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TEXAS AGRICULTURAL EXPERIMENT STATION

A. B. CONNER, DIRECTOR
COLLEGE STATION, BRAZOS COUNTY, TEXAS

BULLETIN NO. 475 JULY, 1933

DIVISION OF ENTOMOLOGY

Ingestion of Poison by the Boll Weevil

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**In cooperation with U. S. Department of Agriculture.
‡In cooperation with Texas Extension Service.
†As of July 1, 1933.

The boll weevil, while crawling normally over cotton plants, has a characteristic habit of bringing the tip of its beak in contact with the surface over which it is moving and, in this manner, accidently accumulates small particles of calcium arsenate on its mouth parts. The poison which is commonly picked up in this way may become dislodged before a quantity sufficient to produce death is swallowed; however, data secured in cage experiments indicate that 65 per cent of the individuals secured a fatal amount of poison in this manner. Additional data show that the weevil may pick up a lethal dose of poison on any portion of the dusted cotton plant, indicating that the most effective control of the insect may be expected when the maximum plant surface is covered with poison during the dusting operation.

The activities of both sexes of weevils, observed under natural conditions and on cotton plants which had been dusted with calcium arsenate or talc, are influenced to a considerable degree by the presence of these dusts on the plants as shown by the number and duration of the feeding periods, the total distance crawled over the plants, the number of fruits visited, and the number of interplant flights performed. An analysis of the crawling activities of weevils under observation indicates that the stems and small branches of cotton are the preferred avenues of travel. When the stems are covered with a film of loosely adhering dust particles, the rate of travel is greatly reduced. The decreased rate of travel by individuals on dusted cotton plants was manifested by a reduction of more than 50 per cent of the number of fruits visited by weevils observed under comparable conditions on non-dusted plants. It was further noted that the rate at which the weevil crawled on stems covered with a dense pubescence was noticeably slower than on smooth-surfaced stems. Since the crawling activities of weevils are materially decreased by the presence of a thick covering of pubescence on the stems and since such plants retain more of the calcium arsenate when applied, it appears that the cotton breeder, by developing the pubescent character, may improve the best strains of cotton for production under boll-weevil conditions.

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INGESTION OF POISON BY THE BOLL WEEVIL

H. J. Reinhard and F. L. Thomas

Knowledge of the manner in which the boll weevil, *Anthonomus grandis* Boh., secures a lethal dose of poison on cotton plants dusted with any arsenical is of fundamental importance to the question of weevil control by the use of poisons under cotton-field conditions. The discouraging results of the earliest attempts to control this insect with arsenical poisons may be attributed to a lack of information regarding this essential point. Prior to 1915, it was the general belief that the boll weevil ingested poison only with the food that was eaten. Since the weevil feeds in deep punctures made in cotton squares and bolls and consumes very little of the external plant tissue, it seemed obvious that successful control could hardly be accomplished under field conditions. However, Coad in 1918 (2) showed beyond doubt that the boll weevil could be effectively controlled in the field by dusting cotton with calcium arsenate. His experiments were conducted with the view of utilizing the water-drinking habit of the weevil, and the high degree of control secured was attributed to the poison ingested by the insects while drinking from drops of dew on the plants. This work revived the interest in poison as a satisfactory method of combating the boll weevil, and experiments in this connection were begun in various states throughout the cotton belt. It was subsequently developed in Texas and elsewhere that the presence of moisture on cotton plants was not an essential requirement for securing satisfactory results in poisoning the weevil. The effectiveness of calcium arsenate in controlling weevils when applied to plants in the absence of dew did not appear attributable to poison ingested with food alone. Furthermore, tests conducted on weevil control by the use of sweetened liquid poison mopped principally on the main stems of cotton plants resulted in some degree of control notwithstanding the presence of a practically poison-free food supply. It therefore appeared certain that the principal manner in which the weevil ingested poison was yet undiscovered.

From 1924 to 1931, the Division of Entomology of the Texas Agricultural Experiment Station conducted field and laboratory experiments with the object of determining how, when, and where the boll weevil secures its lethal dose of poison on cotton plants dusted with calcium arsenate in the usual manner practised for weevil control.

First, on the theory that the weevil might secure a fatal dose of poison by grooming or preening itself after walking over any poison dusted on cotton plants, observations on the activities and habits of the insect, under field conditions, were made to determine this point. Throughout these observations no individual was ever seen to use its beak or mandibles to remove foreign particles adhering to any part of the body. The grooming or preening operations are apparently always performed by use of the legs. With the possibility of the insect commonly ingesting poison during any process of grooming itself duly eliminated, attention was next directed to a generally unknown habit of the weevil discussed in the following paragraph.

Incidental to the observations on the grooming habits of the weevils, it was discovered that individuals, while crawling about normally on cotton plants have the characteristic habit of frequently bringing the tip of the beak with the mandibles moving back and forth, in contact with the surface and often pick up foreign particles in this manner. It was further noted that if a weevil is allowed to crawl over a cotton plant covered by a thin layer of calcium arsenate dust, the tip of the beak soon becomes covered with poison; also that when a group of well-fed weevils were subjected to similar conditions, paralysis and death began to occur in three to eight hours without any opportunity for subsequent feeding. This evidence indicated that some weevils picked up a fatal dose of poison accidently while crawling about on the plants, and the importance of this manner of ingesting poison to the control of the pest under cotton-field conditions was studied in detail. The results secured in these investigations are presented in the present Bulletin.

HISTORY OF ATTEMPTS TO POISON THE BOLL WEEVIL

London Purple and Paris Green in Solution

Shortly after the first appearance of the boll weevil in the cotton-growing regions of south Texas, attempts were made to control the insect by the use of arsenical poisons. Paris green or London purple applied in solution when the bolls began to form was first suggested as a possible measure by Townsend (24) in 1895 after a very brief study of the insect in southern Texas. In 1896, Marlatt, working under the direction of Howard (6), demonstrated conclusively for the first time that boll weevils could be killed on young cotton plants with poison applied in solution. Following this discovery, the U. S. Division of Entomology conducted the first experiments on volunteer cotton in an attempt to destroy the overwintered weevils. Although no data were presented on the effectiveness of the poisons used, this method of combating the boll weevil was considered promising. The first recommendation for the use of poison in protecting the main field crop from damage by weevils early in the season was issued by Howard (7) in July, 1898. From the results secured in the investigations conducted up to that time, it was concluded that the use of poisons, either London purple or Paris green, undoubtedly would be of value but that the prevention of weevil damage was more a question of the adoption of a proper system of cultivation than of remedial measures, such as the use of poisons.

From 1899 to 1902, F. W. Mally, State Entomologist of Texas, conducted extensive experiments on control of the boll weevil. He concluded that cultural methods were most important in producing cotton profitably under boll-weevil conditions in Texas and that the spray poisoning method was a valuable secondary measure which could be used most effectively on the main field crop early in the season before the plants had begun to set squares (12). In experiments conducted under cotton-field conditions, this investigator demonstrated that the weevil population could be reduced 5 to 25 per cent on fruiting plants by applications of a poison mixture of white arsenic, arsenate of lead, molasses, and water. Recommendations for the use of this poison mixture on the main field crop, however, were confined to cotton plants in the pre-squaring stage; the main object was to destroy the overwintered weevils early in the season. Furthermore, Mally recommended this poison for trap plantings and volunteer cotton and first offered the unique suggestion that this method of combating the weevil could be made more effective by removing the squares prior to applying the poison spray. Subsequent attempts by growers in Texas to control the weevil on the main crop by the use of poison sprays proved unprofitable. Following 1902, interest waned in the possibility of successfully poisoning the boll weevil but was again actively revived by B. W. Marston (13), who advocated the use of Paris green in dry or dust form.

Paris Green as a Dust

The efficacy of Paris green, when used as a dry powder, as a remedy for the boll weevil was made the subject of extensive experimentation in Texas during the season of 1904 by planters and by the U. S. Department of Agriculture. Hunter (8), reporting the results of these investigations, concluded that the use of Paris green in controlling the weevil was absolutely futile. This conclusion was based in part upon the following determined facts: "1. Persistent use of Paris green from the time of chopping until picking (in some cases as many as 15 applications) has failed to materially reduce the numbers of the weevils or to increase the yield. 2. Reasons for the impossibility of poisoning weevils successfully are to be found in the facts that only a very small percentage emerge from hibernation before the squares are set upon the plants, that they do not drink the dew on the leaves at night, and that as soon as squares are set all feeding is done within the shelter of the bracts (shuck) beyond the reach of any poison that might be applied."

