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Biology and Control of the Wheat Wireworm, *Agriotes Mancus* Say

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WHEAT WIREWORMS

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BIOLOGY AND CONTROL OF THE WHEAT WIREWORM, *AGRIOTES MANCUS* SAY.[1]

W. A. Rawlins

One of the most important potato problems of upstate New York is the production of tubers free of the blemishes which render them of poor marketable quality. In recent years consumer demand for better and more uniform potato grades has stimulated grower interest in careful grading and packaging. Consumer discrimination against inadequately graded potatoes and subsequent loss of many choice markets have focused growers' attentions on potato defects, and their causes and measures of control.

These defects may be either of an external or an internal nature. Diseases and physiological changes cause various internal disorders that are not commonly noted on the surface. Defects that cause "rough" potatoes are the result of insects, diseases, unfavorable growing conditions, and the mechanics of handling from digger to grader.

A number of insects and allied forms feed on potatoes and produce various kinds of blemishes. In a previous publication (MacLeod and Rawlins, 1933) some of the more common injuries were illustrated and described in detail. Typical injuries were not always apparent in the field because one kind of defect was often masked by another. For instance, millipedes (*Julus* sp.) and scab-gnat maggots (*Sciara* sp. and *Pnxyia scabei*), commonly associated with potato scab, have been found to feed on and completely obliterate certain types of scab lesions. Their injuries are apparently of a secondary nature although there are reasons to believe that scab lesions are deepened or pitted by the invasion of millipedes and scab gnats. The scars, tunnels, and cavities caused by the feeding of wireworms and white grubs are chiefly primary; that is, without respect to other injuries. While each typical injury is distinct, the occurrence of many different types on the same tuber causes a confusing complex.

FIELD SURVEYS

A perspective of this tuber-defect problem may be obtained from field surveys made during the fall seasons of 1931 and 1932. With a number of departments cooperating in these studies and interested in particular phases of the problem, detailed and thorough investigations were made possible. Strictly from the entomological standpoint, it was essential to determine the factors concerned in the distribution of tuber defects and the causative organisms involved. The data obtained not only gave information on the extent of the defect problem but also were used as a basis for experimental field work.

The procedure of the survey was simple. Representative farms in the various potato-producing areas of the State were visited during harvest time and the tubers examined before being picked up in the field containers.

[1]The material presented in this bulletin is a resume of a thesis offered to the faculty of the Graduate School of Cornell University, June 1936, in partial fulfillment of the requirements for the degree of doctor of philosophy.

Author's acknowledgments. The writer is most grateful to Dr. G. F. MacLeod, formerly at Cornell University, for his direction, advice, and encouragement during the course of this work. The keen interest and generous cooperation of potato growers and county agents are also appreciated.

At least twenty samples of five tubers each were selected at random and all the injuries were recorded as to severity and classification. In many instances where more than one soil type existed in the same field, data were collected for each type.

Generally one or more kinds of injury were found in each field, and frequently tubers were damaged with a variety of injuries. The summarized records express in table 1 the relative proportions of the most common defects, exclusive of mechanical injuries, present on the tubers examined. Inasmuch as a large number of fields in most of the upstate potato-producing sections were visited, the survey data accurately indicate the gravity of the defect problem at the beginning of the present investigations.

TABLE 1. PERCENTAGES OF POTATO-TUBER DEFECTS FROM SURVEYS AT HARVEST TIME IN UPSTATE NEW YORK

County	Number of records	Uninjured	Scabby	Rhizoctonia	Wireworms	Gnats	Millipeds
Summary for 1931							
Wyoming	23	46.5	4.5	28.1	19.1	7.7	4.2
Allegany	13	62.4	2.2	20.5	8.7	5.6	1.8
Steuben	26	53.5	3.6	17.1	16.4	7.6	14.6
Erie	12	52.3	....	13.5	19.9	8.4	6.1
Genesee	11	48.6	24.2	19.1	7.9	11.9	11.9
Monroe	18	27.7	17.4	16.8	40.9	15.3	18.2
Ontario	10	30.0	25.7	21.1	16.7	30.7	24.3
Onondaga	10	38.4	24.4	20.0	8.8	19.0	22.9
General average		45.7	11.3	17.5	18.7	11.9	12.2
Summary for 1932							
Clinton	21	39.9	28.5	6.6	17.8	7.0	.2
Franklin	10	47.7	9.8	20.6	17.1	3.2	.7
St. Lawrence	1	38.0	47.0	8.0	10.0	16.0	3.1
Wyoming	8	38.5	11.3	33.6	18.0	13.8	3.8
Steuben	11	41.1	3.3	26.2	33.2	8.6	10.4
Allegany	10	43.0	10.1	26.4	34.3	2.9	3.5
Erie	8	43.1	10.5	7.2	15.9	12.3	37.3
Genesee	13	36.7	19.7	27.2	18.6	11.5	12.6
Monroe	11	13.7	38.4	38.3	31.6	28.1	4.8
Ontario	10	34.2	21.7	25.9	23.0	21.6	13.4
Oswego	13	24.5	10.2	52.8	26.8	8.9	9.8
Onondaga	8	56.4	9.5	17.5	13.1	9.0	8.9
Oneida	9	58.9	10.1	17.1	11.0	10.3	11.9
General average		42.4	15.6	22.6	20.8	10.8	9.6

For the two years 1931 and 1932, referring again to table 1, more than one-half of all the tubers examined were damaged by insects and diseases. Of these injuries, excepting Rhizoctonia which produces a superficial flecking on the surface of the tuber and is therefore not a severe defect, wireworm injury was the most serious and widespread. In the respective two years 18.7 per cent and 20.8 per cent of the tubers were injured by wireworms. The injury was quite generally distributed throughout the State, although it was more important in some counties than in others. Even within neighborhoods the amount of wireworm injury varied considerably from farm to farm. It has been a common experience to find heavily infested fields with seriously injured potato crops near or bordering fields that were comparatively free of the pest.

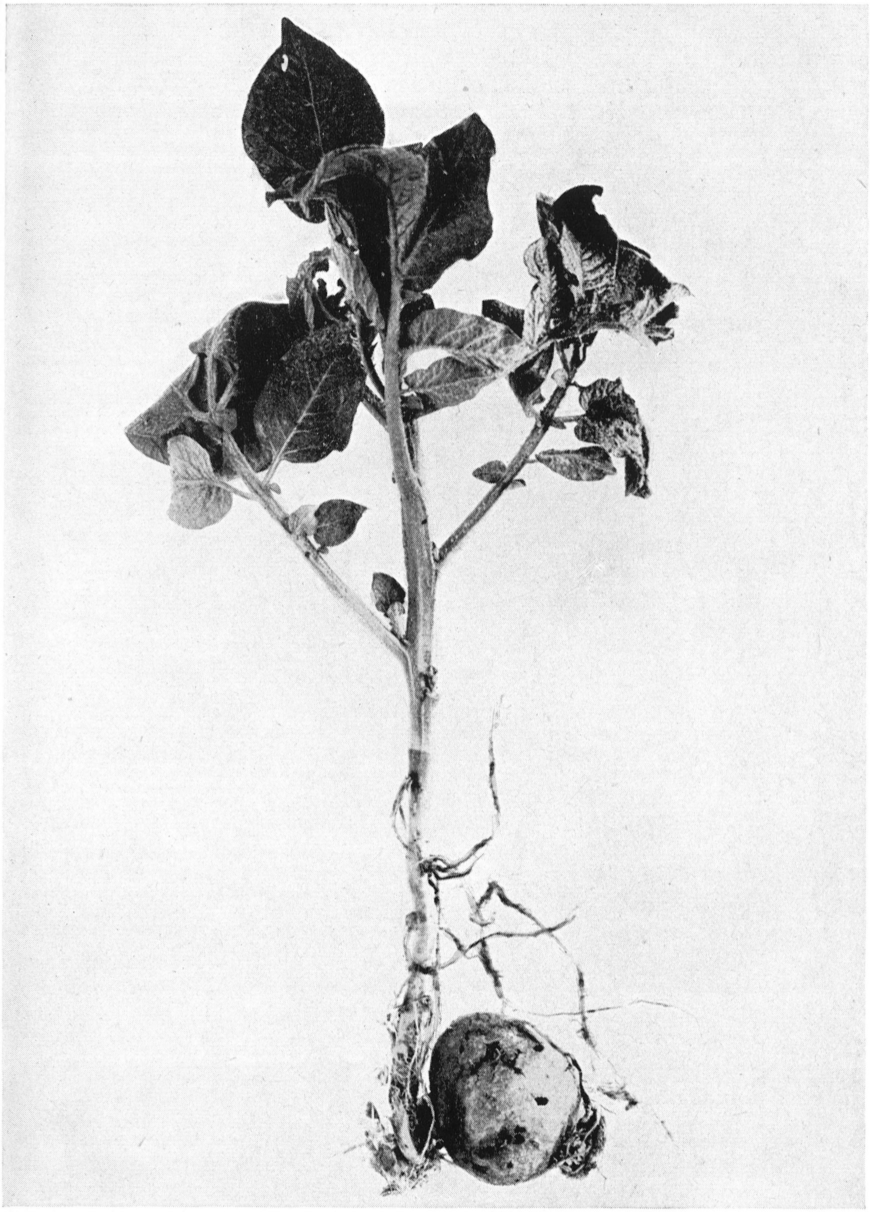


FIGURE 1. WIREWORM INJURY TO THE SEED TUBER
The tunnel entrances can be seen on the uncut surface

WIREWORM INJURY TO THE POTATO PLANT

The underground portions of the potato plant, seed piece, stems, stolons, and tubers are subject to wireworm attack. While injury is usually severe on all these parts, from the production standpoint damage to the tubers is the most noticeable and significant. The damage to tuber quality represents a much greater loss to the potato grower than does reduction in yields caused by wireworms feeding on seed piece and plant.

