THE FEEDING HABITS OF WIREWORMS WITH SPECIAL REFERENCE TO *MELANOTUS* spp. (ELATERIDAE)

by

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INTRODUCTION

Wireworm are larvae of click beetles which belong to the family Elateridae. They are subterranean in habit and therefore offer very difficult problems when an attempt is made to determine accurately and thoroughly their feeding habits. At the present writing very little work has been done to determine the food habits of the early instar larvae. Neither the eggs nor the first instar larvae have been taken in the field. This may be due either to their very small size, or to the fact that the first year the larvae do not feed upon cultivated crops to a sufficient extent to cause injury and thus do not come under observation, or, as some investigators believe, they may live upon organic matter in the soil for the first year.

A thorough knowledge of the life history and feeding habits of any insect, in all its stages, is necessary before proper methods can be adequately formulated for its control. This is especially true of subterranean forms such as wireworms and white grubs. The wireworm is especially adapted to its environment because of its cylindrical form, hard exoskeleton, and pointed body.

An investigation of the feeding habits of a form such as the wireworm, conducted for the purpose of developing control measures, is greatly complicated because of the resistance which these larvae exhibit to poisons and insecticides. Insecticides giving a high percentage of kill are usually either too expensive for practical use, destroy the germination of the seed, kill the plants, or may have a deleterious effect upon the soil.

The life history of wireworms greatly increases their importance as an economic pest. The time required to complete their life histories varies from one to six years, or longer. Some of the more important economic species, particularly those belonging to the genus *Melanotus*, require three to six years in which to complete their life cycles. Very little damage is done by the larvae the first year, but for the remainder of their existence in the soil they are ravenous feeders. It is during this latter period that practically all of the damage is done by elaterids.

Not only the entire larval stage is spent below ground, but also the egg stage, pupal stage, and a portion of the adult stage is passed in this manner. Because of this adaptation the Elateridae are practically free from parasites. Where parasitism is known it has been found to be exceedingly local in nature and is known to occur only upon the larval forms. Predators are likewise greatly reduced, as compared to forms living above ground, although they are a more important factor in control than are parasites.

Wireworms are pests of considerable economic importance in all parts of the world. They have caused great damage to grains, root crops, garden crops, and other plants for many years. Losses due to the feeding of this insect run into millions of dollars annually. It is not known the number of different plants the species of a genus of Elateridae will attack. It is known, however, that different genera vary widely in their food habits. It would, therefore, appear to be important to know the food preferences and feeding habits of each particular genus.

In the eastern third of the State of Kansas, feeding by wireworms, Melanotus spp., results annually in a loss to the corn crop. Larvae of this genus are also known to attack other forage crops, vegetable crops, grasses, and many other plants. Because this is one of the most common genera of elaterids and also one of the most important in the state economically, the writer undertook this problem with the purpose of attempting to determine the feeding habits of certain wireworms at Manhattan, especially early instar larvae, with special reference to larvae of the genus Melanotus.

REVIEW OF LITERATURE

The literature on the feeding habits of wireworms is very comprehensive. However, there are no papers dealing specifically with this subject. Information on feeding habits of wireworms is mentioned only incidentally in the discussion of other investigations. A review of the literature shows that wireworms are distinctly of economic importance in at least sixty-four countries. These include reports of losses from the provinces of Canada, practically every state in the United States, and countries scattered throughout Central and South America. Damage has been reported on the islands of Hawaii, Porto Rico, Philippines, and the West Indies. Crops have been reported seriously damaged in the British Isles, in numerous countries of Europe, from Spain to Switzerland, and to the northermost countries of Asia and Africa. In Australia the wireworm is a serious pest. It can therefore be seen that a study of the feeding habits of wireworms is a problem of world wide importance.

Leng (1920, 1927) lists sixty genera of Elateridae, which include 583 species, for America north of Mexico, including Greenland. In a review of the literature 28 genera, including sixty-two species were found to have definite economic importance. Of these, five genera: *Agriotes*, *Melanotus*, *Monocrepidius*, *Athous*, and *Limonius*, contain the majority of the destructive species, have the widest geographic distribution, and are of greatest economic importance. The literature also shows the genus *Agriotes* to have the widest distribution of any of the genera and apparently to be of the greatest importance economically.

Hyslop (1915) says that "True wireworms, from an economic standpoint, are among the five worst pests to Indian corn and among the twelve worst pests to wheat and oats." He also states that the larvae of *Agriotes mancus* Say have often been observed within potato tubers that have been in a root cellar all winter. The literature also shows that many other crops are seriously damaged by wireworm attack. Some other plants attacked are: rye, vetch, velvet beans, cow peas, soy beans, cotton, rice, vegetable crops such as potatoes, tomatoes, beans, and onions, besides numerous other plants.

According to King (1928) "Crop losses in Saskatchewan in 1926 due to wireworm injury were estimated at three and one-half million dollars. This figure is believed to be the mean annual loss in recent years." Thomas (1930) believes that the injury caused by wireworms has been increasing in recent years. He states that "Depreciation in the value of farm land in the Carolinas due to their depredations has been estimated conservatively at over a million dollars."

Figures given by Gui (1933) on the degree of injury caused by three subterranean insect pests of the potato in Ohio show that the wireworm causes more damage to the potato than both the scab gnat and white grub.

Wireworms vary in their habits, according to Hyslop (1915), some forms living in dead and rotten wood, <u>Alaus</u>, <u>Elater</u>, <u>Adelocera</u>, etc. A number of species abound in heavy, moist soils filled with humus, <u>Melanotus</u>, <u>Agriotes</u>, etc., while some prefer well drained soils, <u>Corymbites</u>, and still others, <u>Horistonotus</u>, are most destructive on high sandy land which is very low in humus. Many wireworms have been recorded as predacious, <u>Alaus</u>, <u>Hemirhipus</u>, <u>Adelocera</u>, etc. This is also stated by McColloch (1928).

Thomas (1930) lists 472 references, the majority of which deal in part on food habits of wireworms. Poison baits have been extensively recommended for the control of wireworms. Lehman (1933) found that poison baits would not be an efficient method of wireworm control on a large scale, since all of the wireworms could not be reached in this manner. He believes, however, that poison baits could be used to advantage on small garden plots where labor involved is not an important consideration. The same general conclusions concerning poison baits were given by Thomas (1930). Tattersfield and Roberts (1920) found wireworms to be among the most resistant to toxic organic compounds of any of the larvae found in the soil.

Wireworms are very marked in their ability to live for long periods without food. Roberts (1919) states that "Apart from the capacity of the larvae for fasting, there is no doubt that they can subsist in any ordinary soil for a very lengthy period with no food other than humus and decaying vegetable matter." H. M. Russell is quoted by Thomas as having kept *Limonius californicus* larvae in moist soil without additional food for thirteen months; at the end of this time they were alive and healthy. The soil was allowed to dry for two months and all the larvae died except one. Roberts concludes that "Wireworms do not thrive under such conditions but life is maintained and it is certain that nourishment is derived from the organic matter contained in the soil. Wireworms are able to fast for a considerable time without apparent inconvenience provided sufficient moisture is supplied. Three larvae of different sizes were isolated in wide glass tubes containing only moistened sand which had been previously sifted and treated with acid. At the end of one month all larvae were alive and active, having apparently suffered no ill effects from the treatment." This shows that summer fallow would not be a factor in the control of at least some species of wireworms.

Thomas (1930) showed that the soil moisture and soil acidity tolerated by wireworms varied considerably with the species, the optimum being different for each species, Melanotus species being most injurious in heavy, sour, poorly drained land. According to Roberts (1919), Agriotes larvae can withstand immersion in water for a very long time. They have withstood immersion from four to thirty days. Thomas (1930) concludes that flooding is impractical and not very effective in controlling wireworms.