Newell and Barber (14) in 1905 and 1906 continued investigations in Louisiana with this method of poisoning the boll weevil. The results of their extensive experiments showed that the production of cotton was not increased by applications of Paris green although carefully conducted cage tests indicated that an average of 34.5 per cent of the weevil population on young plants were killed. The unprofitable use of this poison was attributed to the injury done to cotton plants by Paris green and that all the overwintered weevils were not out of hibernation quarters when the first squares appeared. The discovery of the injurious effect of Paris green to cotton plants resulted in a search for a more suitable poison, and powdered arsenate of lead was first developed and used in these investigations on boll weevil control.

Powdered Arsenate of Lead

The results of preliminary tests with this insecticide proved very promising. During the seasons of 1908 and 1909, Newell and Smith (15), by extensive experiments conducted under cotton-field conditions, demonstrated for the first time that the boll weevil could be profitably controlled with powdered arsenate of lead, especially during the early part of the season. Furthermore, these investigations proved the feasibility of successfully poisoning the weevil on cotton in full fruitage.

Calcium Arsenate Dust and the Manner of Ingestion by the Weevil

In this connection, it should be pointed out that prior to 1915 investigators generally believed that the only manner in which the boll weevil secured poison distributed on cotton plants was by ingesting it during the process of feeding. Based on the fact that the weevil feeds on tender portions of the young plants, the poison treatments were made largely with the idea of destroying the overwintered weevils before the plants began to set squares. Apparently it had been conceded that there was no possibility of profitably poisoning the insect throughout the optimum fruiting period of the cotton plants.

While conducting some biological investigations on the boll weevil during the seasons of 1913 and 1914, Coad (2) noted that weevils confined in cages drank water very regularly. Assuming that under field conditions the weevils would secure water by drinking from drops of dew or rain on the foliage of the plants, this investigator conducted field experiments with special references to poisoning the water which the weevils would drink. A new insecticide, viz., calcium arsenate, was developed in connection with these investigations. This arsenical applied as a dust when the plants were wet with dew proved highly effective in controlling the boll weevil under field conditions. The experimental evidence secured in these poisoning tests conducted at Tallulah, Louisiana, during the seasons of 1915 to 1917, inclusive, demonstrated conclusively that the boll weevil could be successfully and profitably poisoned in the presence of abundant fruit on the plants. In tests where the plants were kept absolutely dry after poisoning, only a very light mortality of the weevils resulted; but when poison was applied to plants wet with dew, the percentage of mortality increased tremendously. From these results it was concluded that the principal manner in which the weevil secured a lethal dose of poison was by drinking from the poisoned dew.

The results obtained in these investigations created an unusual and widespread interest in the possibility of controlling the weevil with profit under field conditions by the use of calcium arsenate. Experiments in this connection were subsequently carried on in practically all cotton-growing states where the boll weevil was an important limiting factor in cotton production. In general, the results proved very promising, and interest was not only sustained in this method of controlling the weevil, but the application of it was greatly increased. In 1919, Newell and Bynum (16) demonstrated experimentally that the presence of dew on plants was not an essential requirement for success in poisoning the weevil. These investigators maintained that the weevil is poisoned largely or entirely by taking a fatal dose with its food. Similar conclusions were reported by Hinds (5) and Warren (25), who also conducted cage experiments to determine if the weevil secures the poison during the process of drinking. The question of the importance of moisture to the practise of controlling the boll weevil with calcium arsenate dust seemed especially pertinent to those sections of Texas where dews are often very light or sometimes entirely wanting for considerable periods of time. To determine any difference in the effectiveness of calcium arsenate in controlling the weevil when applied on cotton plants wet with dew and on perfectly dry plants, a series of field experiments was conducted by the Division of Entomology of the Texas Agricultural Experiment Station in Burleson, Hill, and Collin counties. The unpublished data obtained in these investigations showed that the boll weevil could be successfully controlled when the plants are fruiting abundantly by dusting during the daytime or in the absence of any moisture, although the poison proved to be slightly more effective when applied on plants wet with dew. Apparently the major portion of the weevil control secured was not attributable to the poison ingested during the process of feeding or drinking but to the poison particles picked up accidentally by the weevils while crawling over the dust film on the leaves and stems of the plants. This point, referred to in the introductory paragraphs, is discussed below.

In 1925, Grossman (3) first mentioned the accidental manner by which weevils accumulate poison particles on the tip of the snout while crawling over a dust-covered surface and demonstrated experimentally that the adherent poison may be later ingested along with food. In experiments on ingestion of poison by the boll weevil, conducted during the same year in Texas, Thomas (22) noted that the weevil while crawling touched the surface frequently with the tip of the beak and picked up particles of dust or other foreign substances in the mandibles, or "jaws". It was further noted that, if a group of well-fed weevils were allowed to travel over a glass surface covered with a film of calcium arsenate dust, paralysis and death began to occur in three to eight hours without any subsequent feeding. Experimental data were also presented to support the theory that the weevil commonly ingested the poison by picking it up more or less accidently while crawling about on the plants. This was demonstrated conclusively in a series of cage tests in which weevils were confined on plants dusted with calcium arsenate while the fruits were absolutely protected from the poison by paper bags which were subsequently removed. Although the confined weevils in these tests had free access to fresh, abundant, and poison-free fruits, an average mortality of 56 per cent resulted at the end of the fifth day as compared with a mortality of 88 per cent in the cages where the entire plant was dusted with poison.

In 1926, Thomas (23) presented further evidence to show that the bulk of the poison secured by the weevil was not ingested during the process of feeding. From a chemical analysis made separately of entire squares, of flower buds, and of bracts, all carefully removed from the upper portion of about 200 plants which had been dusted with calcium arsenate at the rate of 10 pounds per acre, and from an analysis of 430 weevils which had been killed by the ingestion of calcium arsenate, it was found that it would be necessary for a weevil to eat all of the poison present on a square, excluding bracts, or on an equivalent surface, in order to secure a fatal dose. In previous experiments it had been determined that the majority of the weevils died the first two days after an application of calcium arsenate was made and that the daily number of feeding and egg punctures made averaged less than seven. Obviously, the total area covered by the sum of all punctures made during two days' time would not nearly approximate that of a square two-thirds grown. In other words, it was concluded that the amount of poison present on the surface of a flower bud consumed by the weevils while eating through the external tissue was not sufficient to constitute a lethal dose, but that the high percentage of mortality during the first two days was due for the most part to the poison particles picked up while traveling about on the plant.

During the same year, 1926, Newell, Grossman, and Camp (17) wrote: "Contrary to the early opinion that poison must be forced into the shucks of the squares, it has been found that a uniform distribution of poison over the surface of the plant results in the rapid poisoning of the weevils. This seems to be due to the fact that the weevil touches the end of its snout to the surface of the plant as it walks about and in this way picks up dust particles on the rough jaws at the end of its snout when it walks across a dusted surface. When the weevil starts to feed, the poison particles which have adhered to the jaws are carried into the stomach and the weevil is poisoned." In 1928, Grossman (4) contributed further evidence, secured in laboratory tests, which verified the essential points hitherto developed with respect to the accidental manner in which the weevil ingests poison.

Sweetened Poison

During the course of investigations of boll weevil conditions in Texas in 1898, Howard (7) reported that the weevils seemed to have a marked fondness for sweets, such as molasses, and would eat the latter when smeared upon cotton plants either with or without an admixture of arsenic. Recommendations were issued for the use of undiluted molasses mixed with one-fourth of its volume of arsenic mopped on volunteer stalks in the spring when the leaves began to form. These recommendations were made in the belief that the weevils would be attracted by the poisoned molasses and be killed, hence obviating the necessity of treating the young planted cotton. In 1902, Mally (12) recommended a spray mixture consisting of one ounce of white arsenic, one pound of arsenate of lead paste, one gallon of molasses, and twenty-five gallons of water to be applied on the crop while the plants were still small.