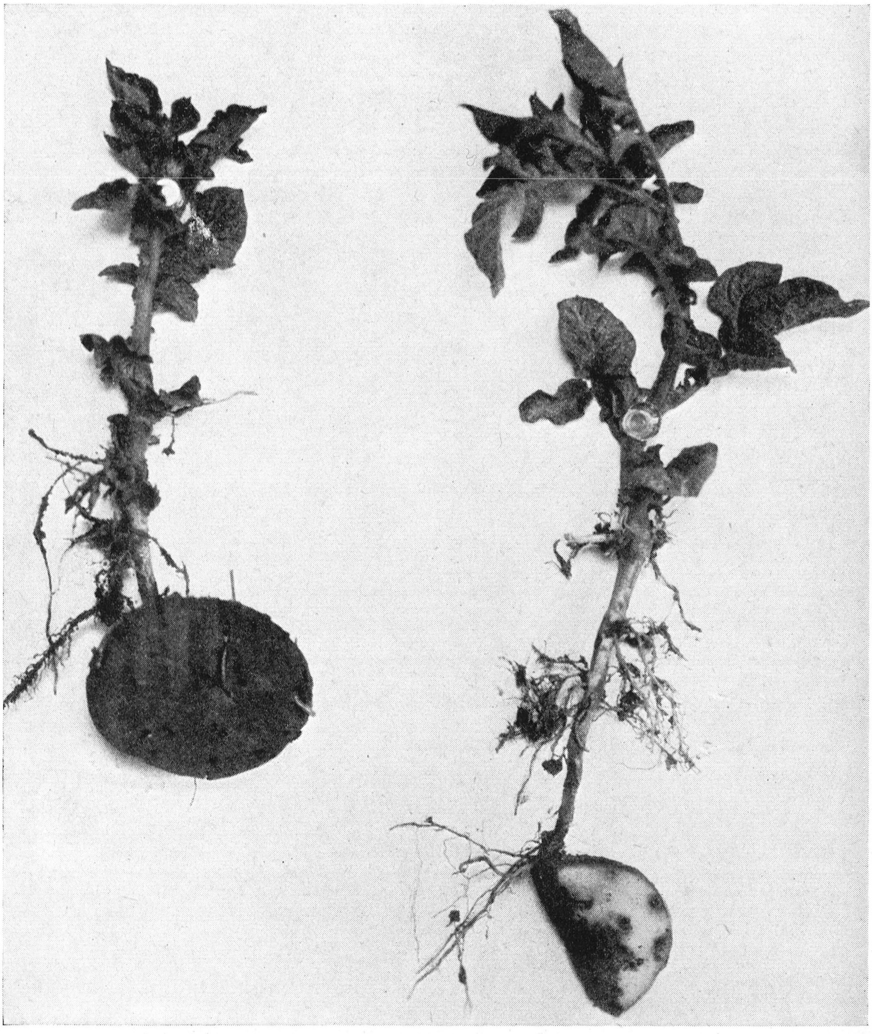


FIGURE 2. SEVERE INJURY TO THE POTATO SEED PIECE
Wireworms tunnel and honeycomb the interior

Seed-piece injury

Soon after planting, wireworms attracted by the seed pieces migrate to the potato hill where they immediately enter the mother tuber (figure 1). Within a short time seed pieces become interlaced with numerous tunnels which, in cases of prolonged feeding, leave the interior completely honey-combed (figure 2). The mother tuber remains attractive to the wire-

FIGURE 3. A GIRDLED STEM OF A POTATO PLANT, CAUSED BY THE FEEDING OF WIREWORMS

worms until the flesh completely disintegrates. Even then, some larvae remain in the rotted spongy interior, which at this time probably contains very little food material. Wireworm feeding on the seed piece not only reduces the tissue in which are stored nutrients for plant growth but also creates entrance points for bacteria and rot fungi, thus promoting rapid seed-piece decay.

Stem injury

The stem is subject to attack from the time the sprout forms until the stalk becomes hard and woody. Injury is usually slight except in cases of heavy wireworm infestations. Much of the stem-feeding occurs after the seed piece has decayed. The wireworms are then no longer attracted to the seed piece and turn their attentions to more favorable food. Although slight scarring of the stem does not seem to cause any depression in growth of the plant, severe injury results in the girdling or severing of the stem (figure 3). Girdled plants make a stunted abnormal growth similar to that resulting from injury by Rhizoctonia disease or by mechanical abrasion. Many small irregularly shaped tubers are produced immediately below the soil surface and frequently aerial tubers form in the leaf axials (figure 4). Such hills are worthless.

Tuber injury

Since the tubers are the crop, tuber injury is the most important of the damage to potatoes and the chief concern to the grower. Wireworms bore into the tubers leaving scars and holes on the surface. The tunnels extend to varying depths into the tuber flesh and may be so numerous that the tubers are completely honeycombed. There are several types of wireworm injury. Enlargement of the tunnels through continued tuber growth after injury or through invasion by soil organisms, causes variations from the typical and more familiar type of injury. For example, the tunnels in newly set and rapidly growing tubers become enlarged with tuber expansion and appear as funnel-shaped cavities characteristic of early wireworm injury (figure 5, A). Tunnels made when the potatoes have matured appear on the surface as small, round, clean-cut holes. This injury, designated as the late seasonal type (figure 5, B), is most typical of wireworm damage. A third variation of injury is locally referred to by growers as *pitting*. Characteristic of pitting are the dark, ragged, cankerous areas at the edges of the holes (figure 5, C), caused by the invasion of the tunnels by Rhizoctonia and other soil fungi. The term for this type of wireworm injury is loosely applied, inasmuch as any defect of a pitted nature, not necessarily caused by wireworms, is often called pitting. Certain other types of wireworm injury occur but are not common. Occasionally tubers are covered with numerous small "warts", or galls (figure 5, D), resembling to some extent enlarged lenticles. These "warts" may be formed, as a response to wounding, through abnormal tissue growth, with the result that the edges of the tunnels protrude slightly. Millipeds and scab-gnat larvae commonly enter wireworm holes and leave additional defects characteristic of their feeding. These various surface scars give injured tubers a rough, spotted appearance. However, it is the network of tunnels within the tuber which causes excessive and annoying waste when injured potatoes are prepared for the table. For this reason wireworm damage is one of the most important of the tuber defects.

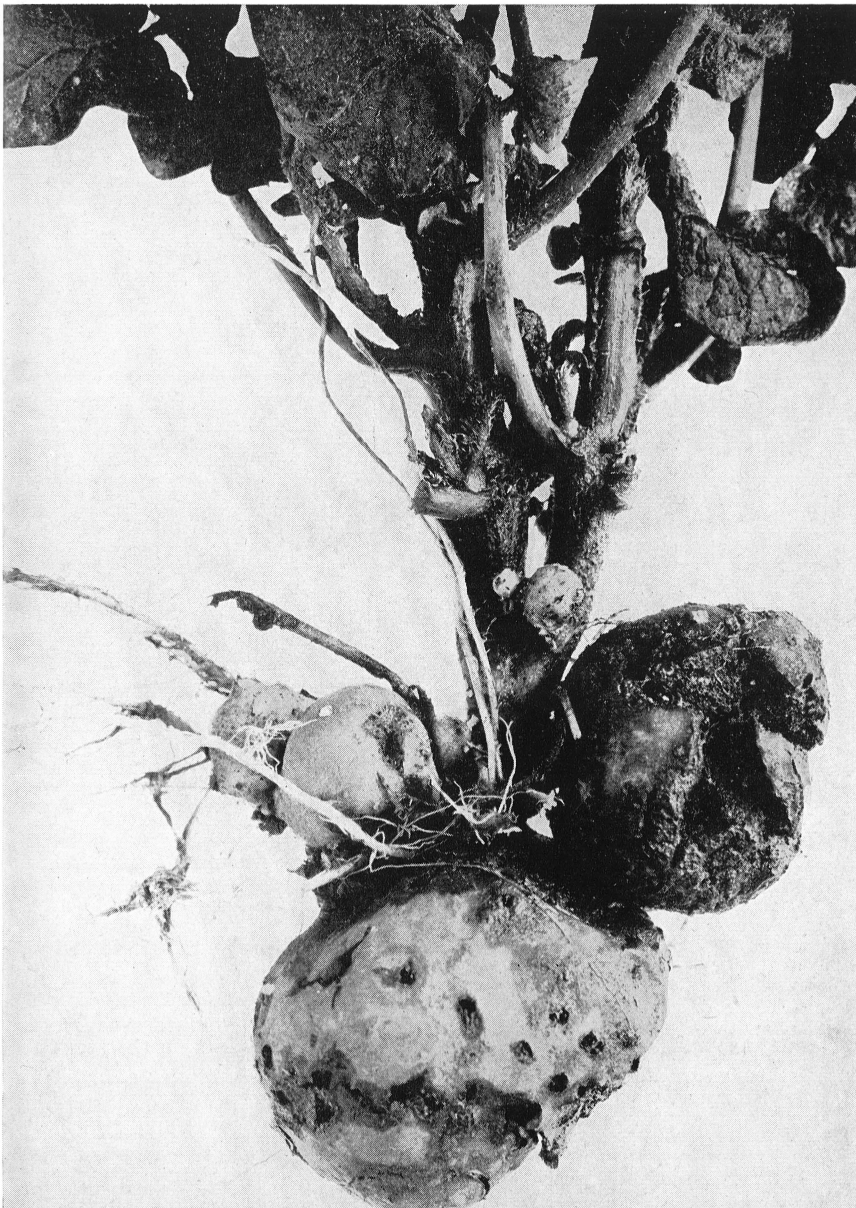


FIGURE 4. INJURY TO THE NEWLY FORMED TUBERS
These tubers will be small, misshapen, and worthless

