THE CABBAGE AND ONION MAGGOTS

NEW JERSEY

AGRICULTURAL

Experiment Stations

200

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With Compliments of
John B. Smith

NEW JERSEY
AGRICULTURAL EXPERIMENT STATIONS
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FEBRUARY 12, 1907.

The Cabbage and Onion Maggots.

BY

JOHN B. SMITH, Entomologist, and
EDGAR L. DICKERSON, Assistant.

Each year, in various parts of the State, cabbages, cauliflowers and other varieties of cruciferous plants, as well as onions, are damaged to a greater or less extent by maggots feeding on the roots, and therefore known as root-maggots. The injury may not be equally severe two successive years in a given locality, or even in various parts of the same district in any one season, or there may be a series of bad seasons. During the past few years, however, the injury has been serious in many sections of our State, the loss on one farm alone in Cumberland county amounting, in 1906, to $1,000 or over, while in many other places from one-third to one-half of the crop was destroyed.

Numerous experiments against these pests have been made from time to time in New Jersey and elsewhere, and many remedies have been suggested, several of which have been used with more or less success; but quite usually remedies that have been apparently successful in one place or in one hand have failed elsewhere or when used by another. To test some of these materials more

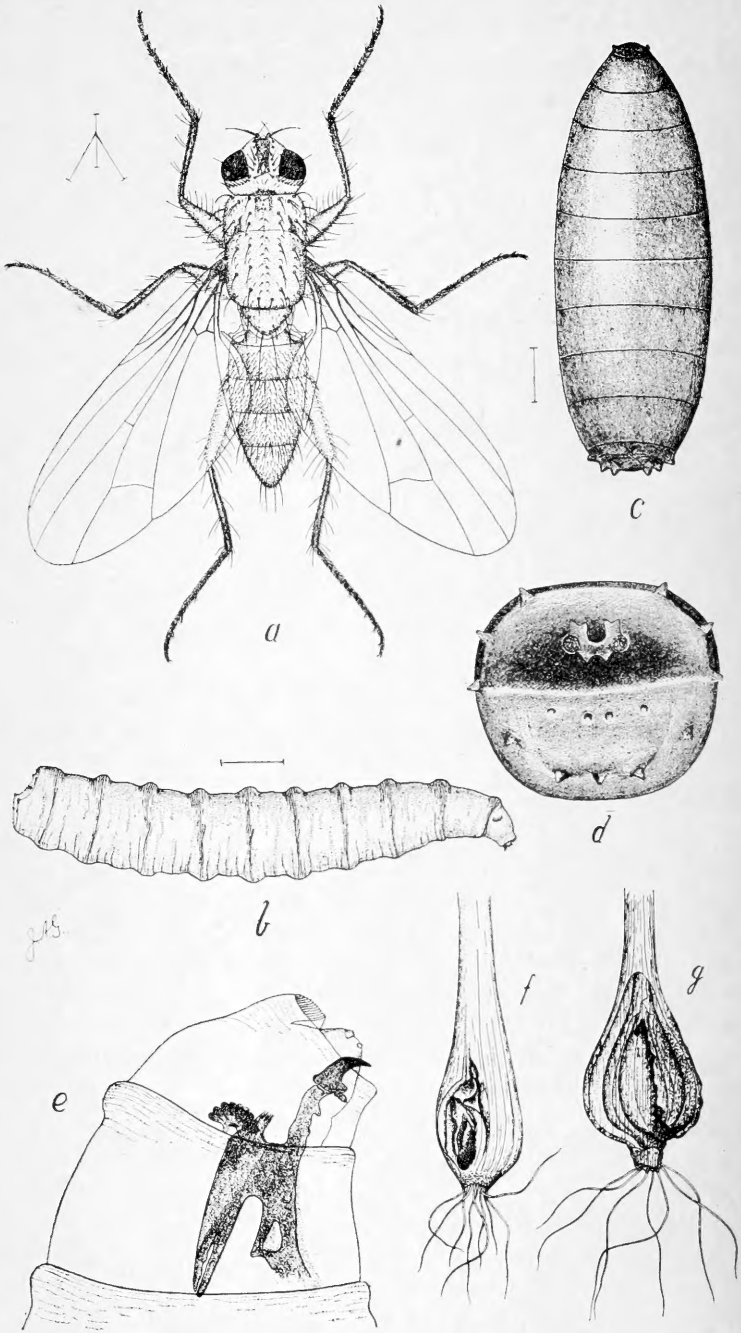

Figure 1.

The onion fly, *Pegomyia cepetorum*, Meade: *a*, adult; *b*, maggot; *c*, pupa; *d*, anal end of maggot with breathing holes; *e*, head with mouth structures—all very much enlarged; *f* and *g* show injury on young onions. Original.

thoroughly, it was decided to conduct a series of experiments under field conditions and in different sections. These were carried on during the season of 1906, principally by Mr. Louis Stemler, of Matawan, Monmouth county; Mr. Arthur Seabrook, of Husted, Cumberland county, and Mr. Howard Taylor, of Riverton, Burlington county, on their respective farms, but under the general direction of this office. The details of these experiments are given in the annual report of this department for 1906, and need not be repeated here. It only need be stated that conclusions in this bulletin are largely based on the results of this work, successes and failures being both represented, and upon the results obtained by other investigators in other States. The observations and experiences of the past fifteen years in New Jersey have also been freely drawn upon in framing the practical recommendations.

There are several species of root-maggots which have been found injuring the onion and cruciferous crops, but only two, or possibly three, occur in destructive numbers in this State, and as the remedies here suggested will do for all, only two forms will be discussed, namely, the cabbage maggot, *Pegomyia brassicæ,* Bouché, and the imported onion maggot, *Pegomyia cepetorum,* Meade, and these will be considered in the order named.

THE CABBAGE MAGGOT.

Pegomyia brassicæ, Bouché.

The cabbage maggot is the larva or young of a two-winged fly somewhat resembling the common house fly, but distinctly smaller, measuring only three-sixteenths of an inch in length, with a narrower and more cylindrical body and proportionately larger wings. In the female the abdomen tapers toward the posterior end while in the male it terminates more bluntly, and in the latter sex the eyes, which are separated in the female, meet on the dorsal surface of the head. In color it is grayish, with a dark stripe extending along the dorsal surface of the abdomen, while the body and legs bear a number of stiff hairs or bristles. If the hind leg of the male fly be carefully examined with a hand lens, a group or tuft of hairs will be found on the underside of the femur at the basal

end, as shown in Fig. 2 (1), and this is a characteristic feature of the species.

It is in this adult stage that the insect hibernates as a rule, although it may also pass the winter as a puparium close to the roots on which the larva has been feeding. During this hibernating period the adults remain in any convenient place, such as the crevices or concealed corners in outbuildings, or in rubbish out of doors, or under the loose bark of trees or logs, and when the

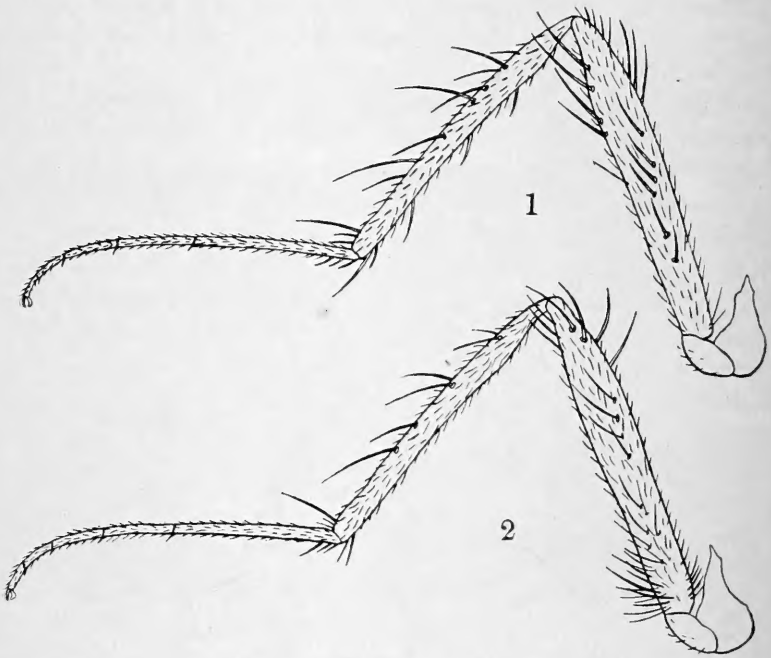

Figure 2.