Some writers believe that wireworm larvae feed throughout the winter on decaying vegetable matter. Roberts (1919) says that "they may be repeatedly found in winter amongst the roots of grasses growing on the surface, even during continuance of frost and snow. Agriotes larvae have a great propensity for animal food alive or dead, being especially cannibalistic in captivity even in the presence of vegetable food."

Wireworms of several genera are known to be predacious in habit. In certain of these cases they are known to be definitely beneficial while in the majority of instances they cannot be regarded of economic importance, although feeding upon destructive insect larvae. Hyslop (1915) reports Pyrophorus luminosus Illiger of the West Indies as a decidedly beneficial insect, as it feeds on the Lachnosterna (Phyllophaga) larvae in the sugar cane fields. Thomas (1931) and Hyslop (1915) list the genera of the Elateridae, Monocrepidius, Agriotes, Alaus, Agrypnus, Adelocera, Chalcolepidius, Hemirhipus, Melanotus, Pyrophorus, and others as containing predacious larvae. An elaterid, Monocrepidius spp., is reported by Box (1926) as being predacious upon the sugar cane moth borers Diatraea spp. attacking sugar cane in British Guiana. Elaterid larvae were occasionally found by Skinner (1930) attacking the larvae of the giant moth borer of sugar cane, Castnia licus Drury, in Trinidad. He states, however, that they cannot be regarded as a controlling factor. In Hawaii the predacious elaterid, Monocrepidius exul Sharp, is listed by Muir and Swezey (1916) as a natural enemy of minor importance to the sugar cane borers, Rhabdocnemis obscurus. W. Zwölfer (1928) of Southern Germany includes wireworms among the list of predators attacking the larvae of the European corn borer, Pyrausta nubilalis Hbn. Elaterid larvae were found predacious upon the small moth borers, *Diatraea* spp. attacking sugar cane in British Guiana by Bodkin (1913).

It was found by Gorham (1924) that *Agriotes* larvae devoured cutworms and other wireworms encountered in the soil. Larvae of *Monocrepidius pallipes*, Esch. are described by Veitch (1919) as beneficial because they are formidable enemies of *Rhabdocnemis vestita* in cane fields of Fiji. Swezey (1920) believes the larvae of *Monocrepidius exul* Sharp are predacious on the larvae of the beetle *Pantomorus fulleri*.

Stahl and Scaramuzza (1929) in using potato as a trap crop observed that *Monocrepidius bifoveatus* larvae were attracted more by decaying potatoes than fresh ones, and vice versa for an amber colored species, indicating that the scavenger habit of *M. bifoveatus* is well developed. *Pyrophorus* larvae were always found associated with injurious species and it is believed that they are of considerable value in reducing the population of injurious species. In captivity they were voracious feeders on almost any kind of larvae.

Headlee and Parker (1913) while digging wheat infested with Hessian fly at Wilson, Kansas, frequently observed that the 'flaxseeds' had been destroyed in plants entirely dead, the puparia being in fragments. A close search showed that wireworm larvae were the agents responsible for the attack, since several were observed actually at work inside the plants. Where these larvae were abundant in the soil, many of the 'flaxseed' had been destroyed. The writers believed the destruction of the fly was only incidental since the interior of the plant was entirely eaten away and in some cases not all of the 'flaxseeds' had been destroyed.

The rate, date, method of planting, and rotation followed, influences the percentage of corn plants injured by wireworms as shown by McColloch (1928), Bryson (1930), Thomas (1930) and Kadocsa (1932). Thomas (1930) shows that depth of planting also influences percentage of wireworm injury. The number of wireworms in a plot of ground is influenced by the type of manure applied, according to Walton (1917), Ostashchenko-Kudryavtzev (1931), and Ustinov (1932).

In Germany, Langenbuch (1932) found that feeding, especially by older _Agriotes obscurus_ L. and _A. lineatus_ S. larvae, was less intense in winter, but if sufficient moisture was present the older larvae of both species could resist a temperature of -14° C. (6.8° F.) for several hours, and frost for several weeks. The larvae showed no preference for a given cereal or for cereals over potato. The optimum soil moisture for the larvae was found to be between sixty and ninety per cent of saturation. He found sufficiently moist soil rich in humus more attractive than slices of potato. Plants are apparently not attacked in the presence of sufficient moisture in the soil. All larvae were found to assemble where the soil had an acid reaction.

French (1916) states that larvae of Limonius californicus are sensitive to heat, being killed in from five to ten minutes by exposure to sunshine or by contact with warm water. Some wireworm larvae are able to live in very hard, dry soil and to withstand starvation for a considerable time according to Adrianov (1916). McDougall (1932) found that older Lacon larvae were able to withstand lack of moisture and absence of food for a much longer period than the younger ones, which require a moist environment. Del Guercio is quoted by Vassiliev (1914) as having found that wireworms feed from October to May on decomposing organic substances. Destruction of weeds in the field was thought to be unimportant in wireworm control.

Experiments conducted by Umnov (1913) on food of Agriotes larvae showed that they preferred cucumbers, beet roots, and carrots, then potatoes, while they ate turnips very unwillingly and did not touch radish. Cannibalism was also observed. Vassiliev (1914) found *Melanotus rufipes* Herbst. and *Agriotes lineatus* L. in meadows and *Athous subfuscus* Müll and *Prosternon holosericeum* Ol. in woods all of which were feeding on rotten dung. Lees (1916) investigating the susceptibility of crops to wireworm damage found no crop, with the possible exception of mustard, immune, yet different crops varied in their susceptibility. He lists his results as follows:

> "Very susceptible: Plants attacked at the fleshy collar and completely killed, dwarfed, or caused to seed prematurely: onions, leeks, celery, and lettuce.
> Rather susceptible: Growth dwarfed, but plant not usually killed: runner bean, dwarf bean, and to a certain extent peas.
> Slightly susceptible: The cabbage tribe and tomatoes. Injured but not so as to endanger the life of the plant: potatoes, the injury as a rule being confined to the tuber."

Conradi and Eagerton (1914) found that the larvae of *Horistonotus uhlerii* Horn live almost exclusively within four inches of the surface except when driven to lower depths by either high or low temperatures or a lack of moisture in the upper soil. The larvae were very cannibalistic, a characteristic observed as soon as specimens were hatched. Especially those larvae that were molting were eaten and it was believed that this is probably the food of older larvae during their migration to the lower soil in winter and the dry spells in summer. Larvae were not thought to rove over a very large area. They ranged over an area of probably twenty or thirty square feet. The greatest amount of movement appeared to be from the top soil to the lower depths (eighteen to twenty inches) and vice versa. The rate of movement of a specimen burrowing into the soil in a glass cage was at the rate of one and one-half inches per minute. In experiments conducted to determine whether or not the larvae could live on humus, it was found humus might be eaten but that it has very little life giving power when eaten without other food. No specimens fed on humus pupated, while others taken at the same time and given corn roots all pupated.

Newly hatched larvae of the sugar beet wireworm were found by Graf (1914) to be quite active, burrowing themselves in loose soil with ease. They were unable to survive in dry earth even for a relatively short time. It was found that the larvae were able, to a small extent, to locate food, consisting of sliced beet. Larvae began feeding noticeably, though slightly, very soon after hatching. Minute black feeding marks could be observed each day on slices of sugar beet when removed from feeding cages. Depressions made by feeding could be discerned only with a hand lens, but black stains, characteristic of wireworm injury, had spread out and were quite conspicuous. Larvae kept in flower pots were distributed throughout the soil but no feeding marks could be found on the main beet root. Larvae do no injury the first year by feeding.