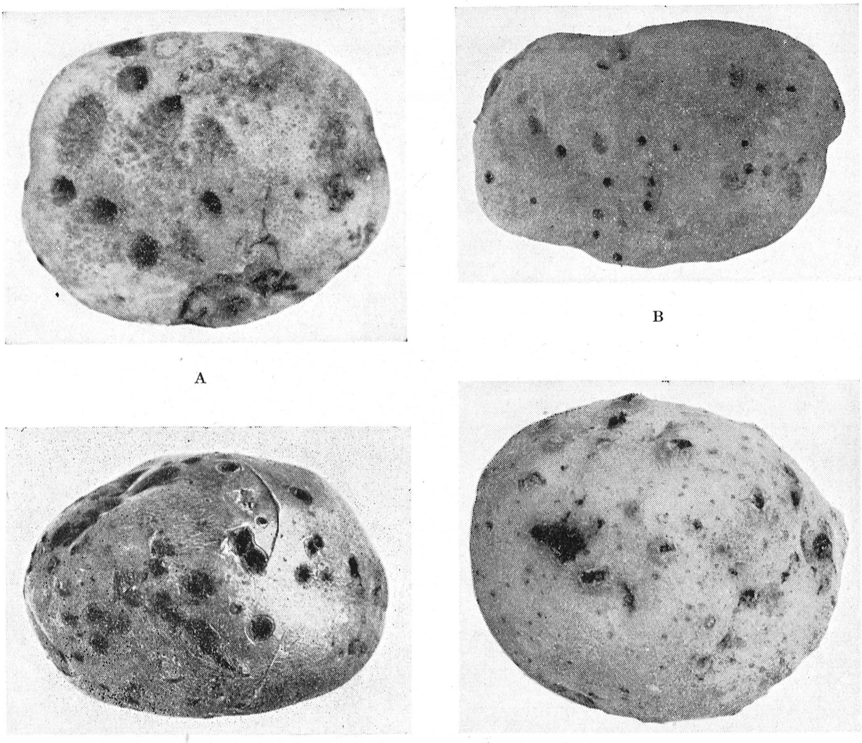


FIGURE 5. WIREWORM INJURY TO POTATO TUBERS

A. Early injury   C. Pitting
B. Late injury   D. "Pimples"

WIREWORMS IN POTATO FIELDS

Although 200 species of Elaterids have been recorded in New York State, only a few of these were commonly found in potato fields. The most abundant ones listed in order of their importance are the wheat wireworm (*Agriotes mancus* Say), the eastern field wireworm (*Limonius ectypus* Say), and the corn wireworm (*Melanotus* sp.). The abbreviated wireworm (*Cryptohypnus abbreviatus* Say), and the wireworm (*Aeolus mellillus* Say), occasionally were numerous but caused little or no damage to potatoes. In two instances while making wireworm surveys in potato fields, populations of abbreviated wireworms were as high as five larvae in each potato hill, but no tuber injury was evident. Generally these wireworms occur with populations of the more injurious species or in similar habitats.

Recent studies of the more common wireworms have quite clearly indicated that they differ considerably in life history and habits. This is important from the practical control standpoint because the most promising and most practical control measures are based upon certain peculiarities in the habits of these wireworms. Therefore, control measures used against one wireworm may not be effective against another species. Hence, it is important for potato growers to acquaint themselves with the distinguishing characters of these wireworms to properly diagnose their wireworm problems. Little difficulty should be encountered since the larvae of each species belong to a different and easily distinguishable group. For practical purposes, color of the wireworm and the shape of the ninth, or last conspicuous, abdominal segment will serve as identifying characters. The wireworm larva has ten abdominal segments, the last of which is small and lies below the larger ninth segment. In actuality the ninth segment, when viewed dorsally, appears to be the caudal segment. The three important wireworms are illustrated in plate I and in figure 6, which indicate comparative differences in larval characters referred to in the descriptions which follow.

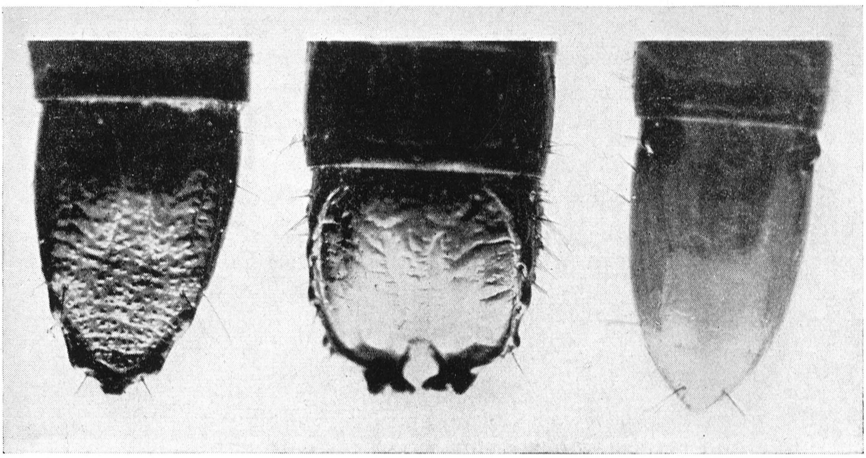


FIGURE 6. THE NINTH ABDOMINAL SEGMENTS OF THE THREE WIREWORMS MOST INJURIOUS TO POTATOES

Left to right: corn wireworm (*Melanotus* sp.); eastern field wireworm (*Limonius ectypus* Say); wheat wireworm (*Agriotes mancus* Say)

Differences in the beetles are not so outstanding as in the larval stages, although size and shape are distinctive characters for those well acquainted with wireworms. Since many species are numerous during the egg-laying and flight period, identification of beetles should be based on careful taxonomical examination. Some idea of the comparative sizes and shapes of the three important Elaterids may be obtained from figure 7.

The wheat wireworm (*Agriotes mancus Say*)

When full grown, the larva, or wireworm, is approximately three-fourths inch to one inch in length, slender, and a waxy light straw color. The caudal margins of each segment are somewhat darker than the remaining portion of the segment; thus, the larva appears ringed. The pointed ninth segment bears two black eyelike spots, or invaginations. This latter character is prominent and easily distinguishable on all of the wireworms belonging to the Agriotes group.

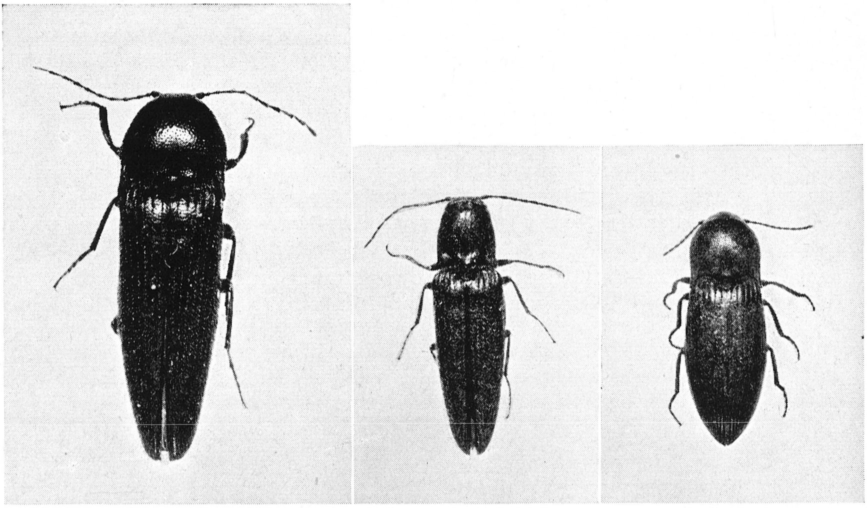


FIGURE 7. BEETLES OF THE THREE WIREWORMS MOST INJURIOUS TO POTATOES
Left to right: corn wireworm (*Melanotus* sp.), ×3; eastern field wireworm (*Limonius ectypus* Say), ×2½; wheat wireworm (*Agriotes mancus* Say), ×3

The beetle of the wheat wireworm is about one third of an inch in length, robust, and dark brown in color. The color varies somewhat from a light brown to almost black but is usually a dark shade. In the field, beetles are generally found near moisture under stones and clods of soil. They are rather inactive and are seldom noted moving about or in flight.

