

BIOLOGY & CONTROL
OF THE ONION MAGGOT
HYLEMYIA ANTIQUA MEIG

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A Study of the Biology and Control of the Onion
Maggot *Hylemyia antiqua* Meig.

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A THESIS

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INTRODUCTION

The Imported Onion Maggot, *Hylemyia antiqua* Meig., has undoubtedly become the most destructive of any of the insects infesting the onion plant. Since its establishment in the United States and Canada, this insect is ever present and widely distributed, but the injuries vary in different localities and from year to year. Some fields suffer more than others, the attacks being both more frequent and more severe. During years of severe infestation, crops are often largely if not entirely destroyed. For in addition to the death of some of the plants, there is a certain amount of injury to the bulbs which makes them unfit for sale. Usually secondary infection, such as bacterial or fungous diseases sets in, which completes the havoc wrought by the maggots.

Such losses cause many gardeners to abandon the growing of onions. These conditions occur frequently in the districts where the growing of onions is the main industry.

During recent years a great deal of work has been done in studying the life-history of the onion maggot and control methods. The measures now adopted in combating this pest has brought great relief to those growing onions, but nevertheless this insect is still a serious menace. It was thought that any further study of the onion maggot problem would perhaps bring forth more information of some value.

HISTORICAL REVIEW

The onion maggot is an importation from Northern Europe and the first records of it as a serious pest on the North American continent came from the states of Massachusetts and New York. It is thought to have been brought over in shipments of onion bulbs from Sweden, Holland, Denmark and England.

This insect was first described in Europe by Meigen in 1826. In 1833 Bouche gave an account of this species, and in 1855 Marquart included it in his "Histoire Naturelle de Diptera".

The onion maggot has been listed under various names. The following are those most frequently met with in the published accounts of this insect.

1826 *Anthomyia antiqua* Meig. Syst.Bescher., Vol.5,p.166,No.145

1830 *Anthomyia ceparum* Meig. Syst.Bescher., Vol.6,p.376,No.217

1844 *Musca liturariae* Ratzeb. Forstins., Vol.3,p.170, No.1.

1851 ? *Anthomyia caepicola* Rob.-Desv. Guer.-Men., Rev.et Mag.

Zool., Ser.2,Vol.3,p.234,No.1.

1882-83 *Chortophila cinerea* Meade nec Fall. Ent.Mo.Mag.,Vol.19,
p.147.

1882-83 *Phorbia cepetorum* Meade. Ent.Mo.Mag.,Vol.19,p.218.

1893 *Anthomyia angustifrons* Strobl nec Meig. Verh.Zool.-Bot.
Ges. Wein, Vol.43,p.259.

Bezzi and Stein in their catalogue of European Anthomyiidae 1907 places the onion maggot under the name *Hylemyia antiqua*. This name has been accepted in Europe and is now the name adopted on the American continent.

The onion maggot has for many years been regarded as a serious pest of onions in Europe and reports of its destructiveness

come from Austria, Britain, Checho-Slovakia, Denmark, Germany, Holland, Italy, Russia, Sweden and Switzerland.

In Great Britain the maggot has been known for a long time, it having been reported as doing considerable damage at Dorking, England (1) in 1840. It now occurs in all the onion growing districts of England, Scotland and Wales. Smith, K.M., (29) in 1922 states, "Hylemyia antiqua has become so abundant of recent years in Great Britain, and particularly in Lancashire and Cheshire, that in certain districts onion growing is impossible".

The onion maggot was first noted in the United States during the year 1841 by T.W. Harris (2) in a report of injurious insects of Massachusetts. Again in 1862 Harris (3) calls attention to the destructiveness of this insect. Other early reports were made by Fitch (4) 1866, Lintner (7) 1882, Fernald (10) 1891, Smith (12) 1893, Slingerland (13) 1894; and many others.

In recent years it has become widely distributed and is now found in the following states - Pennsylvania, New Jersey, New York, Connecticut, Massachusetts, Michigan, Indiana, Wisconsin, Illinois, Minnesota, Iowa, Montana and Oregon. It does not, however, generally occur south of the State of New Jersey (21).

The first reference made to the onion maggot in Canada was in 1875 by Couper (5) and by this time it had become well established in Ontario and other parts of Eastern Canada. Attention was again directed to this pest by Dr. Fletcher (9) in 1885 and in 1891 (11) he stated that it was equal in destructiveness and more difficult to deal with than the cabbage and radish root maggots. Apparently the Province of Quebec did not suffer any serious losses from this insect until 1908, when Dr. Swaine (16) re-

ported it damaging the onion plants at Macdonald College, Ste. Anne de Bellevue. In 1920 many infestations occurred throughout the province and have continued up to the present time. This insect is now considered to be one of the most important pests.

Hylemyia antiqua is now prevalent in Canada, from coast to coast, it having been mentioned as occurring in British Columbia in Dr. Fletcher's report (14) for 1904. During 1914 and 1915, Treherne (27) states that some growers were forced to abandon commercial onion growing in that province.

HISTORICAL REVIEW OF CONTROL MEASURES

The control of the onion maggot has proved to be a very difficult problem. The life habits of the insect are such that the ordinary methods of control have been useless, and special remedies have had to be sought.

The maggot itself lives within its host plant, where it cannot be reached without danger of injury to the plant. The eggs are laid just beneath the soil and close to the plant. The pupae are formed in the soil, often to a depth of five or six inches. These stages of their life history offer very little scope for the application of control measures.

The adult female fly presents the best and apparently the only means of attack, and it is in this stage that the best results have been secured within recent years.

Since a very early date numerous schemes have been devised and tried out, only to be discarded as worthless. Dewdney (1) in 1840, suggested the use of nitrate of soda on the beds.

In 1879, Eleanor Ormerod (6) suggested the use of wood ashes and garden refuse as manure. Again, in 1883, (8) she advised the following remedies -

1. Banking up of the onions with earth.
2. Thick dressing of mustard cake to attract the flies for egg laying.
3. Quick lime and salt as a dressing.
4. Application of lime and dry soot.
5. Sprinkling with water and paraffin oil.

During 1891 various other measures were put forward as pos-

sible means of control. Fletcher (11) mentions spraying with kerosene emulsion along the rows, while Fernald (10) favoured the scattering of pulverized gas lime along the rows, watering with liquid from pig-pens and the killing of infested plants and maggots with carbolic acid or kerosene oil.

A few years later J.B. Smith (12) applied kainit with some results.

The spraying of the plants with carbolic acid emulsion to act as a repellent was recommended. This gave good results, especially on small onion plots. However, on a large scale frequent treatments with this material entail a large amount of time and labour, causing this method to be impractical for commercial purposes.

In 1907, J.B. Smith (15) made use of small early plantings of onions to act as a trap crop, and as soon as these were found to be infested, removed or destroyed. A modification of this system is now employed extensively in conjunction with other control measures and decreases considerably the infestation of the main crop.

A considerable number of soil insecticides have been tested to ascertain whether some substance could be found which would tend to reduce the first-brood maggot infestation on the young onions. Such materials as powdered hellebore, tobacco, dust, dry lime sulphur, carbolated lime, calcium hypochloride, derris, Black leaf 40, pyrethrum insect powder and others have been used at various times.

Certain mineral fertilizers (17) have been tried as deterrents to the fly. In 1923, Smith, K.M., (31) claimed to have ob-

tained good results when he used precipitated chalk as a carrier for tar oils and applied to the soil. Again in 1925 (33), he obtained some success with nicotine sulphate dust in a 5 per cent mixture with precipitated chalk. Spraying the young plants with a Bordeaux oil emulsion (32) is now being given consideration.

Insecticide applications against underground insects are rarely satisfactory because of the difficulty of getting them into contact with the species to be dealt with. A certain substance may kill the maggots well enough, and placed in the hands of competent workmen will perhaps effect a control. While some of the substances used as soil insecticides or repellents were rather efficient, they are perhaps more useful as garden remedies than in field operations. Besides other considerations which prevent their general use, such as initial cost and expense of preparation etc. the value of these materials depend on the number and thoroughness of the applications and are directly influenced by rainfall. The high cost of labour and the time consumed in frequent use, counteracts in a large measure, their value in the field.

Sanders (18) in 1913, attacked the problem from an altogether different angle and endeavoured to lure the female fly to a poisoned bait spray before egg laying began. The bait consisted of molasses diluted with water and sodium arsenite. This method was suggested to him by the results obtained by Severin (19) in his work on the control of fruit flies. The following year Severin (20) carried on further experiments with the poisoned spray and obtained promising results. During 1916, Howard (24) investigated the poisoned bait as a control for the onion fly. He, however, dispensed with the spray and distributed the bait in pans about the field.

Bourne and Fernald (25) made use of baited traps to capture the adult flies. This system would not appeal to most growers, because of the amount of apparatus necessary and the inconvenience in handling.

In Canada, the poison bait spray was first tried during the years of 1916-17 (23) and warranted further trials.

During the season of 1921, control with sodium arsenite as a bait and spray was conducted by Prof. W. Lochhead and Mr. W.J. Tawse (26) in the Montreal district. They found that the poisoned bait placed in pans was the more efficient and economical.

Treherne and Ruhmann (27) did not get satisfactory results in their trials with poisoned baits and resorted to the use of trap onions as the most effective in the "dry belt". The failure of the bait being possibly due to the presence of water in the irrigation ditches attracting large numbers of flies away from the poison.

In 1923 (30) control with the sodium arsenite bait was again carried out in the Montreal district. A combination method consisting of the poisoned bait placed in pans and trap onions as suggested by W.J. Tawse (30) was also tested. The results were very promising and gave every reason of being a success.

The use of the combination trap crop and poisoned bait as a means of control is now generally practiced throughout all the onion growing districts. So far it has proved to be the most practical and efficient remedy on extensive areas.

FOOD HABITS AND NORMAL TROPISTIC REACTIONS OF THE ADULTS

All measures of control directed against the egg and larval stage of the onion maggot, either by the application of chemicals or by mechanical means, have so far not given very satisfactory results. On the other hand, methods of control based on the food habits and normal tropistic reactions of the adults have proved to be most promising. It was thought, therefore, that any additional data obtained on the adults would be of value.

