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The wireworm pest and its control in Central Queensland sugar-cane fields

McDougall, WA
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by

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The Wireworm Pest and its Control in Central Queensland Sugar-cane Fields.

By W. A. McDougall, Assistant Entomologist.

LARVE of certain genera of the Elateride or “Click Beetles,” commonly known as wireworms, are capable of causing great damage to cultivated crops, and for a considerable number of years it has been recognised that wireworms are responsible for damage to sugar-cane in certain parts of Queensland. Jarvis (1927 b) stated that in 1910 wireworms had been observed to inflict serious damage to young cane planted on alluvial flats at Mackay, and that in the same year this pest occurred freely in Isis Central district, where it was reported to be causing more damage to cane than was being done by any other insect. This writer further (1925 and 1927 a) listed a number of possible wireworm control measures. Illingworth (1919) mentioned that there was evidence of wireworm damage in the Mossman district. During the period 1924-30 officers of the Bureau of Sugar Experiment Stations published various reports embodying some field observations, locality records, and recommendations for the control of these pests. Cottrell-Dormer (1924 b and c) reported damage in low-lying country at Mooliba (near Babinda) and in the Homebush and Eton districts, near Mackay. Writing of wireworms in the Mackay district (1929 a) he stated that they do damage mostly during the colder months of the year; it was claimed by some farmers that such damage was worst following a planting of cowpea as a green manure crop. Mungomery (1926) found wireworms attacking cane in the Pialba district, particularly after spring planting, and Bates (1925) reported Monocrepidius sp. attacking eyes of sets at Strathdickie and Tawvale, Freestone null area, during July and August. In 1928 the attention of Burns (1928 a), then Assistant Entomologist at the Mackay Experiment Station, was drawn to a serious wireworm infestation at Te Kowai. Plants were bored into at the ends, and the wireworms were observed to be voracious feeders capable of rapid movement through the soil. Burns (1928 b) observed several species* of wireworms in Mackay canefields, and in his annual report for 1929 mention was made of several large infestations at Walkerston, Te Kowai, Farleigh, Habana, and Racecourse. Following further and more serious damage in this area, a rapid survey was carried out by Mungomery, who reported to the Director (1930) that damage appeared to be most severe in low-lying, poorly-drained land which remained wet and cold. The life cycle of the pest was thought to be at least a year or more, and the period of oviposition of the adults a very protracted one.

Although much had been written about wireworms damaging cane in Queensland and their possible control, no serious attempt had been made to investigate the problem thoroughly prior to 1931. In that

*Specimens at the Mackay Experiment Station labelled by Burns as ‘Wireworms ex canefields 1928’ have been identified as J. sp. Lecon anser and L. variabilis. All those found damaging cane are of the aforementioned species.
year the investigation of the wireworm problem in the Mackay and Proserpine mill areas was made a major project, since in these areas, more so than in any other Queensland cane district, wireworms are, at times, a serious pest. Certain portions of the work carried out by the writer have already been published—McDougal (1934).

**Nature of Wireworm Damage and its Economic Importance.**

The wireworm larvae attack the swollen eyes of cane sets, young shoots, or the underground portions of larger shoots. The damage consists in the eating of only a small tunnel which cuts across the centre of the growing point, thus bringing about the death of the shoot or bud; in some cases a considerable portion of the interior of the buds may be eaten. Examples of damage to growing shoots may be seen in Plate IV, fig. 1. When wireworms are found in the act of eating into buds or shoots, it will be noticed that as a rule a considerable portion of the posterior half of the larva is protruding from the tunnel. In contrast to this mode of attack, the larva of the large moth borer (*Phragnataphila truncata* Walker) enters a shoot by a small hole, and completely houses itself by eating out the centre for some distance above and/or below the entrance hole level (see Plate IV, fig. 2).

When all the eyes and small shoots of a set are attacked no stool results, while when larger shoots are attacked the effect is to produce "dead-hearts" in the primary shoots, the formation of the stool then depending on the formation of secondary shoots. On rare occasions the secondary shoots—in fact, all shoots as they arise—may be destroyed by the pests. The effect of wireworm attack on stools and eyes may thus result in practically a complete failure of germination throughout the field (Plate I, fig. 1.) Such complete failures are unusual, however, and as a rule the misses are lightly or heavily distributed throughout the block or are confined to small or large patches or to the lower ends of fields (see Plate I, figs. 2 and 3; Plate II, figs. 1, 2, and 3).

Damage in the Mackay district is almost exclusively confined to low, badly-drained land. During the past fifteen years considerable areas of this type of country have been planted to cane in the Mackay and Proserpine mill districts, and this has been responsible for the appreciably increased proportion of damaged strikes caused by wireworms. Taking the districts as a whole this proportion is not high, and the majority of the farmers are not troubled by wireworms except, possibly, in an occasional low spot in which a poor strike is considered by many of the farmers to be of little consequence. This fact points to one of the most serious aspects of wireworm damage. If the total damage were more evenly distributed, losses would not be so disturbing, but, unfortunately, there is a small percentage of farms which contain quite appreciable areas of wireworm infested country, and here this pest is most serious.

Losses caused by wireworm depredations consist in the decrease in plant and subsequent ratton tonnages, and an increase in production costs per ton of all cane harvested in wireworm infested fields. This increased cost may be due to the irregular distribution of the stools in the fields, supplying misses (often two or three times) or even replanting,
the initial cost of preparing parts of fields which do not yield any returns whatsoever, wasted fertilizer, increased cultivation costs due to the greater weed growth where poor stands occur, or the cost of some unsuccessful methods of wireworm control which may have been tried after the presence of the pests had become evident in the fields. Ratoon crops do not suffer damage from direct wireworm attack.

The Pest Species.

Jarvis (1927 b) stated that he had reared Monocrepis adults from larvae found in the soil about cane roots in the Bundaberg district, and until 1930 this seems to have been, with one exception, the only rearing work done with wireworm pests from Queensland canefields. It would seem to have been the custom in the past, if naming the pests at all, to refer any wireworms damaging cane anywhere in Queensland to the genus Monocrepis. The first departures from this custom were when Mungomery (1928) stated that Laco variabilis and many Monocrepis species damaged cane in Southern Queensland and when the same author (1930) considered that apparently one species, a Laco species, was responsible for nearly all the wireworm damage reported from the Mackay and Proserpine districts.

During the three years 1931-33 the following Elaterid larvae were collected at different times from Central Queensland cane fields: Laco lateralis Sch., Laco variabilis Cand., Laco assus Cand., Laco humilis Er., Heteroderes carinatus Blbn., Heteroderes cairnsensis Blbn., Agrypnus mastersi Mael., and several other species whose adults are either not known, or, if known, are unidentified. Included in the last group is Laco ‘‘Q’’ sp. It was found that very nearly all wireworm damage observed during the above period was due to L. variabilis.

Specimens of the wireworms found by Mungomery to be damaging cane in the Mackay district were examined and identified as L. variabilis.

It has been established that wireworms have been pests in some particular fields in the Mackay district since as early as 1890, and examinations of the damaged areas in these fields during a planting in 1931, 1932, or 1933, showed the pest to be L. variabilis. Inspections of damaged areas proved to be those referred to in some of the literature as localities of damage by Monocrepis spp., have shown the pest in these localities to be L. variabilis. It seems evident that this species is and has always been the wireworm pest in the Mackay and Proserpine cane fields. Consequently in this paper unless otherwise stated, all discussion will refer to L. variabilis and further references to other species of wireworms found in Central Queensland cane fields will be made only when they may be of help in the identification of the various stages of variabilis in the field and in the formulating of a control for this pest.

Description of L. variabilis.

The Adult.—The adult ‘‘click-beetle’’ is a uniform dark-brown colour on both upper and lower surfaces. It is moderately flat in shape and shows a considerable variation in size ranging from one-third to one-half inch in length, with a width of about one-fifth inch. The elytra or wing covers appear as possessing a series of parallel ridges which run lengthwise.

* Mungomery (1927) listed L. variabilis amongst the insects reared by him during that year from larvae to imagines.
The following descriptive information concerning the genus Lacom is derived from Elston (1924):

"The mandibles are bifid or dentate on the inside. The apical segment of the palp is secundiform. The antennae are short: the first segment is large and somewhat bent, the second and third small, the third somewhat shorter than the second, the following are triangular, the last at the apex truncate or emarginate. The elytra are usually punctate-triarticulate or sericate punctures, the shoulders either rounded or angular, and the epipleura more than twice as broad as long. The antennal furrows on the postero-lateral edge are only to the middle. The sides of the gena may be divided into four sections according to the presence or absence of well-defined tarsal furrows on the pre- and metasternum. One section is represented by L. variabilis, which is without tarsal furrows on the meta- and protosternum, or, if present on the latter, are so ill-defined as to be almost indiscernible."

Elston found that as the name variabilis implies, the species is very variable.