The eastern field wireworm (*Limonius ectypus Say*)

The eastern field wireworm, when mature, is also approximately an inch in length and is more robust than the wheat wireworm. It is darker in color, being a light tan. The ninth segment is distinctive. It is flattened dorsally and divided into two lobes, the points of which curve inward similarly to a pair of calipers. This larval character is found in a number of other species, and hence they may be confused with the eastern field wireworm. However, these other wireworms are rarely abundant and are not important as pests of potatoes.

The beetle of the eastern field wireworm is approximately seven-sixteenths of an inch in length and dark brown in color. Males are usually somewhat smaller than the females and are more slender. This species is more active than the wheat wireworm and is often noted in flight.

The corn wireworm (*Melanotus sp.*)

The corn wireworm is the largest of the three species. It is more than an inch in length and glossy red brown in color. The ninth segment is flattened dorsally and slightly scalloped along its lateral margins. The beetle is slightly more than one-half of an inch in length and glossy dark brown to black in color. It is wedge-shaped because the elytra narrow gradually from the base of the wide thorax. This is a distinctive character of most of the beetles belonging to the Melanotus group.

Distribution

These wireworms are widely distributed throughout the State in most potato-growing regions. Fortunately, few instances have been recorded of mixed infestations in which two or all three species were present in large numbers. Ordinarily, infestations are predominantly one species with an occasional wireworm of another kind. In a few cases heavy populations of both wheat and corn wireworms were found in the same fields. To date, survey records show that eastern field wireworms are seldom intermixed with other species. Of the three wireworms, the wheat wireworm is most abundant and widely distributed, probably accounting for most of the wireworm damage to potatoes in the State.

The regions and soils infested by the various species of wireworms differ greatly. The wheat wireworm is usually found in the heaviest soil types, the silt and clay loams of the dairy-farming regions where sod crops are an important part of the potato rotation. Corn wireworms are found most abundantly in orchard and meadow sods that have been left standing for many years. Occasionally light infestations occur in fields that are rotated frequently with cropping systems that include clover and timothy sod. Eastern field wireworms infest sandy soils almost exclusively. This interesting relationship has been noted in fields with zones of light and heavy soil types. Infestations were restricted to the sandy soils, with the result that injury to crops on these areas was severe, whereas on the heavier soil areas injury was nil.

Although all the above-mentioned wireworms feed on potatoes, the amount of damage varies with the species. This is strikingly brought out from examinations made in many potato fields in western New York. This survey was made in 1934 as a study of the relationship of infestation to injury. Potato hills in a number of fields were selected at random, the injured tubers counted, and the soil sifted for wireworm larvae. When more than one species was found in a hill, that hill was discarded and not considered in the data. In summarizing the data (table 2), the numbers of

TABLE 2. COMPARISONS OF NUMBERS OF WIREWORMS IN RELATION TO FREQUENCIES OF POTATO TUBER INJURIES

	Number of wireworms			
	1 to 2	3 to 5	6 to 9	10 or more
Eastern field wireworms:				
High areas	1:12	1:14	1:4	1:5
Low areas	1:6	1:5	1:4	1:4
Wheat wireworms:				
High areas	1:3	....	....	....
Low areas	1:2	2:3	3:4	6:7
Corn wireworms:				
High areas	1:5	....	....	....
Low areas	1:2	1:1	1:1	1:1

wireworms found were placed in four groups (1 to 2, 3 to 5, 6 to 9, and more than 10 wireworms to a hill). The data from knoll and low areas were recorded separately since wireworm populations and damage in these different sites make an interesting comparison. The amount of damage caused by any one population group is expressed as a ratio of injured to uninjured tubers. Thus the ratio 1 : 10 indicates that one tuber in ten was injured by wireworms. Judged on this basis, wheat wireworms and corn wireworms were most destructive because they injured a proportionately greater number of tubers than did the eastern field wireworms. For example, 3 to 5 wheat wireworms to a hill injured two of every three potatoes, whereas the same number of eastern field wireworms injured only one of every five tubers.

It is interesting too (table 3), that the knoll areas were only slightly

TABLE 3. COMPARATIVE NUMBERS OF FIVE SPECIES OF WIREWORMS IN HIGH AND LOW AREAS OF POTATO FIELDS

Species	Total numbers of wireworms (360 hills)	
	High areas	Low areas
Limonius ectypus Say	182	234
Agriotes mancus Say	25	258
Melanotus communis Gyll	14	112
Cryptohypnus abbreviatus Say	12	42
Aeolus mellillus Say	2	15

infested with wheat and corn wireworms. Hill populations of more than 1 to 2 wireworms were not found in these areas. Eastern field wireworms infested nearly all parts of the field although low areas generally had higher populations than had knoll areas.

INVESTIGATIONS ON THE WHEAT WIREWORM

The yearly losses from wireworms aroused intense interest on the part of growers for an intensive and long-time research program. Therefore, investigations were initiated in 1930 with the establishment of a field laboratory near Gainesville in Wyoming County. During the following six years, laboratory and field studies were conducted on the wheat wireworm and the material presented in this bulletin is the summary of these researches.

HISTORY

The wheat wireworm originally inhabited the forests and grasslands before the advent of the intensive agriculture of today. It is probably one of the oldest pests of potatoes and was frequently mentioned by entomologists and agriculturists in their early writings. In these accounts they summarized the then meager and fragmentary knowledge of the biology and control of wireworms, and suggested further methods of control which had proved of value for some of their correspondents. Although much of this information was not based upon careful investigations, many of the observations have been confirmed through later experiments. Many of the early wireworm "remedies" have been handed down to the present day and are often mentioned as valuable adjuncts to the wireworm-control program. The use of salt, for instance, was highly regarded years ago for repelling or killing wireworms and is still suggested by many growers as beneficial. However, careful experiments have definitely shown that salt has no value against wireworms except in amounts toxic to growing crops.

The first extensive researches were undertaken by Comstock and Slingerland (1888, 1891), and their results were published in the first bulletins issued by the Cornell University Agricultural Experiment Station. After engaging in a large number of carefully executed experimental trials they regretfully reported that their experiments had "failed to discover a single satisfactory method of protecting seed, or of destroying immature wireworms in the soil."

Experimental work then lapsed for some years until resumed by Hyslop (1915–1916) who contributed to the knowledge of life history and control. More recently Hawkins (1936) conducted many and extensive studies on the wheat wireworm in Maine and summarized his results in a detailed bulletin from that Station. Wireworm work was again resumed in New York State with the inception of the present project in 1930, the results of which are similar to those published by Hawkins.

BIOLOGY OF THE WHEAT WIREWORM

EGG STAGE

The tiny pearly white eggs (figure 8, A) of the wheat wireworm are laid in crevices of the soil, or under stones and surface debris. They are nearly spherical in shape, unless distorted when squeezed between soil particles in the process of oviposition. The eggs are very small, 0.5 of a millimeter, or approximately 1/50 of an inch, in length, and 0.45 of a millimeter in width.

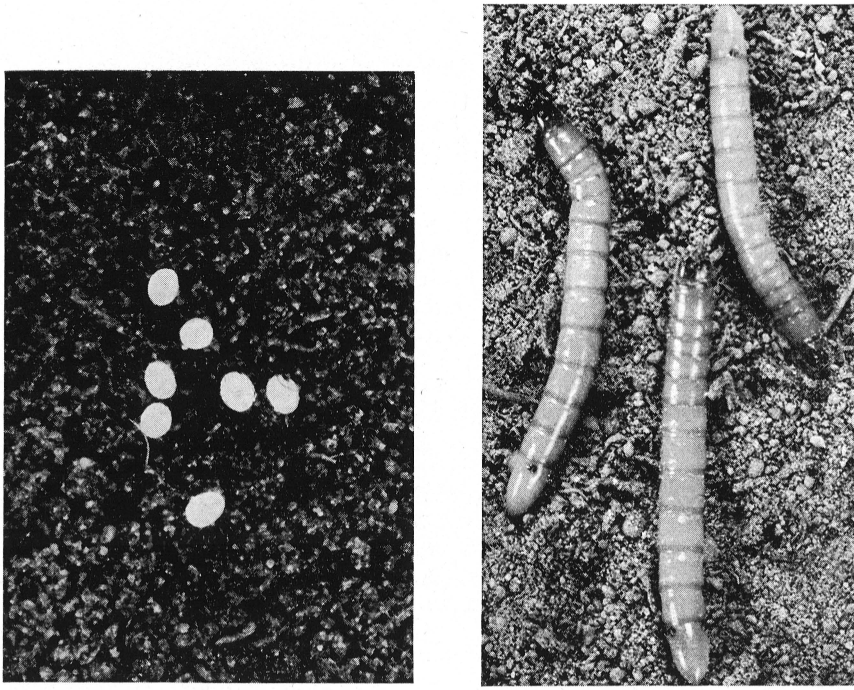
When the eggs are first laid they are covered with a coating of sticky material which cements soil particles to the egg coverings. In such cases it is practically impossible to distinguish eggs covered with soil from small soil particles. Hence, it is difficult to find the eggs in oviposition cages and in the field.