Hind leg of the male onion fly (1) and of the male cabbage fly (2): much enlarged. Original.

weather becomes sufficiently warm in the spring they emerge and seek the cabbage or other cruciferous plants where they may oviposit. In New Jersey the flies may be found in the field during the latter part of April or early May, the time of first appearance depending upon the character of the season, and if the plants be carefully watched at that time the insects may be seen resting upon or moving about them and on the surface of the ground seeking for places to deposit eggs. They are not very active in habit,

and do not ordinarily fly very far in any one direction; nor do they care to fly in windy weather or on wind-swept areas.

The individual egg is about one twenty-fifth of an inch in length, somewhat elliptical or curved in outline, with more or less pointed ends, and, as it is white in color, can be readily seen by the naked eye upon close examination. A female is said to be capable of laying about fifty eggs, and these are deposited either on the surface of the ground near the plant or on the stem of the plant itself, and if any crevices exist either in the plant or in the soil close to it, the eggs will be placed there. They cannot, however, be forced into the plant tissue of the stem, for the ovipositor of the insect, while extensile, is soft and not capable of puncturing. The point at which the egg is deposited is of considerable importance, for if too far from the plant it is doubtful whether the young maggot which hatches from it, and is a rather helpless creature, will be able to reach its food; or if laid around the plant on so hard a surface that the young maggot cannot penetrate it and get to the softer plant tissue under ground, it will in all probability perish, as it will be unable to feed on the hardened tissue of the stem which is above ground. The importance of this point will be seen when we come to consider remedial measures.

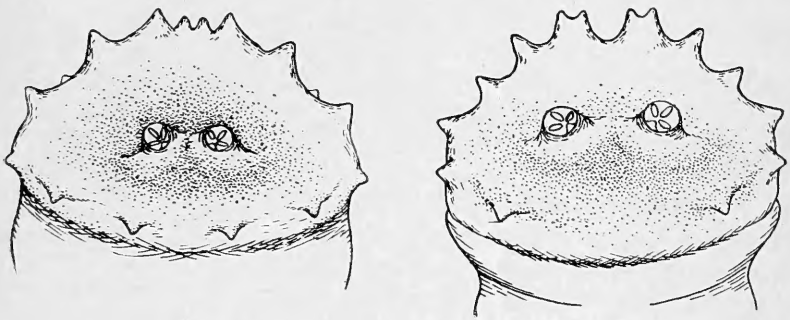

Figure 3.

End segment of the onion maggot (1) and of the cabbage maggot (2): much enlarged. Original.

The length of the egg stage varies from four to ten days, and probably averages about a week. The minute maggot which hatches from the egg grows rapidly if it succeeds in reaching its food, and in three or four weeks becomes one-quarter of an inch or

slightly more in length, white or yellowish in color, cylindrical in outline, terminating abruptly behind and tapering anteriorly, as is illustrated at Fig. 1, *b*. When examined more closely the posterior end will be seen to bear two well-protected spiracles and to be surrounded by twelve conical tubercles, the middle two of which, viewed from above, are slightly cleft, as shown in Fig. 3 (2). The anterior pointed end bears the mouth opening, which is surrounded by fleshy lip-like prominences and contains two protruding hook-like structures, which are dark, hard and interiorly connected with a chitinous framework, which serves for muscular attachment, as shown in the enlarged figure of the head of the onion maggot, Fig. 1, *e*. It is by means of this mouth structure that the maggot secures its food, for, although it cannot bite, it is able to scrape the softer tissue, break the plant cells, and suck up the plant juices and finely-divided tissue. Having once started its work, the maggot continues by a boring-like process, getting into the root if the latter is soft enough, or else moving along the outer surface. It is aided in its work by the decay which sets in at the broken surfaces, causing the further softening of the plant tissue and its consequent easier penetration by the insect.

The maggot has no feet, and moves as follows: The posterior segments of the body are first drawn up toward the anterior end, which is then pushed forward while the hind segments are held rigid, a matter which can be easily accomplished, because the segments are more or less ridged.

There is also on each side of the body, just back of the head, a dark spot, and this, when sufficiently magnified, is found to be a fan-like structure consisting of ten lobes. This is another spiracle or breathing pore, and it has been said that this species may be separated from the onion maggot by the number of its lobes or divisions. This may be true in general, but an examination of our specimens showed the number to vary in both species, so that identification, based upon these structures alone, would be somewhat uncertain.

Having become full-grown, the larva goes into the earth for half an inch to an inch from the root on which it has been feeding, gradually becomes shorter and oval in outline, while the skin becomes harder, smoother and of a chestnut brown color. Sometimes this change takes place on the surface of the root, or even within the galleries made by the maggot. In this stage it is known as a

puparium, formed of this hardened larval skin, which has separated to form a shell-like covering for the true pupa contained within it. The insect remains in the puparium stage about fifteen days, although sometimes this period is extended to several months, after which the adult fly emerges and makes its way to the surface.

This second brood of flies in New Jersey makes its appearance in June, and is soon ready to oviposit and reproduce a second brood of larvæ. Whether or not this brood is not so numerous as the first, whether its natural enemies are more abundant, or whether its members confine themselves more to the wild plants, is not quite certain; at any rate, they do not appear to do as much damage as the first. On the other hand, the cabbage plants are further advanced, the roots and stems are larger and tougher, and hence are better able to stand injury. There are three or more broods in a season, and the maggots may infest chiefly the wild cruciferous weeds rather than the cultivated plants. There is, however, a brood that becomes noticeable late in the season, part of which reaches maturity the same year and part of which passes the winter in the puparium stage and changes to adult flies in the spring. It seems probable that not all the puparia found about the plants in the winter are from the late brood of maggots, but that some are from those of earlier maggots, so that the puparia in hibernation may be from all of the broods. This fact of the insect hibernating as a puparium is of importance when we come to consider remedial measures.

Injury Caused.

We have described the way in which the maggots feed, and it will be well to consider briefly the injury caused by them which is illustrated in some degree in plate Figs. 4 to 7. It has been stated that they feed on a variety of cruciferous plants, and so we find them destroying not only cabbages, but turnips and radishes as well. In fact, beds of both of the latter plants were so badly infested in Cumberland county last season that they were almost completely ruined, and had to be plowed up. Such plots are seen on plate Fig. 12. The radishes and turnips are so fleshy and send out so many fine roots that they do not indicate the presence of the maggots as soon as the cabbage plants do, and while the insects sometimes bore into them, as shown in plate Fig. 4, *a* and *b*, and

plate Fig. 5, *a, d* and *e,* as a rule the tissue is so tough that they simply work over or along the outer surface, especially in turnips, as shown in plate Fig. 4, *c* and *d,* and plate Fig. 5, *b* and *c.* However, the question in these crops is not whether the injury has been sufficient to stop the development of the plant, but whether they are injured at all, for as soon as the maggots have even worked into the surface, as shown in the illustrations, the crops become largely if not altogether unsalable.

In the case of the cabbage it is a question as to whether the plant can maintain enough roots to grow and develop a good head in spite of the injury. As with the radishes and turnips, the maggots frequently destroy only the smaller roots or feed on the surface of the tap root or both, as shown in plate Figs. 6 and 7, but even this often results in a girdling. Sometimes the maggots get even into the center of the root, as is shown in plate Fig. 6, *c,* which was taken from a field patch plant. The presence of the maggot is indicated, especially when the plants are young, by the wilting and drooping leaves, as shown in the illustration of the field and experimental plots, plate Figs. 9 and 10. If the injury is not too severe the plant may make an effort to recover and send out a new supply of roots, as shown in plate Fig. 7, *b;* but unless remedial measures are resorted to as soon as the maggots make their appearance, few of the attacked plants will recover. In the plot just referred to, about sixty per cent. of the plants had been destroyed.

THE IMPORTED ONION MAGGOT.

Pegomyia cepetorum, Meade.