"On some specimens, particularly with the male, the tarsal depression is more or less visible, whilst on others it is entirely absent; the sculpture of the elytra also shows a certain amount of variability, the alternate interstices being more conspicuously elevated on some species than on others."

There is found to be very little variation in the elytral structure of adults reared from larve attacking cane or in adults collected in the Mackay and Proserpine canefields. On examining an elytron it will be found that, excluding the lateral ones, the alternate interstices, which are wider and have three rows of hairs instead of two (Plate VII, fig. 4) are nearly always sufficiently elevated to give a general macroscopic appearance of a distinct series of parallel ridges. In specimens from Rockhampton, on one occasional one collected in Mackay canefields, the alternate interstices are not as conspicuously elevated as in the vast majority of Mackay specimens.

Detailed measurements, in millimetres, of the largest and smallest specimens collected over three years in Central Queensland canefields, are as follows:

<table>
<thead>
<tr>
<th>Size</th>
<th>Total Length</th>
<th>Thorax</th>
<th>Length</th>
<th>Width</th>
<th>Abdomen</th>
<th>Length</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Largest</td>
<td>14-5</td>
<td>3-9</td>
<td>4-4</td>
<td>9-7</td>
<td>4-7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smallest</td>
<td>8-7</td>
<td>2-4</td>
<td>2-7</td>
<td>5-7</td>
<td>2-8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Egg.—The egg is opaque to pearly-white in colour, ellipto-cylindrical in shape, and the ends are broadly rounded and similar. From the measurement of one hundred eggs it is evident that there is little variation in size; the length always approximates very closely to 3-5 mm. and the width to 4-7 mm., i.e., if placed lengthwise there would be about forty-three eggs to the inch. Under a magnification of 80X the chorion is seen to be quite smooth, and that it is tough is shown by the fact that the eggs are easily handled without any changes in their shape, and that during a considerable period after the hatching of the small larve it is difficult to separate the shells from the full eggs.

The Larva.—The active larva or "wireworm" is a worm-like segmented creature, semi-flattened in shape, and, when fully grown, is usually about four-fifths of an inch in length and with a greatest width of approximately one-eighth of an inch. In general appearance it is pale waxy-yellow with the "head" and forked end segment reddish-brown. The short legs are armed with short brown spines. In the field the larve may be recognised by the shape of its end segment as in Plate III, fig. 2B, and Plate VIII.

The greater part of the dorsal and ventral surfaces is pale waxy yellow, with the anterior four-segmented areas a lighter shade. With the exception of the maxilla and mandibles, which are very dark brown to black, the head and the prothorax are reddish-brown. The four prolegs of the two terminal prolegion and the five tooth-like structures on each lateral margin of the flattened dorsal portion of the ninth segment are dark reddish-brown. The spiracles are not conspicuous. The maxilla is tridentate, the prolegs being of equal lengths (Plate VII). The "pseudopodium" (anterior segment) is armed with a strong ascending hook (Plate VII). There is one conspicuous variation in larval setation; conspicuous because it concerns the flattened dorsal surface of the ninth abdominal segment. There, the presence of two tufted hairs situated about the beginning of the distal third is constant. Midway between these two hairs and the anterior margin two smaller hairs will be noticed in Plate III, fig. 2B. In this position as many as five hairs may be present, or none at all.

The following is an example of a detailed measurement, in millimetres, of a full grown wireworm larva:—Total length, 20-9; width, 2-9; prothorax, 2-0, anterior width 2-1, posterior width 2-9; other two thoracic segments, length each 1-0, width each 2-8; length of each of first eight abdominal segments 1-4, width of first 2-0, width of fifth 3-2, width of eighth 2-9; ninth abdominal segment, length 2-4, greatest width 1-9.

The Pupa.—When first formed the pupa is opaque white and, except that the abdomen is slightly longer, very much resembles the adult beetle, into which it will change in both shape and size.

The pupa is microscopically spinose. There are two fleshy thoracic structures or spines on the anterior border of the prothorax above the eye spots. These point upwards, whereas similar ones on the lateral angles of the much broadened posterior angles point upwards and backwards. The spines in the angles formed by the dorsal median line and the posterior border of the prothorax are very small. The bifi nature of the adult mandible is early discernible in the pupa. The antennae, of similar form to those of the adult, lie along the margin of the thorax on the ventral side and reach to the posterior angles. There are nine abdominal segments. The ninth terminal is dorso-ventrally placed. The abdomen is covered with brown barbs. At the close of each wing there is a much smaller spine. During early life the wing cases reach on to one quarter of the ventral side of the fourth abdominal segment and the three pair of legs to one quarter of the fifth. Later—i.e., during the last four days of pupal life—there are considerable visible alterations, including a darkening in colour; the tips of the mandibles are evenly visible as also are the antennal and tarsal segments. The edges of the antennal furrows become pencilled in brown, and the relative position of tips of the wing cases, the posterior legs, and the abdomen segments change very appreciably. The contents of the eighth and ninth abdominal segments retreat into the abdomen segments leaving an empty case. The shape of the seventh abdominal segment of the pupa is very similar to that of the seventh body segment (actually the fifth visible) of the adult. In the pupa all the abdominal terga and sternae can be seen.

Distribution.

According to Elston (1924) L. variabilis is commonly distributed over the whole of Australia and Tasmania. However, with the exception of the records of damage to cane in Central and Southern Queensland it has not otherwise been recorded as a pest. With the exception of five adult specimens labelled "Rockhampton" in the Queensland Museum, a few adults collected in the Bundaberg district, and specimens that had been received from Mackay during the past four years, no adults or
larvae of this species could be found in any of the Queensland collections of Coleoptera examined. These included those of the Queensland Museum, Department of Agriculture and Stock, at Brisbane, the University of Queensland, and of the Sugar Experiment Stations at Meringa and Bundaberg. Wireworms found by Mr. Munro, during the past year, to be damaging cane in the Bundaberg district were reared to adults at Mackay and other specimens collected in the past from southern cane fields were examined; none of these is L. variabilis. However, Mr. Munro has informed the writer that L. variabilis larvae have been found actually damaging cane sets in the Palm a district; this occurrence is responsible for the recording of this species as a pest of cane in Southern Queensland.

In 1931 two species of wireworms reported to be damaging cane sets at Mossman, North Queensland, were forwarded to the writer for examination. The smaller species, one of the cylindrical type of Elaterid larva, was considered by the observer to be the more serious pest; what proved to be the adult of this species could be found in the cane in circumstances similar to those mentioned by Illingworth (1919). The two specimens of the second species could not be distinguished from the sixth larval instar of L. variabilis. Moreover, it seems that wireworm infestations in the Mossman district occur under conditions similar in many respects to those concerned with the habits of and damage by L. variabilis in the Central Queensland fields.

Other Insects which may be mistaken for Lacon variabilis.

There is but one commonly seen Elaterid adult or "click-beetle" in the Mackay and Proserpine districts which more or less closely resembles L. variabilis (see Plate III., fig. 1). This is Lacon humilis Er. As will be noticed in Table II. (page 14), L. humilis is attracted by light, whilst L. variabilis is not. L. humilis is darker in colour than L. variabilis and there are no apparent ridges on the wing covers.

(When the central portion of an elytron of L. humilis is examined it will be seen that the interstices are all of similar width; the clothing is similarly arranged on each, and there is no outstanding elevation of any of them (see Plate VII.).)

Dysphus mackayensis Carter (Plate VII.) is very plentiful and noticeable in Central Queensland cane fields. If wireworm damage is particularly heavy in any field or district, farmers often form the opinion that this beetle is the adult of the wireworm. D. mackayensis is not a "click-beetle," being a member of the family Tenebrionidae and its larvae are quite harmless to cane.

In the larval or wireworm stage many different Elaterid species, which may have quite different habits, very closely resemble one another, but so far as those in Central Queensland cane fields are concerned, it is necessary that the differences between two species only be known. These are Lacon variabilis (the lowland wireworm) and Heteroderes carinatus (the highland wireworm). They are very similar in colouring and general shape, but in the field they may be distinguished by the difference in the shape of their end segments as shown in Plate III., fig. 2, and Plate VIII.

(The name of H. carinatus is perentadentate, the processes being of equal length (Plate VII). There is no strong hook on the pseudopodium (Plate VII.).)

Heteroderes carinatus, although quite plentiful in well-drained fields in the Mackay district, has never been known to seriously damage cane.
The carnivorous larvae of the carab, *Gnaphaphus pulcher* Dej., is generally distributed in many fields and may be present in large numbers in some situations. With its brown head and very pale-yellow to white abdomen it is sometimes mistaken for a wireworm, but it should be easily distinguished from any of the latter by the greater size of its head in proportion to its body, the much softer abdomen, and the presence of two spine-like structures (urogomphi) near its posterior end.