During this season (1925) many observations and experiments were conducted to find out as much as possible of the food habits and reactions of the adults.

Work on the onion maggot this year commenced on May 19th, and on this date onion maggot flies were seen flying low over the onion fields and hovering about the flowering weeds. Upon watching closely the activities of the flies among the flowers, they appeared to be searching for and obtaining the nectar which the flowers contained. The blossoms of the dandelion seem to have a very great attraction for the flies, both male and female. The question then arose whether food of this nature was a necessity to the adults, or only a practice of minor importance. During the emergence period of the first generation flies, the dandelion bloom is very prevalent and would provide an unlimited supply of food. From observations made there seems to be no doubt that the dandelion blossoms are a source of food supply which is very attractive to the adults. On bright, warm, sunny days they are very actively flying from blossom to blossom, carefully robbing each floret of its store of nectar. When feeding, the anterior part of the insect is hidden in the blossom and only a portion of the abdomen showing.

When disturbed, it will withdraw and immediately fly away to another flower.

During the emergence period of second generation adults the dandelion blossoms are still in evidence, along with many other weeds. Nevertheless the dandelion bloom still holds a greater attraction to the flies, although they were seen to visit frequently the blossoms of fruit trees and the various common weeds such as buttercups, golden-rod, hawkweed, mallow, milkweed, mullein, mustards, wild parsnip, pigweed and sweet clover. On introducing bouquets of flowers into cages containing the flies, the dandelion flowers are usually visited first and in greater numbers than the other flowers.

The following experiments were conducted to ascertain the food requirements and normal tropistic reactions of the adults.

Newly emerged adults were placed in all the cages, and the cages kept out of doors under as natural conditions as possible, the flowers used in the cages being replaced each day. Most of the experiments were run in duplicate and in some cases in triplicate.

Experiment No. 1A.

Moistened sand was placed in the bottom of the cage, growing onions planted, water provided and the freshly cut flowers of the various weeds introduced. On July 3rd, fifty-one flies were placed in the cage.

On July 16th a few eggs were laid around the onion plants.

On July 20th -- 27 eggs collected.

On July 23rd -- 9 eggs collected.

On July 25th -- 25 eggs collected.

On July 27th -- 11 eggs collected.

On July 30th -- 26 eggs collected.

On August 3rd -- 4 eggs collected.

On August 7th -- 27 eggs collected.

On August 11th -- 27 eggs collected.

On August 14th -- 10 eggs collected.

On August 16th -- All flies dead.

One of the females in this cage lived forty-three days. The males died several days before the females. The preoviposition period was at least thirteen days, while oviposition required some four weeks. Fertility test was made on 110 eggs and 103 hatched giving 93.6 per cent fertility.

Experiment No. 1B.

This experiment was run as a duplicate of Experiment No. 1A. On July 17th, 108 males and 141 females were placed in cage. The following results were obtained.

On July 30th -- 3 eggs laid.

On August 1st -- 11 eggs collected.

On August 4th -- 53 eggs collected.

On August 8th -- 40 eggs collected.

Eggs were continued to be laid until August 20th and on August 24th all the flies were dead. The longest length of life of a female was thirty-seven days. The preoviposition period was thirteen days and oviposition period required some three weeks.

Experiment No. 2A.

Moistened sand was placed in the bottom of the cage, growing onions planted, water provided and dandelion flowers introduced. Thirty-five males and forth-five females were placed in this cage on July 18th.

On August 4th -- 12 eggs laid around the onion plants.

On August 6th -- 10 eggs collected.

On August 8th -- 18 eggs collected.

On August 10th -- 40 eggs collected.

On August 12th -- 16 eggs collected.

On August 14th -- All flies dead.

Here we see that the longest life of the flies was twenty-seven days, while the preoviposition period was seventeen days. The oviposition period occupied some ten days. Fertility test gave 92.1 per cent fertility.

Experiment No. 2B.

This experiment is a duplicate of Experiment No. 2A.

Thirty-five males and forty-four females were placed in this cage on July 18th.

On August 4th -- First eggs collected around onion plants.

On August 8th -- 18 eggs collected.

On August 10th -- 35 eggs collected.

Eggs were laid around the onion plants until August 19th. On August 21st all the flies were dead.

The length of the longest life was thirty-four days. The preoviposition period was seventeen days, with the heaviest egg laying commencing August 10th, twenty-three days after emergence. The oviposition period lasted fifteen days.

Experiment No. 3A.

Moistened sand was placed in the bottom of this cage, growing onions planted, water provided but food omitted. Thirty-one males and forty-one females were placed in the cage on July 14th.

On July 18th -- 22 males and 25 females dead.

On July 20th -- 6 males and 11 females dead.

On July 21st -- 3 males and 14 females dead.

At most the flies lived only seven days, while the majority died at the end of four days. No oviposition took place.

Experiment No. 3B.

This experiment is a duplicate of Experiment No. 3A.

One hundred and forty-nine males and one hundred and twelve females were placed in this cage on July 13th.

On July 18th many of the flies were dead.

On July 21st only a few flies alive.

On July 23rd all the flies were dead.

Here again the flies lived for only a few days, most of them dying at the end of six days, while the longest life was between nine and ten days. No oviposition took place.

Experiment No. 4A.

In this experiment dry sand only was provided. On June 30th ten males and six females were placed in the cage.

On July 2nd -- 3 males and 1 female dead.

On July 4th -- 5 males and 1 female dead.

On July 5th -- 2 males and 3 females dead.

On July 6th -- 1 female dead.

The greatest number of deaths occurred on the fourth and

fifth days while one female lived for six days. No oviposition took place.

It has been stated by some writers that manure has an attraction for the onion maggot flies and suggested that possibly the flies feed upon this material. I have collected the flies from around manure piles during the early part of spring and on cool days, but on warm days I have taken very few when sweeping. The attraction of the flies to manure is probably due to the presence of moisture, various salts or heat. From the following experiments it is obvious that they derive no direct nourishment from this source.

Experiment No. 5A.

On July 10th, moistened manure, twenty-five male and twenty-seven female flies were placed in a cage, with the following results.

On July 13th -- 1 male and 6 females dead.

On July 14th -- 6 males and 6 females dead.

On July 16th -- 7 males and 5 females dead.

On July 17th -- All the flies were dead.

In this experiment the flies lived at most only six days.

Experiment No. 5B.

This experiment is a duplicate of Experiment No. 5A.

Twenty males and twenty-two females were placed in this cage on July 20th.

On July 25th -- Most of the flies dead.

On July 27th -- All the flies dead.

In this experiment a few of the flies lived seven days.

Conclusions.

The evidence from the foregoing cage experiments indicates quite clearly that food is an essential requirement for the normal developmental processes of the adult flies. This food in nature consists of the nectar of the common flowers. The flies can be successfully reared by supplying them with a solution of molasses, diluted with water, or sugar syrup. The flies are readily attracted to these substances and feed upon them within a few minutes.

In the experiments where the flies were given access to flowers the length of life was from three to four weeks (one female living forty-three days), while the length of life of flies not given access to flowers was from five days to a week. In the cages provided with flowers copulation and oviposition took place, with egg fertility ranging around 92-3 per cent, while in cages not provided with flowers copulation and oviposition^{was} not recorded. It may also be stated that dandelion flowers alone can act as a source of food supply to the flies, normal development taking place.

It was also observed that sunlight is essential to mating and oviposition. In cases where the flies were kept from the presence of sunlight they remained more or less inactive and did not mate, and no eggs laid.

Daily Activities of the Flies.

In the same way that the first appearance of the flies are influenced by climatic conditions, the daily activities of the flies are also influenced. On bright warm days, before egg laying commences, they may be seen flying over the onion fields and hovering among the flowers, or resting on plants and basking in the sunlight. During the hot weather of July and August they remain in somewhat shaded places in the heat of the day and become active again in the late afternoon and morning. In the early morning and on cool or windy days they remain in shelter and more or less inactive about the onions and weeds, or crawling and resting on sunny patches of ground. On rainy days the adults may be found in large numbers perched on the tips of the partially closed dandelion flowers. From casual observations one would be inclined to think that such position is very precarious. This, however, is not the case, for upon closer observation it was noticed that when a drop of rain fell upon the fly it immediately rolled off without wetting its body in the least. In laboratory experiments I found that the flies could be immersed in water for quite a considerable period of time without their bodies becoming wet. If, on the other hand, they sought shelter on the ground under stones or rubbish, they would always be faced with the danger of being washed from place to place or buried in the mud and so destroyed.

ON THE EXISTENCE OF A PREOVIPOSITION PERIOD

The existence of a preoviposition period is a very important consideration. It is the time which elapses after the emergence of the adult until egg laying commences. During this period the females feed, copulation takes place and the eggs mature in the ovaries. It is during this time that control by the poison-bait method is of value, the females being attracted to the poison and killed before egg laying commences. It is quite reasonable to suppose that the longer the preoviposition period, the greater would be the number of flies attracted to the poison and the longer time given for the poison to act.

The following data were obtained from observations made during the cage experiments on the feeding requirements of the adults.

In Experiment No. 1A the flies emerged July 3rd and a few eggs were laid on July 16th, thirteen days after emergence. The majority of the females, however, commenced egg laying on July 20th, seventeen days after emergence.

In Experiment No. 1B the flies emerged July 17th and a few eggs were laid on July 30th, thirteen days after emergence. The majority of the females began laying on August 4th, eighteen days after emergence.

In Experiment No. 2A the flies emerged July 18th and some eggs were laid on August 4th, seventeen days after emergence.

In Experiment No 2B the flies emerged July 18th and the first eggs were collected on August 4th, seventeen days after emergence. The heaviest egg laying commenced on August 10th, twenty-three days after emergence.

Conclusions.

These observations clearly demonstrate the existence of a preoviposition period, which under cage conditions extends from thirteen to seventeen days and to twenty-three days in the case of one cage. The preoviposition period varies somewhat in relation to climatic conditions, but tends to be constant under uniform conditions. Under field conditions, the preoviposition period probably occupies about two weeks and the oviposition period about ten days. Cold weather would have a tendency to lengthen these periods while warm weather would shorten them considerably.