This insect, as well as the fly into which it develops, very closely resembles the species found upon the cabbage in appearance, habits and development. It also hibernates, as a rule, in the adult stage, and with the warmer temperature of spring comes from its winter quarters to deposit its eggs on such onion plants as may be available.

The fly, however, is somewhat larger than *brassicæ,* measuring one-fourth of an inch in length, and is well shown in plate Fig. 1, *a.* As in the other species, the female may be distinguished by the more widely separated eyes and the more pointed abdomen,

while the male lacks the tufts of hair on the inner side of the hind femora at the basal end, as appears in Fig. 2 (1).

The method of oviposition, number and character of the eggs, are similar to those of the other species, and the newly-hatched maggots make their way into the young onions. In from three to four weeks they are full grown, and then measure about five-sixteenths of an inch in length. They very closely resemble the cabbage maggot, but on the posterior oblique extremity, when viewed from above, the two lowest tubercles, instead of being only slightly cleft, are each divided, giving two extra smaller tubercles. Fig. 3 (1). In this species, also, the maggot goes from the plant to form the puparium, and the second brood of flies makes its appearance in June. There may be several broods during the season and the later maggots sometimes prove quite as injurious as the earlier ones. In ordinary seasons such injury is noted in September, and by the end of that month, or first of October, the danger of infestation is over, since the flies which have not then deposited their eggs will have gone into hibernation. But if the season is long and the warm weather continues, infestation may occur even in October, as was the case during the season of 1906.

In feeding the maggots may attack the onion at the side, but they generally work up through the center of the bulb, beginning at the bottom, especially when the onion is small. This they can readily do, because the tissue of the onion is rather soft, and is still further softened by the decay caused by the maggot injury. The plants, and particularly the young ones, indicate the presence of the insects by their sickly, drooping and wilted appearance.

The different stages of this species which have just been briefly described are illustrated on Fig. 1, while the effects of the maggot in young plants are shown on plate Fig. 8.

REMEDIAL MEASURES.

Insecticide applications against underground insects are rarely satisfactory because of the difficulty of getting them into contact with the species to be dealt with. And this difficulty is at once the cause and the explanation of the widely-different results which have been obtained with many of the materials used.

A given substance may kill the maggots well enough, and, placed

in the hands of a man who will use it soon enough, often enough and thoroughly enough, it may do all that could be reasonably expected; but applied too late, after the insects are already working in the plant tissue, or not often enough to reach all the specimens as they develop, or in such manner as not to reach all or any of them, and the result is bound to be disappointing.

And even the character of the soil may cause some difference, because in a light, loose or sandy soil materials may penetrate readily and reach the maggots, where in a heavy, compact or clay ground it would not be more than a surface wetting.

The elements of time, frequency and thoroughness of application are all of the highest importance, and the neglect of any one of them will impair the effectiveness of whatever measure is used.

Stomach poisons are entirely unavailable, apparently, and the plants themselves and their susceptibility to injury must be considered in the selection of materials: the mineral oil emulsions, for instance, which are excellent contact poisons, are even more fatal to the plants than to the insects.

Premising this, our discussion of remedial measures will narrow itself to those cultural and preventive methods and destructive applications which have been more or less effective in our own hands in actual practice in the State or in other States, as published in their reports and bulletins.

CULTURAL METHODS.

While these are not so directly useful against the onion maggot, except in so far as it is advisable to remove all plants in which the insects are found, whenever that is possible, they are of considerable importance in controlling the cabbage maggot. As has already been stated, this insect will breed on the wild as well as the cultivated cruciferous plants, and hence all the former, including some of our most common weeds, such as hedge mustard, winter cress, etc., should be destroyed so far as possible. It has also been pointed out that some of the insects may hibernate in the puparium stage on or near the roots of the plants on which the maggots have been feeding; therefore, remove all roots as soon as they are no longer useful and destroy them with all their contents. Cabbage stumps should be pulled, carried off and dried out or burnt as soon

as the heads are cut, and where beds of radishes, turnips or even onions have been badly infested, late fall plowing and harrowing, followed by a deep early spring plowing, will help in destroying those insects which are in the ground. If such beds are found to be infested early in the season to such an extent as to destroy the crop, or the greater part of it, then plow under as soon and as deeply as possible, or simply turn it up to the surface to be dried out. This will destroy a large number of the maggots and will prevent others from coming to maturity or the flies from emerging from the deeply-buried pupæ.

In like manner, rubbish or brush piles near infested fields should be destroyed. It would be better perhaps to let them remain until the winter, as they would then act as a trap for hibernating flies, which would be destroyed with them.

So, also, the outbuildings and sheds, with drying crates and frames, might be thoroughly cleaned out and whitewashed or fumigated with sulphur, with the resulting destruction of whatever hibernating flies might be in them. In fact, by clean culture, prevent as many as possible of the flies from breeding and destroy as many as possible in hibernation.

Time of Planting.

While this at times may be of little aid, our investigations showed that in some instances it was of considerable importance against onion maggots. It was found that in ordinary seasons scallions started in late August or early September became badly infested, while those started in late September or early October suffered comparatively little. The recommendation is, then, start the scallions at these latter dates, or at least as late as practicable, so as to avoid the late brood of maggots, and as the scallions are desired for an early spring market, have the ground well prepared and use quick-acting fertilizers to force the growth.

Some seasons, however, like the fall of 1906, may be exceptionally late, and then oviposition and infestation may occur even in October. Hence it would be advisable to make, or at least be ready to make, two plantings, so that if the first became infested, the last, at any rate, would remain free.

As an alternative to late planting it may be preferable to make

a small early planting to act as a trap crop, and as soon as these plants are found to be infested they could be carefully taken up, so as to get all the maggots feeding on the roots, and the whole then destroyed. The later planting, made after danger of infestation was to a great extent past, would then remain practically free from the pests, and could be forced along as already mentioned. An additional result from this practice would be that there would be fewer flies to go into winter quarters and less infestation next spring.

In like manner, it was learned that when onion seed was sown in the latter part of April and radish seed sown in early May, the plants were much freer from infestation than those from seed sown earlier. The reason for this is evident, when we consider that the fly comes from hibernation as soon as the weather is sufficiently warm in the spring and deposits its eggs on such plants as are then available, hence the plants from the seed sown on the dates just mentioned make their appearance after the greater part of the egg-laying or ovipositing has taken place. This would also be true of those insects which hibernated in the puparium stage, although the few emerging latest might deposit on these plants. Therefore, have good ground, well prepared, sow at the time indicated and use quick-acting fertilizers so as to mature the crop as rapidly as possible. If an early crop is desired sow very early, fertilize even more heavily to get a very rapid growth, and plow out the later plants if they are infested, to be replaced by the early crop of the later seeding.

Fertilization.

The necessity of a quick-acting fertilizer in conjunction with planting at the right time has just been touched upon, but may be considered further. A combination which was recommended in previous reports of the Entomologist consists of

Nitrate of soda	700	pounds.
Acid phosphate	1,000	"
Muriate of potash	300	"

This, in the case of radishes, can be applied as a top dressing along the rows before they are planted, or just after they are up, at the rate of five hundred pounds per acre. Similar applications