Although the results of subsequent experiments conducted by Hunter and Hinds (9) showed that sweets could not be depended on to attract the weevil, the idea of making the poison attractive to the boll weevil by the addition of molasses gained considerable prominence following the development of the method for dusting with calcium arsenate. The interest that developed in the possibility of controlling the weevil by the use of a mixture of molasses, calcium arsenate, and water was not based on recent experimental data secured by any state or federal research agency. However, the general opinion which prevailed among growers regarding the effectiveness of this method in controlling the insect, resulted in extensive investigations by federal and state research agencies to determine its value in comparison with calcium arsenate dust. The results secured, without exception, verified the previously determined fact, that the weevil is not attracted by sweetened poison. The data obtained in a series of experiments conducted in South Carolina by Armstrong, Moreland, and Gaines (1) showed that sweetened poison (1 pound of calcium arsenate, 1 gallon of molasses, and 1 gallon of water) controlled the weevil when cotton was in the pre-squaring stage, but that it possessed no advantage over calcium arsenate dust in this respect. Pre-square applications of each poison proved about equally effective in destroying the overwintered weevils. However, in continued applications throughout the season calcium arsenate treatments resulted in more than twice the yield secured from comparable plats of cotton treated with sweetened poison.

The Florida, or Square-Stripping Method of Boll-Weevil Control

In 1922, the so-called Florida method of boll-weevil control was described by Smith (20). "In substance, it consists in clearing the cotton field, early in June, of all adult weevils and, at the same time, of destroying their eggs and larvae; thus leaving the cotton plants free to develop squares and bolls without weevil interference for the succeeding seven or eight weeks."

He further states: "When all squares have been removed, the weevils that were not captured by the stripping operation are forced to feed in the tender buds of the cotton plants in the same manner as before the squares developed and then a single dust application of any suitable arsenical will destroy practically all of them."

The essential point of this method, viz., the removal of the squares prior to applying the poison was not new. In 1902, Mally (12), during the course of boll-weevil control investigations in Texas, recommended precisely the same procedure with respect to increasing the effectiveness of poison sprays applied on trap plantings of cotton.

In 1924, Smith (21) presented the results secured in further experiments with the Florida method of combating the boll weevil. The principal change from the previous recommendations, as a result of the latest investigations, was the use of sweetened poison in preference to dry or dust applications. Regarding the advantage of sweetened poison, this investigator states: "If the poison is dusted on the plants there is only one chance of poisoning the weevil and that is by the weevil swallowing the poison while feeding on the tender tissue of the buds or squares. It seems probable that the cotton grower has two additional chances to poison the weevil when syrup mixtures are used, viz., through the weevil's probable fondness for sweets and the desire to satisfy thirst."

Although the Florida method of boll-weevil control was recommended primarily for the northern Florida Cotton Belt, it was tested under conditions obtaining in South Carolina, North Carolina, Oklahoma, Arkansas and found generally unprofitable as shown by Armstrong, Moreland, and Gaines (1), Nickles (18), Leiby and Harris (11), Sanborn (19), and Isely and Baerg (10). Newell, Grossman, and Camp (17) state: "Work done in Jackson county, on the heavy clay soil common in certain districts, indicated that, on June 5, cotton would not have any squares to strip nor would all the weevils be out of hibernation at that time. Under such conditions the successful application of the Florida method in its present form is probably out of the question and dust or syrup applications should be used, starting when the squares are as big as peas."

METHODS OF STUDY

All observations on the habits and activities of the boll weevil reported in this Bulletin were made under local cotton-field conditions. Field-collected first- and second-generation weevils were observed on plants dusted with calcium arsenate or talc and on undusted plants. The sex of the selected individuals was recorded. These weevils were marked with a dyed shellac, and when once released they were kept under constant observation, from a distance sufficient not to interfere with normal activity, from 8 to 12 and from 1 to 5, daytime, or until lost. The distances each weevil crawled over the various portions of the plants or traveled by flight were estimated and recorded as performed. Hibernated weevils, immediately after they emerged in cages, were also marked and released by pairs on specified plants, and an attempt was made to trace their movements in the cotton fields by observations made daily or twice a day.

For the purpose of determining where the boll weevil secures its lethal dose of poison on dusted cotton plants, all fruits or leaves of the selected plants were covered with paper sacks securely tied to prevent any poison from reaching them during the dusting operation. The stems of other plants in the experimental series were protected from the poison dust by wrapping them spirally with narrow strips of muslin. Such prepared plants were then dusted in the ordinary manner. Immediately after the poison was applied, all the protections were carefully removed and 2′ x 2′ x 4′ wood frame cages covered with 16-mesh screen wire were placed over the plants. To facilitate finding the dead weevils, the bottom of each cage was covered with a piece of 8-ounce canvas which was fitted closely around the base of each plant. The number of weevils released in each cage in order to determine the mortality resulting from the different distributions of poison dust was 50 in 1928 and 25 in 1929. The notes on the weevil mortality were made daily over a period of four to six days, and the final mortality percentages which were attributed to each particular combination of poison-dust distribution on the plants, were calculated on a corrected basis. That is, the natural mortality occurring among the weevils in the control tests was deducted before calculating the mortality among the individuals confined on poisoned plants. All the weevils which were used in the mortality experiments were reared in the laboratory from infested squares collected in local cotton fields. Only well-fed weevils were used, and for each series of tests the individuals were taken from lots which emerged approximately on the same date.

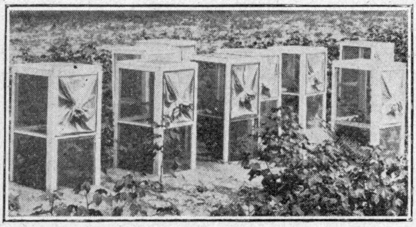

Fig. 1. Cages used in studying the ingestion of poison by the boll weevil.

ACTIVITIES AND HABITS OF THE BOLL WEEVIL OBSERVED IN 1930 AND 1931

The discovery that the weevil commonly picks up and ingests minute particles of poison dust during its course of travel over cotton plants emphasized the importance of more complete knowledge regarding the normal activities and habits of the insect under field conditions on dust-free and dusted cotton plants.

Preliminary observations, in this connection, were made during July and August, 1930. Throughout this period climatic conditions were unusually hot and dry without any protracted cloudy periods. The cotton plants on which the weevils were observed had practically ceased squaring, and there were but few uninfested fruits present. The data secured on the activity of the weevils under these prevailing conditions are presented and discussed in the following paragraphs.

Weevils on Non-Dusted Cotton Plants, 1930

Studies on the activities of the weevil under field conditions on poison-free plants included 43 first- and second-generation individuals, which were kept under constant observation for 3,582 minutes, or for an average period of more than 83 minutes per weevil. The data secured on the activities of these weevils are summarized in Table 1.

Intra-plant travel was most commonly performed on foot, and it will be noted that the distance crawled over the plants for each individual totalled 1404 inches (estimated) per unit day of 8 hours, or at the rate of about

175 inches per hour. On smooth-surfaced plants, however, individuals frequently traveled 12 to 20 inches per minute, but the speed of travel was very materially decreased on those plants covered with the most pubescence. About 52 per cent of all the travel was confined to the stems of the plants. During the extent of these observations, the inter-plant flight per weevil averaged about 75 per day. These flights covered a total distance of 241 feet.

In recording these data, it was repeatedly noted that when the path of a weevil's travel is encumbered by the presence of dense natural pubescence, not only is the rate of travel greatly diminished, but the insect is more prone to bring its beak in contact with the surface over which it is moving. From a practical standpoint, these two points are interesting, if not significant. It appears reasonable to assume that if the rate of travel by weevils on cotton plants can be greatly decreased, it would mean that proportionately fewer squares could be reached for oviposition and hence effect a diminished rate of spread of infestation. Furthermore, if, by increasing the hazards along the main avenues of travel on the plant, namely, the degree and character of pubescence on the stems, the weevil can be forced to increase the normal number of contacts made with the tip of its beak and the surface, the chances for picking up poison accidently are correspondingly enhanced. The additional fact that calcium arsenate dust adheres better on stems copiously clothed with pubescence emphasizes the belief that the best present-day varieties or strains of cotton may be further improved for production under boll-weevil conditions by the development of this character.