Old wireworms were found to honeycomb the old beet roots with their channels. The larvae were carniverous on occasion but under average field conditions cannibalism was unimportant, as the larvae were vegetable feeders by choice. The appeared to be able to locate food at a short distance in the field, though this was not proven conclusively. Wireworms were observed to move several inches daily in the laboratory. Several wireworms, placed in cages eighteen inches by twenty-four inches without food tunnelled throughout the soil within a week or ten days. Wireworms placed in ordinary soil without food lived from one to two years but did not grow normally. From observations on their activities Graf believed that one wireworm could destroy several young beet plants in a season. The greatest injury was done by the maturing larvae.

Roberts (1919) quotes Vassiliev as having fed young larvae up to a month or six weeks old, on rotten dung, while Adrianov found pieces of beet root and carrot eaten to some extent and also found evidence of the larvae having eaten into the roots of rye and wheat. Larvae kept in tubes containing tufty soil were observed, by Roberts, to have eaten partially-decomposed vegetable matter. Likewise larvae kept in moss were observed to have the gut filled with chlorophyll of moss on which they had fed. Some evidence was obtained of potato having been eaten. There was no evidence of attack upon barley from larvae of the first and second instars after six weeks.

Conradi (1918), Fenton (1926), Hawkins (1928), and Bryson (1930) found that wireworms bore into and completely eat out the kernels of corn before germination. They then attack the young plants after germination, boring into the center of the stalks and eating the young roots, thus cutting off food and water supply. Bryson found injury most noticeable when plants are four to five inches high. Observations showed that very few plants, if any, actually recovered from even the slightest injury. He also observed that one wireworm was sufficient to injure an entire hill of corn, and that it might move down the row in which the corn is planted and kill four or more plants spaced fourteen inches apart. Conradi and Eagerton (1914) observed the larvae of Horistonotus uhlerii Horn injured corn, oats, rye, cotton, tobacco, and peanuts by clipping off the tender feeding roots causing the plants to die of starvation. No larvae were observed boring into the stalk or roots of corn.

According to Hawkins (1928) wireworms bore into seed pieces of potato as soon as planted. This may induce rotting, prevent sprouting, or cause the production of weak plants. After vines are formed the roots and underground portions of stems may be attacked, thereby stunting the plant and resulting in weakened plants and a reduced yield of tubers. The attack may be delayed and the potatoes injured after they have become well matured.

There are two types of wireworm injury to sugar beets according to Graf (1914). "In one the tap root is cut off clean and the beet wilts and dies; in the other the wireworm, after eating into the root, turns and descends, eating off a side of the root as it goes down. This scars the root badly, and if the root is young and tender it is apt to die. If, however, the beet is quite strong and the root is swollen a little, so that the injury does not cut off the sap supply, it will recover, though always remaining distorted and undersized."

Swezey (1922) in Hawaii, Anderson and Halloway (1924) in Louisiana, Stahl and Scaramuzza (1929) in Cuba, and McDougall (1931) in Queensland record elaterid larvae as seriously damaging sugar cane. Injury consisted in killing the buds in seed pieces at the time of germination, eating of young roots as well as germinating buds, and feeding of the wireworms in the young stalks just above the junction with the seed piece.

Curtis (1883) gives a complete review of literature on the food habits of wireworms prior to this date. Each species of wireworm known to cause damage to crops in England, at this time, is discussed individually. The season and habitat where each is found is given. Each major crop is also discussed individually, giving part of plant attacked and type of feeding of the larvae. He states that "there is probably scarcely any land where the wireworms might not be found, and but few crops that they will not attack; but some situations are more favorable to their increase than others, and there are particular vegetables to which they undoubtedly give a preference. This may, however, in some measure, arise from the larvae of the different species not having exactly the same tastes."

METHODS AND MATERIALS

Because of the impossibility of securing and caring for large numbers of larvae, especially of the early instar forms, a few experiments were selected as being the best means of attempting this study. In addition to laboratory experiments, field observations were in progress at all times to secure information under natural conditions and which were compared with laboratory results whenever possible.

The writer has assisted in experiments which have been conducted for several years at the Kansas Agricultural Experiment Station by Mr. H. R. Bryson, in an effort to determine the life histories and habits of certain elaterids injurious to the roots of staple crops. It has been generally noted that in attempts to rear larvae from the egg, the greatest mortality occurs in early instar larvae. After this stage is passed the rate of mortality is greatly reduced.

During the spring of 1932 extensive experiments were undertaken to determine the food habits of particularly the early instar larval stages. Three general methods were followed in the study of this problem: (1) the use of individual salve boxes, (2) studies made in jelly glasses, and (3) the use of two six-inch unglazed drain tile set end to end and placed vertically in the soil. Each method will be discussed individually.

In order to secure first instar larvae it was necessary to secure adult Melanotus beetles, collect eggs, and hatch them out. The beetles were captured by banding elm trees with burlap and tar paper bands and examining these each morning. The beetles collected between the bands and the tree. Some beetles were also captured by examining young corn plants and collecting those found in the curl and the leaf sheaths.

Click beetles collected from these sources were placed in individual salve boxes containing a small amount of soil and a small piece of corn or sorghum blade on which was placed a drop of honey to serve as food for the beetle. The soil was examined daily for eggs, after which the beetle was refed and given fresh, moist soil. When eggs were found they were placed in a salve box containing moist soil which had been tamped slightly to give a smooth, solid surface on top and prevent too rapid drying. The eggs were observed closely and as soon as hatched the larvae were transferred to their respective containers.

Salve box method: Newly hatched larvae transferred to salve boxes were placed directly into moist, sifted soil. Three or four kernels of wheat and a little manure were added to serve as food for the larvae. The box was then completely filled with soil and the soil compressed slightly to reduce drying to a minimum. These boxes were examined regularly, the soil changed and more food added. All boxes were kept in a cave, described by McColloch (1917), to insure a more constant temperature and to reduce desiccation.

Tile method: In order to secure more nearly natural conditions for rearing wireworms, unglazed drain tile cages were used, as described by Bryson (1929). A small amount of manure was added to each tile, to serve as food for the young larvae, in addition to wheat as described by Bryson. Twenty-five wireworms were placed in each tile cage.

Jelly glass tests: The most extensive experiments to test the efficiency of certain materials as food for young wireworm larvae were conducted in jelly glasses. These glasses allowed more accurate observation than either of the other methods and contained considerably more soil than the one-ounce salve boxes, therefore, proved more convenient and efficient rearing containers. Each glass was three-fourths full of moist, sifted soil, slightly packed. The material used as food in the test was placed on top of the packed soil and about one inch of loose soil placed on top of this. Five wireworms were placed in each glass. The following materials were tested: one-eighth cake yeast foam, two drops honey, manure, germinating grain, pollen (pumpkin), raw carrots, crushed beetles, mixture of one-eighth cake yeast and crushed beetles, moist soil, pollen (corn), chopped corn roots, cotton seed, and insect larvae.

Each of the glasses was examined from time to time and more food added. On November 25, 1932, March 30, June 22, and July 20, 1933, the soil was examined and all wireworms measured.

Wireworms for the following experiments were secured by turning over rocks in grassy areas in the early spring, and by collecting them in moist cow manure in native prairie pastures. Many larvae were also collected while feeding on young corn from rotation plots, corn after oats, at the College farm. Corn plants showing signs of injury were dug up and the larvae collected. From one to eight larvae were collected to the plant. Many valuable notes on the feeding habits of wireworms were secured by observation while collecting larvae in the above manner.

Because of the supposed selectivity of food plants by wireworms, different crops have been recommended by many writers either as trap crops or as repellents. On May 15, 1933, an experiment was begun to determine the selectivity of wireworms for some of the more common crops, and also for some of those recommended as trap crops or for their repellent powers. It was also hoped to secure data on the type of feeding on the different plants tested and something on the horizontal movement of wireworms in the soil.