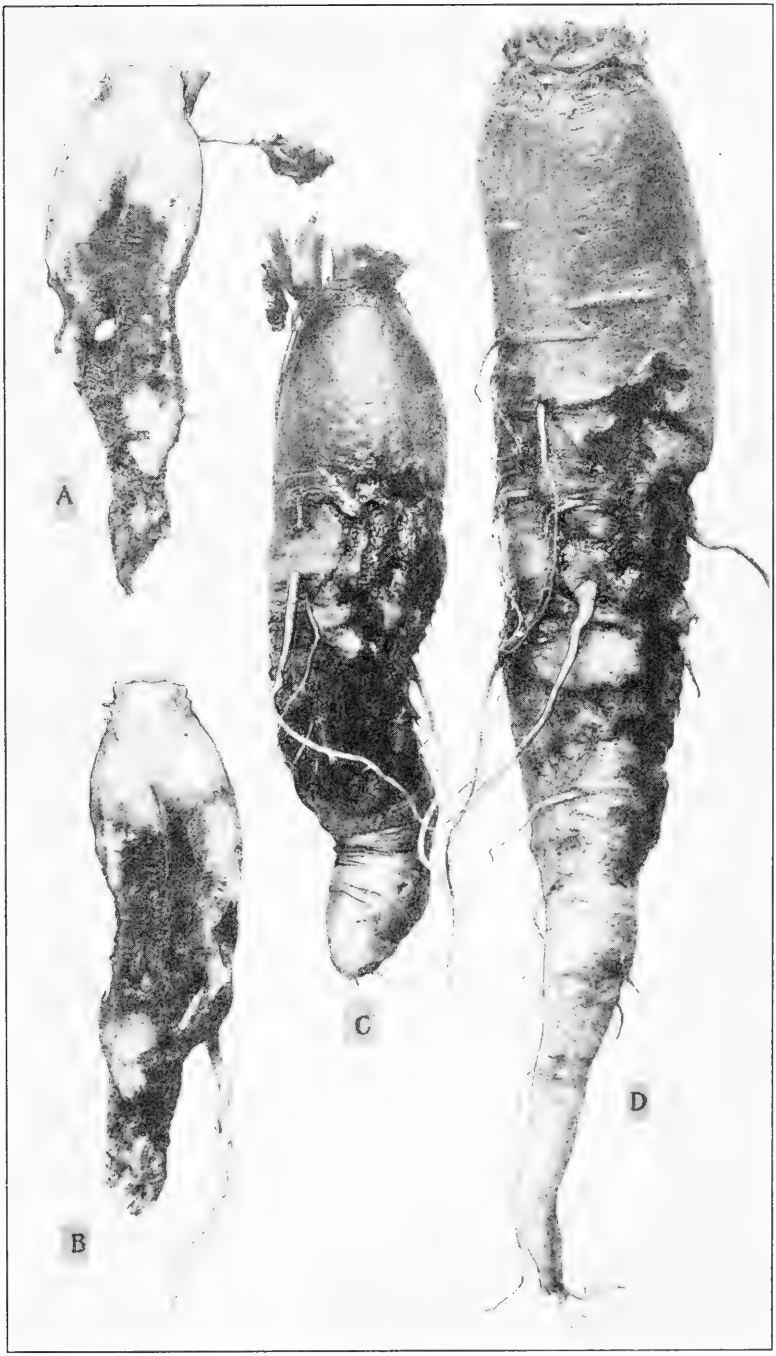

Figure 4.

Radishes damaged by maggots: *a* and *b*, sections, showing internal injury; *c* and *d*, injury caused by maggots feeding on the surface of the radish. From original photos.

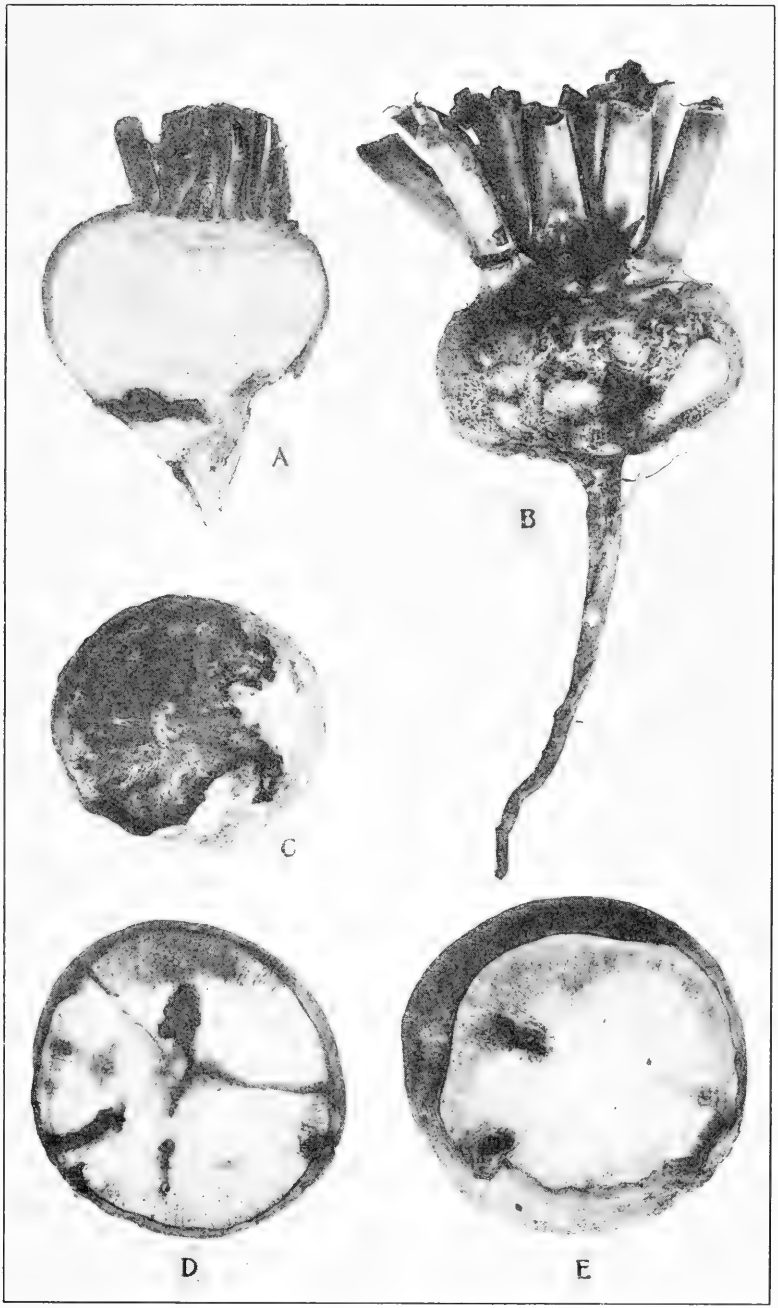

Figure 5.

Turnips injured by maggots: *a*, longitudinal, and *d* and *e* cross sections through root, showing internal injury; *b* and *c*, damage due to maggots feeding on the surface. From original photos.

Figure 6.

Cabbage roots injured by maggots: sections showing root badly injured both externally and internally (*a*); only on outer surface (*b*); both externally and internally, and maggots feeding within the root (*c*). From original photo.

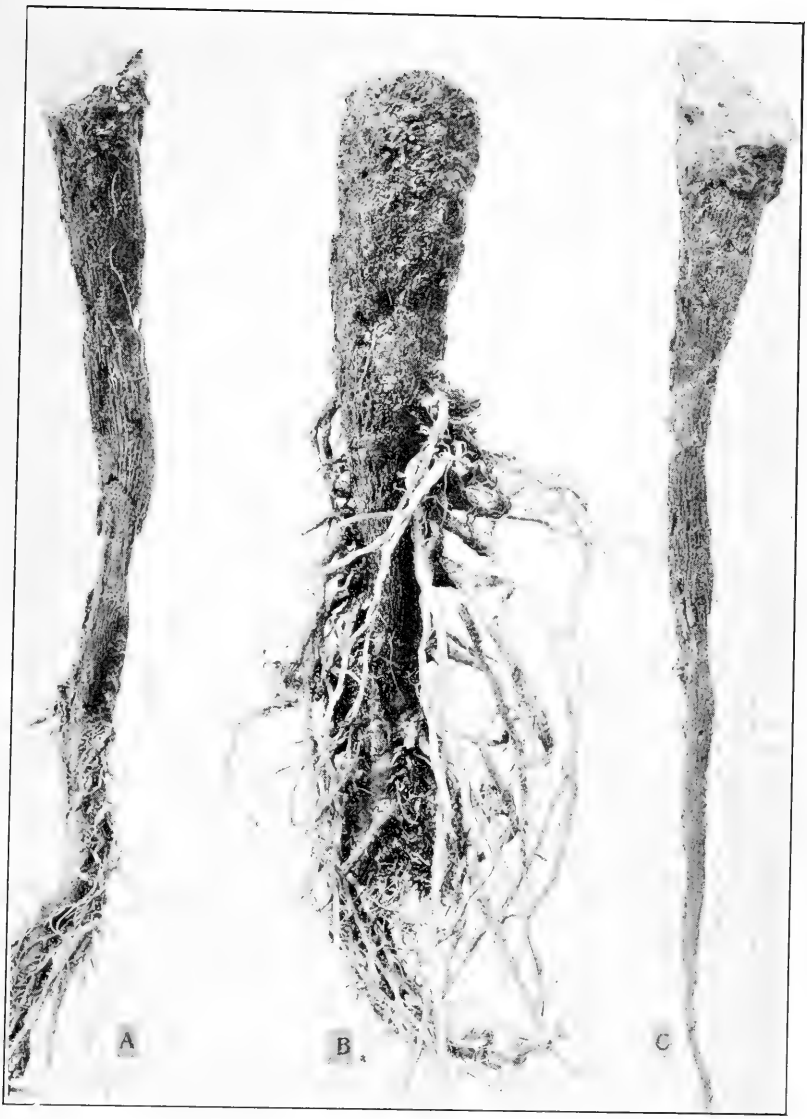

Figure 7.