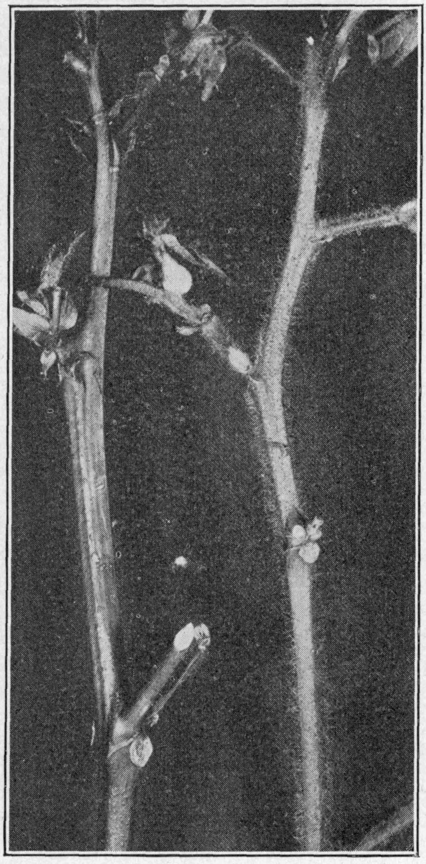

Fig. 2. Variations in the degree of pubescence on stems of a common variety of cotton taken from the same field. Pubescent stems like that shown on the right retain more poison dust, particles of which are picked up by weevils when traveling on the stems. Selection of the pubescent strains would enable better weevil control.

Weevils on Cotton Plants Dusted With Calcium Arsenate, 1930

A summary of the activities of 23 first- and second-generation weevils

Table 1. Comparison of the activities of boll weevils on dust-free and calcium-arsenate-dusted cotton plants, under field and caged conditions, July and August, 1930.

Treatment of cotton plants	Number of weevils observed	Duration of observations minutes	Per unit day of 8 hours: Feeding periods		Per unit day of 8 hours: Inter-plant flights		Total distance crawled inches	Distance weevils crawled on: Stems		Leaves Upper surface		Leaves Lower surface		Fruits, blooms and terminal buds	
			Number	Duration minutes	Number	Distance feet		Inches	Per cent	Inches	Per cent	Inches	Per cent	Inches	Per cent
Not dusted	43	3582	8.1	52.2	75.5	240.8	1404	3433	51.9	1587	24.0	771	11.7	822	12.4
Dusted with calcium arsenate	23	1196	0.7	7.2	27.8	264.7	529	296	38.0	218	28.0	210	27.0	54	7.0
Dusted with calcium arsenate (caged)	21	2073	-------	-------	-------	-------	329	462	42.2	375	34.3	150	13.8	106	9.7

observed under field conditions on plants dusted with calcium arsenate is given in Table 1. The mean constant observation period for this lot of individuals was 52 minutes per weevil. Under comparable conditions, except the presence of calcium arsenate dust, these weevils traveled only slightly more than one-third the distance that was recorded for the weevils on the poison-free plants. The weevils on cotton plants dusted with calcium arsenate performed 20 per cent more of their travel on the foliage than the individuals observed on the non-dusted cotton. This increased preference for travel on the leaves was largely restricted to the lower sides, where the dust film of calcium arsenate was lightest.

In traversing a surface covered by a film of dust, the weevil's feet soon become coated with a layer of dust particles which impedes its progress and ability to cling securely to the plant. Considerable time is spent in endeavoring to free the feet from foreign matter. This is always attempted by rubbing the feet together and never by the use of the mouth or mandibles.

The difficulty these weevils experienced in crawling over plant surfaces covered with particles of calcium arsenate dust was not manifested by an increased number of inter-plant flights as might be expected. The number of inter-plant flights was about one-third less than for the weevils observed on the poison-free cotton plants; however, the distance covered by the weevil flights originating on the dusted plants was approximately three times the distance of the inter-plant flights made by the weevils on the non-dusted plants. The evidence that the presence of calcium arsenate on cotton plants is a sufficient stimulus to cause the weevil to seek a more favorable environment is not considered conclusive, although the longer or apparently more determined inter-plant flights seem to show that such may be the case.

The distance a weevil crawls over a surface coated with a film of calcium arsenate is not the determining factor in measuring its subsequent life-period. Weevils frequently died in two to four days after crawling 12 to 24 inches over a poison film, while others after crawling five or six feet under identical conditions were not poisoned. The fact that the weevil's mouth becomes coated with particles of poison does not mean that a lethal dose will always be ingested. Many instances were observed where the tips of the beak became coated with poison which was dislodged before a quantity sufficient to produce death was swallowed; in other words, the ingestion of poison after being picked up during the process of travel over the plant appears to be entirely accidental.

First- and Second-Generation Weevils on Non-Dusted Cotton Plants, 1931

During July and August, 1931, detailed studies on the activities of weevils of known generation and sex were conducted under local cotton-field conditions. Practically normal temperatures prevailed throughout the period of observations, but the rainfall was 1.63 inches below the normal. With very few exceptions the character of the day on which weevil activity was

Table 2. Comparison of the activities of both sexes of boll weevils on dust-free and talc-dusted plants, July and August, 1931.

Treatment of cotton plants	Number of weevils observed	Duration of observations minutes	Per unit day of 8 hours						Distance weevils crawled on							
			Feeding periods		Inter-plant flights		Number of fruits visited	Total distance crawled inches	Stems		Leaves Upper surface		Leaves Lower surface		Fruits, blooms, and terminal buds	
			Number	Duration minutes	Number	Distance feet			Inches	Per cent	Inches	Per cent	Inches	Per cent	Inches	Per cent
Not	29 males	6513	1.3	17.2	47.3	167.1	21.3	452	2258	44.5	1328	26.1	749	14.8	740	14.6
dusted	23 females	5863	2.0	20.4	24.0	116.4	18.8	380	2214	57.9	637	16.6	344	9.0	630	16.5
Weighted average			1.6	18.6	37.0	144.7	20.2	420								
Totals	52	12376							4472	50.2	1965	22.1	1093	12.3	1370	15.4
Dusted	24 males	5127	1.4	31.0	19.7	273.5	8.0	170	692	39.4	331	18.9	440	25.0	292	16.7
with talc	11 females	3577	1.4	42.1	17.1	178.3	8.1	184	803	52.8	175	11.5	258	17.0	284	18.7
Weighted average			1.4	34.5	18.9	243.6	8.0	171								
Totals	35	8704							1495	46.5	506	15.5	698	21.3	576	17.6

noted, ranged from clear to partly cloudy, and no opportunity was available to note any effect of wholly cloudy days on the normal activity of the insect.

From July 20 to August 21, 52 first- and second-generation weevils, including 29 males and 23 females, were kept under constant observation for periods totalling 12,376 minutes on non-dusted cotton plants under field conditions. A summary of the data obtained on the activities of these weevils is presented in Table 2. It will be noted that there appear to be no very marked differences between the activities of the sexes. The average periods of observation were 225 and 255 minutes per male and female weevil, respectively. The average distance traveled per day on the plants by the males was 452 inches, and that by the females was 380 inches (estimated). Approximately 3.5 per cent of the total observation period for both sexes was spent in feeding. The male weevils visited about 13 per cent more fruits than the females. Both sexes averaged about 21 inches of travel for each newly visited square, bloom, or boll. Inter-plant flights made by the males were twice the number recorded for the females, but the average distance covered per flight was greater in case of the females. The distribution of the total distance crawled over the cotton plants by these weevils again showed the stems to be the main avenues of travel for both sexes. The difference between the distance covered on the plant stems in favor of the females was about 13 per cent, while the males performed a correspondingly greater amount of travel on the foliage.