The three false wireworms most common in Mackay and Proserpine canefields are the larvae of the *Tenebrionidae*, *Dysticus mackayensis*, and of the Cistelids, *Hybrenia elongata* Macle. and *Dimorphochilus poscoet* Macle. The latter two when seen in the field are much larger than most of the local semi-flattened wireworms. All resemble the cylindrical type of wireworms (none of which damage cane in ploughable canefields in Central Queensland) more than the semi-flattened type of which *L. variabilis* is a member. The false wireworms possesses a distinct farina whereas wireworms and other Elaterid larvae do not.

**Insect Damage which resembles that caused by Wireworms to Cane.**

In Central Queensland cane areas there are three insects that may cause damage to cane which superficially resemble that caused by wireworms. These are a small black beetle *Pentodon australis* Blhm. (Plate IV.), the caterpillar of the large moth borer (*Phragmatiphila truncata* Walker), and small white grubs of *Rhyparida* species. Of these *Pentodon australis* is of the most importance, and like the wireworm it causes "dead-hearts" in growing shoots and eats the eyes of sets. This damage may be effected in either high or low land, and damage by Pentodon in high land in which larvae of *H. carinatus* have been observed, is often debited to wireworms.

When a wireworm attacks a shoot the hole is surrounded by small amounts of fibrous material (Plate IV., fig. 1). On the other hand the Pentodon beetle, which is larger than the wireworm and a much grosser feeder, in its attack on the underground portions of the shoots, makes much larger holes, at the edges of which are considerable masses of frayed fibrous material (Plate IV., fig. 2)—a beetle in the act of feeding is shown on the extreme right). When the Pentodon beetle attacks the eye of a set it does not tunnel to the centre but gouges it out completely. Damage to strikes by the larvae or grubs of the Pentodon beetle is more common in early than in late plantings; these grubs chiefly damage eyes and sets by eating out large cavities.

Plate IV., fig. 2, shows the small, neat holes in shoots caused by the large moth borer. This insect does not attack eyes of sets. Attacks by *Rhyparida* spp., although sometimes severe, are comparatively rare.

**Habits and Characteristics of *Lacon variabilis*.**

Few eggs or first-stage larvae have been seen in the field. Washing and sieving (after Shiree (1930)) of soil samples from localities where

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*According to C. E. Chadwick, Eltham, N.S.W. (in a communication dated 25th July, 1933) this species was described by Olliff under the name *Heteronycha variegata*, and in the South Australian Museum collection all specimens of this species, including a copy of *Pentodon australis* Blhm., stand under the name *Mecandroides ussuriensis* Olliff. The name *P. australis* is used in this publication for the reason: (a) as to the present no published accounts of the synonymy of this species have been found; (b) for many years the insect has been widely known under this name to cane farmers in Queensland and New South Wales.*
adults were known to have been present four or five weeks prior to the
date of sampling, gave very poor yields. In the laboratory, gravid female
adults, caged under conditions made to resemble as nearly as possible
those which would most likely be encountered by them in the field,
usually deposit eggs either singly on the soil surface or in batches in
crevices at a depth not exceeding two inches. The eggs are not covered
by any secretion, and when laid in batches are not connected in any way.
No egg chambers are constructed. Observed first batches of eggs
deposited by an adult have consisted of from two to seventeen eggs, but
usually ten to fifteen, while later batches deposited by the same adult
have consisted of as many as twenty-three eggs or as few as two. Table I.
is a sample of a series of the recorded observations on the number of
eggs deposited (and dates of deposition) by thirteen beetles during the
1931-32 summer, and twenty-three beetles during the summer of 1932-33.
The maximum number of eggs deposited by any one female was thirty-
six, the minimum two, and the mean for the thirty-six beetles was twenty-
three.

**TABLE I.**

<table>
<thead>
<tr>
<th>Lab. No. of</th>
<th>Number of</th>
<th>Date of</th>
<th>Remarks.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female.</td>
<td>Eggs Deposited,</td>
<td>Deposition.</td>
<td></td>
</tr>
<tr>
<td>A 1 (confined with 2 ♂♂)</td>
<td>15</td>
<td>8-1-32</td>
<td>On 24-2-32 female still alive; dissection showed 65 well-developed eggs in egg-tubes</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>3-2-33</td>
<td></td>
</tr>
<tr>
<td>A 2 (with 2 ♀♀)</td>
<td>13</td>
<td>10-1-32</td>
<td>On 24-2-32 female still alive; dissection showed 86 well-developed eggs in egg-tubes</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>28-1-32</td>
<td></td>
</tr>
<tr>
<td>A 7 (with 1 ♂)</td>
<td>4</td>
<td>3-12-31</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>1-2-32</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>3-2-32</td>
<td></td>
</tr>
<tr>
<td>A 8 (with 3 ♀♀)</td>
<td>10</td>
<td>20-11-32</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5-12-32</td>
<td></td>
</tr>
<tr>
<td>A 9 (with 1 ♂)</td>
<td>12</td>
<td>9-12-33</td>
<td>All females alive on 29-3-33 with well-developed eggs in egg-tubes</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>18-12-33</td>
<td></td>
</tr>
<tr>
<td>A 10 (with 4 ♀♀)</td>
<td>12</td>
<td>7-12-32</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>16-12-32</td>
<td></td>
</tr>
</tbody>
</table>

The eggs have withstood immersion in water for a period as long as
five days, and young have hatched out from eggs exposed to a soil
environment ranging from moderately dry to free water present. The
young larvae emerge from the eggs through small holes eaten in the shells.
Dispersion through the upper two or three inches of soil quickly follows
and, at this stage in larval life, feeding largely consists in the ingestion
of soil. The average length of the newly-hatched larve is 2.1 mm, and
the width 27 mm, the widest parts being the head capsule and the prothorax.
Towards the end of the first larval stadium the length may
be as great as 3-38 mm, and the width 43 mm, the abdominal segments
being then the widest parts.

During a moult the skin usually splits along the median dorsal line of
the thorax only; sometimes the head capsule and the anterior
abdominal segments are included in the splitting. The thoracic segments
first emerge through the split and are followed by the head and abdomen.
The pulling of the abdomen through the unsplit portion of the moulted
skin or exuvium causes a certain amount of telescoping of the exuvial
segments; the result is that the moulted skin appears as a distinct head
capsule and a distinct ninth abdominal segment connected by a mass of
telescoped intermediate segments. An exuvium of this type is
comparatively compact and does not break up very quickly in loose
soil; such exuviae from the larger instars are often found complete in
the field.

After a number of ecdyses, or molts, pupation takes place in
earthen cells at a soil depth which depends upon the disposition of the
moisture in the soil at the time when the mobile larve assume a torpid
prepupal state. This change of state invariably takes place in the top
two inches of visibly moist soil. If the weather has been showery the
pupe will be found within an inch of the soil surface, whilst following
dry times, pupe have been collected at soil depths as great as seven
inches.

Adults are seldom seen in the field unless special search is made for
them in suitable localities at certain times of the year. After light
showers of as little as ten points, or after heavy rains in November or
December, they may be found in their greatest numbers behind the
lower leaf sheaths of cane growing in depressions or in any other low-
lying part of a canefield where wireworm damage was evident during
germination. In these low-lying areas adults may also be found under
clods, at the base of grass clumps, or under any debris which may be
present. Often adults of other Elaterid species and false wireworms
will be found along with L. variabilis. **Under one small plant in
November, 1931, there were found as adults, nineteen individuals of**
*L. variabilis*, **three of* L. assus, numerous H. coarzensis, and many
Dytalabis macayensi** Carter, together with larvae and a few pupe of
the last-mentioned. Occasionally as many as fifteen *L. variabilis* adults
have been collected from behind one leaf sheath, but usually not more
than five will be so found. When disturbed the beetles drop and remain
inert for some time. Structurally they are capable of strong flight but
are seldom seen in flight. During three years' observations less than
twenty adults have been seen in the field other than under the various
previously-mentioned covers. These observations were made during all
hours from 4 a.m. to 12 p.m. After suitable rains on one occasion,
twelve adults were taken after flight from cane leaves at 9 p.m.; fairly
heavy rain had been experienced during the day.

**Migration and Initial Infestation of Fields.**

There seems to be no doubt that the adults will in time migrate
from their native habitat (i.e., swampy grass lands), and slowly invade

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*During ecdyses of the cylindrical type of wireworm, and of the Tenebrionid larve studied, the splitting of the skin along the mid-dorsal line is not confined to the thorax but is continued along the first seven or eight abdominal segments as well. Exuviae of these larve quickly fall to pieces.*
any part of a field where structural work such as the building of a railway, road, or tramline, or other cause has made the drainage insufficient. It appears, however, that migration of adults from one locality to another in badly-drained cultivated country is even slower, but once the species is present in a cultivated field its population density may increase. This is in marked contrast to the behaviour of several other Laco species, such as L. humilis, L. lateralis, and "Q" species; larvae of the first-mentioned two species are seldom found in cultivated fields although their adults are sometimes there. Laco "Q" sp., together with L. variabilis, may be found damaging striped in new, badly-drained country which had been broken up for the first time during the early part of the year.