Cabbage roots injured by maggots: tap root girdled and badly damaged (*a*); badly damaged but making an effort to put out more roots and recover (*b*); badly girdled and injured and stripped of roots (*c*). From original photo.

Figure 8.

Seedling onions injured by maggots; the two outer plants are healthy, while the three center ones have been completely eaten out and the tops withered. From original photo.

Figure 9.

Riverton Experiments, May 21st. At the left a view of cabbage rows infested with maggots; at the right a nearer view of rows with dying plants. From original photos.

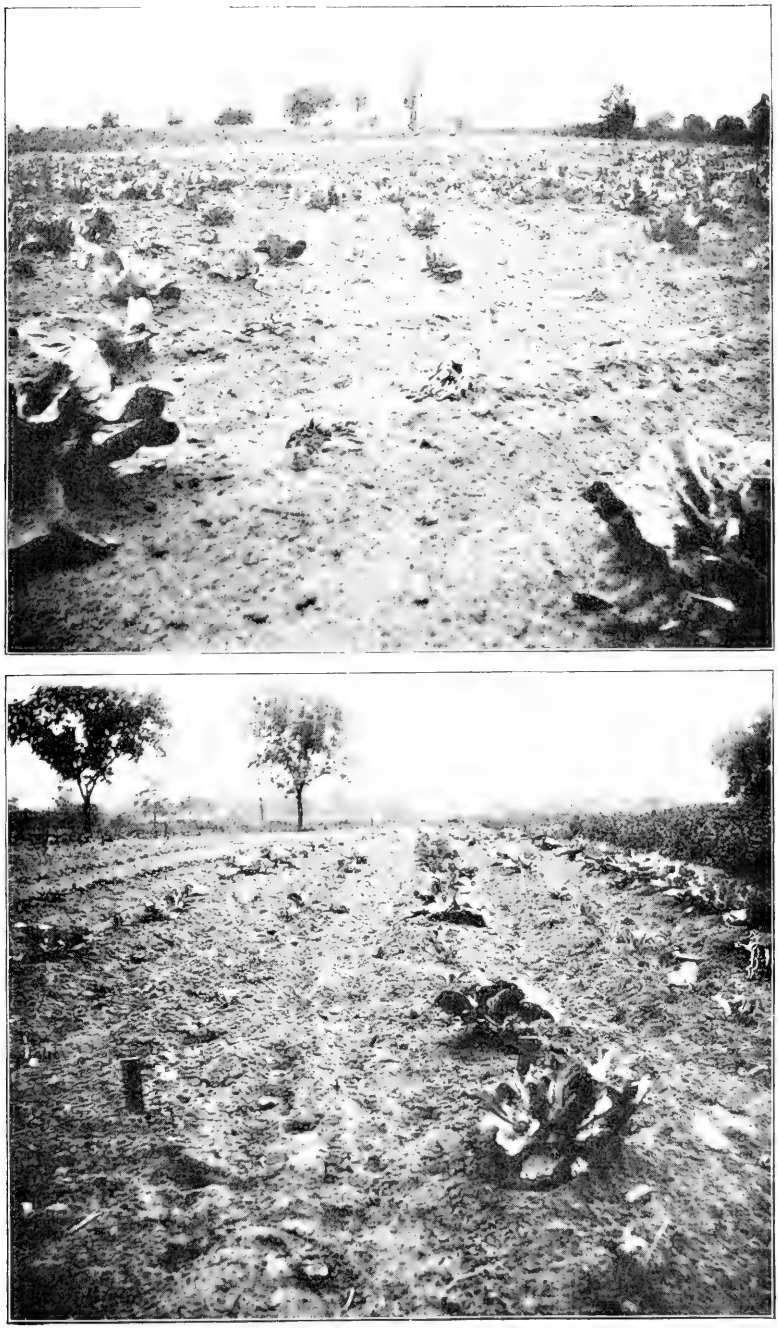

Figure 10.

Riverton Experiments, June 8th. Views across and parallel with cabbage rows to show the large percentage of infested plants. From original photos.

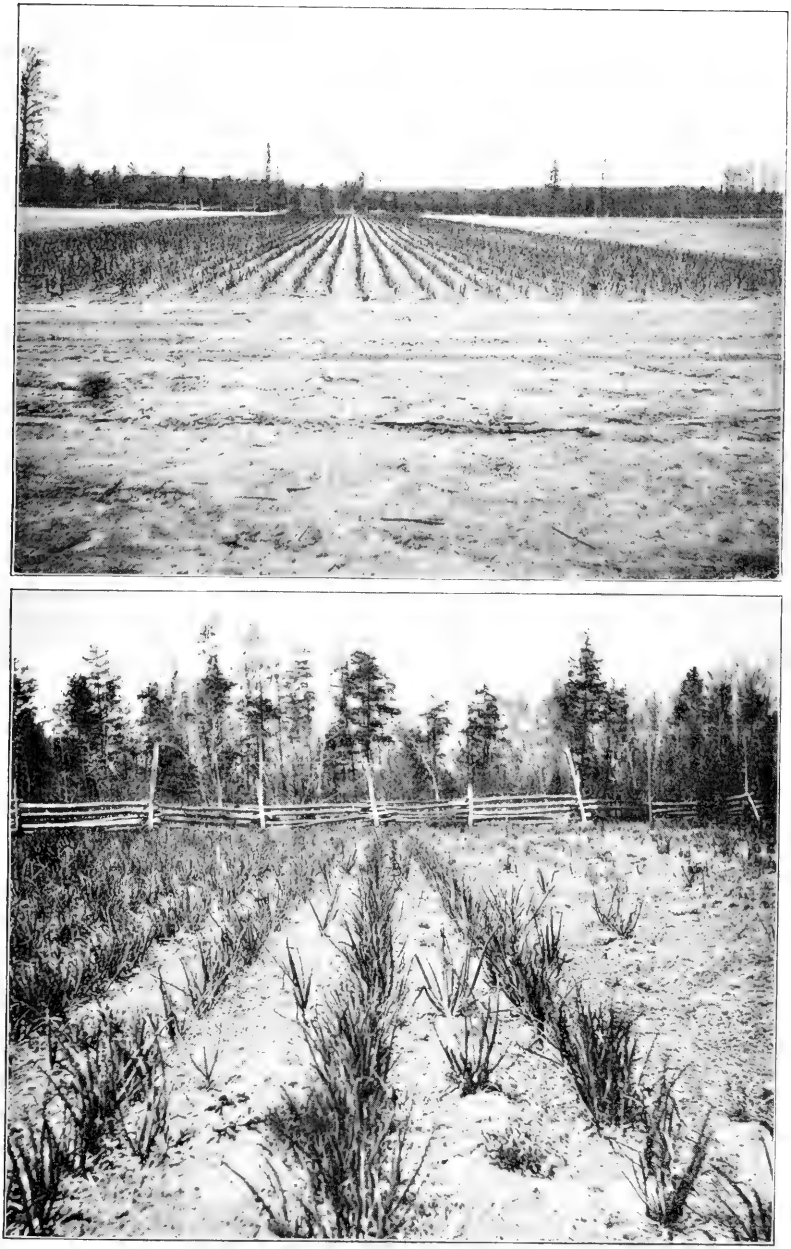

Figure 11.