ON THE ACT OF OVIPOSITION AND FACTORS INFLUENCING SAME

As previously stated, before egg laying commences, the adult females pass through a preoviposition period, during which time feeding and mating takes place.

Newly emerged flies placed in cages in the morning were noticed copulating in the afternoon. No record of the exact time that first copulation took place, but probably within a few hours when conditions are favorable. The act of copulation was of short duration.

The Proportion of Male to Female Emergence.

The proportion of male to female flies emerging is fairly even, with perhaps a larger number of males present in the field during the beginning of the emergence period and a greater number of females present during the later part. This may be accounted for by the fact that the females as a rule live several days longer than the males.

The following table shows the ratio of male to female emergence.

<u>Dates</u>	<u>Males</u>	<u>Females</u>	<u>Dates</u>	<u>Males</u>	<u>Females</u>
June 23rd	10	11	July 11th	65	54
June 27th	3	5	July 12th	67	56
June 28th	19	13	July 13th	76	59
June 29th	3	3	July 14th	117	90
July 1st	3	3	July 15th	54	70
July 2nd	27	24	July 16th	54	71
July 3rd	14	12	July 17th	27	40
July 4th	15	16	July 18th	28	32
July 5th	14	16	July 19th	18	12
July 6th	9	14	July 20th	10	7
July 7th	14	11	July 22nd	9	19
July 8th	15	15	July 28th	29	33
July 9th	12	14	July 29th	11	14
July 10th	13	14	July 30th	2	11
TOTALS	- 738 Males	739 Females			

These flies emerged from infested onions taken from the field and held over in the laboratory.

As already mentioned, food, moisture and sunlight are essential factors which bring about the maturing of the eggs in the ovaries and induces oviposition. When these conditions are present, egg laying commences about two weeks after emergence and lasts for some two weeks. Weather conditions tend to prolong or shorten these periods.

During favorable weather conditions, bright, warm, sunny days, the female flies will be seen resting on the onion plants and crawling over the surface of the soil, looking for suitable places to lay their eggs. Some of the males may be observed, resting on the onion plants or adjacent shrubs, apparently watching the activities of the females.

Time of Day that Egg Laying Takes Place.

The time of day that egg laying takes place is controlled largely by climatic conditions. During the cool portions of the morning and evening the flies are not very active, their activities increasing with increasing temperature. On extremely hot days, especially in dry weather, more eggs are laid directly after the period of excessive heat.

The succeeding table gives the number of eggs collected at different times during the day for five days. The weather conditions during this period were fairly uniform, with a shower very early on the morning of June 11th. All the eggs were cleared away from the plants on June 9th at 8.00 A.M.

The Number of Eggs Laid at Five Plants.

<u>Date</u>	<u>Time</u>	<u>No.1</u>	<u>No.2</u>	<u>No.3</u>	<u>No.4</u>	<u>No.5</u>
June 9th	11.00 A.M.	0	0	0	0	0
June 9th	3.30 P.M.	4	12	0	12	0
June 9th	5.05 P.M.	0	0	0	0	0
June 9th	8.00 P.M.	0	0	0	0	0
June 10th	10.15 A.M.	0	0	0	0	0
June 10th	3.00 P.M.	0	0	8	20	60
June 10th	5.15 P.M.	0	0	0	0	0
June 10th	8.15 P.M.	0	0	0	0	0
June 11th	10.05 A.M.	5	0	7	9	7
June 11th	3.40 P.M.	53	5	3	34	5
June 12th	9.45 P.M.	34	5	29	61	56
June 12th	11.40 A.M.	30	0	0	0	7
June 12th	4.00 P.M.	25	12	10	8	143
June 13th	10.00 A.M.	12	6	7	5	51
June 13th	3.15 P.M.	29	9	0	0	25
June 13th	7.55 P.M.	0	0	0	14	8

From the above table it would appear that most of the egg laying activities occur between 9.00 A.M. and 4.00 P.M. with probably the majority of the eggs being laid between 10.00 A.M. and 4.00 P.M.

Egg Placement.

The first generation females usually select plants that have attained considerable growth around which to lay their eggs. Thus during the earlier part of the spring, volunteer and trap onions are heavily infested, while the young seedlings are untouched. This season (1925) eggs were taken in considerable numbers from around the trap onions on May 22nd, but it was not until June 2nd that eggs were taken from the seedlings. All during the time that the trap onions and volunteer onions were in the field they bore the bulk of the infestation.

Fifty trap onions were pulled from the field on June 11th and placed in a cage to secure the number of flies which would emerge. Eggs for experimental purposes had been collected from around these plants up until the time they were pulled. The following figures do not then represent the possible number of flies that might have

emerged. It gives, however, a rough idea of the number of maggots that would normally be present. The number of males emerging was 247, and the number of females 238, making a total of 485 flies.

Onion plants whose bulbs are set deep in the ground with their leaves branching out from near the surface of the soil prove more attractive for oviposition than those sets in which the bulbs have a distinct neck and the leaves branch off some distance above the surface of the ground.

The second generation flies usually select plants that have already been attacked or are diseased. During August onion plants infected with onion smut are usually heavily infested with maggots, the stronger odor of the diseased or decaying onions offering a greater attraction for egg laying.

Freshly plowed or cultivated soils are usually more heavily infested. This is probably due to the moisture conditions of such soils.

This discrimination in the choice of host-plants is noteworthy, when we consider possible control measures.

The eggs are generally laid just below the surface of the soil, within an inch or so of the plant. During the warm days of mid-summer the eggs are usually found in the soil on the shaded side of the plant. During the last week of July and through August, however, the eggs are often laid in great numbers in the axils of the leaves. The eggs are also found in this position, in great numbers, immediately after heavy rains. If the soil around the plants is hard the eggs are deposited in the crevices in the soil about the plants. Large numbers will be found in the opening formed at the surface between the onion stalk and the ground.

The act of the fly laying her eggs in close proximity to the host plant and slightly under the soil is one of instinct, which insures a large number of the newly hatched larvae reaching their source of food and against destruction of the eggs through lack of moisture and exposure to the direct rays of the sun. Any eggs seen on the surface of the soil is probably due to accident. During my observations on oviposition I have never seen a female laying eggs on top of the soil surface.

On rainy days and during cold weather egg laying ceases. Just before a thunderstorm the flies are inactive and oviposition interrupted. Sometimes a day elapses before egg laying recommences. On warm, windy days more eggs are laid than would be expected. This is due to the fact that the females seek shelter in crevices about the onion plants and during their stay many eggs are laid in these pockets.

Oviposition.

During the height of the oviposition period many of the females appear to be in a highly excited and nervous state. They will be seen on the onion plants moving quickly from place to place. From my observations this condition is an indication that oviposition is about to take place. If a fly be disturbed or dissatisfied with the plant, she will immediately fly to another. When, after a close examination, the plant suits her needs, she will run quickly down the stalk to the ground. Here she will encircle the plant several times, examining the ground very thoroughly for a suitable place to lay her eggs. When a spot is located which apparently fulfils her requirements, she will insert her ovipositor and feel about with it. If the right spot cannot be found around a plant,

she will fly or crawl to another nearby plant. The fly exhibits a great deal of care in selecting a place to deposit her eggs. She will examine the soil around a dozen or more plants until a suitable location is found. When crawling about the ground her ovipositor is often somewhat extended and dragging on the ground. When a suitable spot is detected, she will back up to it and immediately burrow her ovipositor gradually into the soil. When a sufficient depth is reached, she pauses a moment before laying an egg. After the egg is laid, the female may fly to another place or remain in the same place and continue to lay eggs. One fly under observation laid eight eggs in one batch. The time occupied was some fifteen minutes.

EXPERIMENTS TO DETERMINE THE EFFECTS OF TEMPERATURE, SUNLIGHT
AND MOISTURE ON THE EGG.

The following experiment was carried on to determine the effect of temperature on the length of incubation period of the egg. The eggs were incubated on moist blotting paper placed in petri dishes. The eggs used in this experiment were collected from around the same onion plants every twenty-four hours, all the eggs being cleared away each time.

The following table shows the results of the experiment.

Number of Eggs	Approximate Temperature	Number of Days Required to Hatch		
		Minimum	Maximum	Average
25	60° F.	4	6	5.5
25	65° F.	4	6	5.5
25	68° F.	4	5	5
25	71° F.	3	5	4.5
25	75° F.	2.5	4	3.5

From the above table it would appear that increase in temperature causes the incubation period to shorten. Eggs incubated under exactly the same conditions vary often in the number of days to hatch. Under ordinary laboratory conditions the majority of eggs hatched in four or five days.

In the field during the cool weather of May and June the incubation period should be longer than in the warm months of July and August, and from general observations this seems to be the case.

The following experiment was conducted to determine the effect of sunlight and dryness upon the egg.

Conditions of the Tests	Number of Eggs Used	Number of Eggs Hatched.	Per cent of Eggs Hatched
On moist blotting paper exposed to strong sunlight in petri dish.	40	7	17.5%
On dry blotting paper exposed to strong sunlight in petri dish.	35	0	0
On moist sand exposed to strong sunlight in petri dish.	50	16	32.0%
On dry sand exposed to strong sunlight	30	2	6.6%
On moist blotting paper in shade in petri dish.	75	62	82.7%
On dry blotting paper in shade in petri dish	50	12	24.0%
On blotting paper and placed in humidity jar.	50	41	82.0%
On blotting paper and placed in desiccator	80	0	0

From the above table it is apparent that sunlight and dryness play an important role in preventing the development of the embryo within the egg. This role is probably one of desiccation, although direct sunlight may affect the egg in other ways.

During the hot, dry weather of July and August many eggs fail to hatch owing to the dryness of the soil and exposure to the direct rays of the sun. In examining the soil around onion plants many eggs are noticed lying exposed on the surface of the soil.

This condition may be brought about by the winds blowing the soil from off the eggs, cultural operations, or washing away of the earth by a shower.