A box eight foot square by one foot deep was constructed, using twelve-inch boards for both sides and bottom. Screen wire was tacked over the bottom to prevent larvae escaping through the cracks. The box was placed in a hole, just its size, dug in the ground. Soil removed from the hole was then placed in the box, care being taken to remove all insect larvae and adults. The box was filled with soil until it was level with that on the outside, then it was divided into areas of one square foot each, by stretching string lengthwise and crosswise of the box, one foot apart. This formed sixty-four plats of one square foot each.

The following plants were planted: corn, onions, wheat, peas, cotton, beans, oats, radishes, kafir, potatoes, mustard, beets, and a blank plat. Ten seeds of each crop tested were planted to each square foot, with the exception of oats, wheat, and mustard, for which twenty seeds were planted, while five onion sets and three seed pieces of potato were used. Five replications were planted for each crop tested with the exception of beets. The replicated plats were arranged throughout the box as much as possible to allow more selectivity by the wireworms. This method is illustrated by Plate 1.

The plants were allowed to grow three to four weeks to allow the wireworms sufficient time to burrow through the soil and make selections as to food plant. The soil was then removed a plat at a time and carefully examined for the presence of wireworms. Observations were also made on type of injury to plants. Six hundred forty wireworms, or ten to the square foot were placed in blank plats, diagonally located in the center of the box.

After the soil had been thoroughly examined it was again placed in the box, the plats replanted, wireworms placed in the center of the box and the experiment repeated. There was a considerable reduction in the number of larvae recovered in the first experiment due to the fact that the soil was left uncovered for a period of two days after the plants had germinated, during which time the robins dug out an unknown number of larvae before their attack was noticed. A wire frame was then placed over the box to keep out all predators that might destroy the larvae.

Because of the large amount of literature recommending treatment of seed before planting for control of wireworms, a few of the more common commercial compounds recommended for this purpose were tested, to observe the type of feeding on the seed. Tests were started June 9, 1932, using maize as the plant treated.

The seed was treated by dipping in the commercial compound to be tested, allowed to dry over night and then planted. Ten kernels were used for each treatment, in each of the following compounds: Antrol, Palustrex, Evergreen, Oil of Wintergreen, Kip, Black Leaf 40, and a check which received no treatment.

Two boxes, one twenty inches by twenty inches by three inches and the other twenty inches by seventeen inches by three inches, were filled with moist sifted soil. Each box was divided into four equal parts and seed treated with a different compound planted in each square, with a check in each box. One box contained seed treated with Evergreen, Palustrex, Antrol and a check; the other Oil of Wintergreen, Kip, Black Leaf 40, and a check. Ten wireworms were placed in the center of each box. The maize was allowed to grow three to four inches high, after which each part was dug out separately and carefully examined. Records were kept of the location of each wireworm recovered and the presence of injury to kernels and plants, also the effect of the treatment upon the seed whenever possible.

After all the soil was examined it was returned to the box, more seed treated and the experiment repeated. The boxes were set in a definite position and with each re-planting the different treatments were rotated so that each treatment was grown in each of the four spaces in the box. The experiment was repeated four times and examined as above after each treatment.

During the summer and fall of 1932 experiments were also conducted to determine whether wireworms were predacious upon other larval forms, such as white grubs as well as to determine the distance a single wireworm would travel in moist, firmly packed soil. An experiment was also conducted to determine whether or not wireworms can live in moist soil without food other than that derived from the soil itself.

DISCUSSION

The amount of injury caused by the feeding of wireworms is unknown. It is not known whether wireworms feed upon the cells of the plant attacked or upon the organisms or enzymes contained within the plant. A much larger hole is often eaten into a plant than would appear necessary if the larvae were feeding upon the plant cells alone. The injury to the Irish potato is a good example of this type of feeding. In the majority of cases the feeding holes extend into the tuber from one-eighth to one-fourth inch; others extend an inch or more into the tuber, while occasionally they run entirely through the potato. Typical feeding tunnels are shown by Plate 5.

More wireworm damage is caused to maize throughout the corn belt than to most other crops. Serious injury is caused by the larvae eating into the seed before germination especially if soil conditions are unfavorable to germination of seed. Frequently the entire inner portion of the seed is eaten away, leaving only the hull. Larvae are often found in the seed to the extent of one-half their length. There is no definite place at which attack may begin.

Young plants are attacked soon after germination. The greatest injury is caused by larvae boring into the stem in the region of the crown. Typically, a hole is made just large enough to admit the larvae into the plant where the center of the stem is eaten out and the bud injured. Translocation of water and plant foods to and from the leaves is stopped and the plant soon wilts and dies. In heavy infestations, a single plant may be attacked several times, often resulting in the stem being tunnelled completely and occasionally severed from the roots as illustrated by Plate 2.

Injury to young plants is first indicated by wilting of the central curl of leaves. As these leaves turn yellow and die the wilting progresses outward until the entire plant is dead, the outer leaves usually dying last. Such injury is very noticeable in the field. An attempt is often made by the plant to recover from this injury by sending up suckers. After the plants reach a height of between two and three feet they are usually no longer seriously affected by the presence of wireworms.

Because of the destruction of seed and young plants it is often necessary to replant large acreages of maize. It has been observed that maize, replanted in the same hills may be either killed or greatly weakened. If the seed is replanted on ridges directly opposite the first planting it may escape injury. This shows that the larvae either remain in the same general locality or follow down the planter furrow as the line of least resistance.

Thirty-eight maize plants showing typical signs of wireworm injury were selected at the Agronomy farm, June 7, 1932, and examined for injury. Thirty of the plants had been bored into at the crown by wireworms. Four had been fed upon one-half inch above the crown and one at one inch above the crown. No injury was found on three plants. The plants ranged from six to twenty-two and five-tenths inches in height, with an average height of thirteen and four-tenths inches. Twenty-one of the plants showed typical wireworm injury, with a wilting and dying of the central curl of leaves. Seven plants were dead and eight, or twenty-one per cent, showed typical wireworm injury, but were attempting to overcome this by producing suckers as illustrated by Plate 3. Four of the plants had produced two suckers each. The stalk of one plant, ten inches high, had been tunnelled its entire length.

Two maize plants which illustrated typical injury in a field of corn were received from Eureka, Kansas, June 16, 1932. One plant measured forty-one inches in height and showed wireworm injury one inch above the crown. The second plant was twenty-two inches high and had been eaten into twice, once at the crown and again one inch above the crown. The center of the stalk had been eaten out for two and one-half inches above the crown.

The above observations show that injury to maize by wireworms usually occurs in the region of the crown or slightly above. The plant often attempts to recover by sending out suckers. This would indicate that replanting should not occur in the original hills.

In experiments conducted during the summer and fall of 1932 to determine whether or not wireworms were predacious upon other insect larval forms, one wireworm and one white grub were placed in each of ten one-ounce salve boxes and covered with moist soil. The larvae were observed daily and the soil changed once or twice a week. No food was given them other than that found in the soil. During the experiment five wireworms were observed to have killed the grubs placed in their boxes and to have fed upon them. In one instance a white grub killed a wireworm.

Observations were made by Mr. S. G. Kelly, student assistant at Field Insectary, on July 30, 1927, of a wireworm feeding on a dead corn root worm larva, which was apparently killed by the wireworm. Also, August 13, 1928, he observed three wireworms feeding on fly maggots in salve boxes. A wireworm larva, _Melanotus_ sp., was observed feeding upon a dead army cutworm, Chorizagrotis auxiliaris Grote by Professor H. R. Bryson at the Horticultural farm, Manhattan, Kansas, April 7, 1933. The larva was feeding inside the body of the cutworm, with about one-half of its body buried within the worm.

