested and stored on a tight dry floor, the larvae perish.

8. Adults are difficult to poison due to their habit of feeding within the pods of peas.

9. According to results of field experiments during 1931-35, calcium arsenate is significantly more efficient than any other insecticide tried for controlling the cowpea curculio; sodium fluosilicate is next in efficiency. The percentages of control for the various materials used in the experiments were as

follows: calcium arsenate, 74.53; sodium fluosilicate, 67.11; magnesium arsenate, 61.57; acid lead arsenate, 50.93; barium fluosilicate, 40.06; cryolite, 26.22; pyrethrum, 28.68; florote, 3.71; derris, –2.97 per cent. Both calcium arsenate and acid lead arsenate caused severe burning of foliage.

10. According to the results of a series of replicated field experiments in 1936, an efficient insecticide applied as a dust to cowpeas on small plots reduces the cowpea curculio infestation on adjacent plots. The percentages of control, 70.72, 64.28, and 65.10 for autoclaved calcium arsenate, magnesium arsenate, and "extra light" sodium fluosilicate, were not significantly different. It is believed that the drifting of dusts may account for the absence of significant differences.

11. Sodium fluosilicate is the most satisfactory material for the control of the cowpea curculio. This material should give 70 to 75 per cent control under farm conditions.

12. Control measures must be limited to peas grown exclusively for human food as it would not be practicable to apply methods now known to large acreages of hay and feed crops of cowpeas.

13. The annual cost of dusting an acre of peas is approximately $6.00. The value of the peas protected may be estimated conservatively at $25.00.

14. Exact recommendations for control practices must be determined by local conditions, but it is desirable to supplement dusting with farm practices. These practices might include the growing of peas in areas isolated from other cowpeas, the frequent picking of ripe pods, and the intelligent rotation and manipulation of cropping systems so as to prevent infestation by insects from hay and other crops of cowpeas.

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