In future plantings in this type of country it will be found that, when the season is suitable, L. variabilis will be present in larger numbers than before, whilst Laco "Q" sp. larvae will have practically completely disappeared. In the laboratory it is not difficult to induce L. variabilis to oviposit in fairly loose soil, but when gravid females of the other three mentioned Laco species are confined under similar conditions only a few eggs are obtained. All these species will, however, lay eggs in flower pots in which the soil has been pressed down and left until grass has grown in them.

Reaction of Adults to Light.

White to yellowish light does not attract L. variabilis adults and this species is very seldom found amongst the "click-beetles" which come to light in houses during the wet season or after the early summer rains. Using an acetylene light and white sheet, attempts to collect Elateridae were made in several locations at different times during October-February periods. In Table II, are found details of some of the collections.

<table>
<thead>
<tr>
<th>Species</th>
<th>No. 1</th>
<th>No. 2</th>
<th>No. 3</th>
<th>No. 5</th>
<th>No. 10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4th Nov., 1931</td>
<td>10th Nov., 1931</td>
<td>7th Nov., 1931</td>
<td>10th Nov., 1931</td>
<td></td>
</tr>
<tr>
<td>L. assus</td>
<td>7</td>
<td>52</td>
<td>23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L. humilis</td>
<td></td>
<td>98</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L. variabilis</td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L. lateralis</td>
<td></td>
<td></td>
<td></td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>H. carinatus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>26</td>
</tr>
<tr>
<td>H. caesarinensis</td>
<td></td>
<td></td>
<td></td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Other Elaterids</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

It was whilst making collection No. 5 in a field of plant cane which had been slightly damaged by wireworms (this field was bedded up during the final ploughing), that variabilis adults were seen on cane leaves. No. 5 was made in a low, wet scrub following heavy rain during the day and No. 10 in a well-drained stock paddock in very close proximity to a depression in a cultivated field where variabilis adults were known to be present. On some occasions, when collecting with lights in a wireworm-infested field, the lower leaf sheaths of cane have been bent down to expose the beetles but none came to the lights. If adults are exposed to light during the day time they may fall to the ground, but in any case, after remaining inert for a short period they seek shelter under any available cover as quickly as their comparatively sluggish movements will allow.

Adults of the Heteroderis species move much more quickly than do those of the Laco species studied; also the former sometimes take wing when disturbed. This shelter seeking is not wholly caused by heat from the sun, as it also happens in cool, shady situations.

Feeding Habits of Adults.

The adult stage of L. variabilis is not directly injurious to cane. In the laboratory it was found that females bred from larvae would not oviposit until after very light feeding, and potato tuber was provided for them. It is thought that, in the field, the softer underground portions of plants are their chief source of food.

Distribution of Larvae in the Fields.

As previously stated the larvae of this species are confined almost exclusively to badly-drained country or parts of fields. The soil in most of these situations is from 9 to 14 inches in depth, light in colour, poor to fair in quality, and with an impervious clay subsoil. However, provided drainage is bad, soil type seems to be of little consequence in so far as L. variabilis habitation is concerned. (Note briefly Table III. *) These wireworms are present in the darker flood country at Proserpine, in "glue-pot," and during some seasons strikes in excellent alluvial flats with several feet of soil over gravel may show "wireworm" misses here and there in the bottom of depressions.

Distribution of Larvae in the Soil.

First-stage larvae seldom leave the top 2 or 3 inches of soil. The other larval instars have been found at soil depths depending upon soil moisture conditions at the times of examination. When fork hoeing, or supplying after rain (also after heavy dews in very low, wet country) many larvae are to be found within an inch of the soil surface, whilst after a spell of very dry weather the older larvae, if in the mobile state, descend to immediately above the clay. The movement of larvae in the soil, according to moisture distribution, has resulted, on occasions, in rather spectacular effects. It has happened that some fields known

* At one time some attention was paid to the water-holding capacity of the soils. Later during this wireworm investigation, but before complete mechanical analyses of the soils were done, it was considered unnecessary to continue with the project. The moisture equivalents and sticky points observed are given in this table.
to be inhabited by a considerable *L. variabilis* larval population had been planted when the soil moisture had been very low. The results were good sowings of primary shoots. At this stage a shower of rain was experienced. The larvae came up to the top 2 or 3 inches of moist soil and, as this moisture quickly disappeared they descended. During this movement of the larvae they came into contact with primary shoots &c., with the result that within three days following the shower fully 70 per cent. of the originally healthy primary shoots showed *dead-hearts*.

**TABLE III.**

**Relationship of Density of Larval Population to Drainage, Percentage Organic Matter, Soil Type, and Location.**

<table>
<thead>
<tr>
<th>No. of soil Sample</th>
<th>Farm</th>
<th>Moisture Equiv. (50 g. per 100 g. water)</th>
<th>Sticky Point</th>
<th>Percentage Organic material</th>
<th>Soil Type and Location</th>
<th>Density of Larval Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>50-45</td>
<td>5-2</td>
<td>Wash in water-course planted to cane</td>
<td>Large in suitable seasons, had strikes; larval damage</td>
<td>Very much smaller than No. 1</td>
</tr>
<tr>
<td>2</td>
<td>A</td>
<td>50-60</td>
<td>5-2</td>
<td>In a shallow depression</td>
<td>Large in suitable seasons, had strikes; larval damage</td>
<td>Very much smaller than No. 1</td>
</tr>
<tr>
<td>3</td>
<td>A</td>
<td>55-75</td>
<td>5-2</td>
<td>In a depression; drained</td>
<td>Large in suitable seasons, had strikes; larval damage</td>
<td>Very much smaller than No. 1</td>
</tr>
<tr>
<td>4</td>
<td>A</td>
<td>55-60</td>
<td>5-2</td>
<td>Dark, sandy, well-drained land</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
</tr>
<tr>
<td>5</td>
<td>A</td>
<td>55-60</td>
<td>5-2</td>
<td>In a depression; drained</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
</tr>
<tr>
<td>6</td>
<td>B</td>
<td>50-60</td>
<td>5-2</td>
<td>In a depression; drained</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
</tr>
<tr>
<td>7</td>
<td>B</td>
<td>50-60</td>
<td>5-2</td>
<td>In a depression; drained</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
</tr>
<tr>
<td>8</td>
<td>B</td>
<td>50-60</td>
<td>5-2</td>
<td>In a depression; drained</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
</tr>
<tr>
<td>9</td>
<td>B</td>
<td>50-60</td>
<td>5-2</td>
<td>In a depression; drained</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
</tr>
<tr>
<td>10</td>
<td>C</td>
<td>50-60</td>
<td>5-2</td>
<td>In a depression; drained</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
</tr>
<tr>
<td>11</td>
<td>C</td>
<td>50-60</td>
<td>5-2</td>
<td>In a depression; drained</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
</tr>
<tr>
<td>12</td>
<td>C</td>
<td>50-60</td>
<td>5-2</td>
<td>In a depression; drained</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
</tr>
<tr>
<td>13</td>
<td>C</td>
<td>50-60</td>
<td>5-2</td>
<td>In a depression; drained</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
</tr>
<tr>
<td>14</td>
<td>D</td>
<td>50-60</td>
<td>5-2</td>
<td>In a depression; drained</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
</tr>
<tr>
<td>15</td>
<td>D</td>
<td>50-60</td>
<td>5-2</td>
<td>In a depression; drained</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
</tr>
<tr>
<td>16</td>
<td>D</td>
<td>50-60</td>
<td>5-2</td>
<td>In a depression; drained</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
</tr>
<tr>
<td>17</td>
<td>D</td>
<td>50-60</td>
<td>5-2</td>
<td>In a depression; drained</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
<td>No larval damage; no <em>L. variabilis</em> larvae ever found in this district</td>
</tr>
</tbody>
</table>

On one occasion when making inspections in a field where several trash-bound stools of cane were growing, it was seen that all the soft eyes amongst the damp trash to a height of 6 inches above ground level had been damaged by wireworms. In three instances a *Lacan variabilis* larva was found in an eye.

No larvae have been found to enter the clay subsoil although this point has been investigated in suitable localities on a number of occasions. In the laboratory a series of drain pipes were filled with soil and clay in a manner such as to simulate natural field conditions as nearly as possible. Six half to full grown *Lacan variabilis* larvae were placed in each pipe and a glass tube was let down to a different depth in each of the pipes. The soil and clay were allowed to dry out slowly, except near the ends of the glass tubes down which small volumes of water were poured periodically. Invariably the larvae, if mobile, were found in the small amounts of damp soil near the ends of the glass tubes which did not enter clay. In the pipes where only the top portion of the clay and the soil immediately above it were slightly damp the larvae were found in the damp soil only. Where the top portion of the clay and all the soil had very nearly dried out the mobile larvae were found scattered in the soil.