In October, 1932, Dr. R. H. Painter, Assistant Entomologist of Experiment Station, reported finding wireworms in stems of volunteer wheat heavily infested with Hessian fly on the Agronomy farm. Observations were not made however, for injury to 'flaxseed'.

Elaterid larvae are very cannibalistic. It was found necessary to place wireworms in individual salve boxes to keep them from killing each other. They are very sluggish at the time of molting, but appear to have very ravenous appetites and to be exceedingly cannibalistic after completing a molt. First instar larvae hatched on moist soil in salve boxes were observed feeding upon each other August 26, 1932. This observation would indicate that wireworms are probably cannibalistic at all ages.

While collecting wireworms, in the spring of 1933, from moist cow manure it was observed that wireworms were most abundant in those cow droppings containing the largest number of dung beetle grubs. On closer observation forty-three wireworms were taken actually feeding upon grubs in the manure and one feeding upon a cutworm. Fourteen and three-tenths per cent of the larvae collected were observed actually feeding. Many more were probably feeding at the time but were disturbed upon breaking up the manure. This would indicate that the wireworms do not come above ground and enter piles of cow manure because of moisture content or organic content of the manure itself, but enter the cow droppings because of the abundance of food in the form of grubs.

Ten Melanotus larvae were placed in individual salve boxes, June 17, 1932, to determine the ability of wireworms to live in the soil without food other than that derived from the soil itself. The soil was changed at regular intervals to prevent desiccation, but at no time was food added. The boxes were kept in a cave so as to approximate outside soil temperatures. During the course of the experiment one wireworm died September 13, 1932, and one emerged as a normal adult September 6, 1932. The eight remaining larvae appeared to be normal in every respect after thirteen months. It is therefore proved that certain Melanotus larvae can live in soil entirely free from vegetation for very long periods without serious injury. This is an important fact to consider when cropping practices such as crop rotation are desired for wireworm control. It is also seen that they can live in soil for a considerable time without interfering with their metamorphosis. Death of the one larva was probably due to causes other than lack of food.

Several Melanotus larvae accidentally left out of doors, in a pocket tobacco can, through an eight-tenths inch rain were found dead approximately thirty-six hours later. The soil was completely saturated and the wireworms had apparently died from drowning. This appears to indicate that although the larvae require moisture in the soil they cannot withstand immersion for long periods.

One wireworm placed in a box twenty-two inches by eight inches by six inches deep on August 4, 1932, was observed on September 17, 1932, to have burrowed throughout the entire box, both vertically and horizontally. The ramblings of the burrows appeared to indicate that the larva was in search of food. Further observations, on the distance that wireworms travel in the soil, are given in the experiment on food selection.

Nineteen wireworms were collected under rocks March 27, 1933. Observations made for feeding showed eleven wireworms, or fifty-seven and eight-tenths per cent of those collected, feeding on green sprouts of bluegrass at the edges of the rock. At this time neither wireworms nor dung beetle grubs on which the former feed were found in piles of moist cow manure. This indicates that wireworms come to the surface, under rock, in the early spring to feed upon the young tender growth of grass found there, before grubs can be found in the manure. The rock also furnishes protection from brief cold spells of early spring. Wireworms were observed feeding upon grass stems as late as May first, but by this time a large number of them had entered cow manure and apparently fed upon grubs.

During the summer of 1932 observations were made on two wireworms feeding above ground in the stem of a cocklebur. One wireworm was also collected feeding in the stem of a sunflower and another in the stem of big bluestem grass. Onions harvested July 19, 1932, were found to have wireworm injury. This is illustrated by Plate 5. Three-fourths acre of potatoes grown at Manhattan were found to be practically one hundred per cent damaged by wireworms. By this is meant that practically all of the potatoes were injured but not totally destroyed. Some of the burrows extended entirely through the tuber. After removing the potatoes the wireworms migrated to volunteer sorghum and attacked the roots and crowns of the plants. Twenty per cent of the radishes harvested from insecticide plots at the Entomology field insectary in June, 1933, were injured by wireworms.

Plate 4, illustrating the effect of different foods and different methods of feeding on early instar wireworm larvae, shows that insect larvae, raw carrot, grain and manure, and manure alone failed to produce growth to the same extent as other materials tested. There was also a high mortality with these foods. Measurements of larvae fed on insect larvae and on manure were based on the average lengths of two larvae out of ten original larvae. Measurement of larvae fed on raw carrot were based on the average lengths of three surviving larvae out of ten originally started, and grain and manure on the average lengths of twenty-four out of one hundred and forty original larvae.

Larvae fed cotton seed and honey showed a greater growth than those previously mentioned. However, the effect of the cotton seed was based on the measurements of four surviving larvae out of ten originally started, and honey on one surviving larvae out of five originally. One-eighth cake yeast foam and crushed beetles were each very good foods. However, a mixture of one-eighth cake yeast foam and crushed beetles was much better than either of the above alone, apparently due to the combination of yeast plants and organic material from the beetles. The first measurement of larvae fed one-eighth cake yeast foam appears much longer than later measurements because only one jar of larvae, hatched early in the spring, was measured. Later measurements included larvae hatched the latter part of August which were very much smaller and thus reduced the average length. The slight discrepancy noticed in measurements of wireworms in tile, crushed, beetles, and cotton seed is thought to be due to faulty measurement but is not great enough to be significant. Discrepancies may have also been due to irregularity in the number of larvae measured.

Those larvae fed in salve boxes showed little or no growth and by the time of the third measurement had all died, while those fed insect larvae had all died by the time the fourth measurement was taken. This shows the high mortality resulting from rearing by these methods. Wireworms placed in tile showed a slight increase in growth and were longer than those fed in salve boxes or most of the other feeds. The measurements of larvae removed from tile are most accurate because they are based on the average lengths of seventy-five larvae out of an original four hundred and fifty.

Results of the experiment indicated that a combination of yeast and crushed beetles was the best food for rearing young larvae. Yeast and crushed beetles were next of importance in the order named. Rearing in tile was next in efficiency, using grain and manure as food, while there was a very high mortality and little growth when salve boxes were used.

Figures in Table I indicate the ability of Melanotus larvae to select one food plant over that of another, and to show something of their horizontal movement in the soil. The table shows that at the first digging fourteen and six-tenths per cent of the wireworms were still in the blank plats, 28 and 37, in which they were placed at the start and twenty-five and eight-tenths per cent and thirty-four and three tenths respectively at the time of the second and third diggings. In the first test nineteen and six-tenths per cent, in the second thirty-three and nine-tenths per cent, and in the third thirty-four per cent of the wireworms were in plats immediately surrounding the blanks. Twenty-six and eight-tenths per cent, ten and eight-tenths per cent and seven and seven-tenths per cent respectively, of the total number of wireworms recovered, were in the outer margin of the plat. The great majority of the larvae were within two feet of the blank plats in which they were introduced. The larvae were evenly distributed in all directions, but the plats of any one crop had no significantly larger percentage of the total number of wireworms than any other plant tested. This shows that the wireworms