To overcome this difficulty it is necessary to wash soil containing the eggs through a 60-mesh sieve, which is fine enough to retain the eggs. A gentle stream of water is carefully applied to avoid forcing the eggs through the screen or causing injury. The eggs are then sorted from the debris and lifted out by a blunt dissecting needle or by a camel's hair brush.

A flotation method is useful, especially in field work where large soil samples are handled. The debris and eggs remaining after thorough washing of the samples are mixed with a strong solution of either common salt or magnesium sulfate. The eggs float on the surface of the saline solution and are then readily separated from soil particles, which settle rapidly to the bottom. The eggs should be washed free of the salt to avoid injury to the developing embryos.

After removal of the eggs from the water they may be dried by a short exposure to dry air. However, they are so extremely susceptible to desiccation that exposures of one-half hour to dry air or soil will cause the eggs to lose moisture and collapse. They are then no longer viable.

Determination of hatching is difficult when the eggs are mixed with soil. Because of their small size, magnification is necessary and the separation of newly hatched larvae from the soil mass is time-consuming. A satisfactory method of observing the eggs and at the same time protecting them from molds is to keep them under water. Eggs hatch normally under water and the young larvae remain alive from two to three days.



A B

FIGURE 8. EGGS AND LARVAE OF WHEAT WIREWORM

A. The eggs are tiny and pearly white (×8)
B. The characteristic black eyelike spots can be seen on the ninth abdominal segment of the larva (×2½)

Under temperatures prevailing in the field laboratory, the eggs hatched after periods varying from 22 to 28 days. The average incubation period was approximately 25 days. For each batch of eggs laid during a 24-hour period, two to four days elapsed between the beginning of hatching and the end.

LARVAL STAGE

Wireworms in the first year

Young larvae upon hatching are milky white in color and exceedingly small, measuring 1.5 to 2 millimeters in length. They grow slowly during the first year, attaining a length of from 3.5 to 6 millimeters. This is a noticeable variation in size and occurred even in laboratory-reared populations of the same approximate age. Measurements of first-year wireworms taken from field samples were found to follow the usual distribution curve with an average at approximately 4.5 millimeters.

Wireworms in the second year

During the second year the wireworms grow more rapidly and are particularly injurious at this time. Molting in the field occurred chiefly during two periods, in the spring (May and June), and again in the fall

THE THREE WIREWORMS MOST INJURIOUS TO POTATOES

Left to right: corn wireworm (*Melanotus* sp.); eastern field wireworm (*Limonius ectypus* Say); wheat wireworm (*Agriotes mancus* Say)

(August and September). During the molting periods larvae cease feeding and become quiescent while the new cuticule is forming.

At the end of the second year, variations in larval size are still evident. This is shown from measurements taken on wireworm populations found in two fields on the same farm, one cropped to potatoes and the other in sod. Infestations in both cases started in sod the two years before, and only the second- and third-year wireworms were considered in the measurements. The wireworms found at harvest time in the potato field measured 9 to 20 millimeters in length (figure 9), a spread of 11 millimeters. Most of the larvae were in the larger intervals, 15 millimeters and above. Wireworms in the sod, exclusive of the current season's infestation, varied in size from 6 to 18 millimeters. The greater proportion of the population was between 8 and 13 millimeters. This bit of evidence indicates that some crops influence the growth of wheat wireworms and thus may influence the length of the life cycle. This presents an interesting problem that may be of significance in planning control measures.

Wireworms in the third year

Most of the larval growth, provided conditions are favorable, takes place during the second year. Previous to pupation in the third year, wireworms are 15 to 22 millimeters in length. However, size is not a true criterion of maturity, as judged by the onset of pupation. In both laboratory-reared and field populations only a portion of the third-year wireworms pupated. The remainder required a fourth year of growth before transformation. It is possible that a few individuals may require five years for full larval development.

Hibernation

During the winter months, wireworms hibernate at varying depths in the soil. Although there is a slight migration downward in the soil, many

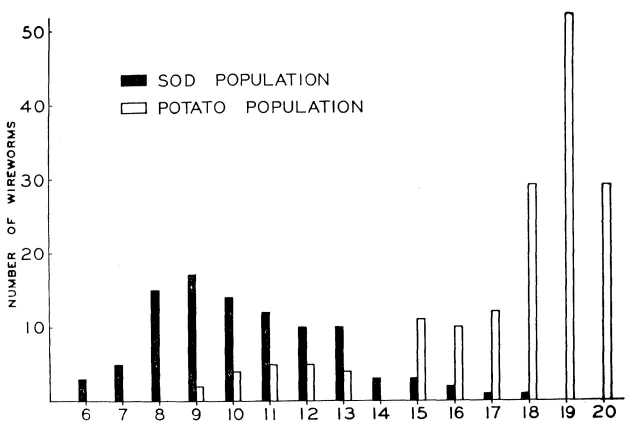


FIGURE 9. SIZE VARIATIONS OF SECOND- AND THIRD-YEAR WIREWORMS FROM POPULATIONS IN FIELDS PLANTED TO CLOVER-TIMOTHY SOD AND TO POTATOES

of the wireworms remain within the frost zone. In many instances wireworms found in frozen soil revived and appeared normal. Many workers have reported that exposures to extreme cold temperatures will kill wireworms. However, such temperatures are seldom reached during the normal winter even in the frost zone. Early in the spring the wireworms move upwards to feed on available plant roots. When the topsoil is moist, wireworms are often found under stones and surface debris.

Food and food plants

Wireworms are indiscriminate feeders. Their food consists of the underground parts of living plants and, according to many authorities, it also includes humus and small soil-inhabiting animals. The list of food plants is almost an endless one. Injury is particularly severe to sprouting seeds, seedlings, transplants, roots, and tubers. Crops severely injured are usually designated *susceptible*, as distinguished from *immune* crops, which are able to withstand wireworm attacks without loss or damage.

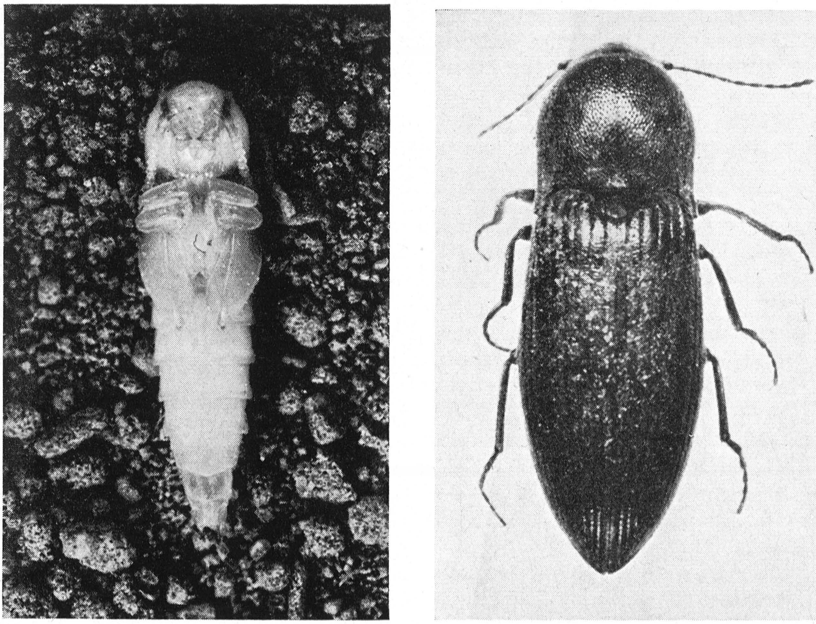
The role of humus as food for wireworms is a controversial question. Some investigators believe that the decaying organic material of the soil is a predominant part of the wireworm diet. In fact the use of farmyard manure and green-manure crops has been suggested as a means of reducing injury, since it was believed that wireworms attack growing plants only in the absence of humus. However, wheat wireworms have caused severe damage to potatoes in soils well supplied with organic matter.

The food of the newly hatched wireworm is composed chiefly of the succulent underground parts of living plants, the roots, stems, and tubers. Although humus is abundant in soils infested by wheat wireworms it is not important in their diet. Newly hatched larvae fail to survive in these soils unless roots of growing plants are available for food. If these newly hatched larvae ingest particles of humus they are either unable to utilize this material as food or the humus does not contain enough food substance to support life.

The older second- and third-year larvae are considerably more resistant to starvation than are newly hatched wireworms. Individuals have remained alive in soil without growing plants for at least two years, but larval growth was apparently static during this time. However, a high mortality occurred during the first year of the starvation period and only a few of the original number remained alive when the experiment was discontinued.

PUPAL STAGE

A few days previous to pupation during the latter part of July and throughout the month of August the mature wireworms cease feeding and construct their pupal cells (figure 10, A). By rolling and twisting movements the larvae form small cavities large enough to accommodate the pupae. The larvae then become quiescent, and within a short time transform to white wax-like pupae which bear a close resemblance to the beetles in size and shape. From this apparently lifeless form the beetles emerge in approximately two weeks. Unless disturbed they do not venture from their pupal cells until the following spring.