Eggs that had been in the desiccator for eight days were placed under normal conditions but failed to hatch, showing that under such extreme conditions they could not be revived.

Excessive amounts of moisture did not seem to have any detrimental effects upon the egg. Eggs totally immersed in water, hatched normally but the resulting larvae soon died if not removed from the water.

Observations made during the course of the above experiments showed that moisture conditions surrounding the egg do not influence the incubation period but rather the percentage of hatch.

THE RESULTS OF SOME EXPERIMENTS WITH THE LARVA.

The onion maggot apparently restricts its feeding habits to onions, garlic and the leek. The common weeds and cultivated plants about the onion plots were frequently examined for onion maggots but without results. The larvae were introduced into the stalks and roots of many weeds and plants but they soon died without apparently feeding.

Because of the similarity which exists between the Onion Maggot (*Hylemyia antiqua*, Meig.) and the Cabbage Root Maggot (*Hylemyia brassicae*, Bouche) attempts were made to rear the onion maggot on cabbage and the cabbage maggot on onions. All attempts failed. Attempts were also made to rear the onion maggot on lettuce, but the maggots died shortly after being introduced.

From many observations made during the course of experiments on the larvae, it was noticed, that frequently some larvae would pupate before full grown. Several experiments were conducted in which larvae slightly over half grown were induced to pupate. This phenomenon was brought about by cutting off their supply of food, in which case, quite a number would go into pupation. Thus in the field it is possible that half grown larvae may pupate if their food failed, and thus carry themselves over such a period.

Onion Maggot Migration.

The question has often arisen whether the maggot confines its operations to one plant or whether it will migrate from plant to plant. Frequently the number of eggs laid at a single plant is very large, so large that the resultant larvae could not be sustained by it. On May 28th I gathered 112 eggs from a single plant and commonly as many as thirty or forty. However at this time of year, the onion plants are far too small to support such a number. The average number of maggots per seedling runs from four to six while a greater number could be maintained by a larger plant. If the great majority of the larvae are to survive, they must be able to migrate from a plant, which is failing them in food supply, to a fresh one. The eggs are usually placed within an inch or so of the plant and this would appear to be the limit which a newly hatched larva can migrate.

A series of experiments were conducted to ascertain the extent of migration of the larvae and other activities beneath the soil. These experiments were carried out in duplicate and under as natural conditions as possible.

The Extent of Migration of Newly Hatched Larvae.

This experiment was carried out to find the extent of migration of newly hatched larvae to their food plant. Onion maggot eggs were placed on the soil of a flat containing onion seedlings, so that they would be between the source of light and the plants. This precaution was taken because of the negative phototropism exhibited by the larvae.

The following table sets forth the results when the eggs were placed at varying distances from the plants.

<u>Number of Eggs Used</u>	<u>Distance Placed From the Plant</u>	<u>Number of Maggots Reaching Plant.</u>
15	0.5 inches	12
15	1.0 inch	9
15	1.5 inches	1
15	2.0 inches	0
15	2.5 inches	0
15	3.0 inches	0

From the foregoing table one-half inch appears to be the optimum distance while one inch the maximum distance which newly hatched larvae can migrate.

The following experiment was conducted in an effort to find out the manner in which the maggot reached its host plant.

Seedling plants were used and twelve newly hatched maggots were placed within half an inch of the plants. Most of the maggots began burrowing into the soil immediately. The operation of burrowing consists of thrusting the anterior portion of their body into the soil while the posterior portion of the body describes circles in the air, the whole presenting a wriggling motion. This operation takes considerable time and it was nearly two hours before all the maggots were beneath the soil. In twenty hours the maggots were in the bulbs.

Eggs were also placed in the axils of the leaves. Upon hatching the larvae entered the leaves and worked their way down to the bulb, feeding as they progressed.

The Extent of Migration of Half Grown Larvae.

Several experiments were carried out with regard to the distance half grown larvae would migrate and any factors which might influence migration.

Twelve half grown larvae were selected and placed on the surface of the soil sixteen inches from onion plants in such a position that they would have to travel towards the sunlight in order to reach the plants. A few of the maggots burrowed into the soil but the majority began to crawl along the surface away from the source of light in the opposite direction to the plants. Upon examination two hours afterwards they were still moving away from the plants.

The phototropic and chemotropic responses were considered to the following extent. The maggots were arranged as before with regard to their food plants and the source of light. Trails were made from the maggots to the onion plants by saturating the surface soil in strips with an infusion of onions. The maggots however were not attracted to the onions by means of these trails, and were found to be crawling away from the onions and the source of sunlight.

The maggots were now placed twenty-six inches from the onions in such a position that in moving away from the source of sunlight their course was directed towards the plants. A few of the maggots burrowed into the soil while the remaining migrated over the surface of the soil. At the end of two hours the maggots had reached the plants and were burrowing into the ground at the base of the plants.

The Extent of Migration of the Larvae from Plant to Plant.

The following experiments were instituted to obtain data on the migration of the maggots from plant to plant.

Two flats were set out with six onion plants in each. The plants were placed seven inches apart and numbered as shown in figure No. 1. Forty eggs were placed around plant marked "1". In the first flat fourteen days afterwards the plants were examined. This length of time was allowed so that plant marked "1" would be more or less consumed and the maggots induced to migrate in search of further food supply.

The following results were obtained from the first flat. Plant No. 1 was heavily infested and reduced to a sodden mass of decaying material.

Plant No. 1 contained 15 maggots.

Plant No. 2 contained 3 maggots.

Plant No. 3 contained 0 maggots.

Plant No. 4 contained 1 maggot.

Plant No. 5 contained 1 maggot.

Plant No. 6 contained 9 maggots.

In the second flat thirty eggs were placed around plant marked "1". Upon examination ten days afterwards plant No. 1 was heavily infested and reduced to a sodden mass.

Plant No. 1 contained 12 maggots.

Plant No. 2 contained 3 maggots.

Plant No. 3 contained 0 maggots.

Plant No. 4 contained 1 maggot.

Plant No. 5 contained 1 maggot.

Plant No. 6 contained 5 maggots.

Two other flats were set out with fifteen onion plants placed four inches apart as shown in figure No. 2. In the first flat a hundred eggs were placed around the central plant marked "8". Fourteen days afterwards the plants were examined and the following results obtained.

Plant No. 1 contained 0 maggots.

Plant No. 2 contained 1 maggot.

Plant No. 3 contained 4 maggots.

Plant No. 4 contained 0 maggots.

Plant No. 5 contained 0 maggots.

Plant No. 6 contained 1 maggot.

Plant No. 7 contained 2 maggots.

Plant No. 8 contained 35 maggots.

Plant No. 9 contained 8 maggots.

Plant No.10 contained 0 maggots.

Plant No.11 contained 1 maggot.

Plant No.12 contained 1 maggot.

Plant No.13 contained 39 maggots.

Plant No.14 contained 0 maggot.

Plant No.15 contained 1 maggot.

In the second flat ninety eggs were placed around plant marked "8". This flat was examined fourteen days afterwards with the results noted below.

Plant No. 1 contained 1 maggot.

Plant No. 2 contained 1 maggot.

Plant No. 3 contained 3 maggots.

Plant No. 4 contained 0 maggots.

Plant No. 5 contained 0 maggots.

Plant No. 6 contained 0 maggots.

Plant No. 7 contained 2 maggots.

Plant No. 8 contained 33 maggots.

Plant No. 9 contained 10 maggots.

Plant No.10 contained 3 maggots.

Plant No.11 contained 1 maggot.

Plant No.12 contained 2 maggots.

Plant No.13 contained 21 maggots.

Plant No.14 contained 2 maggots.

Plant No.15 contained 2 maggots.

The degree of migration of the maggots along a row of seedlings was next investigated. Twelve seedlings were planted in a row, one and one-half inches apart in the row, as shown in figure No. 3. Fifty eggs were placed around plant marked "1". These seedlings were examined in fourteen days time. The first nine plants were attacked by the maggots, while the others were uninfested.

From the experiments on larval migration from plant to plant, it is evident that newly emerged larvae can travel but a short distance, one inch being probably the maximum. Larvae that have attained partial growth can and will migrate considerable distance to more suitable environment. The tendency of migration is away from the source of light, rather than in any definite direction to a plant. One heavily infested plant may be the origin of infestation to a number of plants in its immediate vicinity, especially if the plants are close together. Onion plants in the seedling stage probably suffer more as a consequence of migration of maggots than when they are more advanced in growth. Estimates from the above

experiments show that about fifty per cent of the maggots migrated successfully from a heavily infested plant while about 7 per cent were lost.

THE RESULTS OF SOME EXPERIMENTS WITH THE PUPA.

It has been noted that pupae under the same conditions behave differently. Pupae in the same breeding cage and subject to similar moisture, temperature and other environmental conditions do not develop in the same length of time.

The following experiment was conducted to obtain data on length of pupal stage, variation in length of pupal stage, mortality and presence of parasites.

On June 30th, two hundred newly formed pupae were placed with moistened sand in a cage. The following table sets forth the results.

Date of Emergence	Number Emerged		Parasites
	Male	Female	
July 14th	59	34	0
July 16th	40	49	0
July 18th	3	2	0

Mortality ----- 6.5%

From the foregoing figures, it is seen that nearly half of the flies emerged on the fourteenth day, and practically all the others on the sixteenth day. Five took eighteen days to complete their development, making a range of four days, thus at least five showed quite a difference in rate of development. The mortality was 6.5 per cent and from this lot no parasites were recorded.

The Effects of Moisture on Pupal Development.

Severe or unfavorable conditions affect certain individuals differently, some are more able to withstand these conditions than

others. In the following experiment on moisture in relation to pupal development it is noted that with fifteen pupae placed in oven-dried soil and maintained in this condition, two pupae were able to withstand the desiccation while the others could not. Under optimum conditions there probably exists a normal period of development, and under abnormal conditions a disparity in development.

In this experiment newly formed pupae were placed in vials, each vial containing a hundred grams of oven-dried soil. Water was added to the vials to give the various percentage of moisture. Fifteen pupae were placed in each vial and the whole weighed and tightly stopped with cotton. Weighings were made each day and water added to make up losses through evaporation.