First- and Second-Generation Weevils on Cotton Plants Dusted with Talc, 1931

To secure comparable data on the activities of weevils on dusted cotton plants, observations were also made from July 27 to August 21 on 35 first- and second-generation individuals, which included 24 males and 11 females. These weevils were kept under constant observation under cotton-field conditions for periods totalling 8,704 minutes on plants dusted with talc at weekly intervals at the rate of six pounds of dust per acre. The activities recorded for these weevils are summarized in Table 2. With the exception of one factor, viz., the presence of talc dust on the plants, these weevils were observed under conditions practically identical with those affecting the weevils on the non-dusted plants. The presence of the dust film on the plants resulted in a marked reduction in the rate of travel by the insects. The average distance covered per day on the talc-dusted cotton plants was about 174 inches (estimated) for both sexes. This is a marked decrease in comparison with the distance of 420 inches traveled by the weevils on non-dusted cotton plants during the same period of time. The difficulty which the insect encountered in traversing the surface of cotton plants covered by a film of dust was further manifested by the smaller total number of fruits visited. On the dusted plants the 35 individuals under observation visited only 40 per cent as many fruits as was recorded for the individuals on non-dusted cotton plants. The number of inter-plant flights performed by these weevils was approximately one-half the total number recorded for the weevils on talc-free plants; however, the mean distance covered per flight was about three times as great. The same was true for the weevils under observation in 1930. These data furnish additional evidence that weevils on dusted cotton plants make a definite effort to seek a more favorable environment. Approximately 7 per cent of the total observation period, covering the activities of both sexes, was spent in feeding. The difference between the distance traveled by these weevils on the stems and foliage was smaller than that noted for the weevils on the non-dusted plants. The males, especially, traveled less on the stems and performed a greater amount of travel on the foliage. It is of further interest to note that there was a marked increase in the amount of travel by weevils on the lower surface of the leaves of the talced cotton plants over that recorded for the weevils on the dust-free plants.

Hibernated Weevils on Non-Dusted Cotton Plants, 1931

From June 4 to 24, as weevils emerged in local hibernation cages, 55 pairs were marked with dyed shellac and released in the field at various intervals on designated plants. Search was made to determine their location, with respect to the point of release, each day over a period of two weeks. The cotton plants on which the movements of these weevils were observed averaged 18 to 24 inches in height, with abundant fruit present. There was practically no boll-weevil infestation excepting in a few restricted, isolated areas during the last week of the observations. Although an attempt was made to trace the weevils for a period of 14 consecutive days from the date of release, the time during which the sexes were actually observed averaged 8.7 and 4.5 days for the males and females, respectively.

The trend of movement for each sex, under the conditions of this experiment, based on the estimated maximum distance and time each individual was noted from the point of release is graphically illustrated in Figure 3. It will be noted that the tendency for the female weevils is to begin travel sooner and continue at a more rapid rate than the males. The regression lines which were calculated from the individual tests, indicate that female weevils may be expected to travel nearly three times the distance covered by the males during the first seven days on well-fruited cotton plants

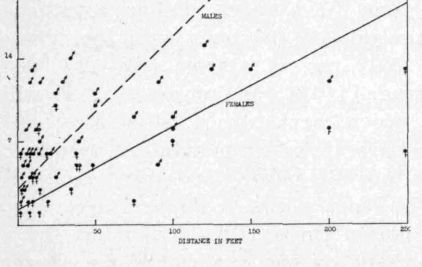

Fig. 3. Regression lines showing the trend of movement of overwintered weevils after release in the field, June 1931. Broken line, males; solid line, females.

when released immediately after emergence from hibernation, but the distance traveled was less than 100 feet for each sex.

Detailed records on the activities of hibernated weevils on poison-free cotton plants were also made under field conditions in the manner described above for the first- and second-generation individuals. The weevils used in these studies were kept under constant observation daily for eight-hour periods during 2 to 24 days. The data secured on the activities of these individuals showed no striking differences with respect to the preferred avenues of travel, rate of crawl, the total distance covered, and the number of fruits visited, as was recorded for the succeeding generations of weevils. However, during the first seven days of observation these hibernated weevils performed a fewer number of inter-plant flights and spent more time feeding and resting than was noted for first- and second-generation individuals.

Ingestion of Calcium Arsenate by the Boll Weevil

Studies on the mortality of the boll weevil as a result of the ingestion of calcium arsenate dusted on cotton plants were conducted under field conditions during the seasons 1928 and 1929.

It seemed desirable in the course of these investigations to determine the approximate amount of arsenic required to constitute a lethal dose for the insect. A chemical analysis of one lot of 430 boll weevils which were killed apparently by the ingestion of calcium arsenate, was made after first thoroughly removing any of the poison which may have adhered to the outside of their bodies. According to the analysis made under the direction of G. S. Fraps, Chief of the Division of Chemistry, each insect contained an average of .004 mg. of arsenous oxide ($AS_2 O_3$).

An analysis was also made of a sample consisting of 100 cotton squares which were collected on the same day that calcium arsenate dust had been applied at the rate of 10 pounds per acre when dew was present. This analysis showed that each square retained .019 mg. of arsenic ($AS_2 O_3$). In addition, determinations were made of the amount of arsenic on the bracts and the buds, separately, of one lot of 400 squares which were carefully taken, without handling, from the same field under similar conditions as the samples mentioned above. Analysis of 400 buds with the bracts removed showed that each bud had .0049 mg. of arsenic ($AS_2 O_3$), and the three bracts from each bud averaged .0194 mg. of arsenic. It will be noted that the amount of arsenic which constitutes a lethal dose, .004 mg., approximates the total amount of arsenic which is retained by a bud, .0049 mg., when calcium arsenate is applied under favorable conditions at the rate of 10 pounds per acre. In other words, it appears necessary, in order to secure a lethal dose of poison through feeding alone, for a weevil to consume all the poison present on the surface of the flower bud.

In the following studies an attempt was made by means of mortality tests to evaluate the poison placed on the fruits, stems, and foliage of the plants by hand-operated dusting machines regulated to deliver the poison dust at the rate of five to seven pounds per acre. Reared and well-fed weevils of comparable ages were used in all the mortality tests. The technique employed to restrict the poison dust to particular portions of the plants and the type of cage used in the tests have been previously desccribed under methods of study. To determine the effect of confinement on the activities of the boll weevil, 21 individuals were kept under continuous observation for an average period of about 99 minutes per weevil under cotton-field conditions on caged plants dusted with calcium arsenate. The results are given in Table 1. Although these individuals traveled less per unit day of 8 hours, the preferred avenues of travel were not strikingly unlike those recorded for the weevils on uncaged dusted plants. The percentage of weevils killed by the ingestion of poison in all tests was calculated on a corrected basis.

It was soon recognized in the course of these studies that experimental errors occurred which apparently were beyond control. The principal sources of these errors were the following: (1) accidental dislodging and removal by natural agencies of particles of poison from the dusted surface of a plant to other portions of the plant intended to be poison-free; (2) variations in individual weevils and in the cotton plants used; (3) variations in amounts of poison dust applied to different plants. For these reasons many replications of the tests were conducted, involving the use of several thousand weevils.

Poison-Ingestion Experiments, 1928

From July 22 to September 8, eighty-two separate cage tests, including the use of 4,100 weevils, were conducted under cotton-field conditions. The weevils were released in lots of 50 per plant under three different conditions of poison distribution on the plants, viz., the entire plant poisoned, the fruits poison-free, and the stems poison-free. The mortality occurring among the weevils released on the plants was recorded at 24-hour intervals over a period of four days. The data obtained in these tests are presented in Table 3. It will be noted that in some cases the mortality of weevils totalled 100 per cent, but it must be remembered that these individuals were confined in cages and had no other recourse except to feed on plants with fruit and foliage poisoned.

Entire Plant Poisoned, 1928

The results obtained in 24 tests on 1,200 weevils confined on these plants indicate a mortality ranging from 58 to 100 per cent at the end of the fourth day. Almost 70 per cent of the weevils in these tests ingested a fatal dose of poison during the first 48 hours of release on the plants. The large number of weevils confined on each plant undoubtedly was an important factor in producing this rapid and high degree of mortality by effecting an increased activity or travel of the weevil over the plants. After the majority of individuals was eliminated, the rate at which the

Table 3. Per cent of weevil mortality in cage tests on cotton where the entire plant was poisoned and where poison was confined to certain parts of the plant, on four successive days after application of calcium arsenate, 1928.