**Food and Feeding Habits of Larvae of *L. variabilis*.**

The larvae ingest soil, *eat into the soft and distended eyes of sets and the sides of the underground portions of cane shoots, and burrow into the ends of the sets themselves. When soil has been the chief food the straight alimentary canal shows through the integument as a dark line. The eyes of sets are not attacked until they become swollen and soft. The softer rind of top plants, the root bands, root eyes, and rootlets* sometimes show the results of *L. variabilis* feeding. Sliced potato tuber and sprouting seeds of corn and wheat have been successfully used as food for larvae during rearing work in the laboratory. Attempts to persuade larvae to attack whole potato tubers always failed; when this material is used as food the larva will burrow into the cut surface only.

As is usual with many wireworm species when a number of *L. variabilis* larvae are confined together in a small amount of soil cannibalistic tendencies are shown. Even second instars have been observed feeding on the internals of their fellows of somewhat similar size. The older larvae, when in captivity, will also attack small larvae of the *Scarabaeid* and of the *Asilidae*.

The larvae are voracious but, normally, feeding* is a continuous process throughout larval life. Under conditions such as the presence

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*Wireworm feeding on rootlets and roots has no appreciable effect on cane under any climatic conditions in Central Queensland.*

† *Wireworm damage to cane has evidently made such an impression in the Mackay district that these pests are thought by many persons to damage locally grown potatoes, beans, and many other plants. In every case investigated the Potato Moth (Phthorimaea operculella Zel.) was responsible for all damage to potatoes, and the Bean Fly (Agromyza phaseli Coq.) was the cause of damage to beans. The damage to potatoes was usually observed during storage.

‡ More detailed accounts of larval feeding, larval instars and their stadia, and the relationship between larval growth and the moisture and temperature of larval habitat are given in a previous publication (McDougall, 1934).
of vegetable material and suitable soil moisture, it is limited to short periods immediately following each larval moult.

Response of Larvae to Extremes in Environmental Conditions.

Any of the larval instars can withstand excessively wet soil environments for considerable periods. In the laboratory larvae have been kept for five months in soil with moisture content well above its sticky point. Larvae have been found in cultivated fields on which water has been lying for as long as four weeks; such larvae are always in a healthy condition.

During rearing work it was found that the early larval instars require excessive soil moisture for their existence at summer temperatures for Mackay. The smaller instars died if the moisture of the soil was allowed to fall to a point lower than about three-quarters of its sticky point. Half to full-grown larvae, however, have been kept alive for six months in soil (sticky point 29.8) which dropped during that period from a moisture content of 15.7 per cent. to 5.1 per cent. (calculated on oven-dry weight of soil). Absence of vegetable food has very little serious effect on any of the larval instars other than retarding the normal rate of development. Larvae have been reared through as many as four instars in pots of fresh soil, moist or wet as required, without addition of other food at any time. A parallel series of larvae was reared in similar pots, and to these latter small pieces of potato were added at different times. Provided no larva had moulted since confinement and had not progressed as far as the immobile pre-ecdysial state, the tuber was always eaten into within a day of its being supplied.

Life History.*

The species *Lacan variabilis* has one main generation a year; the adults appear from late October to early February, but in greatest numbers from November to early December. Within a fortnight after their emergence from the soil, adults may no longer be found under the various covers as they have by then disappeared into crevices of the soil; the depth to which they penetrate is often three inches. At about three to four weeks after the emergence of the females the first batches of eggs are deposited. In the laboratory male adults have been kept alive in pots of damp soil for as long as six months and in glass tubes without soil or food for three weeks but field observations indicate that the life of a female adult under natural conditions seldom exceeds seven weeks. It has been found to be more difficult to keep males alive in captivity for more than four weeks. When adults of both sexes which have been reared from pupae were confined in pots of damp soil, the males died at or just after the time when the first batches of eggs were laid. The egg stage usually occupies eight or nine days occasionally seven or nine, and rarely ten. There are eight larval instars and, under suitable conditions, the mean duration in days for each of the stadia was, from first to eighth, 9-5, 14-9, 18-9, 20-2, 28-2, 32-8, 38-2, and 152-0, respectively. Each stadium is found to be varied by the absence of vegetable food and by soil moisture fluctuations due to the changes in weather conditions. The pupal stage occupies from thirteen to sixteen days, usually fourteen days.

Although very little economic importance there is a small percentage of the *L. variabilis* population which exhibits a two-generation a year life cycle. From eggs deposited during the period November to January there arise a few larvae which pupate during the following March or April. Females from the April-March pupation have been kept alive in the laboratory until the following February, but attempts to induce some of them to oviposit at such a late stage of their unnatural existence failed. Intensive search for adults has been made in suitable localities in fields during late June to September, but since none has been found, these autumn adults evidently live no longer, under natural conditions than do those which emerge during early and mid-summer. Some autumn adults occasionally oviposit under field conditions and a few of their progeny become imagines in the following summer. When the stadia of the larvae which become adults in autumn are compared with those of larvae which take around three hundred days to complete their larval life a shortening of some is evident. The seventh and eighth are greatly reduced whilst many of the others also experience some reduction. The earlier stadia of larvae from autumn adults are considerably lengthened at the expense of a shortening of the later ones.

Some of the larvae of both of the short-lived generations pupate after passing through only six larval stadia. However, the majority that ultimately give rise to adults have the normal number of larval instars.

Control.

Much has been written about the control of wireworms* in many parts of the world, but as remarked by Graf (1914) "probably no other insects have had more remedies tried for their control and with less success." As *L. variabilis* has been a pest to cane in Central Queensland mill areas for many years, it is but to be expected that a number of the remedies referred to above have been tried out by farmers with varying results. Also several field observations have become the bases of hypotheses offered as help in arriving at a successful solution of the problem under discussion. During the present investigation it was considered necessary to undertake some work along the lines suggested by previous recommendations as well as following what is now generally accepted as a standard method of attacking the problem of controlling a wireworm pest of a crop such as sugar-cane. In some instances these two parts of the project overlapped. Methods of control are discussed under the three headings of Biological, Chemical, and Mechanical. The methods which are advocated for the control of this pest under general farm conditions are set out on page 36.

* C. A. Thomas (1930) has reviewed the literature on the control of wireworms up till July, 1930; an excellent bibliography of the more important publications is appended to this review.
Biological Methods.

No parasites or predators of the larval, pupal, and adult stages of *L. variabilis* which could be considered to be of any economic importance have been found. Up to the present the egg is the only stage which has not been intensively studied in the field. The entomologists of the Experiment Station of the Hawaiian Sugar Planters’ Association have also searched unsuccessfully for natural enemies of wireworms in some Queensland cane fields. The fungi which are sometimes found on pupae, adults and larvae in the rearing pots or on *pupae* in the field, are considered to be *merely* saprophytic. Mites, even when present in moderately large numbers, have no apparent effect on larvae kept in captivity or on adults in the field. It is interesting to record, however, that dissections made during November to January of the somewhat toad-like frog *Phractophryne* (*Chirodactes*) *australis* *Gray*, showed *L. variabilis* adults along with several other insects, amongst the contents of the alimentary canal.

Chemical Methods.

All of the chemical methods tried have been directed against the larval stage of *L. variabilis*. It was early found that positive evidence derived from the use of poisons against wireworms in tins of soil in the laboratory was of little value when the experiments were repeated in the field. The experimental results here given concerning chemical methods are, unless otherwise specifically mentioned, from small field plots put out with the necessary checks in suitable localities only during early planting (March-April) or its immediate replanting. Plots put out during late plantings (July-August) were often very unsatisfactory. After taking into consideration larval feeding habits and larval stadia this could be expected (see "Times of Planting," p. 29).

The criterion which was taken as showing the success or otherwise of any poison was the amount of damage to eyes of sets and shoots. Four methods of applying the different poisons (cyanides excepted) were used:—

1. Dipping or dusting sets.
2. Placing poisons in drills with the sets.
3. Incorporating the poison with the soil surrounding the sets at the time of planting.
4. Introducing the poison into the soil close to the sets at a time when it was considered that the eyes were approaching a condition suitable for wireworm attack.