Lot Number	Percentage of Moisture	Number of Adults Emerging	Percentage of Adults Emerged
1	0%	2	13.3%
2	2%	9	60.0%
3	4%	14	93.3%
4	8%	13	86.6%
5	16%	12	80.0%
6	32%	8	53.3%
7	48%	1	6.6%

From the above data 4 per cent moisture seems to be the most favorable for pupal development, while a high percentage of emergence was obtained in the vials ranging from 4 per cent. to 16 per cent. The soil in the vial containing 32 per cent of moisture was practically saturated. The soil in the vial containing 48 per cent of moisture was supersaturated. It thus appears that within wide limits, soil moisture does not seriously affect pupal development.

A dish of oven dried soil containing ten pupae was placed in a calcium chloride desiccator. The pupae were unable to withstand the desiccation and no flies emerged.

Effect of Temperature.

Gradual increases in temperature will hasten pupal development, while extremes in temperature will retard development, until such a point in temperature is reached where development ceases. During dry hot periods in summer, emergence is retarded until favorable conditions arise. This explains, somewhat, the variation from year to year in the number of flies present in the field during July and August. It has been noticed that the adults of the second brood are frequently delayed in emerging and that these may be delayed for some weeks and perhaps not appearing until September and thus swelling the numbers of the third generation flies. This occurrence is not incidental but in close relationship to the existing climatic conditions.

SEASONAL INFESTATION

Flies of the first generation were captured in the field on May 19th. In all probability the flies made their first appearance in the field several days before this date, as a few eggs were taken from around volunteer onions on May 20th. The maximum emergence of the flies of this generation was between June 4th and June 10th. The first generation flies, however, were present in the field all during June, but after June 19th they were very scarce.

The oviposition period of the first generation adults lasted from May 20th until June 19th. The height of the oviposition period being between June 5th and June 15th. It was on June 2nd that the first eggs were taken from around the seedlings.

The first generation larvae were present in the onions from May 30th to July 10th, while the greatest numbers were present during the period between June 20th and June 25th. It is during June, the last week in May and the first week or so in July that most of the permanent damage is done to the onion crop.

On July 2nd, adults of the second generation appeared in the field, and were observed in the field until September 10th. These flies commenced egg laying on July 10th and in all probability continued depositing eggs until September. These gave rise to second generation larvae and pupae, the majority of the pupae wintering over. Some of the early formed pupae produced third generation adults, which made their appearance on August 15th and continued in the field until the 2nd of October. Second generation larvae and pupae were present in the field up to the time that the onions were harvested.

There is a considerable amount of overlapping of the generations in the field. Eggs were laid continually from May 20th to the end of September, but over half of the total number of eggs were laid during June and August.

RELATIVE RESISTANT POWERS OF DIFFERENT VARIETIES OF ONIONS TO
MAGGOT ATTACK.

It was thought that perhaps some varieties of onions would have a greater attraction to the females for oviposition or that some varieties would offer greater resistance to maggot attacks. The following varieties were tested and counts made of the infestation. It is noted that these varieties at least showed very little difference in degree of infestation.

<u>Variety</u>	<u>Infestation</u>
Ohio Yellow	2.1%
Southport White	2.5%
Southport Yellow	2.7%
Australian Brown	3.2%
Yellow Globe Danvers	3.25%

ON TYPES OF SOILS IN REFERENCE TO ONION MAGGOT INFESTATION.

Introduction.

In looking over numerous onion plots, attention is attracted by the "patchy" appearance of many of the fields. Some spots in a field being heavily infested with the maggots while other portions are relatively free from attacks. Examination of these fields from year to year indicate that the "pattern" and position of infested areas are frequently the same depending of course on the general prevalence of the insects.

The thought therefore suggested itself that insects might have a certain preference in the selection of soils for oviposition, and that a preliminary investigation might yield data which would warrant more detailed study.

Selection and Method of Taking Soil Samples for Study.

This season was a comparatively light one so far as maggot infestation of onions was concerned, but satisfactory conditions (from an entomological standpoint) existed on the farm of the McEvoy, at Rosemount, Montreal, to permit a study of the soil preferences of the maggots. In taking samples, considerable care had to be observed that smut injury should not be mistaken for maggot injury. Smut was quite prevalent in some fields, but where soil samples were taken, which were classed as infested types, care was taken to note the actual presence of the maggots, so as to eliminate as far as possible any chance of confusion with smut injury.

The following samples of soil were taken:-

Sample A - From a field which had been uninfested by maggots for a considerable number of years, and for this reason had been planted to onions continuously. A composite sample was taken by

mixing thoroughly soil obtained from five different spots in the field. Care was taken that there was no maggot infestation near the spots where the samples were obtained. An uninfested soil sample (Fig. 4)

Sample B - From four "patches" infested with maggots. An infested soil sample.

Sample C - From the half of a field which was badly infested with smut and maggot (Fig. 5). This section of the field had been top dressed with manure the previous fall, the fertilizer having been plowed under in the spring before planting the crop. An infested soil sample.

Sample D - From same field as "C" but the other half. This half of the field was top dressed at the same time as the first half in the fall, but the dressing was not plowed under in the spring owing to lack of time. The crop was good and showed very little damage either from smut or maggot, in marked contrast to other half. Composite sample from four places. An uninfested soil sample (Fig.6).

Sample E - From the same portion of field described in "C" but from uninfested spots which occurred therein. Composite sample from three places. An uninfested soil sample from an infested field. (Fig.5)

Sample F - From an onion field in an old orchard. Composite samples from five spots well in the field. This field was new ground for onions and the infestation was not heavy. Some trouble from cutworms was experienced in June. An uninfested soil sample.

Sample G - From the same field as "F", but from one corner where maggots had stuck in a little. An infested soil sample from a field

with a very low infestation.

Sample H - From badly infested areas in one of the fields. A considerable percentage of the injury in this region was due to smut. An infested soil sample (Fig. 7).

Sample I - From same field as "H" but from uninfested end of field. An uninfested soil sample.

All the above samples were taken on the same afternoon.

As the attracting or repelling principle (if any) would be located in the upper layers of soil, the samples were not taken deeper than four inches. The majority of the maggots would be found above this depth normally in any case. The spots selected were pressed with the foot to firm the soil, and an ordinary drinking glass pressed down into the ground and the soil within the circle formed by the glass carefully scooped up and placed within a paper bag.

Poison bait pans were used throughout the fields, but with the exception of the field from which sample A was obtained, were placed out at too late a date to be of very much practical value. The first flies were noticed emerging on May 20th, and the pans were not put out for at least a month later. In the upper field of sample A the pans were out early in June, but as this had always been a field with singularly small maggot infestation it is doubtful if the degree of injury was affected thereby to any appreciable degree.

Trap onions were employed in the fields where samples C,D,E,H and I were obtained.

Method of Making Physical Analysis.

The method of analysis was similar to that outlined in Chapter VI, "Soils", by Lyon, Fippin and Buckman.

The name of each separate and the size of particles in it are

as follows in the U.S. Bureau of Soils classification -

Name of Separate	Diam. of Particles			
Fine gravel -----	1.	-	2.	mm.
Coarse sand -----	.5	-	1.	"
Medium sand -----	.25	-	.5	"
Fine sand -----	.10	-	.25	"
Very fine sand -----	.05	-	.10	"
Silt -----	.005	-	.05	"
Clay -----	.0000	-	.005	"

Results of Physical Analysis.--

The preliminary sifting of the entire sample, to remove any matter over 2 mm. (classed as gravel), yielded the following percentages of that separate -

A -----	8.33%
B -----	4.00%
C -----	15.55%
D -----	12.36%
E -----	11.11%
F -----	9.03%
G -----	6.43%
H -----	7.24%
I -----	6.55%

Duplicate samples were then analysed to find the relative percentages of sand, silt and clay. From these samples the gravel had already been extracted as indicated above.

The following percentages of these three separates were obtained.

Sample	Sand	Silt	Clay
A	81.10	12.96	5.94
B	77.27	13.39	9.34
C	77.49	15.75	6.75
D	78.33	14.43	7.23
E	78.30	14.84	6.85
F	70.35	21.79	7.85
G	78.75	14.69	6.55
H	82.54	11.51	5.94
I	75.28	17.46	7.25

The finer sand separates of samples "A", "C", and "D" were also obtained as representative of uninfested and infested soil. It was thought unnecessary to carry the other soil samples further through the somewhat tedious process unless results from the three selected might appear to warrant it.

The following figures were obtained for these separates:-

Separate	A	C	D
Fine gravel	.276	.209	.420
Coarse sand	.786	.937	1.057
Medium sand	1.675	1.327	1.090
Fine sand	.435	.393	.421
Very fine sand	.891	1.026	.953
Totals	4.063	3.892	3.941

The above represent the average actual weights of the separates in five grams of soil.

From the above the average percentages of sand, silt and clay for infested and uninfested fields would be as follows:-

	Uninfested	Infested
Sand	76.671%	79.017
Silt	16.296	13.835
Clay	7.024	7.145

In comparing the soils taken from infested and uninfested plots it was found that the percentage of the soil separates, i.e., from gravel to clay, was not a controlling factor influencing the degree of infestation. The predominance of any one separate or group of separates, such as would normally occur in fields suitable for the growth of onions, did not render a field more liable to possible onion maggot infestation.

Degree of Acidity of Soils:-

In order to obtain as much data as possible, tests to determine the relative acidity were made of all the nine samples of soils which were subjected to the physical analyses already described.

The tests revealed the following figures for uninfested and infested soil:-

<u>Uninfested Soils:-</u>	Sample A	7.0	
	" D	6.8	
	" E	6.8	
	" F	6.6	
	" I	6.8	Total 34.0

<u>Infested Soils:-</u>	Sample B	.....	6.8	Ph	
	" C	.....	6.9	"	
	" G	.....	6.8	"	
	" H	.....	6.8	"	Total 27.30

Average Ph for uninfested soils 6.8

" " " infested " 6.825

Loss From Ignition:-

When the original samples were tested for the percentage of combustible matter, the following duplicated results were obtained:-

A	.....	14.48%
B	.....	7.62
C	.....	10.20
D	.....	14.25
E	.....	11.30
F	.....	10.56
G	.....	7.94
H	.....	6.52
I	.....	9.86

The average percentages for infested and uninfested soils would be therefore:-

Uninfested	.....	12.09%
Infested	.....	8.07%

It will be noted that no uninfested soil had a percentage of combustible matter as low as the average for infested soils, and that no infested soils had a percentage as high as the average for uninfested soils.