Experiment conducted	Cage	Entire plant poisoned						Stems and leaves poisoned						Fruits and leaves poisoned						Rainfall	
		No. tests	Mortality at end of				Per cent killed (corrected)	No. tests	Mortality at end of				Per cent killed (corrected)	No. tests	Mortality at end of				Per cent killed (corrected)	Amount inches	Number days
			1st day	2nd day	3rd day	4th day			1st day	2nd day	3rd day	4th day			1st day	2nd day	3rd day	4th day			
July 22	Control		1	0	1	0			1	0	1	0									
to 26	Treated	2	37	16	3	7	61.5	2	23	19	11	6	57.3							1.22	1
July 29 to	Control		1	0	0	0			1	0	0	0									
Aug. 2	Treated	3	43	59	25	7	89.2	5	44	38	47	30	63.2								
Aug. 3	Control		1	2	0	1			1	2	0	1									
to 7	Treated	2	15	50	15	12	91.3	2	15	15	18	13	57.0							0.95	1
Aug. 5	Control		1	1	1	0			1	1	1	0									
to 9	Treated	1	33	6	7	0	91.5	1	36	3	5	0	87.2							0.95	1
Aug. 9	Control		1	2	1	2			1	2	1	2									
to 13	Treated	1	29	13	8	0	100.0	1	29	5	2	5	79.5								
Aug. 10	Control		2	2	0	0			2	2	0	0									
to 14	Treated	1	39	8	1	0	95.7	1	31	7	8	1	93.5								
Aug. 11	Control		2	2	0	0			2	2	0	0			2	2	0	0			
to 15	Treated	1	34	15	1	0	100.0	1	36	9	1	0	91.3	2	80	13	5	0	97.8		
Aug. 14	Control		1	4	1	1			1	4	1	1			1	4	1	1			
to 18	Treated	1	5	4	14	9	58.1	1	4	5	1	8	25.6	2	23	24	16	12	70.9		
Aug. 15	Control		1	1	3	3			1	1	3	3			1	1	3	3			
to 19	Treated	1	22	17	7	1	92.9	1	14	5	12	4	64.3	2	30	40	24	0	92.9		
Aug. 16	Control		2	2	3	0			2	2	3	0			2	2	3	0			
to 20	Treated	2	52	22	10	5	87.2	2	21	10	11	15	50.0	1	27	20	2	1	100.0		
Aug. 19	Control		1	2	0	2			1	2	0	2									
to 23	Treated	2	41	36	12	5	93.3	3	46	42	19	8	74.1							0.07	1
Aug. 21	Control		3	3	0	4			3	3	0	4			3	3	0	4			
to 25	Treated	1	24	18	1	4	92.5	1	13	16	7	4	75.0	1	20	15	4	3	80.0	0.07	1
Aug. 22	Control		1	0	1	1			1	0	1	1									
to 26	Treated	1	12	24	7	2	89.4	2	16	24	15	10	62.8							0.07	1
Aug. 25	Control		0	4	1	1			0	4	1	1									
to 29	Treated	1	20	23	4	2	97.7	2	16	43	11	13	80.7							0.32	2
Sept. 2	Control		0	1	0	0			0	1	0	0			0	1	0	0			
to 6	Treated	3	37	54	24	19	89.1	5	65	77	39	21	80.4	1	18	15	4	5	83.7	0.48	1
Sept. 3	Control		1	0	1	1			1	0	1	1									
to 7	Treated	1	14	22	8	3	93.6	1	10	10	8	8	70.2							0.72	1

remaining weevils died decreased gradually to the end of the sixth day. The mortality of all the weevils under observation in these tests at the end of the fourth day of exposure averaged 88.9 per cent.

Fruits Poison-Free, Stems and Leaves Poisoned, 1928

The percentage of mortality secured in 31 tests on 1,550 weevils that were released on cotton plants dusted with calcium arsenate having the fruits protected during the dusting operation, varied from about 26 to 93 per cent. The evidence presented by these data appears to be quite conclusive with respect to the importance of the manner in which the weevil accidently ingests a lethal dose of poison while traveling over plants thinly covered with calcium arsenate dust. In other words, more than half the number of weevils which succumbed to the effect of the poison ingested it accidently. Apparently it is largely through this means that effective control of the insect is possible by poison applications under field conditions on cotton plants, either in full fruitage or in the pre-squaring stage. The mortality of weevils in all these tests averaged 71.5 per cent. Of plants with the fruits, as well as the rest of the surface, subjected to a cloud of calcium arsenate dust the mean weevil mortality was 88.9 per cent, indicating that the presence of poison particles on the fruits increased the mortality by 17 per cent.

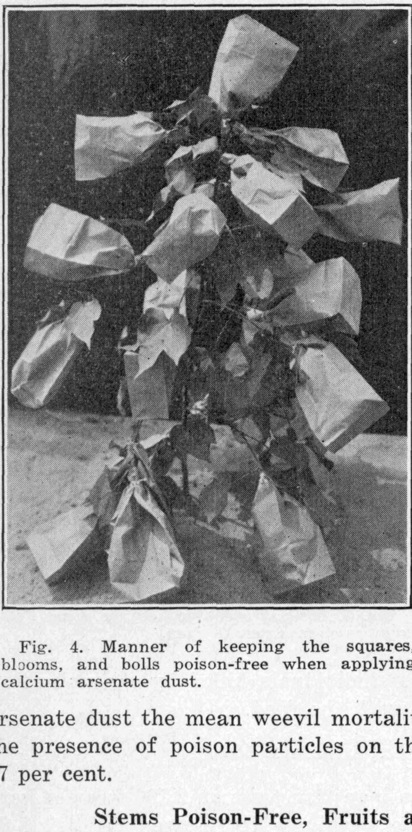

Fig. 4. Manner of keeping the squares, blooms, and bolls poison-free when applying calcium arsenate dust.

Stems Poison-Free, Fruits and Leaves Poisoned, 1928

In nine tests on 450 weevils released on these plants the rate of mortality due to the ingestion of poison approximated that occurring among the individuals confined on plants with the entire surface subjected to a cloud of calcium arsenate dust. In the discussion of the weevil activities it has been pointed out that the insect normally crawls a greater distance on the stems than on any other portion of the plant. However, the data secured in these tests indicate that the amount of poison ingested while the weevil traveled over a thin layer of poison dust on the foliage and fruits, in addition to that amount consumed with food, effected a rapid and high degree of mortality. About 72 per cent of all the individuals under observation in the tests ingested a fatal amount of the poison during the first 48 hours of release on the plants. The number of weevils which died in the separate tests, as a result of the poison dusted on the plants, ranged from about 71 to 100 per cent. The mortality of weevils recorded for all the tests averaged 89.1 per cent. While this figure slightly exceeds the average mortality of the weevils recorded for all tests in which the entire plant surface was dusted with calcium arsenate, a statistical analysis of the data secured in the comparable tests indicates that the difference in the weevil mortality secured under the conditions of this experiment is not significant.

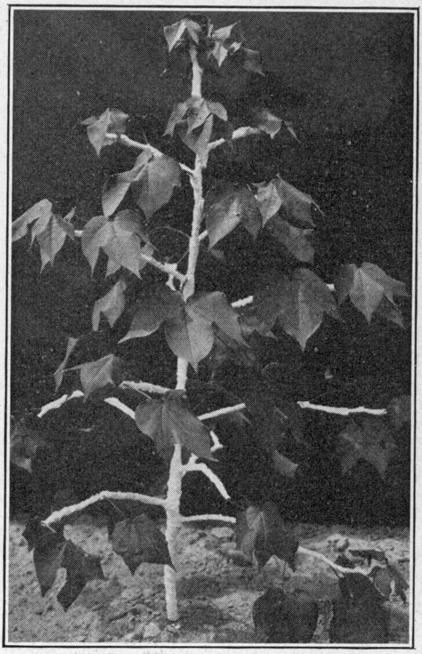

Fig. 5. Method used for keeping stems free from calcium arsenate dust.

A summary of the data obtained in the poison-ingestion experiments on the boll weevil conducted in 1928 is presented in Table 4. It will be noted that the weevil mortality that occurred among individuals on plants with the entire surface exposed to calcium arsenate dust, was approximately 17 per cent greater than that recorded on plants with all the fruits free from poison. Obviously, the additional number of weevils killed by the poison on the fruits is quite significant; however, it seems impossible to determine what percentage of individuals killed by the poison on fruits ingested a fatal amount along with the food.