A B

FIGURE 10. PUPAL AND ADULT FORMS OF THE WHEAT WIREWORM
A. Pupa (×4)
B. The dark-brown adult, or click beetle (×6)

ADULT STAGE

The beetles, known as *click beetles*, or *skip jacks*, because of their ability of springing into the air when turned on their backs, leave the pupal cells as soon as the soil warms up in the spring and make their way to the surface during late April and May (figure 10, B). They are not ordinarily noticed in the field unless special efforts are made to collect them. Beetles emerging in cultivated fields hide under stones, soil clods, and other surface objects, where they collect in large numbers especially during the mating season. In sod and grasslands the beetles find shelter in the crowns of the plants and in crevices in the soil. The heavy cover of sod and grass offers so many hiding places for the beetles that they are difficult to find except by sweeping with an insect net.

Migration

Wheat-wireworm beetles are most active during warm days when the temperatures are above 85° F. They are not so active, however, as many other Elaterids. In cultivated fields an occasional individual may be seen during the daytime running from one place of concealment to another. Sometimes they are noticed perched on stones or clumps of soil. Spasmodically they make feeble attempts to take flight.

During warm days of May and June large numbers of the beetles may be conveniently collected from sod and weedy growth in infested fields.

A large proportion of these are males. Upon close examination they are found resting on the stems and foliage of the vegetation. When disturbed they immediately fall to the ground and disappear into the foliage cover. Observations have been made many times of beetles resting on foliage and flowers, but no evidence of feeding has been noted. In cages the beetles chew the cut edges of grass clippings and apparently ingest some of the pulpy material. They also feed voraciously on sugar syrup, molasses, and honey.

On a few occasions wheat-wireworm beetles were noted in flight. The evidence indicates, however, that they are not active fliers and probably migrate very little by flight. Beetles were seldom taken in sweepings on bushes and shrubs along woodlands and fence rows bordering infested fields. Other species of the genera Limonius, Ludius, and Melanotus are common on wild cherry, blackberry, and other shrubs. Beetles captured on tanglefoot traps were chiefly of these species. The traps were constructed of hardware cloth tacked to frames and mounted on posts four to five feet from the ground. Tanglefoot was liberally applied to the wire cloth to make a sticky surface. Beetles flying against the tanglefoot were captured and retained on the screens. The summarized catch records of table 4 indicate that wheat-wireworm beetles are not as active fliers as the other species.

Beetles are extremely susceptible to desiccation and succumb when exposed to long periods of dry air or soil. They are usually found in moist places close to the soil surface. For this reason fields covered with vegetation are more favorable to adult life than are cultivated fields. Many investigators have suggested that the beetles migrate to grasslands for oviposition. Observations by the writer have not intimated such a migration.

TABLE 4. TANGLEFOOT-TRAP RECORDS OF ELATERID BEETLES CAPTURED IN 1934 AND 1935

Number of trap	Crop in field in which trap was located	Numbers of *Agriotes mancus* beetles captured	Numbers of other species captured
1	Sod	0	2
2	Sod	0	14
3	Sod	5	65
4	Oats	3	7
5	Potatoes	0	45
6	Potatoes	0	11
Total		8	144

The attractiveness of moisture and places of concealment provided a means of collecting beetles in fields frequently tilled by harrow or cultivator. Baits similar to those suggested by Comstock and Slingerland (1891) were used. These baits consisted simply of a handful of grass or weeds placed on moist soil and covered with a shingle. During the night the beetles, attracted by the baits, congregated in the foliage and were collected the following day. This method of collecting beetles works very well for cultivated fields but is ineffective in sod and grasslands.

Beetles were present in large numbers on cultivated fields during the egg-laying period as long as moisture conditions were favorable. A thorough survey of two fields by the use of baits showed that beetles did not migrate from infested areas to those uninfested. As mentioned before, infestations of wheat wireworms are spotted. They occur chiefly in the low portions of the field. The collection data for the two fields show that the beetles do not migrate from the low areas of the fields to the knolls, which are relatively free of wireworms.

This is not surprising since beetles migrate chiefly by running over the soil surface. The distances traversed are therefore limited. This is brought out in an experiment designed to obtain further information on beetle migration. A large number of marked beetles were released on a cultivated field and allowed to disperse. Daily bait catches were examined for marked beetles during the period of beetle activity. More than half of the beetles released were again captured in the numerous baits surrounding the point of release. The longest recorded distance traveled by the beetles was about eleven yards.

Bait records taken in three fields during the years of 1934 and 1935 shed some light on beetle activity. The spring of 1934 was marked by a shortage of rainfall, whereas precipitation was more plentiful in 1935.

In 1934 the topsoil surface dried out quickly, especially after cultivation. When the soil had dried out, unfavorable conditions prevailed and the beetles disappeared. After the start of egg-laying in the laboratory (table 5) on June 10, only one beetle was captured in the traps. Dead

TABLE 5. BAIT-TRAP RECORDS OF WHEAT-WIREWORM BEETLES IN A CULTIVATED FIELD, 1934

Date of baiting	Number of beetles	Observations
May 28	146	Soil moist; beetles under stones and lumps of soil
May 30	122	Same as above
June 2	176	Field harrowed; soil drying out
June 5	34	Soil very dry
June 10	...	Egg-laying began in laboratory
June 13	1	Potatoes planted; topsoil very dry
June 27	0	Plants above ground; weeded

beetles which had apparently succumbed from desiccation were found under stones and under the piles of dried grass thrown aside after use in the baits. This would explain the absence of beetles in the baits after June 5, at which time the topsoil was very dry.

In the spring of 1935 rains were frequent and the seasonal rainfall was normal. The soil surface did not dry out so thoroughly as in the previous year, even with a number of cultivations. Beetles were collected in traps throughout June after egg-laying had started (table 6). Dissection of female beetles at each collection indicated that they had laid nearly all of their eggs at that time. In this instance, at least, migration of beetles to grasslands for oviposition was not substantiated.

Oviposition

Eggs are deposited in the soil either singly or in groups. In laboratory cages, the females place their eggs in cracks and crevices of the soil and under surface objects. No attempts are made by the beetles to burrow

TABLE 6. BAIT-TRAP RECORDS OF WHEAT-WIREWORM BEETLES IN TWO CULTIVATED FIELDS, 1935

Date of baiting	Number of beetles	Observations
Field 1		
May 28	163	Soil moist
June 7	189	Soil drying out slightly; egg-laying started June 6 in laboratory
June 13	201	Same as above
June 14	701	Soil moist
June 30	21	Soil moist
July 5	8	Soil moist
Field 2		
May 29	16	Oats planted in this field; soil moist
June 4	94	Soil moist; egg-laying started June 6 in laboratory
June 11	24	Soil moist throughout the baiting period
June 22	12	
June 29	12	
July 1	6	

deeply into the soil as do some other Elaterids. The eggs are usually deposited in the upper one-half inch of soil.

The number of eggs laid by single female beetles varies considerably under laboratory conditions. For ten individuals, the maximum number laid was 176 and the minimum number was 48. The average number was 104.9. Considerable difficulty was experienced in obtaining data on egg-laying because most of the female beetles died before laying all of their eggs. Beetles collected early in the spring did not oviposit unless fed on sugar solutions. Food appeared to be necessary during the oviposition period. However, the food requirements for the beetles is incompletely known at the present writing.

SUMMARY

The story of the life history is graphically indicated in figure 11. Beetles of the wheat wireworm leave their pupal cells early in the spring and appear on the soil surface during a period from May to late July. Eggs hatch in approximately three weeks. The young wireworms grow very slowly the first year, barely measuring a quarter of an inch in length by fall. Growth is most rapid during the second year. Some of the wireworms reach maturity and pupate during the third year of the life cycle. The remaining larvae transform to pupae the following year. Pupation occurs in late July and August. The final transformation to the beetle stage two weeks after the start of pupation completes the life cycle. The interval of time between the appearance of generations is three to four years.

CONTROL MEASURES FOR THE WHEAT WIREWORM

The efforts of entomologists have been directed towards efficient and practical methods of wireworm control since the beginnings of applied entomology. In a comprehensive review, Thomas (1930) briefly summarized the present knowledge of wireworm control, as included in more than two hundred references contributed from all parts of the world. A survey of this mass of literature reveals a wide diversity of ideas and considerable conflicting opinion. This is not surprising since the practical success of any control measure depends upon a complexity of factors which differ with wireworm species, crops, climates, and agricultural practices.