The plowing under of the top dressing of "C" would be expected to result in a lower figure than "D" where the manure was not plowed under but only mixed with the surface layer in the ordinary course of cultivation by harrows, hoes, etc.

Conclusions:-

1. That from the general information that could be obtained some farms, fields, and even parts of fields, appear to be more susceptible to injury from the onion maggot than others.
2. That a physical examination of uninfested and infested soils did not yield any proof for the belief that a slight predominance of any of the soil separates, gravel, fine gravel, coarse sand, medium sand, fine sand, very fine sand, silt or clay, such as might be found within the ranges of soil suitable for the growth of onions, is influential in rendering the soil more liable to onion maggot infestation.
3. The Ph values of the soils tested were not sufficient in range to draw definite conclusions with regard to the degree of maggot infestation. However, within the range obtained, the Ph value of the soil did not play an important part in rendering the soil more liable to maggot infestation.
4. That the results obtained by the ignition tests are interesting, but not carried over a wide enough range to be conclusive. They are, however, indicative of a possible means of combatting this insect, and should warrant fuller experimentation.
5. It is possible that, if the fourth conclusion is later backed by further proof, it may be found that different degrees in infestation may be due, not so much to a preference by the flies for certain soils, but rather that conditions may be better for the development of their natural enemies in some soils (more) than others.

FIELD EXPERIMENTS TO DETERMINE THE RELATIVE CHEMOTROPIC RESPONSES
OF DIPTERA TO CERTAIN SUBSTANCES, WITH SPECIAL REFERENCE TO THE
ONION MAGGOT.

Introduction.

The most satisfactory means of controlling the onion maggot are the Trap Crop method, the Poisoned Bait method or a combination of the two. The poisoned bait method is based on the fact that a pre-oviposition period of some ten days exists during which time the female flies feed before egg laying commences. Poisoned material is placed in the field, which attracts the flies for feeding purposes. The female flies, feeding upon this bait, are thus killed before deposition of their eggs.

Previously the bait used with the greatest success is one made up according to Sander's formula (22)

Sodium arsenite	1/4 ounce
Molasses	1 pint
Water	1 gallon

The lethal principle of the bait consists of the soluble poison sodium arsenite, while the attracting factor is the molasses. In tests of the killing power of this bait, it was found that fifty per cent of the flies were killed during the first twenty-four hours. The remainder died within forty-eight hours after having access to the mixture. (28)

The attracting power of a mixture of molasses and water for the flies is very high, but upon the addition of sodium arsenite this is reduced somewhat. A long series of tests were made of various substances to find which might prove to be of greatest value as attractants, as poisons or combination of both. It was thought

that some chemical might be discovered which could be added to the sweetened baits and considerably increase the chemotropic response of the adult onion maggot to them.

Method.

The materials to be tested were put in petri dishes containing wads of cotton batting and then transferred to the onion plots. Minnesota fly traps (Fig. 8) were placed over the dishes, with the bottoms of the traps raised about two inches above the ground. The number of flies caught in the traps was used as an index of the attractiveness of the various substances used. It is possible that all the flies which visited the baits did not enter the traps. The number escaping however is probably small and would not affect the comparative figures obtained, so that it could be disregarded.

The experiment was not started until August 2, owing to the delay in securing the necessary equipment. Fifty-five different baits were tried over periods of varying length, the number of trials depending on the promise shown by the material. The traps were examined at frequent intervals, the flies killed and removed. The baits were replenished when necessary. Each catch was kept separate and counts made of the males and females of the onion maggot fly, but the other flies were counted in toto. Check traps using molasses diluted with water, and water alone as baits were run throughout the entire period of investigation.

Weather conditions played an important role in the number of flies caught. As would be expected, a bright warm day gave more flies than a day that was cool or cloudy. During rainy spells the flies are more or less inactive and not attracted to the traps. The occurrence of rain gave some trouble by diluting the baits or

causing an overflow in the dishes. The catch also varied from day to day due to seasonal prevalence of the flies.

The relative position of the traps in the field was changed from time to time, but this did not prove to be a factor causing increase or decrease in the numbers of flies attracted to the traps.

The traps were tried at various distances above the ground in order to ascertain at what height they would be most efficient. Molasses diluted with water was used as the attractant. The results obtained from these traps were compared with those obtained from check traps, which were kept at a height of two inches above the ground. This test was carried on from August 27, to October 2, and Table 1. gives the results obtained. Counts were kept of the onion maggot fly (male and female) and all miscellaneous Diptera. In the second column of the table the number of days (in brackets) represents the number of days the trials ran before collections were made. The number of flies caught at each trial by the check traps, were given a value of 100 per cent and the numbers caught at the experimental traps were compared to these figures on a percentage basis. From the data given in the table, it will be noted that those traps with the bottoms raised two inches above the ground secured the greatest catch.

Results of the Field Experiments.

In the course of the following experiments which covered the period of August and September some 2905 adult onion maggot flies were recorded. Of these, 1767 were females and 1138 were males. Generally the number of females caught outnumbered the males, although on some days this was reversed.

The number of miscellaneous flies taken approximated nearly 20,000 individuals, representing many species. The identification of the various species has not yet been completed.

Traps baited with the following oils showed them to be of very little value as attractants and in some cases probably acted as repellents. The extent to which they might act as repellents was not investigated. In Charts 3 and 4 will be found the actual number of onion maggot flies and miscellaneous flies taken from these traps.

Kerosene		Oil of Hemlock.
Oil of Anise		" " Lemon
" " Camphor		" " Mustard
" " Cedarleaf		" " Nutmeg
" " Cedarwood		" " Origanum
" " Cinnamon		" " Pulegii
" " Citronella		" " Sassafras
" " Cloves		" " Spruce.
" " Rose of Geranium		

Other organic compounds tried, which did not prove successful as baits were ethyl alcohol, ethyl acetate, methyl acetate, acetic acid butyric acid, formic acid and lactic acid. The volatility of these substances rendered them unattractive after a day, even during the first day, small catches were secured. The necessity of constantly refilling the dishes makes the use of these materials impracticable and costly in labor and materials.

Charts 1 and 2 give the dates with the number of onion maggot flies and miscellaneous flies caught. The total numbers of onion maggot flies taken from the experimental and check traps during the above tests are recorded in Table 2. The figures in the last column of the table express in per cent the number of flies caught at each experimental trap and they are based on the numbers caught at each check. The table shows that the general average was very

low for the materials used as compared to the checks. Table 3 illustrates the comparative value of these substances as attractants to miscellaneous flies. Here again we see that they possess very little value as baits.

TABLE 1

Table Showing the Relationship Between the Height of the Traps Above the Ground Level and the Number of Flies Caught.

Date	Height of Trap Above Ground.	No. of Miscellaneous Flies Caught at Traps		No. of Onion Maggot Flies Caught at Traps.				Percentages of Experimental Traps Compared to Check.		
		Traps Of Experiment	Check	Traps of Expt. Male	Female	Check Male	Female	Misc. Flies	Onion Maggot Flies Male	Female
Aug. 27th.	3.5 inches	34	203	3	0	8	7	16.7	37.5	0
" 28th.	3.5 "	21	214	0	1	8	11	9.8	0	9.0
" 29th.	4.5 "	27	219	3	0	13	7	12.3	23.0	0
Sept. 1st.	5.5 "(3 dys)	155	919	8	8	34	22	16.8	23.5	36.3
" 2nd.	5.5 "	54	240	3	6	7	11	22.5	42.8	54.5
" 3rd.	6.0 "	25	128	0	1	5	16	19.2	0	6.2
" 4th.	6.0 "	33	225	1	1	13	18	14.6	7.6	5.5
" 5th.	5.0 "	40	232	2	1	3	10	17.2	66.6	10.0
" 6th.	5.0 "	108	359	7	4	11	14	30.0	63.6	28.5
" 7th.	4.0 "	39	200	6	12	7	15	19.5	85.7	80.0
" 8th.	3.0 "	90	189	1	5	7	12	47.6	14.2	41.6
" 9th.	3.5 "	55	191	4	2	5	3	28.7	80.0	66.6
" 15th.	3.5 "	158	112	4	4	5	8	141.0	80.0	50.0
" 17th.	3.5 "(2 dys)	77	200	10	11	9	23	38.5	111.1	47.8
" 19th.	3.5 " "	388	405	7	25	14	22	95.8	50.0	113.6
" 21st.	2.0 " "	336	255	2	13	5	7	131.7	40.0	185.7
" 22nd.	2.0 "	157	55	1	1	1	1	285.4	100.0	100.0
" 24th.	2.0 " "	224	199	0	3	0	3	112.5	-----	100.0
" 25th.	1.0 "	5	8	0	2	0	2	62.5	-----	100.0
" 29th.	1.0 "(4 dys)	1222	1240	2	5	5	16	98.5	40.0	31.2
" 20th.	1.0 "	156	187	1	0	0	3	83.4	-----	-----
Oct. 1st.	1.0 "	147	168	---	---	0	1	87.5	-----	-----
" 2nd.	1.0 "	95	261	---	---	0	0	36.3	-----	-----

The Number of Onion Maggot Flies Attracted.

TABLE 2.