Poison-Ingestion Experiments, 1929

During July and August, 108 poison-ingestion tests on 2,700 weevils were conducted under field conditions. The weevils were released in lots of 25 on each caged plant under four different conditions of poison distribution. In one series of tests the entire plant was subjected to a cloud of calcium arsenate dust; in others the fruits, stems, and leaves, respectively, were kept free from poison in an attempt to determine where the weevil secured the poison. Mortality among each lot of individuals placed on these plants was recorded at 24-hour intervals over a period of four days. The data secured are presented in Table 5. Climatic conditions throughout the period of these studies were unfavorable, and only 24 tests were not affected by some rainfall. The number of days with precipitation and the total amount which occurred during the period of each test are indicated. Although

Table 4. Summary of the per cent of weevil mortality in cage tests on cotton where the entire plant was poisoned and where poison was confined to certain parts of the plant, on four successive days after application of calcium arsenate, 1928.

Treatment	No. of tests	Total No. weevils used	Mortality of weevils at end of 1st day		2nd day		3rd day		4th day		Total No. dead	Total per cent killed (corrected)
			No. dead	Per cent dead	No. dead	Per cent dead	No. dead	Per cent dead	No. dead	Per cent dead		
Control (no treatment)	18	900	19	2.1	26	2.9	13	1.4	16	1.8	74	
Entire plant poisoned	24	1200	457	38.1	387	32.2	147	12.3	76	6.3	1067	88.9
Stems and leaves poisoned	31	1550	419	27.0	328	21.2	215	13.9	146	9.4	1108	71.5
Fruits and leaves poisoned	9	450	198	44.0	127	28.2	55	12.2	21	4.7	401	89.1

the showers of rain which fell on various dates between July 28 and August 13 were too brief to wash any considerable amount of poison from the dusted plants, the tests in progress during this period probably were affected more by the water's carrying particles of poison from the dusted to the poison-free portions of the plant.

Entire Plant Poisoned, 1929

In 24 tests conducted from July 10 to August 18, the mortality records obtained on 600 weevils released on these plants ranged from 58 to 100 per cent at the end of the fourth day. The number of weevils which succumbed to the effect of the poison during the first 48 hours of exposure averaged 9 per cent less than in similar tests conducted in 1928 when twice the number, or 50 weevils, were released in each cage. The smaller unit number of weevils per cage resulted in a less abnormal activity, which effected a slower rate of mortality. As the supply of fresh squares on the caged plants was rapidly diminished, the activities of confined weevils were increased apparently through efforts to locate suitable food. This increased amount of travel over the surface of the poisoned plants was followed by an average mortality of 19.2 and 12.3 per cent on the third and fourth day of exposure, respectively. The mortality of weevils attributable to the ingestion of poison in this series of tests averaged 92 per cent at the end of the fourth day of confinement on the dusted plants.

Fruits Poison-Free, Stems and Leaves Poisoned, 1929

The mortality records obtained in 24 tests on 600 weevils caged with cotton plants on which all fruits were thoroughly protected by paper bags during the time the poison dust was applied ranged from 22 to 88 per cent at the end of the fourth day. The significant feature in the results of these and similar tests conducted in 1928 is the evidence of the accidental manner in which the weevil frequently ingests a fatal amount of poison while crawling over the surface of a dusted plant. It is of further interest to note that the average mortality of the weevils having free access to clean fruits was 33 per cent less than on plants entirely subjected to a cloud of poison dust. Apparently the smaller number of weevils killed was due to the absence of poison on the fruits. The principal reason for this diminished rate of mortality appears attributable mainly to the fact that a large proportion of the weevils released on these plants reached the clean fruits before a lethal amount of poison was picked up and ingested. When thus favorably located the weevil is comparatively free from being poisoned until forced to move over the plant in search of food. After the third day of exposure to the poison, the mortality of the weevils in these and similar tests conducted in 1928 was higher than that noted among the weevils in comparable tests on plants which had been entirely subjected to calcium arsenate dust. In fact, the mortality of the weevils was three times as great on the fifth and sixth day in the tests conducted on plants

Table 5. Per cent of weevil mortality in cage tests on cotton where the entire plant was poisoned and where poison was confined to certain parts of the plant on four successive days after application of calcium arsenate, 1929.

Experiment conducted	Cage	Entire plant poisoned					Stems and leaves poisoned					Stems and fruits poisoned					Fruits and leaves poisoned					Rainfall	
		Mortality at end of				Per cent killed (corrected)	Mortality at end of				Per cent killed (corrected)	Mortality at end of				Per cent killed (corrected)	Mortality at end of				Per cent killed (corrected)	Amount inches	Number days
		1st day	2nd day	3rd day	4th day		1st day	2nd day	3rd day	4th day		1st day	2nd day	3rd day	4th day		1st day	2nd day	3rd day	4th day			
July 10	Control	0	0	0	1		0	0	0	1		0	0	0	1		0	0	0	1			
to 14	Treated	28	5	17	0	100.0	16	4	7	6	64.6	17	9	16	2	87.5	25	12	12	0	97.9	0.08	1
July 14	Control	0	1	0	0		0	1	0	0		0	1	0	0		0	1	0	0			
to 18	Treated	8	23	12	6	97.9	3	10	8	5	50.0	5	11	11	10	72.9	9	17	21	2	97.9	0	0
July 17	Control	0	0	2	0		0	0	2	0		0	0	2	0		0	0	2	0			
to 21	Treated	14	10	6	14	87.0	4	6	6	14	56.5	10	16	14	2	82.6	16	18	8	2	87.0	0	0
July 18	Control	0	1	0	0		0	1	0	0		0	1	0	0		0	1	0	0			
to 22	Treated	14	17	9	10	100.0	10	8	5	12	68.8	8	22	9	7	91.7	12	18	6	8	87.5	0.18	1
July 21	Control	0	1	0	0		0	1	0	0		0	1	0	0		0	1	0	0			
to 25	Treated	19	18	7	2	91.7	8	12	3	3	50.0	9	17	14	4	87.5	13	16	7	4	79.2	0.44	2
July 22	Control	0	0	0	0		0	0	0	0		0	0	0	0		0	0	0	0			
to 26	Treated	8	18	8	8	84.0	5	6	2	5	36.0	3	11	6	10	60.0	10	18	7	6	82.0	0.74	3
July 25	Control	0	0	0	0		0	0	0	0		0	0	0	0		0	0	0	0			
to 29	Treated	7	9	6	7	58.0	3	4	1	3	22.0	2	10	10	7	58.0	3	6	7	10	52.0	0.40	2
July 28 to	Control	0	0	0	0		0	0	0	0		0	0	0	0		0	0	0	0			
Aug. 1	Treated	11	20	10	8	98.0	8	14	5	6	66.0	3	11	15	16	90.0	12	15	9	12	96.0	0.04	1
July 30 to	Control	0	0	1	1		0	0	1	1		0	0	1	1		0	0	1	1			
Aug. 3	Treated	11	22	12	4	97.8	8	4	11	15	73.9	11	15	17	2	89.1	8	16	15	6	89.1	0.04	1
Aug. 7	Control	2	1	0	0		2	1	0	0		2	1	0	0		2	1	0	0			
to 11	Treated	17	18	11	4	100.0	9	8	6	11	63.6	15	16	10	7	95.5	12	14	9	13	95.5	0.02	1
Aug. 9	Control	0	1	1	1		0	1	1	1		0	1	1	1		0	1	1	1			
to 13	Treated	19	17	8	5	97.7	7	23	9	6	88.6	12	15	11	8	90.9	18	13	9	3	84.1	0.02	1
Aug. 14	Control	0	1	1	0		0	1	1	0		0	1	1	0		0	1	1	0			
to 18	Treated	10	20	9	6	89.1	8	10	6	3	50.0	5	16	14	6	80.4	9	12	13	5	76.1	0	0

with the fruits free from poison. This increased rate of mortality is largely a result of the increased activity and accidental ingestion of poison by the weevils moving about in search for fresh squares. What proportion of the greater mortality on the plants entirely dusted was due to the ingestion of poison while feeding is not known.

Leaves Poison-Free, Stems and Fruits Poisoned, 1929

In 24 tests on 600 weevils released on plants with the poison confined to the stems and fruits, the mortality at the end of the fourth day ranged from 58 to 95 per cent (Table 5). Under the conditions of this series of tests, the poison-free plant surface exceeded by many times that exposed to the poison dust. However, the number of weevils which secured a fatal amount of poison on the stems and fruits alone was only 9 per cent less than in comparable tests where weevils were confined on plants entirely dusted with calcium arsenate. The maximum number of weevils died on the second and third day of exposure to the poison, and the mortality at the end of the fourth day averaged practically 83 per cent. This seems unusually high and may have been partly due to the fact that in the preparation of the plants excessive protective material was necessary (Fig. 6), and in the operation of poisoning a heavier cloud of dust was usually applied. This concentration of dust on the stems and fruits followed by the high mortality further emphasizes the desirability of producing strains of cotton that possess greater pubescence for increasing the adherence of poison applied in dust form.