Table I

Food Preference and Horizontal Movement of Wireworms

	1 Corn	2 Onions	3 Wheat	4 Peas	5 Cotton	6 Beans	7 Oats	8 Radishes
A.	6	3	8	4	4	4	2	4
B.	1	2	4	7	4	3	1	1
C.	1	0	2	5	3	4	0	2
	9 Peas	10 Wheat	11 Onions	12 Corn	13 Blank	14 Mustard	15 Potatoes	16 Kafir
A.	2	3	5	10	7	3	4	7
B.	1	1	1	9	10	6	1	2
C.	2	4	1	10	5	3	1	1
	17 Cotton	18 Beans	19 Oats	20 Radishes	21 Kafir	22 Potatoes	23 Mustard	24 Beets
A.	5	7	8	17	18	8	2	4
B.	4	1	10	25	16	7	8	3
C.	2	4	6	22	3	7	0	1
	25 Corn	26 Onions	27 Wheat	28 Blank	29 Beets	30 Beans	31 Oats	32 Radishes
A.	10	5	19	43	13	10	10	6
B.	3	4	30	83	32	11	10	1
C.	2	4	26	109	27	5	6	1
	33 Oats	34 Cotton	35 Peas	36 Beets	37 Blank	38 Mustard	39 Potatoes	40 Kafir
A.	4	10	6	25	32	15	13	5
B.	1	5	23	52	55	11	4	4
C.	3	9	20	75	87	25	3	3
	41 Beets	42 Mustard	43 Potatoes	44 Kafir	45 Radishes	46 Oats	47 Beans	48 Cotton
A.	8	2	6	9	12	13	12	8
B.	2	2	11	18	31	8	1	2
C.	0	0	7	6	19	28	3	1
	49 Kafir	50 Potatoes	51 Mustard	52 Blank	53 Corn	54 Onions	55 Wheat	56 Peas
A.	4	5	8	9	4	5	3	3
B.	1	2	2	7	4	3	1	1
C.	0	0	3	3	3	0	0	0
	57 Radishes	58 Oats	59 Beans	60 Cotton	61 Peas	62 Wheat	63 Onions	64 Corn
A.	4	5	4	8	7	4	3	2
B.	0	1	1	3	2	0	0	3
C.	3	3	1	2	1	0	0	1

A. Examined June 9, 1933. B. Examined July 7, 1933. C. Examined July 27, 1933.

did not select a certain plant to attack but fed upon any plant with which they came in contact, some plants being fed upon to a greater extent than others, however. The majority of the wireworms did not move over two feet in a horizontal direction. The plant attacked was a matter of distance from the blank plat in which the wireworms were placed and not a matter of food selection. Table II shows that the plats of no one plant contained an appreciably greater or lesser percentage of wireworms than those of any other plant, with the exception of those containing beets and the blank plats. The high percentage of wireworms recovered in the beet plats was due to the position of two of the plats adjoining the blanks in which the wireworms were placed. The high percentages of the blank was due to the inactivity of the larvae.

Table II

Percentage of Wireworms Recovered to Each Crop

Date of Digging	5-9-33	7-14-33	7-24-33	Average
Corn	6.2	3.7	2.9	4.2
Onions	4.0	1.8	.8	2.2
Wheat	6.8	6.7	5.6	6.3
Peas	4.2	6.3	4.9	5.1
Cotton	6.8	3.3	2.9	4.3
Beans	7.2	3.1	2.9	4.6
Oats	7.9	5.8	7.5	7.0
Radishes	7.6	6.7	8.2	7.5
Kafir	8.3	7.6	2.2	6.0
Potatoes	7.4	4.8	3.1	5.1
Mustard	5.8	3.9	5.4	5.0
Beets	9.7	16.6	18.0	14.7
Blank	17.7	29.0	35.7	27.4

Observations made on type of feeding showed that kafir, beans, peas, and mustard were the least injured, in the order named. Kafir showed no signs of injury. Beans and peas had feeding marks on the stems but they were not deep enough to cause serious injury to the plants. Occasionally a pea plant would be found with the root completely eaten off and the plant killed. Mustard roots were observed with feeding marks entirely encircling the plant but they were not sufficiently bad to seriously injure the plant's growth. Wheat and oats were seriously injured. Both the seed and plants were attacked.

Many seeds were eaten before germination and the young plants were killed. Maize was attacked by feeding just above the crown, as described previously. The bulbs of small onions were completely eaten away and the larvae had burrowed into the stem in a few instances. Cotton was very seriously injured. The entire stalk below ground was eaten away until it was only about one-half normal size. As a result the plants were dwarfed or killed. The seed was also attacked, the larvae eating into the seed coat and completely eating out the kernel. Seed pieces of potato were completely hollowed out by tunnels. No feeding was noticed on the sprouts. Radishes and beets were injured by feeding on the roots. In some instances the root was completely eaten in two, while most generally there was only a slight puncture, but this caused the roots to become deformed and in the case of radishes, to split following rapid growth.

Table III, the effect of treating seed of maize with a few commercial compounds on the feeding of wireworms, shows that Evergreen and Black Leaf 40 had a slightly repellent effect, while Palustrex and Oil of Wintergreen reduced germination slightly. The wireworms fed upon kernels treated with each commercial compound without any apparent ill effects. The results show that seed treated with these compounds cannot be depended upon as a means of controlling wireworms. This test was conducted merely to determine whether the larvae would select the check in preference to the treated seed.

Table III

Effect of Treating Maize with Commercial Compounds on Feeding of Wireworms

Treatment	Number of Wireworms Recovered 6-9-32	6-22-32	7-9-32	8-3-33	Total	Germination Count Total	Injured Kernels (6-9-32 & 6-22-32)
	Box 1	Box 3	Box 5	Box 7			
Check	2	2	4	1	9	36	10
Antrol	0	2	3	1	6	33	9
Evergreen	1	4	3	5	13	33	4
Palustrex	6	2	0	2	10	22	8
	Box 2	Box 4	Box 6	Box 8			
Check	3	1	2	3	9	35	4
Kip	1	6	4	2	13	33	10
Oil of Wintergreen	3	1	2	1	7	26	11
Black Leaf 40	3	1	2	1	6	36	3

SUMMARY

Wireworms are especially adapted to their environment because of their cylindrical form, hard exoskeleton, and pointed body.

Maize was attacked before the kernels germinated and again in the region of crown, in young plants. The seed pieces of potato were completely eaten and later the plants and potatoes were attacked.

Melanotus spp. larvae were found to be predacious upon white grubs, cutworm larvae, corn root worm larvae, 'flax-seed' of Hessian fly, and fly maggots.

Elaterid larvae were cannibalistic at all ages, but especially in the older larvae following molt periods.

Wireworms lived in moist soil, without additional food, for thirteen months. There was no apparent injury to the wireworms, thus fallow would be of little value as a method of control. It was certain that the larvae fed on the humus in the soil.

Moisture was found to be necessary in the soil but the larvae could not withstand immersion for long periods.

Field observations showed wireworms above ground, under rock, in the early spring feeding upon young, tender grass

stems. A little later they were found in piles of moist cow droppings feeding upon dung beetle grubs. Larvae were observed feeding in the stems of cocklebur, sunflower, and big bluestem grass.

A combination of yeast and crushed beetles was found to be the best material tested as food for early instar wireworm larvae. Both yeast and crushed beetles, used separately, proved to be excellent food materials, but were not equal to the combination of the two.

Tile rearing ranked fourth, but it is believed that it would have outranked certain other methods if as large a number of larvae had been used in the latter measurements as for the tile. Honey and cotton seed produced fairly good growth, but there was a high mortality with each. Manure, grain and manure, raw carrot, insect larvae and feeding in salve boxes produced little growth and there was a very high mortality, indicating that these materials were very poor foods. Larvae fed pumpkin pollen, corn pollen, chopped corn roots, and those placed in moist soil all died.

Melanotus larvae showed no indication of food selection. They traveled but short distances, horizontally, in the soil, attacking the first plant encountered.

Kafir, beans, peas, and mustard showed the greatest resistance to injury. Cotton, wheat, oats, corn, and potatoes were injured to the greatest extent, while all plants were attacked to a greater or less degree.

Commercial compounds used in seed treatment were found ineffective against wireworm injury, the seed being attacked the same as that not treated.

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LITERATURE CITED

1. Adrianov, A. P.
Desirable work on the study of wireworms and their control. [In Russian] Proceedings of the conference on pests of clover in Central Russia. Ent. Sta. of the Zemstvo. of the govt. of Tula. p. 192-205. 1916.