Table IV gives results of most of the poison experiments; each has been duplicated in two different fields.
# THE WIREWORM PEST AND ITS CONTROL IN CENTRAL QUEENSLAND SUGAR-CANE FIELDS

## RESULTS OF SMALL FIELD TRIALS WITH CHEMICALS AGAINST *L. variabilis* LARVAE

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Dosage</th>
<th>Method of application</th>
<th>Results</th>
<th>Check Plots</th>
<th>Treated Plots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead Arsenate</td>
<td>10% solution</td>
<td>No. 1</td>
<td>14 out of 15</td>
<td>13 out of 17</td>
<td></td>
</tr>
<tr>
<td>Mixture of chopped grass, sodium benzoate (1 lb.) and muriates (3 lb. in 10 gallons of water)</td>
<td>50 lb. of acre to per acre</td>
<td>No. 2</td>
<td>19 out of 30</td>
<td>22 out of 30</td>
<td></td>
</tr>
<tr>
<td>Paris green</td>
<td>200 lb. per acre</td>
<td>No. 1</td>
<td>23 out of 30</td>
<td>29 out of 30</td>
<td></td>
</tr>
<tr>
<td>Sulphur</td>
<td>540 lb. per acre</td>
<td>No. 3</td>
<td>25 out of 30</td>
<td>28 out of 35</td>
<td></td>
</tr>
<tr>
<td>R.Y. 4 Soil Cleanser (33% free sulphur, 30% polyphosphates and hydrolyphosphate)</td>
<td>680 lb. per acre</td>
<td>No. 3</td>
<td>31 out of 31</td>
<td>27 out of 33</td>
<td></td>
</tr>
<tr>
<td>Slaked lime</td>
<td>510 lb. per acre</td>
<td>No. 1</td>
<td>19 out of 30</td>
<td>23 out of 30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,000 lb. per acre</td>
<td>No. 2</td>
<td>20 out of 30</td>
<td>17 out of 27</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2,000 lb. per acre</td>
<td>No. 3</td>
<td>19 out of 30</td>
<td>15 out of 31</td>
<td></td>
</tr>
<tr>
<td>Naphthalene and slaked lime.</td>
<td>400 lb. per acre of each ingredient</td>
<td>No. 2</td>
<td>19 out of 30</td>
<td>17 out of 30</td>
<td></td>
</tr>
<tr>
<td>Naphthalene</td>
<td>800 lb. per acre (400 lb. each application)</td>
<td>Nos. 3 and 4 combined</td>
<td>14 out of 15</td>
<td>15 out of 20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>600 lb. per acre (300 lb. each application)</td>
<td>Nos. 3 and 4 combined</td>
<td>5 out of 20</td>
<td>2 out of 23</td>
<td></td>
</tr>
<tr>
<td>Naphthalene (1 oz.) Carbon bisulphide (2 fluid oz.) and soap after Krauss (1931)</td>
<td>2 pints of 10% solution per nine feet of drill</td>
<td>No. 4</td>
<td>31 out of 31</td>
<td>3 out of 31</td>
<td></td>
</tr>
<tr>
<td>Carbon bisulphide</td>
<td>250 lb. per acre</td>
<td>No. 4</td>
<td>19 out of 35</td>
<td>16 out of 34</td>
<td></td>
</tr>
<tr>
<td>Parachlorbenzene and CS₂</td>
<td>300 lb. per acre</td>
<td>No. 4</td>
<td>19 out of 35</td>
<td>14 out of 31</td>
<td></td>
</tr>
<tr>
<td>Parachlorbenzene</td>
<td>680 lb. per acre</td>
<td>No. 2</td>
<td>23 out of 30</td>
<td>24 out of 33</td>
<td></td>
</tr>
<tr>
<td>Parachlorbenzene and slaked lime</td>
<td>680 lb. P.D.B. and 510 lb. lime per acre</td>
<td>No. 3</td>
<td>23 out of 30</td>
<td>19 out of 30</td>
<td></td>
</tr>
<tr>
<td>Orthochlorbenzene</td>
<td>600 lb. per acre</td>
<td>No. 4</td>
<td>14 out of 15</td>
<td>12 out of 15</td>
<td></td>
</tr>
<tr>
<td>Mustard oil and water. (50 ml. of oil made up to 500 ml.)</td>
<td>One litre per chain of drill at each application</td>
<td>Nos. 3 and 4 combined</td>
<td>2 out of 30</td>
<td>9 out of 11</td>
<td></td>
</tr>
<tr>
<td>25% Kerosene emulsion</td>
<td>1 litre per half chain of drill</td>
<td>No. 4</td>
<td>21 out of 31</td>
<td>2 out of 23</td>
<td></td>
</tr>
</tbody>
</table>

* A late plant plot.
† 147 running chains of drill per acre.
‡ Only eyes not damaged by chemicals were counted.

Kerosene, orthochlorbenzene, and mustard oil were found to kill sett eyes on contact and, when using carbon bisulphide, it was found necessary to be careful so as not to damage the eyes.

To the above list of poisons which were found to be ineffective in controlling *L. variabilis* when applied by the different methods as indicated, borax and sodium fluorosilicate may be added. A chlorpercin plot was put out during a late plant; both the results of the plot and methods of handling this migrant were unsatisfactory. Mention of a laboratory experiment with Paris Green may be of interest. The cut surfaces of twelve pieces of potato tuber were thoroughly coated with Paris Green, but on six of the pieces so treated small areas of the poisoned surface were well cleaned. Each of the twelve pieces of tuber was then placed in a pot containing damp soil and three-quarters grown *L. variabilis* larvae which had just moulted. It was found that the thoroughly-protected food supply had not been touched, whereas of the other six pieces of potato three had been tunnelled by larvae entering through the small, clean areas on the poisoned surfaces. It would seem that a similar happening takes place when cane sets, planted in a wireworm-infested locality, are dusted with Paris Green. As soon as an eye swells and shoots a vulnerable portion of the plant is out of range of the poison protection applied during planting.

Various cyanides have been recommended as controls for wireworms attacking a number of crops including sugar-cane. In many instances, mention is made also of the possible harmful effect of these materials on plant life. Using cyanogas (calcium cyanide) no practical method has been found of successfully applying this material to the control of *L. variabilis* in the Mackay district without seriously injuring the eyes of sets. Even assuming the finding of an efficient attractant it is considered that pre-baiting is economically impossible.

Small doses of cyanogas when placed in the drills with the plants killed all the eyes. If placed at a minimum distance from the plants so as not to damage the eyes, the material was of no use in combating wireworm attack.

Portions of a *L. variabilis* infested field were drilled out (drills 2 feet apart) and a dose of 200 lb. per acre of cyanogas was buried. Four weeks later, cane planted in these areas was attacked to the same extent as in the untreated parts of the field.

### Mechanical Methods

**Hand Collecting of Larvae.**—It has been found that the laborious work of collecting larvae from furrows behind ploughs is of very little help in decreasing the *L. variabilis* population in any field. Very few larvae of this species will be seen during ploughing, and on a number of occasions, two hours' following of the plough in certain portions of fields has resulted in the collection of not more than fifteen larvae. When these same portions of fields have been planted, however, as much as 50% per cent. of each of the strikes has been affected by wireworms.

The same point is concerned when it is desirable to know before planting (particularly an early planting) if wireworms are likely to be troublesome. It was found that the apparent absence of larvae during ploughing operations was not a reliable guide and that the planting and subsequent inspections of trial sets, usually in lots of five in the lowest parts of the fields, was the only satisfactory method of obtaining the desired information.

**The Utilisation of Cane Varieties.**—A few farmers consider that some varieties of cane are able to "resist" wireworm attacks to a greater extent than others. During the establishment of plots against wireworms many different varieties of cane were used and all were, under similar
conditions, equally damaged by these pests. When slow-striking varieties were planted out against quick-striking canes in a variety trial, many eyes of the latter class were destroyed before those of the former had been touched. Ultimately, however, the strikes of all the varieties were quite similarly attacked by the wireworms.

In Hawaii cane varieties have been put to good use in helping to solve a wireworm problem. Quoting from a communication (1-231) from E. Pember, Entomologist to the Experiment Station of the Hawaiian Sugar Planters' Association, "At present our wireworm problem has become less important because of the utilisation of cane varieties, such as Uba, which need be planted only once every ten or twelve years. As the plant crop is the only one that suffers, our Elaterid damage to a field is really very slight." Unfortunately, the habitat of the pest, its uneven distribution in many fields, the lack of varieties suitable for the purpose, and climatic and soil conditions make this excellent method of combating wireworms impossible in the case of *Lacanobia variabilis* in Central Queensland.

Rapid Early Growth and Use of Manures.—The getting away of plants as quickly as possible is often given as a subsidiary recommendation for the reduction of wireworm damage to sugar-cane, it being reasoned that when growth is slow the period of exposure to injury is prolonged. In the Mackay district, farmers point out that in seasons when there is relatively quick striking in "wireworm" country there is very little damage by the pests (*L. variabilis*). Probably, if immediate and apparent planting conditions are similar, the fundamental reason for the quicker striking in some years than in others is that following lighter or moderate wet seasons the soil has not been waterlogged for as lengthy periods (if at all) as when the wet seasons are heavy. As will be demonstrated later (""Times of Planting and Seasonal Incidence," p. 29) there is a very good correlation between the density of the wireworm population in any year and the intensity of the preceding mid-summer rains. Quick striking of cane and the amount of wireworm damage are both dependent, to some extent, on the wet season, but it has not been found that quick striking is of much help at all in fields where feeding larvae of *L. variabilis* are actually present in appreciable numbers. It must be remembered that the eyes of sets are not attacked until they are soft and swollen; soaked sets with swollen eyes or small shoots were planted during an early planting in a portion of a field where wireworms were known to be present and the planting moisture was good, but within three days after planting all eyes and shoots had been destroyed.