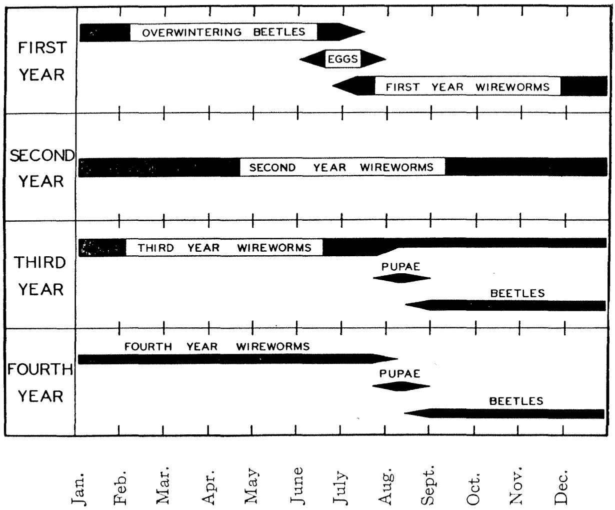


FIGURE 11. LIFE HISTORY OF THE WHEAT WIREWORM

Measures recommended and employed for the control of wireworms are as varied as they are numerous. Such methods employ the use of (a) soil fumigants and sterilizers, (b) seed protectants and repellents, (c) and cultural practices. Soil fumigants and sterilizers such as cyanides, chloropicrin, dichloroethyl ether, and others are injected into or mixed with infested soil. The toxic gases released rid the soil of the wireworms and other noxious organisms. Soil fumigation should be extremely practical because it would lend itself to most conditions and most of the soil fumigants have been found effective and useful. However, fumigating the soil is not practical for potato growers in New York and is therefore not recommended. Some of the objections to soil fumigants are their cost, mechanical difficulties in application, and toxicity to the crop.

Seed treatments with poisons and repellents have not proved of any value. Many of these materials quickly lose their repellency before the sprouts develop resistance to wireworm attack. The protection of the potato seed piece does not protect the developing tubers after the mother tuber has disappeared from decay. Very few substances used as seed treatments are either repellent or toxic to wireworms.

CULTURAL AND ROTATIONAL PRACTICES

Cultural and rotational practices are among the oldest and most commonly recommended methods for control of the wheat wireworm. Some of these practices are extremely effective in reducing damage and are practical because they can be fitted into the general farming systems. Wireworm control through proper revision of the potato rotations is being effectively used by growers.

The abundance of wheat wireworms in grasslands and long-standing sod crops has been often noted by investigators and potato growers. As early as 1867, Fitch (1867) in his eleventh entomological report stated that "it may be received as an axiom that wherever grass will grow the wireworms may be found for the roots of the various species all afford sufficient nourishment for their support." He then recommended that farmers follow meadows or sod with at least three years of cultivated crops before planting corn or potatoes. Many other workers since that time have suggested that the best method of control for the wheat wireworm is continued cultivation of infested fields.

One of the common potato rotations in New York, particularly in dairy-farming regions, includes three crops, sod (clover and timothy), potatoes, and spring grain. This rotation cycle requires three to four years for completion. Although the progression and kinds of crops vary from farm to farm, potatoes usually follow sod or hay crops. This system is well adapted to dairy-farming and is commonly used by the growers with small acreages. On the large potato farms potatoes are planted continuously or rotated with green-manure soil-building crops. Long-standing and forage crops are not included in these short, more intensive rotations.

In the study of the relation of rotations to wireworm infestation it was necessary throughout the work to obtain representative populations present in each crop of the rotation system. Hence a large number of soil samples were examined for wireworms. The soil was sifted through several screens to facilitate collection of even the smallest individuals. Although this method was slow and laborious, it was found most effective for the field conditions in western New York. At the time of sampling in September and October the wireworms were usually in the upper eight inches of soil. After the wireworms were collected, they were measured and placed in the following classes: first year (3 to 6 millimeters in length), second year (7 to 15 millimeters), and third year (more than 16 millimeters). While larval length is not a positive criterion of age, this system of measurement was sufficiently accurate to meet the needs of field work.

At the outset of the investigations a number of farms were selected for the study of relation of farm crops and rotations to infestation. Through cooperation with the owners, changes in cropping systems and sequence of crops were made when necessary for observation and detailed study. The area of the fields was from 5 to 20 acres, and according to the growers had been infested with wheat wireworms for many years.

FIELD CROPS AND WHEAT-WIREWORM INFESTATIONS

The results of the preliminary field studies show a very definite relation between the crop and the incidence of infestation. In summarizing the data in table 7, the crops surveyed for wireworms are placed in sequence as they occur in the rotation. The first-year larvae occur almost exclusively in sod. Sod crops remaining for a second year are again infested during the second season. Wireworm infestations did not start in either potatoes or spring grain, since these crops are comparatively free of first-year larvae. The larval population in potatoes following sod consists predominantly of second- and third-year wireworms. A year later in the spring-grain crop most of the wireworms in the population are either in the large-size group or have matured and transformed to beetles. The appearance of beetles the next spring will then coincide with the hay crop seeded in the spring grain. In these rotations, sod appears as a crop every third year (3-year rotation), or third and fourth year (4-year rotation). With the completion of the wireworm life cycle in three to four years, potato rotations which include sod every third and fourth year are continuously reinfested.

TABLE 7. RELATION OF THE COMMON ROTATION SYSTEMS IN WYOMING COUNTY TO WIREWORM POPULATION AND SIZE OF WIREWORMS

Year	Crop	Total population	Beetles	Third-year larvae	Second-year larvae	First-year larvae
1930	Sod					
1931	Potatoes					
1932	Grain					
1933	Sod	465	43	59	14	349
1930	Potatoes					
1931	Grain					
1932	Sod					
1933	Potatoes	1025	22	625	371	7
1930	Grain					
1931	Sod					
1932	Potatoes					
1933	Grain	733	233	437	63	0
1930	Potatoes					
1931	Grain					
1932	Sod					
1933	Sod	542	9	26	245	262

SUSCEPTIBILITY OF CULTIVATED AND SOD PLOTS TO INFESTATION

The relative susceptibility of cultivated and sod fields to infestation is shown from a series of small-plot experiments. Small areas in six sod fields were plowed, fitted, and planted to crops such as potatoes, beans, and grain, referred to as *cultivated crops*. These plots alternated with sod plots of the same size and were replicated. In the fall representative soil samples were examined, and wireworms measuring 3 to 6 millimeters were recorded and considered as first-year larvae. A striking contrast of populations in the sod and cultivated plots may be noted from table 8. The number of

TABLE 8. A COMPARISON OF FIRST-YEAR-WIREWORM POPULATIONS IN SMALL PLOTS PLANTED TO SOD AND CULTIVATED CROPS

Field	Crop	Number of replications	Number of samples	Number of first-year larvae	Population per acre
1	Sod	4	29	139	52,272
	Cultivated	4	29	1	376
2	Sod	3	18	65	39,204
	Cultivated	3	18	0	0
3	Sod	4	20	109	60,984
	Cultivated	4	20	3	1,612
4	Sod	2	20	182	100,188
	Cultivated	2	20	2	1,089
5	Sod	2	26	91	50,529
	Cultivated	2	13	0	0
6	Sod	2	12	234	284,447
	Cultivated	2	8	14	25,700

first-year wireworms in the sod plots was many times the populations in corresponding cultivated plots.

As is sometimes the case, it is possible that these small-plot experiments did not give a true picture of what would happen under average field conditions. As mentioned previously, beetles migrate short distances by crawling over the soil surface. Beetles emerging on the small cultivated plots probably moved to more attractive shelter in the sod plots. In large areas the beetles remained on the fields during the egg-laying period as was the case in the spring of 1935. There was then a question of reinfestation in these fields in which sod had been eliminated from the rotation.

MODIFICATION OF THE POTATO ROTATIONS

Reduction in wireworm population

It is therefore of interest to trace the trends of wireworm populations in fields with modified rotations. Four severely infested potato fields were subsequently cropped continuously with potatoes or spring grain. One heavily infested area in each field was sampled for a number of years following the heavily populated sod. Different but comparable sampling methods were used in the two crops to allow for differences in the distribution of the larvae in grain and hill crops. The census figures summarized in table 9 show rapid decreases in wireworm populations following modification of the rotation by continuously planting either potatoes or spring grain. After three years from the sod crop, the wireworm population had practically disappeared. These fields were not reinfested by new generations of wireworms. Normally reinfestation takes place every third and fourth year coincident with the sod crop.

TABLE 9. CULTIVATION OF INFESTED FIELDS AS AFFECTING THE WIREWORM POPULATIONS AND REINFESTATION OF THOSE FIELDS

Field	Year	Crop	Number of samples	Number of beetles	Number of mature and second-year larvae	Number of first-year larvae
1	1929	Sod				
	1930	Potatoes	13	1	119	0
	1931	Potatoes	13	19	83	0
	1932	Grain	13	10	17	0
	1933	Potatoes	13	0	3	0
2	1930	Sod	13			
	1931	Potatoes	13	1	88	0
	1932	Potatoes	13	42	23	0
	1933	Potatoes	13	6	9	1
	1934	Potatoes	13	2	3	0
	1935	Potatoes	13	0	1	0
3	1931	Sod	20			
	1932	Potatoes	20	..	96	0
	1933	Potatoes	20	..	35	0
	1934	Potatoes	20	..	6	0
	1935	Potatoes	20	..	2	0
4	1929	Sod	13			
	1930	Potatoes	13	0	121	0
	1931	Grain	13	33	88	0
	1932	Potatoes	13	18	9	0
	1933	Grain	13	0	2	2

Reduction in wireworm injury to potatoes

A decline in the wireworm populations following the elimination of sod from the potato rotation is correspondingly reflected in the injury. The heavy infestations of wireworms which had originated in the sod crop caused severe injury to the first crop of potatoes. Injury decreased sharply thereafter and became practically nil after three years of cultivated crops, as indicated in table 10.