2. Anderson, W. E. and Halloway, T. E.
Wireworms injuring sugar cane. Jour. Econ. Ent. 17:602-603. 1924.

3. Bodkin, G. E.
Insects injurious to sugar cane in British Guiana, and their natural enemies. Jour. Board of Agr., Br. Guiana, 7:29-32. 1913. (Abs. in Rev. Appl. Ent. 1:521.)

4. Box, H. E.
Sugar cane moth borers (Diatraea spp.) in British Guiana. Bul. Ent. Res. 16:249-266. 1926. (Abs. in Rev. Appl. Ent. 14:102.)

5. Bryson, Harry R.
A method for rearing wireworms (Elateridae). Kans. Ent. Soc., Jour. 2:15-21. 1929.

6. Bryson, Harry R.
A study of field practices as related to wireworm infestations (Elateridae). Jour. Econ. Ent. 23:303-315. 1930.

7. Conradi, A. F.
Report of the Entomology Division. 31st Ann. Rept. South Carolina Exp. Sta., p. 27-33. 1918.

8. Conradi, A. F. and Eagerton, H. C.
Corn and cotton wireworm (Horistonotus uhlerii Horn). South Carolina Agr. Exp. Sta. Bul. 180, 16 p. 1914.

9. Curtis, John.
Farm insects ... London. John Van Voorst, p. 152-210, 452-454. 1883.

10. Fenton, F. A.
Observations on the biology of Melanotus communis and Melanotus pilosus. Jour. Econ. Ent. 19:502-504. 1926.

11. French, J. N.
Wireworm control. Calif. St. Comm. Hort. Mo. Bul. 5:225-235. 1916.

12. Gorham, R. P.
Notes on Agriotes mancus Say, at Dartmouth, N. S. Acadian Ent. Soc. Proc. 9:69-72 (1923) 1924. (Abs. in Rev. Appl. Ent. 12:496.)

13. Graf, John E.
A preliminary report of the sugar beet wireworm (Limonius californicus). U. S. Dept. Agr. Bur. Ent., Bul. 123, 68 p., 9 figs., 23 plates. 1914.

14. Gui, Harry L.
[Degree of injury caused by three subterranean insect pests of the potato.] In the potato scab-gnat, Pnyxia scabiei (Hopkins). Ohio Agr. Exp. Sta. Bul. 524, fig. 6, p. 12. 1933.

15. Hawkins, J. H.
Wireworms affecting Maine agriculture. Maine Agr. Exp. Sta. Bul. 343, 20 p. 1928.

16. Headlee, T. G. and Parker, G. B.
The Hessian fly. Kans. Agr. Exp. Sta. Bul. 188, p. 87-138. 1913.

17. Hyslop, J. A.
Wireworms attacking cereal and forage crops. U.S. Dept. Agr. Bul. 156, 34 p., 8 figs. 1915.

18. Kadocsa, G.
Green-crop and soil treatment in combating wireworms. [In Russian] Arch. Zool. 16:1028-1045, 11 refs. 1932. (Abs. in Rev. Appl. Ent. 20:717.)

19. King, Kenneth M.
Economic importance of wireworms and false wireworms in Saskatchewan. Sci. Agr. 8:693-706. 1928.

20. Langenbuch, R.
Contributions to the knowledge of the history of Agriotes lineatus L. and Agriotes obscurus L. Ztschr. Angew. Ent. 19:278-300, 12 figs., 12 refs. 1932. (Abs. in Rev. Appl. Ent. 20:492.)

21. Lees, A. H.
Miscellaneous notes on plant pests and their treatment. Ann. Rept. for 1916, Agr. and Hort. Res. Sta., Long Ashton, Bristol. p. 36-38. 1916. (Abs. in Rev. Appl. Ent. 6:425.)

22. Lehman, Russell S.
Field experiments with various poison baits against wireworms, Limonius (Pheletes) canus Lec. Jour. Econ. Ent. 26:243-252. 1933.

23. Leng, Charles W.
[Elateridae.] In catalogue of coleoptera of America, North of Mexico. Mount Vernon, N. Y., John D. Sherman. p. 166-168. 1920.

23.(a) Leng, Charles W.
[Elateridae.] In catalogue of coleoptera of America, North of Mexico, Supplement. Mount Vernon, N. Y., John D. Sherman. p. 29. 1927.

24. McColloch, J. W.
A method for the study of underground insects. Jour. Econ. Ent. 10:183-188. 1917.

25. McColloch, J. W.
Some problems in the control of underground insects. Fourth International Congress of Entomology, 2:306-315. 1928.

26. McDougall, W. A.
Elaterids damaging sugar cane in report of assistant to entomologist, Mackay. 31st Ann. Rept. Bur. Sugar Exp. Sta. Queensland. p. 47-48. 1931.

27. McDougall, W. A.
Damage by an elaterid, Lacon sp. in report of assistant entomologist, Mackay. 32nd Ann. Rept. Bur. Sugar Exp. Sta. Queensland. p. 57. 1932.

28. Muir, F. and Swezey, O. H.
The cane-borer beetle in Hawaii and its control by natural enemies. Rept. Hawaiian Sugar Planters Assoc. Exp. Sta., Honolulu Ent. Bul. 13, 102 p. 1916. (Abs. in Rev. Appl. Ent. 5:53.)

29. Ostashchenko-Kudryavtzev, N. P.
Effect of manuring on the number of the wireworms in sunflower plantations. [In Russian] Plant Protection 8:253-258. 1931. (Abs. in Rev. Appl. Ent. 20:232.)

30. Roberts, A. W. R.
On the life history of wireworms of the genus Agriotes Esch. with some notes on that of Athous Haemorrhoidalis F. Part I Ann. App. Biol. 6:116-135, 6 figs., 1 plate. 1919.

31. Skinner, H. M.
Wireworms attacking giant moth borer of sugar cane in The giant moth borer of sugar cane (Castnia licus Drury). Trop. Agr. Suppl. 8, 8 p. 1930. (Abs. in Rev. Appl. Ent. 18:251.)

32. Stahl, C. F. and Scaramuzza, L. C.
Soil insects attacking sugar cane in Cuba. Tropical Plant Research Foundation. Cuba Sugar Club Exp. Sta. Bul. 10, 10 p., 18 figs. 1929.

33. Swezey, O. H.
Wireworms as cane pests in Hawaii. Hawaiian Planters' Record 23:1-5. 1920. (Abs. in Rev. Appl. Ent. 8:461.)

34. Swezey, O. H.
Wireworm damage in Hamakua. Hawaiian Planters' Record 26:6-10. 1922. (Abs. in Rev. Appl. Ent. 10:196.)

35. Tattersfield, F. and Roberts, A. W. R.
The influence of chemical constitution on the taxicity of organic compounds to wireworms. Jour. Agr. Sci. 10:199-232, 18 diags. 1920.

36. Thomas, C. A.
A review of research on the control of wireworms. Penn. St. Col. Agr. Exp. Sta. Bul. 259. 52 p., 472 refs. 1930.

37. Thomas, C. A.
The predatory enemies of Elateridae (Coleoptera). Ent. News 42:137-140, 158-167. 1931.

38. Umnov, A.
Report of the work of the Entomological Bureau of the Zemstvo of Kaluga for the year 1913. [In Russian] 36 p. 1913. (Abs. in Rev. Appl. Ent. 2:265-266.

39. Ustinov, A. A.
A review of pests of tobacco in Abkhazia observed in 1931. [In Russian] Roy. v. 8, 33 p. 1932. (Abs. in Rev. Appl. Ent. 21:55.)