Materials Used			Total Catch				Per Cent.	
			Expt. Traps		Checks		Expt. Traps	
			Male	Female	Male	Female	Male	Female
Ethyl Alcohol	3%		10	26	94	89	10.6	29.2
"	"	5%	9	31	94	89	9.6	34.8
"	"	7%	17	30	94	89	18.1	33.7
"	"	10%	5	19	94	89	5.3	21.3
Acetic Acid	0.3%		0	9	36	27	0	33.3
"	"	0.5%	3	14	36	27	8.3	51.8
"	"	1.0%	1	4	36	27	2.8	14.8
"	"	2.0%	6	8	36	27	16.7	29.6
Ethyl Acetate	1%		1	3	8	11	12.5	27.3
"	"	3%	2	5	8	11	25.0	45.5
"	"	5%	3	0	8	11	37.5	0
"	"	10%	2	4	8	11	25.0	36.3
Lactic Acid	0.1%		0	0	8	5	0	0
"	"	0.3%	0	0	8	5	0	0
"	"	0.5%	1	1	8	5	12.5	20.0
Methyl Acetate	1%		0	1	40	17	0	5.9
"	"	3%	0	4	40	17	0	23.5
"	"	5%	1	4	40	17	2.5	23.5
"	"	10%	0	5	40	17	0	29.4
Butyric Acid	0.1%		2	4	40	23	5	17.4
"	"	0.3%	4	5	40	23	10	21.7
"	"	0.5%	4	4	40	23	10	17.4
Formic Acid	0.1%		0	2	29	25	0	8.0
"	"	0.3%	0	0	29	25	0	0
"	"	0.5%	0	0	29	25	0	0

The Number of Miscellaneous Flies Attracted.

TABLE 3.

Materials Used		Total Catch		Per Cent.
		Expt. Traps	Checks	Expt. Traps
Ethyl Alcohol	3%	84	1297	6.5
"	"	51	1297	3.9
"	"	129	1297	9.9
"	"	36	1297	2.8
Acetic Acid	0.3%	18	520	3.3
"	"	13	520	2.5
"	"	21	520	4.0
"	"	21	520	4.0
Ethyl Acetate	1%	9	261	3.4
"	"	3	261	1.1
"	"	29	261	11.1
"	"	14	261	5.4
Lactic Acid	0.1%	4	375	1.1
"	"	3	375	0.8
"	"	10	375	2.7
Methyl Acetate	1%	41	1053	3.9
"	"	28	1053	2.6
"	"	55	1053	5.2
"	"	59	1053	5.6
Butyric Acid	0.1%	14	892	1.6
"	"	20	892	2.2
"	"	30	892	3.3
Formic Acid	0.1%	5	636	0.7
"	"	3	636	0.4
"	"	4	636	0.6

Results with Sweetened Poisoned Baits.

The following group of inorganic poisons: ferric chloride, sodium fluoride, sodium cyanide and mercuric chloride were tested over a long period. These chemicals were made up into baits using the same formula as described for sodium arsenite. Traps baited with sodium arsenite were run in conjunction with this experiment and used as a basis for comparison. A bait made up of molasses and water of the same concentration as the above was adopted as a check. The experiment was started on August 2nd, and run continuously until August 19th, when the tests with ferric chloride, sodium fluoride and mercuric chloride were discontinued. Sodium cyanide which showed the greatest promise as a bait was continued along with sodium arsenite until October 6. Charts 1 and 3 give in detail the number of onion maggot flies attracted by the various baits. Charts 2 and 4 give the number of miscellaneous flies attracted.

Tables 4 and 5 contain the summarized results of the number of onion maggot flies and miscellaneous flies caught up to August 19th. It is interesting to note the similarity between the relative numbers of onion maggot flies and miscellaneous flies attracted to the various baits. The data included in the two tables shows, that in both the number of onion maggot flies and miscellaneous flies attracted, the sodium cyanide bait is far superior to the others. Sodium arsenite, ferric chloride and sodium fluoride may be ranked together, while mercuric chloride is far below these in value.

The Number of Onion Maggot Flies Attracted.

TABLE 4

Materials Used	Total Catch				Per Cent.	
	Expt. Male	Traps Female	Checks Male	Female	Expt. Male	Traps Female
Sodium Arsenite	33	73	138	132	23.9	55.3
Ferric Chloride	37	72	138	132	26.8	54.3
Sodium Fluoride	45	55	138	132	32.6	41.7
Sodium Cyanide	141	104	138	132	102.2	78.8
Mercuric Chloride	15	69	138	132	10.9	52.3

The Number of Miscellaneous Flies Attracted.

TABLE 5

Materials Used	Total Catch		Per Cent.
	Expt.	Traps	
Sodium Arsenite	529	2096	25.2
Ferric Chloride	407	2096	19.4
Sodium Fluoride	671	2096	32.0
Sodium Cyanide	2187	2096	104.3
Mercuric Chloride	221	2096	10.5

The Number of Onion Maggot Flies Attracted

TABLE 6

Materials Used	Total Catch				Per Cent.	
	Expt. Male	Traps Female	Checks Male	Female	Expt. Male	Traps Female
Sodium Arsenite	74	156	329	372	22.5	41.9
Sodium Cyanide	295	242	329	372	89.7	65.0
Water	7	30	329	372	2.1	8.1

The Number of Miscellaneous Flies Attracted

TABLE 7

Materials Used	Total Catch		Per Cent.
	Expt. Traps	Checks	
Sodium Arsenite	1548	9355	16.5
Sodium Cyanide	5840	9355	62.4
Water	172	9355	1.8

The continued tests with sodium cyanide and sodium arsenite presented further proof of the superiority of sodium cyanide to sodium arsenite. A survey of the figures in Tables 6 and 7 shows quite conclusively the value of the sodium cyanide bait to be very much greater than sodium arsenite in attractiveness. It is quite evident that the attracting power of molasses for the flies is reduced very little upon the addition of sodium cyanide. On the other hand, when sodium arsenite is added to molasses its usefulness as an attractant is decreased considerably. The difference in the number of flies caught by the two baits is quite outstanding, leaving no doubt as to the value of sodium cyanide. The sodium cyanide having attracted 74.9 per cent more males and 35.5 per cent more females than the sodium arsenite.

Toxicity.

To determine the toxicity of the baits, counts were made of the number of dead flies found at the traps. The mortality of the flies at the traps containing the poisoned baits was compared to the mortality at the checks. It is quite possible that the difference in mortality of the flies in the traps containing the poisons and the check traps was not due entirely to the presence of these poisons. However any great difference must have been caused by the action of the poisons. In many cases some twenty-four hours or more may elapse after taking the poison before death occurs. The traps were usually cleared daily so that in all probability a number of flies would be collected before the poison became effective. Occasionally a few of the flies attracted by the bait make their way up into the inner compartment of the trap before feeding. Once in this compartment they are unable to reach the bait. Owing

to the influence of the above factors, any record of mortality at the traps cannot be accepted as a true criterion. However some inference may be drawn from the data thus obtained.

Table (8) contains the data obtained from these records. The last column gives the difference in per cent between the number of dead onion maggot flies taken from the poison bait traps and the check traps. It is assumed that these differences in percentages are due to the lethal factor of the poisons present. The possible mortality occasioned by the sodium arsenite is 30.7 per cent while that of sodium cyanide is 28.5 per cent, a difference of 2.2 per cent. This difference is so slight as to be almost negligible. Thus the sodium cyanide bait is not only more efficient as an attractant but also practically equals it in toxicity. Referring again to the table we see that while 108 dead onion flies were collected from the sodium arsenite trap there were 217 taken from the sodium cyanide trap, an increase of 50.2 per cent.

Table (9) Gives the data from counts taken of the number of dead miscellaneous flies. Here again the above inferences are borne out, the difference between the sodium cyanide and sodium arsenite being very small.

The Number Of Dead Onion Maggot Flies Collected from Traps

TABLE 8

Materials Used	Expt. Traps		Checks	Expt. Traps
	No. of Dead Flies	Per cent Mortality	Per Cent Mortality	Possible Mortality Due to Poison
Sodium Arsenite	108	51.9	21.2	30.7
Ferric Chloride	35	36.4	36.6	----
Sodium Fluoride	42	44.7	36.6	8.1
Sodium Cyanide	217	49.7	21.2	28.5
Mercuric Chloride	32	41.0	36.6	4.4

The Number of Dead Miscellaneous Flies Collected from Traps

TABLE 9

Materials Used	Expt. Traps		Checks	Expt. Traps
	No. of Dead Flies	Per Cent Mortality	Per Cent Mortality	Possible Mortality Due to Poison
Sodium Arsenite	582	53.1	27.5	25.6
Ferric Chloride	147	43.1	37.9	5.2
Sodium Fluoride	367	63.6	37.9	25.7
Sodium Cyanide	1651	48.3	27.5	20.8
Mercuric Chloride	100	56.4	37.9	18.5

ADDITION OF PORTIONS OF THE ONION PLANT TO THE MEDIA.

Results from the Addition of Portions of Onions.

In connection with the tests on the attractiveness of the various baits, additional traps were run with the respective media where parts of the young onion plants were added. Owing to the limited supply of apparatus, trials were not made with the addition of pieces of onions to the poisoned baits. However, separate tests were made with diluted molasses and with water alone. Crushed onion leaves were added to one set while crushed onion bulbs were added to another. There was little or no difference between the attractiveness of the onion bulbs or onion tops.

As a rule the addition of pieces of growing onions to the molasses increased the attracting power of the bait about twice for each sex. The ratio between the number of females and males caught was apparently not altered upon the addition of onions. The increase in attractiveness of the onion and molasses baits over the sodium arsenite and sodium cyanide was about four times. The attractiveness of media containing portions of onions was increased after standing for a day or two. The addition of portions of onion to water alone increased the number of flies attracted many times, but not comparable to the total numbers attracted by the sweetened baits. Table 10 gives the results observed in detail.

Percentage of Gravid Females Attracted to the Baits.

In an attempt to determine the type of females attracted to the most important baits, some 262 individuals were dissected, and the number of eggs present in each was noted. The flies were taken over a period from August 3, to September 17, inclusive, representative

catches being examined as shown by table 11.

It will be noted that in all cases those flies having over twenty eggs present were more numerous than the spent females or those having under twenty eggs. Thus it would appear that the greatest percentage of females attracted to the baits were those which were gravid or at least carried over twenty eggs.