Fig. 6. Manner of protecting the foliage prior to application of calcium arsenate dust.

Stems Poison-Free, Fruits and Leaves Poisoned

In a series of 24 tests the mortality records secured on 600 weevils, released on cotton plants with poison dust restricted to the leaves and fruits, varied from 52 to 98 per cent at the end of the fourth day. These results might be anticipated when considered on a basis of the total plant area covered with poison dust. However, there appears to be no very marked relation in this respect since the poison on the stems and fruits produced nearly the same degree of mortality as that resulting from the poison on the leaves and fruits because the weevils did not come in contact with the dust any more on the leaves than on the stems. According to the data presented in Tables 1 and 2, it will be noted that the weevils crawl approximately an equal distance on the stems as on the foliage. The mortality of the weevils resulting from the poison used in these tests averaged 86 per cent at the end of the fourth day of confinement on the plants.

A summary of the data on the mortality of the weevils secured in the poison-ingestion experiments conducted in 1929, is presented in Table 6. It will be noted that when either the fruits, leaves, or stems were protected from poison during the dusting operation, the mortality among the weevils subsequently placed on these plants was smaller in comparison with that recorded for the insects confined on plants entirely dusted. The mortality of weevils released on cotton plants dusted with calcium arsenate but having free access to poison-free fruits was nearly 33 per cent less than where the fruits were also subjected to the poison dust. Apparently it would seem that the presence of poison on the fruits has a very important bearing on control of the weevil. However, attention has been called to the fact that the presence of clean fruits on dusted plants merely retards the rate of mortality for three or four days when the conditions are such that the supply of fruit is strictly limited. This was manifested by the increased number of weevils which succumbed by the end of the sixth day of exposure. When the effectiveness of the poison is considered on this basis, the presence of poison on the fruits does not appear essential for securing a satisfactory degree of weevil mortality. Under the conditions prevailing in these experiments, it seems impossible to evaluate the poison on any particular portion of the plant. It is obvious, from the data secured, that a large majority of the weevils will secure a lethal dose of poison within four or five days when it occurs on either combination of leaves and stems, stems and fruits, or leaves and fruits. The reason for the decrease in mortality five or six days after application of poison is due to the fact that practically all loose particles of the dust have fallen from the plants and that the remainder adhere too closely to be picked up by the weevil. The failure of poison sprays to control the weevil seems due to the fact that the particles of poison are not usually distributed in as great abundance as when dust is applied; furthermore, the particles applied by means of spray adhere more closely to the plant surface and are not as readily picked up by the insect.

GENERAL DISCUSSION

The earliest attempts to control the cotton boll weevil by the use of arsenical poisons were made without definite knowledge of the principal manner in which the insect secures a lethal dose of the poison placed on the cotton plants. During the present studies, beginning in 1924, it was discovered that in the course of its natural activities the weevil possessed a peculiar habit of dipping the beak while crawling thus bringing the mouth-

Table 6. Summary of the per cent of weevil mortality in cage tests on cotton where the entire plant was poisoned and where poison was confined to certain parts of the plant, on four successive days after application of calcium arsenate, 1929.

Treatment	No. of tests	Total No. weevils used	Mortality of weevils at end of								Total No. dead	Total Per cent killed (corrected)
			1st day		2nd day		3rd day		4th day			
			No. dead	Per cent dead	No. dead	Per cent dead	No. dead	Per cent dead	No. dead	Per cent dead		
Control (no treatment)	12	300	2	0.7	6	2.0	5	1.6	3	1.0	16	
Entire plant poisoned	24	600	166	27.7	197	32.8	115	19.2	74	12.3	552	92.0
Stems and leaves poisoned	24	600	89	14.8	109	18.2	69	11.5	89	14.8	356	59.3
Stems and fruits poisoned	24	600	100	16.6	169	28.2	147	24.5	81	13.5	497	82.8
Fruits and leaves poisoned	24	600	147	24.5	175	29.2	123	20.5	71	11.8	516	86.0

parts in contact with the surface and in this way accumulated poison-particles on the mouth while merely walking over the surface of cotton plants dusted with calcium arsenate. The results secured in cage experiments conducted in the field showed that about 65 per cent of the weevils under observation secured a fatal dose of poison in this manner. Additional data secured in these experiments show that the weevil may pick up the poison on any portion of the cotton plant, indicating that the most effective control of the insect may be expected when the maximum plant surface is covered with the poison during the dusting operation.

Weevils kept under continuous observation under field conditions on both dusted and non-dusted cotton plants traveled the greatest distance on the stems. On plants covered with a thin layer of talc dust the weevils under observation crawled about 175 inches per unit day as compared with 420 inches for the individuals noted under comparable conditions on non-dusted plants. The decreased rate of travel by the weevils on the dusted plants was manifested by a reduction of more than 50 per cent in the number of fruits visited by the weevils on the dust-free plants. The number of inter-plant flights performed by weevils on dusted cotton plants was only one-third to half the number recorded for the individuals on dust-free plants, but the distance covered by these flights averaged more than twice as much. Detailed records on the activities of hibernated weevils on non-dusted cotton plants showed no striking differences with respect to the main avenues of travel, rate of crawl, the total distance covered, and the number of fruits visited per unit day of 8 hours, as was recorded for first- and second-generation weevils. During the first week after emergence from hibernation these weevils performed a fewer number of flights and spent more time in feeding and resting than was noted for later-generation individuals.

The average mortality among weevils released in lots of 25 and 50 per caged plant was 90.4 per cent when the entire plant surface was subjected to a cloud of calcium arsenate dust. In similar tests with the weevils having free access to unpoisoned or clean fruits, the mortality averaged 65.4 per cent. These data appear conclusive with respect to the importance of the accidental manner in which the boll weevil accumulates and ingests a lethal dose of poison while crawling over cotton plants dusted with calcium arsenate. Apparently it is largely through this means that effective control of the weevil is possible by poison-dust applications under field conditions on cotton plants either in full fruitage or in the pre-squaring stage. Under the conditions that these experiments were conducted, it seems imposible to evaluate the poison on any particular portion of the plant. From the data secured, it is obvious that the majority of the weevils will secure a lethal dose of poison when it occurs on either combination of leaves and stems, stems and fruits, or leaves and fruits. The presence of moisture on the plants is not an essential requirement for securing successful control of the weevil by poison applications.

ACKNOWLEDGMENTS

The writers are indebted to Prof. H. G. Johnston, L. O. Ellisor, R. H. Young, and C. Siddall for aid in recording detailed data of the activities of the weevils in the field, and also to the members of the Division of Entomology, who have assisted in various ways.

CONCLUSIONS

1. Approximately 65 per cent of the boll weevil mortality on dusted cotton occurred as a result of the accumulation of poison on the mouth parts and the accidental ingestion of poison by the weevils while crawling on the leaves, stems, or fruits of cotton.
2. The crawling activities of weevils are quite significant with respect to weevil control, which results largely from the manner in which the poison is picked up and ingested accidently.
3. To be most effective, calcium arsenate dust should be applied in a manner to uniformly cover all portions of a cotton plant. The failure of poison sprays to control the weevil seems due to the fact that the particles of poison are not usually distributed in as great abundance as when dust is applied; furthermore, the particles applied by means of spray adhere more closely to the plant surface and are not as readily picked up by the insect.
4. The determined lethal dose of poison for the weevil approximates the total amount of poison retained on the surface of a bud as a result of the usual rate of five to seven pounds at which calcium arsenate is applied.
5. The presence of dust on cotton plants retarded the crawling activities of weevils by 60 per cent and reduced the number of fruits which were visited by 50 per cent.
6. The presence of dense pubescence on the stems and leaves not only retards the crawling activities of the weevils but also causes the insect to bring its beak into more frequent contact with the loose particles of poison which are retained in greater abundance by the pubescence. The development of this character may improve the best strains of cotton for production under boll-weevil conditions.

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