40. Vassiliev, E. M.
Report of the work of the experimental Entomological station of the All-Russian Society of sugar refiners in 1913. [In Russian] (Abs. in Rev. Appl. Ent. 2:466.)

41. Vassiliev, E. M.
Pests of maize and measurements against them. [In Russian] South Russian Agr. Gaz. 1914 (5):10-11, (11):8-10, (17):14-15, (32):9-10, and (38):8-9. (Abs. in Rev. Appl. Ent. 3:541.)

42. Veitch, R.
Notes on the more important insects in sugar cane plantations in Fiji. Bul. Ent. Res. 10:21-39. 1919. (Abs. in Rev. Appl. Ent. 8:26.)

43. Walton, C. L.
Some insect pests observed in the Aberystruyth area, 1913-1916. Ann. App. Biol. 4:4-14. 1917.

44. Zwölfer, W.
Corn borer controlling factors and measures in Southern Germany. Internat. Corn Borer Invest. Sci. Rep. 1927-1928, p. 135-142. 1928. (Abs. in Rev. Appl. Ent. 16:217.)

EXPLANATION OF PLATES

Plate 1. Plat showing arrangement of food test squares used in feeding tests with wireworms.

Plate 1

plate 2. Wireworm injury to corn stalks.

Plate 2

Plate 3. Attempts made by injured corn stalks to recover from wireworm injury by producing suckers from base of injured stalks.

Plate 3

Plate 4. Chart showing the effect of different feeds on growth of early instar wireworm larvae.

Plate 4

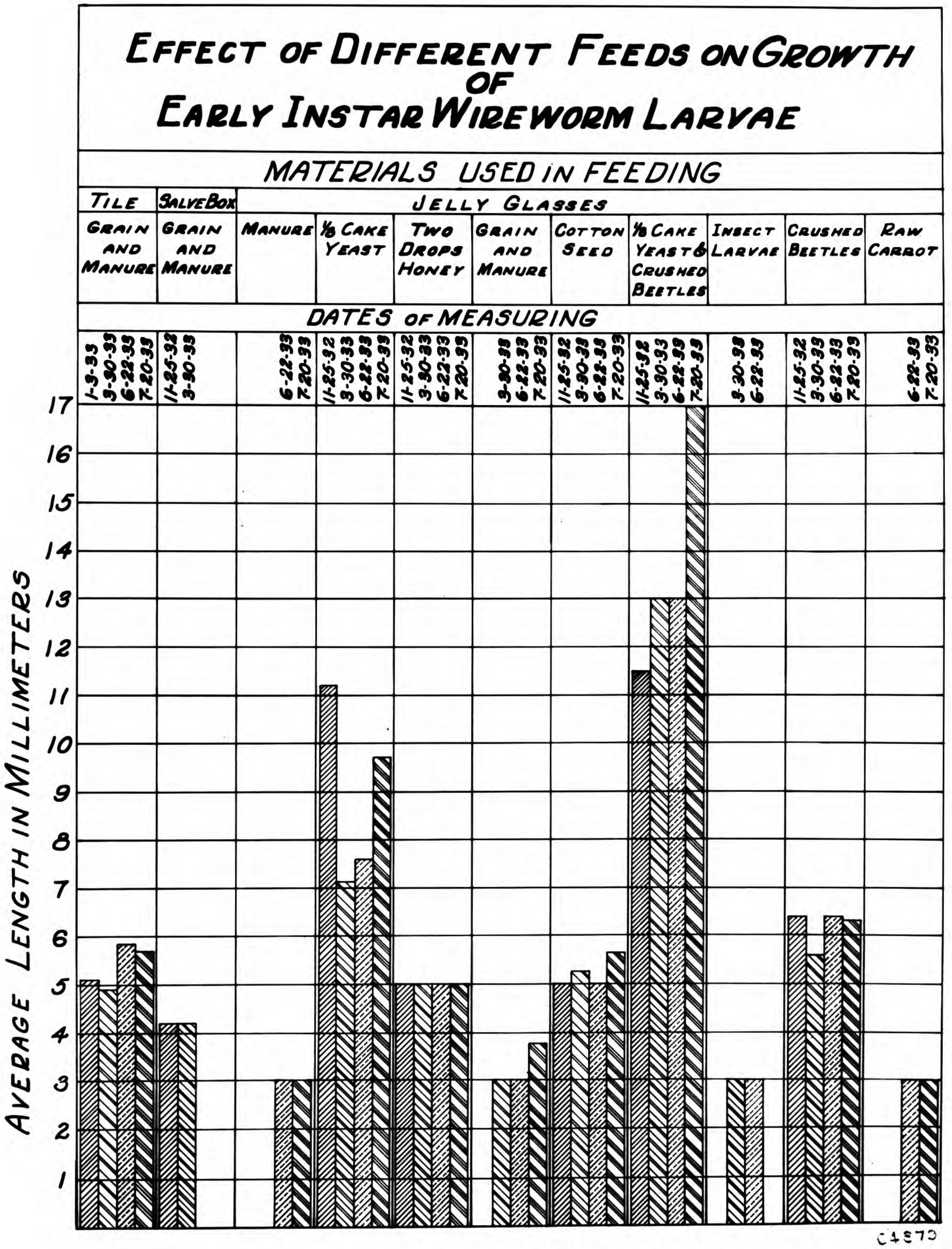
EFFECT OF DIFFERENT FEEDS ON GROWTH OF EARLY INSTAR WIREWORM LARVAE
MATERIALS USED IN FEEDING
TILE
SALVE BOX
JELLY GLASSES
GRAIN AND MANURE
GRAIN AND MANURE
MANURE
1/8 CAKE YEAST
TWO DROPS HONEY
GRAIN AND MANURE
COTTON SEED
1/8 CAKE YEAST & CRUSHED BEETLES
INSECT LARVAE
CRUSHED BEETLES
RAW CARROT
DATES OF MEASURING
1-9-33 3-30-33 6-22-33 7-20-33
11-25-32 3-30-33
6-22-33 7-20-33
11-25-32 3-30-33 6-22-33 7-20-33
11-25-32 3-30-33 6-22-33 7-20-33
3-30-33 6-22-33 7-20-33
11-25-32 3-30-33 6-22-33 7-20-33
11-25-32 3-30-33 6-22-33 7-20-33
3-30-33 6-22-33
11-25-32 3-30-33 6-22-33 7-20-33
6-22-33 7-20-33
AVERAGE LENGTH IN MILLIMETERS
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
C4879

Plate 5

Fig. 1. Wireworm injury to onions at harvest time.

Fig. 2. Wireworm injury on exterior of potatoes.

Fig. 3. Injury on interior of potatoes from wireworm attack.

Plate 5

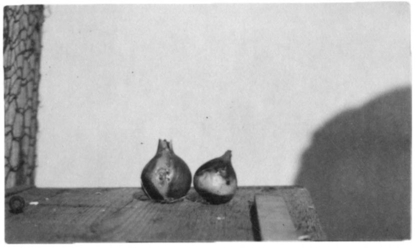

Fig. 1

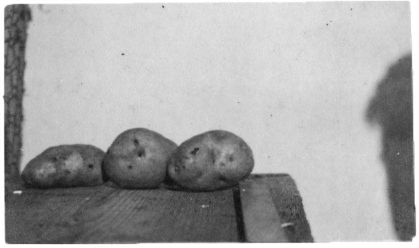

Fig. 2

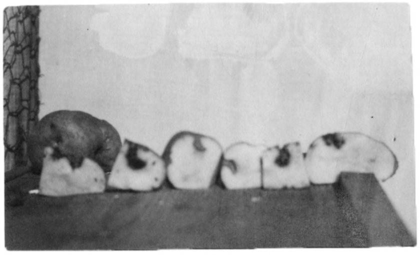

Fig. 3