Husted Experiments, April 23d. Above, a bed of onion sets, in good condition. Below, a bed of "scallions." The straggling plants between rows show location of rows destroyed October, 1905, the present good rows being planted after original rows were killed off. From original photos.

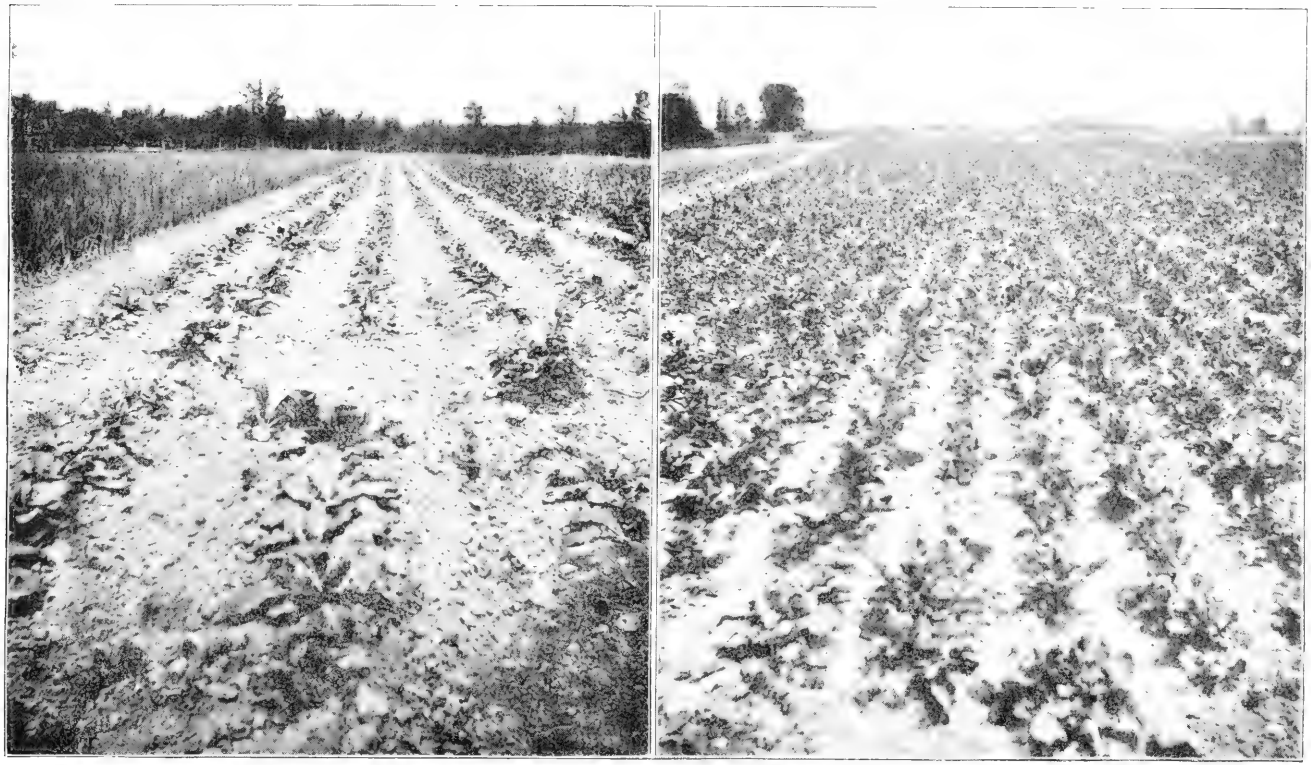

Figure 12.

Husted Experiments, May 26th. To the left, five rows of turnips so injured as to be plowed up. To the right, a bed of radishes abandoned after a few pickings. From original photos.

can be made on turnips or onions, and in the case of cabbages they would be especially advantageous where the infestation was slight, as the plants would be induced to make stronger growth and more roots on which to maintain themselves under the maggot attack.

The practice of plowing away from onion rows when infestation is noted and applying the above combination, or even nitrate of soda alone, has been followed with good results in Cumberland county, but it has failed on heavier soils where the fertilizer did not get so quickly through the soil and into direct contact with the plants and maggots. Both the nitrate of soda and the muriate have insecticide qualities, but the acid phosphate has none.

Manure and organic fertilizers should be avoided, if possible, as the group of insects to which these root-maggots belong are naturally feeders in decaying matter, and hence such conditions tend to invite them.

Cultivation.

Although it does not follow that planting on new ground will secure exemption from maggot attack, yet such is the tendency, and hence it will be well to plant or sow these crops as far as possible from any field which has been infested the previous season. The adult flies do not travel very far under normal conditions, and if they find shelter near their place of hatching are likely to hang around that place, and they will accept any substitute wild plant rather than fly to distant points hunting for cultivated plants. The farther the plants are grown from previously infested areas the more apt will they be to remain free from attack, as a rule, and yet even in new ground, especially near a woods or in a sheltered situation, they sometimes become more or less infested. It is probable that in such cases there are wild cruciferous plants in the neighborhood in which the insects have been breeding or shelter in which the flies have hibernated, and it further emphasizes that no matter where the crop is grown a close watch should be kept for the insect, and when once noted active measures should be begun at once. Likewise, avoid planting such crops on ground infested the previous season, and follow such infested plots with something other than onions or cruciferæ.

Setting.

When cabbage and cauliflower plants are set out the soil should be tightly pressed around the stem of the plant at the surface, and the soil itself should be pressed down smooth, flat and firmly. The newly-hatched maggot is very feeble and if it fails to get under cover promptly it is killed by the sun or falls victim to some of the prowling predatory insects that are continually on the lookout for food. On heavy soils this in itself affords a large measure of protection, and plants on such soils are not so much attacked. On lighter, sandy soils it will be less useful, but will add to the difficulties of the maggot in establishing itself.

PREVENTIVE MEASURES.

While cultural methods and the selection of the time and place of planting help much in preventing the deposition of eggs, a watch should be kept for the latter, and when they are once observed it means active measures and thorough work to prevent the larvæ from gaining entrance to the plant and becoming established. Stress has been laid by some observers on the fact that the eggs laid on the ground do not readily hatch after they have been disturbed, and it has been suggested that when they are observed the earth around the plants should be scraped toward the center of the rows. This will cause some of the eggs to be exposed and dry up, or the young maggots from those that hatch will not be able to find food within their reach. As some of the eggs are also deposited on the plants, the latter should be rubbed, so as to destroy any that may be on them. This may be practicable where only a few plants are raised, but when they are grown on a large scale it would not be, nor in any case with turnips and radishes.

A number of substances have been used placed on the ground around the base of the plants, partly as repellants, partly as destructive agents. It is questionable whether many of these act as direct repellants or really disguise the odor of the plants, so that they are not recognized as proper food by the insects, although this is apparently the case, to some extent at least, with the lime and carbolic acid mixture mentioned later. What they do, however, is to form coverings around the plants, and so prevent the maggots

after they hatch from getting to the feeding places, and in some instances they act also as contact insecticides and kill the freshly-hatched young. Hence the necessity of making the applications early, frequently and thoroughly, beginning just as soon as the plants are well established or have made their appearance above ground, or when there is evidence of the fly's presence about the plants. Some of the substances which have been recommended and tried with more or less success are here noted, and the differences in the results which have been obtained may have been due to the differences in the time, amount and thoroughness of the applications, and in this connection what has been said about the oviposition of the fly should be remembered.

Tarred Paper Cards.

These are simply discs or cards of tarred paper, measuring two and one-half to three inches in diameter, applied around the stalk of cabbage or cauliflower plants at the surface of the ground. They may be round, square or any other shape, but for convenience and economy they are made hexagonal with the tool and in the manner shown in Fig. 13. The tool consists of a piece of wood, to the lower end of which has been attached a band of steel, bent so as to form half a hexagon, with a line running to the center, where is situated another metal piece which makes a star-shaped cut. The piece of tarred paper is cut along the lower edge, as indicated in the lower left-hand outline of Fig. 13, and then beginning at the left a cut is made by the tool as represented by the dotted line. The result is a perfect hexagon with a slit extending from one of the angles to the central star-shaped cut, as shown in the upper left-hand figure. The lower cutting edge of the tool should be beveled on the outer side, so that it may be readily sharpened when required. The paper used is that known as "one-ply tarred felt."