The use of manures in wireworm control is usually attributed to the stimulating effects on plant growth rather than to any direct contact insecticidal value. In the case of lime it is thought that its real value is due to its effect upon the physical condition of the soil. During 1931 a large lime and fertilizer trial against wireworms was established in the form of a 4 x 4 Latin square. On harvesting it was found that the yields from plots which had received an application of fertilizer in the drills and of lime in the drills were significantly better than the check plots. Results are not significant, however, in so far as the counts of "dead-hearts" and misses caused by wireworms concerned.
Further trials with planting mixtures and complete fertilizers did not indicate that manures would be of any use whatsoever in helping to reduce damage by *Lacon variabilis*.

Some farmers have found by sad experience that it is a waste to place manure in the drills with plants in unimproved wireworm country. Nevertheless, the idea persists in some localities that superphosphates placed in the drills at the time of planting is a control for wireworms, and still other farmers consider that the use of burnt lime alone is helpful in decreasing the damage by this pest. Particular attention has been paid to the use of these materials against *Lacon variabilis*.

Lime (see also Chemical Methods, p. 21).—In addition to several smaller plots, two large plots (4 x 4 Latin squares) were set out incorporating different lime treatments in badly-drained depressions in two fields. The treatments were:

A.—1 ton of slaked lime per acre, broadcast.
B.—2 tons of slaked lime per acre, broadcast.
C.—No treatment.
D.—1 ton of slaked lime, broadcast, with 3 cwt. of lime per acre in the drills.

Lime was applied broadcast immediately before final ploughing. Neither of the plots could be harvested; in one the strike was a complete failure; while in the second, which had to be very heavily supplied, relevant counts did not give significant results.

A pH survey of wireworm-infested fields showed that *L. variabilis* larvae inhabited soil ranging in pH (in N/1 KCl) from 3.5 to 5.5, and that parts of any field inhabited by the pests were usually more acid than the remainder of the field. Soil samples for the purpose of this survey were taken from thirty-seven fields in different localities in both the Mackay and Proserpine districts. In the laboratory a series of nine jars containing soils, which at the beginning of the experiment covered a pH (in water suspension) range from 3.5 to 7.0, was adjusted by the addition of calculated amounts of N/5 sulphuric acid and water or burnt lime and water to a soil of pH 5.5. In each of these jars *Lacon variabilis* larvae not smaller than the fourth instar were placed. It was found that in soil over the pH range under consideration, these larvae could be quite easily reared to adults. It consequently does not seem that the addition of lime to a wireworm field would affect the wireworms inhabiting it by virtue of changing the pH of their environment. Larvae have also been kept for considerable periods of time in jars containing half slaked lime and half soil; their behaviour was normal.

Superphosphate.—During the eight to nine months following March, 1932, larvae were kept in soil and superphosphate; the largest amount of the fertilizer in any of the jars was equivalent to an application at the rate of 150 tons per acre. Ninety-two per cent. of the larvae, the smallest of which were fourth instars when the experiment was initiated, passed through the larval molts in normal fashion, voraciously attacked
potato tuber when it was supplied to them, and finally emerged as adults. Six out of ten larvae in the jars containing the very heavy dressing came through to adults. There is no doubt that superphosphate as a direct insecticide, or as a factor in changing environmental conditions, has a deleterious effect on *L. variabilis* larvae.

In addition to the several trials with fertilizers containing superphosphate, four small plots with superphosphate only were put out. The following is an example of the layout of these small plots and the count (Table V.) as usual, indicates the futility of using this material against *L. variabilis* during a season when the pest is active in any field:

| Check (1) | ... | Super (2) | Date of planting: 3–1.32. |
| Check (3) | ... | Super (4) | Variety: Q. 813. |
| Super (5) | ... | Check (6) | Treatment: Superphosphate placed in the drills at the time of planting at the rate of 882 lb, per acre, |
| Check (7) | ... | Super (8) | Size of plot: One chain by 4 drills. |

Four replications.

**TABLE V.**

**Count of a Superphosphate Trial against *L. variabilis*.**

**Date of Inspection—1.3–32.**

<table>
<thead>
<tr>
<th>No. of Small Plot</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of swollen eyes on plants</td>
<td>79</td>
<td>70</td>
<td>79</td>
<td>74</td>
<td>72</td>
<td>76</td>
<td>72</td>
<td>72</td>
</tr>
<tr>
<td>No. of apparently good shoots</td>
<td>14</td>
<td>8</td>
<td>5</td>
<td>4</td>
<td>11</td>
<td>6</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>No. of shoots damaged by wireworms</td>
<td>17</td>
<td>14</td>
<td>19</td>
<td>30</td>
<td>16</td>
<td>18</td>
<td>14</td>
<td>27</td>
</tr>
<tr>
<td>No. of eyes damaged by wireworms</td>
<td>40</td>
<td>44</td>
<td>44</td>
<td>40</td>
<td>38</td>
<td>49</td>
<td>45</td>
<td>38</td>
</tr>
<tr>
<td>No. of shoots and eyes damaged by <em>P. australis</em></td>
<td>6</td>
<td>4</td>
<td>2</td>
<td>7</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td><em>No. of shoots and eyes being attacked by wireworms at the time of inspection</em></td>
<td>11 (7)</td>
<td>8 (6)</td>
<td>6 (3)</td>
<td>2 (2)</td>
<td>1 (1)</td>
<td>1</td>
<td>1 (1)</td>
<td></td>
</tr>
<tr>
<td>Percentage of possible shoots and eyes damaged or being damaged by wireworms</td>
<td>90–14</td>
<td>86–26</td>
<td>97–68</td>
<td>94–33</td>
<td>86–15</td>
<td>93–15</td>
<td>85–51</td>
<td>98–51</td>
</tr>
</tbody>
</table>

*This includes apparently good shoots (in brackets) if, at the time of inspection there were no indications above ground level of "dead-hearts."

**The Growing of Green Manure Crops and Fallow Following.—** Many acres of cane land in the Mackay district are planted to green manure crops each year. On well-drained country it is not asserted that these cover crops, which are normally grown between October and March, have anything to do with wireworm infestations, but where the low lands are concerned—i.e., where wireworm damage occurs—many farmers are of the opinion that the growing of these legumes encourages wireworms. When a green manure crop is successfully grown and ploughed into a wireworm-infested field, it is thought that the increase in humus may be responsible for the pests attacking the setts. When the green crop is a failure, through water-logging or other reason, it is often considered that this failure may be the partial cause of the wireworms attacking the plants.

As indicated in Table III., wireworm damage occurs in fields covering a range of percentages of organic material in the soil, which is fairly wide for the Mackay district. Again the ploughing-in of an exceptionally heavy bean crop does not to any great extent effect the position of the percentage organic material in the soil in a range of 9 to 5-4. From field observations, and the results of field surveys and laboratory experiments, there seems to be no relationship between the percentage organic material in the soil and the incidence of wireworm damage.

It might be thought that the growing of cover crops during November-February—i.e., the period of the adult existence of the pest—may provide excellent and attractive cover for the click-beetles. There is no evidence to show that adults of *L. variabilis* have a preference for green manures as cover; in fact, it has been found that they are not selective in this regard. An attempt to keep a portion of a low, badly-drained wireworm field as nearly a clean fallow as practically possible over a November-February period, did not result in the absence of wireworms in the portion of the field during the following twelve months.

**Eradication of Couch Grass.**—Of all the true grasses in the Mackay and Proserpine canefields, one of the most persistent and one of the most difficult to eradicate is Couch grass (*Cynodon dactylon*), which is very often to be seen in low hollows or depressions, and sometimes elsewhere in otherwise clean fields. It has been suggested that this grass attracts wireworms, and that its removal from fields would be of some use in freeing the soil of the pests. Probably the true explanation of the observations on which this suggestion is based is that Couch grass is quite likely to be present in the habitat desired by *L. variabilis* larvae, and also that Corab larvae have been mistaken for wireworms. Considerable numbers of larvae of *Gnathophorus pincher* (see page 10) are to be found amongst the roots of Couch grass. During the past three years over 200 specimens of this larva have been received by us as wireworms found under Couch grass.

**Times of Planting and Seasonal Incidence.**—It is well known that while early plantings (March–April) may be severely damaged by wireworms, replants in July-August (the time of late planting) in the same fields may sometimes be affected but little if at all. In this connection, the following points in the life history and habits of the pest are of interest:—

1. The adults are present in the fields in greatest numbers during late November and early December; over the period mid-December to February, the adult population decreases very rapidly.
2. Taking early December as the time when the adult emergence is greatest, and adding four weeks for the preoviposition period, two weeks for the oviposition period, eight days for the egg stage, and 163 days for the first seven larval stadia, the time around which very many of the larvae pass into the eighth larval instar, may be computed to be early July.