TABLE 10. REDUCTION OF WIREWORM INJURIES TO POTATO TUBERS FOLLOWING ELIMINATION OF SOD FROM THE ROTATION

Field	Year	Crop	Per cent of injury to potato tubers
1	1929	Sod	
	1930	Potatoes	92.0
	1931	Potatoes	17.7
	1932	Grain	......
	1933	Potatoes	0.04
2	1930	Sod	
	1931	Potatoes	85.0
	1932	Potatoes	4.0
	1933	Potatoes	0.75
	1934	Potatoes	1.7
3	1931	Sod	
	1932	Potatoes	77.7
	1933	Potatoes	57.1
	1934	Potatoes	2.8
	1935	Potatoes	2.04
4	1929	Sod	
	1930	Potatoes	100.0
	1931	Grain	......
	1932	Potatoes	10.4
	1933	Grain	......

Present rotation projects

The studies on the relation of rotation to wireworm injury has been expanded to include other insects, diseases, yields, and other phases of potato-growing. The Departments of Vegetable Crops, Plant Pathology, and Agronomy, at Cornell University, are cooperating in these projects, started in 1936 and located in three widely separated areas of the State. One plot field is near Malone in northern New York, another in Genesee County, and the third in Steuben County.

Nine different rotation systems are being compared in each plot field. Each experiment includes a large number of small plots covering approximately four acres. An airplane view of the plots in Steuben County is shown in figure 12.

Heavy infestations of wheat wireworms are present in two of the experiments. Results of tuber injury to date confirm the previous work as reported in this bulletin. Infestations start in the clover-timothy plots and potatoes planted in these plots are severely injured. The short rotations that do not include sod have not been susceptible to infestation and the amount of wireworm damage has been low as compared with the injury in long rotations.

NATURAL ENEMIES OF THE WHEAT WIREWORM

The efficiency of natural enemies in reducing wireworm infestation is difficult to evaluate under field conditions. Wireworms in their subterranean habitat are not only admirably protected from their enemies but are also concealed from observation. It is therefore difficult to determine the agencies responsible for natural reduction under field conditions.

Wireworms are, however, subject to destruction from parasites and predators. Birds and predacious insects prey on all stages of Elaterids, particularly the beetles during the flight period. Parasitism is commonly reported in the beetles. Disease is troublesome in rearing cages, sometimes destroying entire populations. Several fungi have been isolated

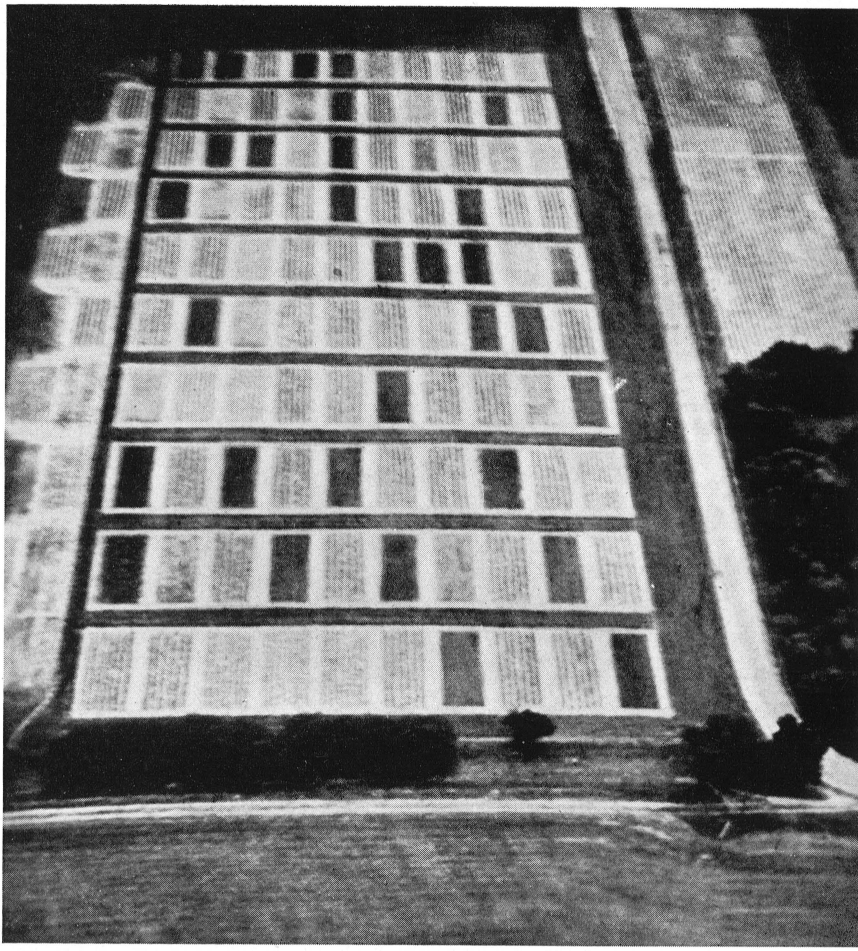


FIGURE 12. AERIAL VIEW OF THE POTATO-ROTATION TRIALS ON THE FARM OF C. D. WOLCOTT AND SON, COHOCTON, NEW YORK
The experimental plots cover an area of approximately four acres

from diseased specimens but apparently the pathogenicity of these fungi has not been thoroughly established.

In analyzing the data accumulated from the yearly wireworm census of a number of fields, an unaccountable reduction was noted in populations from year to year. Referring to table 11, if no mortality occurred during a year, the total population, beetles and larvae, would closely approximate the larval population of the previous year. For instance, in field 1 the total population (65) of the second-year crop of potatoes was 23 less than the number of larvae recorded in similar samples of the previous year. Similar reductions of 10 to 75 per cent were noted in six of seven cases, and indicate that considerable natural mortality occurs from year to year.

TABLE 11. REDUCTIONS OF WIREWORM POPULATIONS BY NATURAL FACTORS UNDER FIELD CONDITIONS

Field	Crop	Number of samples	Number of beetles	Number of larvae	Reduction of population	
					Number	Per cent
1	Sod					
	Potatoes	13		88		
	Potatoes	13	42	23	23	26.14
	Potatoes	13	6	9	8	34.78
2	Sod					
	Potatoes	13		119		
	Potatoes	13	19	83	17	14.29
	Potatoes	13	10	17	56	67.47
3	Sod					
	Potatoes	13		121		
	Grain	13	33	88	0	0.0
	Potatoes	13	18	9	61	69.32
4	Sod					
	Potatoes	15		214		
	Potatoes	15	18	36	160	74.77

Although sampling errors may have been considerable, the magnitude of the decreases is such that sampling variations probably do not account for the reductions. The natural agencies responsible for the observed decreases are not known since dead larvae were seldom found in the field. Natural mortality is generally considered to be only partially effective in wireworm control, and artificial methods have to be used to reduce populations.

SUMMARY

The importance of the potato-tuber-defect problem in upstate New York is indicated from field surveys made during 1931 and 1932. These surveys show that more than one-half of all the tubers examined were injured by insects, diseases, and the mechanical operations of harvest. Wireworm injury was one of the most important of the defects.

Three species of wireworms are commonly found in potato fields. Of these three, the wheat wireworm (*Agriotes mancus* Say) is the most abundant and injurious. The other two species, the eastern field wireworm (*Limonius ectypus* Say), and the corn wireworm (*Melanotus* sp.), while not as widespread as the wheat wireworm, are nevertheless injurious in many potato-producing areas.

All portions of the potato plant, seed piece, stems, stolons, and tubers are subject to injury. Tuber damage as it affects the market quality of the crop is of chief concern to the grower. Wireworms burrow into the tuber flesh, leaving tunnels which cause excessive waste when injured potatoes are prepared for the table. There are a number of variations of wireworm injury caused by growth of the tuber after injury or invasion by soil organisms into the tunnels.

A study of the biology and control of the wheat wireworm was made during a six-year period from 1930 to 1936. The life cycle is three to four years in length. Eggs are laid in the soil from June to July and hatch in approximately three weeks. The wireworms grow slowly to larval maturity in two to three years. Pupation then occurs from late July through

August and concludes with the appearance of the beetles, which remain in their pupal cells over the winter.

Infestations of wheat wireworms start in grass and sod crops. Potatoes, corn, and similar crops are not subject to new infestations. The common potato rotation in upstate New York includes a sod crop every third and fourth year. Potatoes generally follow the sod. The appearance of the beetles during the third and fourth years of the life cycle occurs simultaneously with the sod crop in the rotation. Potato crops in this rotation are therefore usually infested.

Marked reductions in wireworm populations and in resultant damage to potatoes followed elimination of the sod crop from the potato rotation. Continuous use of cultivated crops on infested fields reduced wireworm injury to a minimum after three years. The control of wheat wireworms by short rotations is not due to mechanical action of cultivation but rather to unfavorable conditions for oviposition and survival of the young larvae in cultivated crops. Such short rotations should include crops that can be tilled during the egg-laying period during June and July.

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