The method of applying the card is to separate the two edges of the slit running to the center, slip the card around the plant when it is set, and see that it fits snugly about the stem. This can readily be accomplished because of the star-shaped cut at the center of the card. The object is to have the cards fit snugly around the stem at the center and lie flat on the ground so that the fly cannot get under it. She will then be forced to lay her eggs, if at all, on the card or

on the dirt beyond it. If laid beyond the card, the maggots, when they hatch, will be unable to reach the plant, and if laid on the card they will almost inevitably dry out before the larvæ develop. Such larvæ as may develop will be unable to penetrate the tough skin of the stem above the surface.

The cards can be easily and cheaply made at odd times and can be quickly and readily applied when setting plants, so that the method is well worth trying. Large growers in New York State who have used thousands of the cards have done so with marked success, but in Minnesota, on account of different methods of culture, they have been less successful.

Carbolic Acid and Lime.

In our experimental work last season this proved to be the most effective material tested. It was used by Mr. L. A. Stemler on his onion patch and appeared to act as a preventive and a repellant. The method of application and the conditions under which it was used are as follows: The patch where the applications were made was situated near a previously infested plot. One application of carbolic emulsion—considered on a succeeding page—was made over the rows before the plants were above ground, after which a mixture of crude carbolic acid and lime was applied once a week. The application, made with a sprinkling can or a spray nozzle, was very thorough, so that the material formed a crust on the ground around the plants, and the odor of the acid was perceptible for several days thereafter. That the material acted as a repellant seems probable because even the untreated check rows showed a very slight infestation, while the treated plants suffered scarcely at all, and this is significant, in view of the fact that the plants of the surrounding neighbors all suffered to a considerable extent.

The method of making the material is: Slake the lime to a thin cream, use three pints to a gallon of water, and to this add one tablespoonful of crude carbolic acid. Apply along the rows as already mentioned, getting it well around the plants, so that the surface will be coated to the plants. It may be used on all kinds of plants subject to maggot attack, and the theory of its action is exactly like that of the tarred cards. It forms a covering through which

the young maggots are not able to penetrate to reach their food, even should any fly be hardy enough to brave the white surface and carbolic odor. The young plants seem to find no difficulty in growing through the lime coating. The preliminary application of the carbolic acid emulsion is hardly necessary.

Kerosene and Sand.

This mixture is made by adding to a pail of dry sand half a pint of kerosene and mixing thoroughly. As with the rest of the materials, the applications should be begun early, made frequently and applied thoroughly around the plants in the case of the cabbage and along the rows in the case of the radishes and onions. Make the first application as soon as the plants are above ground, follow in five days or so with a second, and later apply at week intervals. The flies do not readily deposit their eggs in this mixture and if any maggots on hatching come in contact with the kerosene they will be killed. This application is not so easily made as the carbolized lime and is hardly suited for use on large fields. There is also an element of danger to the plants and care must be taken not to have more kerosene than is recommended, nor to pile too much of the sand around the plant at one time.

Powdered Tobacco.

This has been used as a preventive with some success and in our experiments appeared to protect treated plants to a certain extent, even though applied very late. With this material, likewise, timely, frequent and thorough applications are necessary. The fly undoubtedly does not care to deposit its eggs in the tobacco, and if forced to do so the young larva should find a covering so thorough that in attempting to reach a suitable feeding place it would come into contact with the tobacco, which, especially if wet, would serve as a killing agent. The tobacco, in addition, is a fertilizer, so that in any event its application would be of advantage to the plant sufficiently great to pay for its use. It should be as finely ground as it is possible to get it.

Powdered White Hellebore.

This is a finely-ground material, applied in the same manner as the powdered tobacco, and what has been said in regard to that material will apply equally well to the hellebore, which, however, is not a fertilizer. In one of our experiments it was slightly more effective than the tobacco. Hellebore has also been used in the form of a decoction to kill the maggots, and will be again referred to among the destructive measures.

It has been claimed that dipping the plant into the powdered hellebore just before setting will act as a protection, and this is not unlikely. To do this most effectively, the plant should be first dipped in water and then into the powder, that a complete coating may be formed. This will not interfere with the growth of the plant, nor will it injure the roots. Professor Washburn has found the dipping in the hellebore decoction of some benefit, but I believe the dry powder dipping will be even more effective.

Dry Lime.

A handful of this material thrown around the cabbage plant a day or two after setting, and applied frequently enough to keep the surface covering complete, has been recommended. Personally we have not had any experience with it, but as good results are reported in other States, it is worthy of trial, both on cabbage and along the rows in the case of onions and radishes. It acts in somewhat the same manner as the carbolized lime, but does not form a crust. The important points here are keeping the covering complete at all times and in close contact to the plants, so that the maggots cannot slip down into the ground between the plants and the lime.

Bran and Glue.

This mixture was reported as having been used successfully against the cabbage maggot in Minnesota by Prof. F. C. Washburn. It consists of two pounds of glue, dissolved in one gallon of water, and this mixed with one-half pound of bran. A handful of the material is placed around each plant a day or two after

setting, and it forms a covering three or four inches in diameter on the ground and closely around the stem, through which the maggot when it hatches from the egg is unable to make its way to the plant tissue below the surface. It is worthy of trial in this State, and it acts like the carbolized lime. Professor Washburn states that the mass is very resistant to weather, and remains intact as long as there is any danger of maggot attack. It need, therefore, be applied once only, and was originated as a substitute for the tarred paper discs. Its advantages are convenience of application, that it fits itself perfectly to the surface of the soil in which the plant grows and around the plant itself, leaving no way for the maggot to get to the roots.

DESTRUCTIVE METHODS.

If for any reason the maggots are not prevented from getting a foothold in the plants, measures should be taken to destroy them as soon as their presence is noted, and for this purpose one of the following substances may be used:

Carbon Disulphide.

As a killing agent, this substance seems to be very effective, but its use is practically limited to the maggot on cabbage and cauliflower, and then only to cases where but a few plants are to be treated. It is applied by making a small hole in the ground, by means of a stick or otherwise, two or three inches from the plant and extending obliquely down as far as the roots, and pouring or injecting into it a spoonful of the liquid. The hole is then closed by pressing the earth over it, and the fumes permeate through the soil, come into contact with the maggots and kill them. Care should be taken that the liquid is not poured directly on the roots, which would result in injury to the plants. At one time this substance was much recommended, and a special tool for using it, known as the "McGowen injector," was placed on the market, but for a variety of reasons the bisulphide failed to gain general approval, and the injector is no longer obtainable.

Carbolic Acid Emulsion.

This is perhaps the most effective of all the destructive agents, but its value also depends upon timely, frequent and thorough applications. It has failed in some hands, chiefly because the work was not begun early enough. The method of making the emulsion is as follows: Dissolve one pound of soap in one gallon of boiling water; to this add one pint of crude carbolic acid and churn thoroughly with a pump until a good, creamy emulsion is obtained. This emulsion, properly made, will remain stable for several days. For use, dilute one part of the emulsion with thirty parts of water and apply thoroughly around the plants, from four to six fluid ounces to each. The object is to get it down to the roots and into actual contact with the maggots feeding upon them. The application should be begun as soon as the presence of the maggots is noted, or, better still, as soon as the eggs are observed on the plants. Make the first two applications four or five days apart, and later once a week for a month. If the work is thoroughly done and begun early enough, it should destroy the young maggots as they emerge and before they get a chance to protect themselves within the plant tissue. Well-grown maggots are quite resistant to the emulsion. This material can also be used against the maggots on radishes and onions by making thorough applications along the rows.

Hellebore Decoction.