3. As, under normal field conditions, the larve feed only immediately after moulting, many of those which passed into the eighth instar during late June and early July will have finished feeding by the middle of July.

4. From a consideration of the normal feeding times of a larve, and the fact that the larval stadia progressively increase, it follows that the percentage of smaller to moderate sized instars in the population at any time will bear a direct relationship to the percentage of the larval population feeding at that time.

Briefly summarising these points and their consequences, it is found that during early planting, when many of the larve are small or of moderate size, the feeding of the population as a whole is practically continuous. By the middle of July many of the larve have finished feeding, while the majority of those present which are still feeding do so individually at less frequent intervals. From the middle of July onwards, the percentage of the larval population which has finished feeding rapidly increases, and chances of obtaining strikes free from wireworm damage improve accordingly.

In July, 1938, many early plantings were affected by wireworms, and if the usual July-August planting had been possible, there is no doubt that it would have given these pests an opportunity to add to the total of their damage to cane for that year. Winter and spring rains, however, prohibited late planting in wireworm country before September, with the result that strikes free from wireworm attacks were obtained.

Damage to cane by *L. variabilis* is more extensive and more intensive during some years than during others. It is known (McDougall, 1934) that the weakest point (and it is comparatively very weak) in the life cycle of this pest is during the period of the earlier larval instars which must have excessively wet conditions for their survival, especially at Mackay summer temperatures. In Table VI, is set out the rainfall for the past eleven years during the months when the vast majority of the larve are present in the fields as earlier instars. When these rainfalls are correlated with the remarks on wireworm damage to strikes during the different years, it will be seen that, as would be expected, the amount of rain during any mid-summer has a very decided bearing on the amount of wireworm damage during the succeeding year. As the rainfall is concerned with wireworm existence inasmuch as it helps, with topographical conditions, to provide suitable environments for the smaller larval instars, its distribution as well as its total amount should be noted. Usually, if the total amount is fairly large, the distribution is such that it helps to keep certain localities excessively wet during a considerable portion of a December-February period. Planting year 1924 (Table VI.) provides a possible exception; here the 14.29 inches in the last part of February would have had more effect on the amount of wireworm damage for that year had it fallen, say, during the middle of January.
Supplying and the Uses of some Cultural Practices performed immediately before or after planting.—As would be expected from a consideration of the preceding section dealing with times of planting, the supplying of wireworms with sets is very unsatisfactory. Such supplying to a damaged early planting usually means a more or less constant performance if a full stand of cane is to be obtained. Supplying to a late planting may not be a distinct success unless the operation is deferred until as late as September or October.

In Fiji and Hawaii (Williams, 1931) a rather effective measure used against wireworms there is to plant sufficient sets, over and above the regular amount, so that later on, if need be, the surplus can be used to fill in any gaps in the rows caused by the pests. ’The cost of labour, extent of damage in a large proportion of wireworm-affected fields, and weather conditions militate against the economic possibility and success of this transplanting in Central Queensland.

More as a matter of interest than as an experiment from which practical results could be expected, a trial was set out in which three-eye sets were planted vertically. One eye was just above ground-level. Certainly, the two lower root-bands of each sett provided roots, and the top eye, in many instances, a shoot, but the resultant stand of cane was very unsatisfactory.

It has been found that the thorough preparation of the land by ploughing operations or the rolling of the land and/or drills after planting has no effect whatsoever in preventing damage by *L. variabilis*. If these pests have become established in a field in sufficient numbers to cause appreciable damage, it can be safely stated that their presence will be felt, irrespective of any economic cultural practices which are likely to be undertaken around normal planting times.

**Drainage.**—The important finding of several workers on the control of ”low land” species of wireworms is briefly stated by Metcalfe and Flint (1926)—”Certain species of wireworms are abundant only in poorly-drained soils. The proper drainage of such soils will entirely prevent damage by these species.”

Naturally, as on many occasions, wireworm damage in Central Queensland mill areas had been noticed in low, badly-drained country, drainage had been recommended as a control of the pests, but drainage as practised by most of the local farmers did not seem to reduce wireworm damage. Nevertheless, as this investigation proceeded, it became more and more apparent that there must be some fundamental connection between bad drainage and the incidence of wireworm damage.

In a consideration of drainage as a control of *L. variabilis* there are several points from field observations concerning this pest and *Heteroderes carinatus*, from the studies of the life histories and habits of these two Elaterids, and from local drainage practice, which stand out as being very significant. These are—

1. The adults of both species will oviposit in soil under similar conditions. *Lacan variabilis* adults are usually found in very damp situations, but it is considered that the only reasons for this are—(a) the disinclination of the species to migrate; and (b) the secluded habits of the beetles making the finding of them in the fields, if they are not present in numbers, rather difficult.
2. The smaller larval instars of *Lacan variabilis* must have excessively wet soil environments for their survival, whilst under similar conditions at the same room temperature those of *H. carinatus* cannot exist; in this latter instance a moderately moist soil environment is needed.

3. The older larval instars of both species can withstand varying environmental soil conditions. They flourish under similar conditions in the laboratory, but in the fields the larvae of *L. variabilis* are almost exclusively confined to low, badly-drained country, and those of *H. carinatus* to the well-drained lands.

4. In fields or portions of fields where damage by *L. variabilis* occurs there are no natural or other permanent drainage systems. Drainage, if any, generally consists of the bedding-up of the fields during the ploughing operations immediately prior to planting.

If it is feasible to assume, as indicated above, that the distribution in the fields of *L. variabilis* and *H. carinatus* (the two species of Elaterid larva most commonly found in cultivated cane fields in Central Queensland) is, to a large extent, dependent upon the soil moisture conditions encountered by their smaller instars, the drainage of *L. variabilis* infested country during the time when the larval instars are very small should control the pest. Similarly, it would follow that the bedding-up of wireworm fields immediately prior to planting—i.e., when the majority of the larvae are over their early stages, would have no controlling effect on the pest. Local drainage methods as carried out in No. 4 above have time and again proved the latter portion of this conclusion to be correct.

From October, 1932, to June, 1933, weekly soil moisture samples were taken from both wireworm-infested and wireworm-free parts of fields on four farms in widely-separated localities. The different soil types encountered and the lack of an entirely suitable “single value” soil constant do not tend to make the interpretation of the results of this sampling either easy or accurate. However, for most field purposes, it can be said that on *L. variabilis* infested parts of fields, surface water will be present during considerable portions of the December-February period prior to the planting year (see Plate V.). The most heavily wireworm-infested portion of any of the fields concerned in the soil moisture sampling was under water for six weeks (periods of one and a-half weeks and four and a-half weeks) during December-February.

For the purpose of correlating laboratory and field work on the relationship of wireworm existence and soil moisture of environment, the results of the soil moisture sampling were taken as indicating that when the soil moisture of a part of a field is very close to or above its sticky point for considerable periods over December-February it is a suitable habitat for *Lacan variabilis*.

During the years 1932 and 1933 several farmers found that their strikes in erstwhile wireworm fields were quite free from damage after they had scooped headlands, filled in or drained depressions, bedded up the fields, and provided efficient outlet channels for the surface water during the midsummer rains prior to plantings (Plate VI., figs. 1, 2, and 3).
RECOMMENDATIONS.

The following methods, given in order of preference, for combating the wireworm *Lacornus variabilis* as a pest of sugar-cane in the Mackay and Proserpine mill areas, are recommended as worthy of being put into general farm practice. Several progressive farmers have used these methods and, up to the present, have found them to be quite satisfactory:-

1. Permanent drainage of low-lying fields.
   2. If, for economic or other reasons, permanent drainage is not practicable, the fields should be thoroughly drained as early as the mid-summer rains or wet season immediately prior to planting, and not left on the flat until ploughing operations during the month before planting.
   3. If proper drainage is not carried out, planting should be left until as late as possible. Perhaps two reasons why fields may not be adequately drained could be mentioned:-(a) It is well known that the incidence of wireworm infestations in many fields is seasonal, and it is considered by some to be worth while trusting to luck for good strikes on these low fields or parts of fields at normal planting times. Often the initial expense of improving say, a depression of 1 acre in a field of 5 acres is not considered to be worth the immediate benefits obtained from such work. The fact that such an improvement is nearly always a permanent improvement and asset to the farm is overlooked; (b) some fields are so low that during most wet seasons it is not possible to drain them efficiently other than by a community drainage scheme, or at a very high cost. Many of these very low fields consist of a rather sandy soil above impervious clay. The low sticky point of the soil adds to the difficulties of draining these fields to a degree of efficiency sufficient to prevent wireworm habitation. The few damaged strikes found during a poor “wireworm” year are on this type of country.

Those who entertain reason (a) should be prepared, if their normal plantings are failures, to replant in September-October, and hope that the following early and mid-summer rains are such as to allow of reasonable working of the young cane.

ACKNOWLEDGMENTS.

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LITERATURE CITED.