This has been very successfully used in Canada and some other localities, but has not given, on the whole, such good results as the carbolic acid emulsion in New Jersey. It is made by steeping two ounces of the powdered hellebore in a quart or two of boiling water for half an hour, stirring occasionally so as to help the extraction of the poison, and then diluting so as to make one gallon of liquid. Apply in the same way and under the same conditions as recommended for the carbolic acid emulsion. The decoction may be made at any time and may be kept for use as needed in tight jars or bottles. It will keep in tubs or barrels for two or three weeks, or even longer, in the concentrated form, but should always be stirred up before using. The sediment or extracted powder may

be used with the liquid. It should be fully understood that this is not to be applied as a spray, but through a spout in quantity sufficient to soak around the plant to the roots—say, from four to six ounces to a cabbage or cauliflower plant, and proportionately along the radish, turnip or onion rows.

Hand Method.

This consists of taking up the plants carefully, as soon as they show evidence of maggot attack, with all the earth around the roots, so as to get all the insects. The roots are then washed in a solution of soap or hellebore, the maggots are all removed and the plants are reset. This seems like heroic treatment and is certainly effective. It is claimed by those who have tried it that the plants show no ill effects after a week or two, and in the garden it is quite feasible to use it on cabbage and cauliflower plants. On radishes, turnips and onions it is, of course, unavailable.

One kind of handwork is always in order, especially in the onion field. It happens not infrequently that there is only a slight infestation—a few plants here and there—and not enough to make the farmer feel like making any general treatment. The infested onions are always useless and should be taken out with a trowel, so as to get all the maggots, and put into a pail, which, when all infested plants have been placed in it, can be drenched with kerosene. One of the largest and most successful onion-growers I have known always carried a tin pail and trowel with him into the field, and by keeping a constant lookout prevented the insects from getting any considerable start. When he saw reason to believe in the danger of a more general attack he used the fertilizer application by first turning away from the rows with a hand plow and then turning back again after the application. His crops never suffered materially, although those of his neighbors did.

Oil Mixtures.

In our experimental work last season two other substances were used, namely, scalecide, which is one of the soluble oils, and kerosene emulsion. They were used against both the onion and the cabbage maggots, and in an experimental cabbage plot more plants

were lost in the rows where these substances had been applied than in the untreated check rows, due in part to the injury produced by the materials and in part to the ineffectiveness of the substances against the maggot. Like results were reported where the mixtures were tried on onions. The use of such oily mixtures, therefore, is not advised against these insects.

RECOMMENDATIONS.

The recommendations, then, based on the life history and habits of the insects, are as follows: By clean culture, prevent as many insects as possible from reaching maturity or from propagating. Clean out the outbuildings, sheds and similar places during the winter to destroy hibernating adults, and destroy rubbish piles out of doors. Remove infested plants and crop remnants, such as cabbage stumps, just as soon as they are no longer useful, and destroy all cruciferous weeds about the place. Having made the land as clean and free from infestation as possible, plant on ground not infested the previous season, and as far as practicable from any that was infested. Then regulate, as has been already discussed, the time of planting to avoid the deposition of the eggs on or around the plants, fertilize well with quick-acting mineral fertilizers, avoiding manures, and plant when feasible an earlier trap crop, which when infested can be carefully removed and destroyed with its maggot contents. In addition, protect the plants and prevent the eggs from being laid about them or the maggots from getting to the roots by applying some material or covering on the surface of the ground around the stem of the plant. For cabbages and cauliflower the tarred paper discs or bran and glue may be used, or on both the crucifera and onions the carbolized lime or one of the other materials already considered. In the work of 1906 the carbolic acid and lime mixture showed up to the best advantage. Whatever is used, it must be borne in mind that to insure success the applications must be begun early, and made frequently and thoroughly. Apply immediately after the plants are set or have made their appearance above ground, make the first two applications at five-day intervals, the later ones not more than a week apart, and continue at least a month.

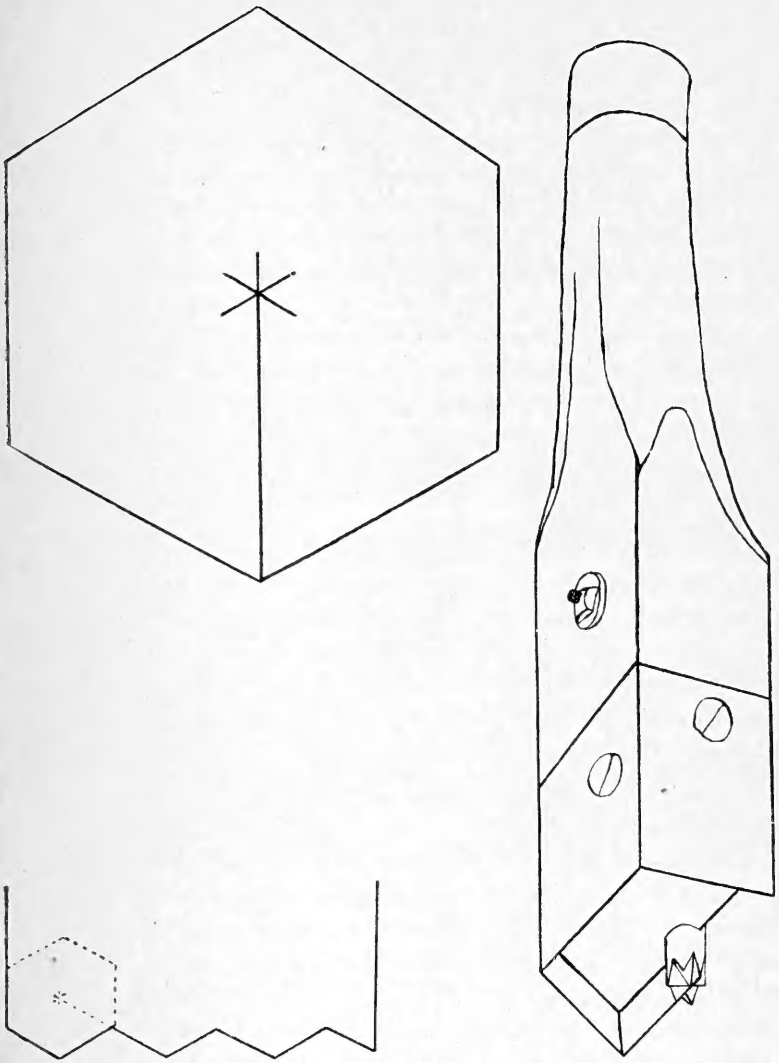

Figure 13.

Tarred paper card and method of cutting. Upper figure, outline of tarred paper card, natural size. Figure on right, tool for cutting the cards, about half size. Lower figure on left, diagram showing how the tool is used. The dotted line indicates the position of the edge of the tool. After Goff, from Cornell Bulletin No. 78.

If the maggots succeed in getting a foothold, apply carbolic acid emulsion or hellebore decoction as recommended just as soon as their presence is observed, and if this is the only material used, applications should be begun as soon as the plants are established or when the eggs are noted and continued at intervals of five or six days until all signs of the maggots have disappeared. In the case of cabbage and cauliflower in gardens, the plants might be carefully removed, the roots washed in a soap or hellebore solution so as to destroy the maggots, and the plants then reset.

In all this work it must be borne in mind that the more maggots are destroyed the less there will be to breed, and if active measures are continued persistently for two or three years the infestation may be reduced to so great an extent that keeping them down will be an easy task.

Exempt Varieties.

It appears that some varieties of cabbage and cauliflower suffer more from maggot attack than others, but except for the Holland cabbages there are none, so far as we know, that will not be badly injured by these pests. Both from our own State and elsewhere the Holland cabbages are reported as being quite free from maggot attack and need little, if any, treatment.

Enemies.

Several species of predaceous beetles have been observed feeding on the maggots in the field, while minute parasitic wasps and predatory mites have been found infesting the eggs in great numbers. It is certain that many of the pests are thus destroyed, but practically the benefit derived by the farmer is relatively small, as is evidenced by the large amount of injury done by the maggots each year. None of them can be relied upon to relieve the grower from the necessity of active work in his own behalf.

Club-Root.

It is sometimes asked whether the deformity on the roots of the cabbage known as club-root is caused by the maggot or has any relation to it, and so it may be well to state that the maggot and club-root have no connection whatever. The latter is a fungus disease and when maggots are found in diseased cabbages they are present as an accident merely.

The observations and experiments made during the season of 1906 were by or under the supervision of Mr. Dickerson, who has also prepared the general account giving the life histories of the insects.