As for the attracting power of the two poisoned baits, sodium cyanide and sodium arsenite, as compared with molasses and water, taken purely from the gravidity of the females, there seems to be but slight differences. In the sodium cyanide bait traps, 69.4% of a total of 81 females examined carried over twenty eggs. In the sodium arsenite bait traps 76.6% of a total of 73 females examined carried over twenty eggs. In the case of molasses and water bait traps 71.1% of a total of 108 females examined carried over twenty eggs.

It was thought that the addition of portions of onion leaves or onion bulbs to the baits would have a tendency to attract a greater percentage of gravid females. Referring to Tables 11 and 12 it will be seen that this is not the case, for in those baits containing onion leaves or onion bulbs, there is no appreciable increase in the percentage of gravid females. The addition of portions of the onion plant to the baits, as already stated in this paper, increases the total number of female flies caught and thus ~~increases the total number of female flies caught and~~ increases the total number of gravid females destroyed.

The Increase in Number of Onion Maggot Flies Attracted to the Baits
Due to the Addition of Crushed Onion Leaves or Crushed Onion Bulbs.

TABLE 10

Materials Used	No. of Flies Attracted				Per Cent	
	Expt. Male	Traps Female	Checks Male	Female	Expt. Male	Traps Female
Sodium Arsenite	12	49	38	84	31.6	58.3
Sodium Cyanide	17	20	38	84	44.7	23.8
Crushed Onion Leaves and Water	13	44	96	183	13.5	24.0
Crushed Onion Leaves and Molasses	63	148	38	84	165.8	176.2
Crushed Onion Bulbs and Water	30	70	96	183	31.2	38.2
Crushed Onion Bulbs and Molasses	64	93	38	84	168.4	110.7

The Percentage of Gravid Females to Spent Females Attracted to the Baits

TABLE 11.

Date	Sodium Cyanide				Sodium Arsenite				Molasses and Water			
	No. of Flies Exam-ined.	Spent Females	Under 20 Eggs Present	Over 20 Eggs Present	No. of Flies Exam-ined.	Spent Females	Under 20 Eggs Present	Over 20 Eggs Present	No. of Flies Exam-ined	Spent Females	Under 20 Eg- Pres- ent.	Over 20 Egg Presen-
Aug. 3	10	10%	40%	50%	9	11.2%	0%	88.8%	5	20%	20%	60%
Aug. 9	8	25%	25%	50%	7	14.3%	28.6%	57.1%	15	33.4%	0%	66.6%
Aug. 11	7	14.2%	42.9%	42.9%	10	30%	10%	60%	12	16.6%	8.4%	75%
Aug. 14	6	0%	16.7%	83.3%	4	0%	25%	75%	6	33.4%	0%	66.6%
Aug. 17	6	16.7%	16.7%	66.6%	7	0%	14.3%	85.7%	11	9.1%	18.2%	72.7%
Aug. 19	10	0%	10%	90%	7	14.3%	14.3%	71.4%	8	0%	25%	75%
Aug. 25	5	20%	20%	60%	3	33.4%	0%	66.6%	3	33.4%	0%	66.6%
Aug. 29	5	20%	40%	40%	4	0%	50%	50%	7	42.9%	0%	57.1%
Sept. 2	3	0%	0%	100%	2	0%	0%	100%	10	10%	10%	80%
Sept. 7	9	0%	0%	100%	4	0%	25%	75%	12	0%	8.3%	91.7%
Sept. 15	6	16.7%	16.7%	66.6%	9	11.2%	0%	88.8%	8	37.5%	12.5%	50%
Sept. 17	6	16.7%	0%	83.3%	7	0%	0%	100.0%	11	8.3%	0%	91.7%
Aver. %	81	11.6%	19.0%	69.4%	73	9.5%	13.9%	76.6%	108	20.4%	8.5%	71.1%

Total number of flies examined to give the above results:- 262

The Percentage of Gravid Females to Spent Females Attracted to
Baits containing Portions of the Onion Plant.

TABLE 12

Date	Molasses and Onion Leaves				Molasses and Onion Bulbs			
	No. of Flies Exam- ined.	Spent Females	Under 20 Eggs Present	Over 20 Eggs Present	No. of Flies Exam- ined	Spent Females	Under 20 Eggs Present	Over 20 Eggs Present
Sept.11	----	----	----	----	6	16.7%	0%	83.3%
Sept.15	15	13.3%	6.7%	80%	15	33.3%	6.7%	60.6%
Sept.17	15	6.7%	6.7%	86.6%	15	6.7%	13.3%	80.0%
Aver. %		10%	6.7%	83.3%		18.9%	6.6%	74.5%

SUMMARY

1. Food is an essential requirement to the adult onion maggot fly. In nature this is obtained as nectar from the various flowering plants. This was borne out in cage experiments, one female living forty-three days.
2. Flies placed in cages with dandelion flowers were able to complete their normal development and length of life. In nature this flower appears to be a favourite source of food supply.
3. Flies given access to water alone, failed to complete their normal development and lived only a few days.
4. Flies provided with manure did not derive any nourishment from that source.
5. The normal length of life of the adult flies is probably from four to five weeks. The males usually die a few days before the females.
6. Sunlight is essential to mating and oviposition.
7. The normal life-history and habits of the onion maggot are largely dependant on the climatic conditions.
8. A preoviposition period exists, which under cage conditions lasted from thirteen to seventeen days. Under field conditions this period probably occupies about two weeks.
9. The proportion of males to females emerging is fairly even.
10. On bright, warm, sunny days egg laying takes place between 9.00 A.M. and 4.00 P.M. On excessively hot days egg laying takes place during the cooler portions of the day.
11. The female usually selects onion plants with a low, flaccid type of growth. Second generation flies usually deposit

their eggs at plants that have already been attacked or diseased.

12. Freshly plowed land attracts a greater number of flies for egg laying.
13. The eggs are generally laid just below the surface of the soil, within an inch or so of the plants.
14. There is a cessation of egg laying on rainy or cold days and before thunderstorms.
15. Increases in temperature causes the incubation period of the eggs to shorten.
16. Sunlight and dryness play an important role in preventing the development of the embryo within the egg. Excessive amounts of moisture did not seem to have any detrimental effects upon the eggs. Moisture conditions influence the percentage of hatch rather than the incubation period.
17. Some larvae were noticed to pupate before full grown. This was possibly due to food shortage.
18. The maximum distance newly hatched larvae can migrate appears to be from one to two inches. Partially grown larvae can migrate considerable distances from plant to plant.
19. The maggots are strongly negatively phototropic.
20. Some pupae are more able to withstand adverse conditions than others.
21. Within wide limits, soil moisture does not seriously affect pupal development.
22. Gradual increases in temperature hastens pupal development, while extremes in temperature retards it.
23. The several varieties of onions tested did not show any

difference in degree of infestation.

24. Onion fields frequently present a "patchy" appearance. This is due to some portions being more heavily infested than others.
25. The physical properties of the soil is not a factor influencing maggot infestation within ranges suitable to onion growing.
26. The amount of organic matter in the soil might possibly have an influence on infestation. This may be due to more favourable conditions for the multiplication of their natural enemies.
27. In the use of the poison bait pan method of control, the position of the bait pans in the field is not a factor influencing the number of flies attracted to them.
28. Of the various baits tested, the sweetened, poisoned baits proved to be the most effective.
29. Sodium cyanide used in a sweetened bait was much more efficient than sodium arsenite in attractiveness. The sodium cyanide attracted 74.9 per cent more males and 35.5 per cent more females than the sodium arsenite.
30. The toxicity of the sodium cyanide bait was practically equal to that of the sodium arsenite.
31. The addition of portions of onions to the sweetened baits increased their attractiveness for the onion maggot fly to a considerable extent.
32. The greatest number of female onion maggot flies attracted to the baits were gravid, ranging from 69 to 76 per cent.
33. The addition of portions of onions to the plants did not increase the percentage of gravid females attracted.

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ATTRACTIVENESS OF VARIOUS BAITS TOWARDS ONION MAGGOT FLIES DURING AUGUST 1925

[illegible]

CHART 2

ATTRACTIVENESS OF VARIOUS BAITS TOWARDS MISCELLANEOUS FLIES DURING AUGUST 1925

Bait	3	4	5	6	7	8	9&10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Sodium Arsenite	36	22	10	15	15	35	120	99	34	35	16	26	32	24	10	5					36	30	32	18	33	42
Ferric Chloride	47	13	8	7	12	15	96	65	41	52	15	7	6	5	18	9										
Sodium Fluoride	52	23	13	18	10	6	61	46	100	180	54	34	28	18	28	12										
Sodium Cyanide	124	70	54	95	48	68	325	322	164	131	79	68	276	201	162	116										
Mercuric Chloride	18	12	9	9	8	11	23	19	45	24	10	9	9	7	8	4				248	105	137	121	234	86	
Molasses + Water	18	13	8	15	84	70	325	500	282	67	65	75	109	204	261											
Water	8	3	7	5	2	3	3	0	72	16	18	4	10	8	1	5				375	166	309	203	214	219	
Ethyl Alcohol 3%		11	9	15	2	4	17	10	16											4	0	1	0	0	0	
Ethyl Alcohol 5%		5	0	5	0	3	15	11	12																	
Ethyl Alcohol 7%		30	9	11	6	9	34	16	14																	
Ethyl Alcohol 10%		15	10	10	1	0	0	0	0																	
Acetic Acid 0.3%										4	1	1	4	8												
Acetic Acid 0.5%										4	2	0	3	4												
Acetic Acid 1.0%										4	9	2	3	3												
Acetic Acid 2.0%										6	0	7	6	2												
Ethyl Acetate 1%															9	15	17	16	14							
Ethyl Acetate 3%															3	9	7	11	8							
Ethyl Acetate 5%															29	26	29	21	20							
Ethyl Acetate 10%															14	32	22	11	7							
Lactic Acid 0.1%																		2	1	8	4					
Lactic Acid 0.3%																		2	0	5	3					
Lactic Acid 0.5%																		7	1	12	10					
Methyl Acetate 1%																					14	3	14	10		
Methyl Acetate 3%																					11	3	10	4		
Methyl Acetate 5%																					19	9	15	12		
Methyl Acetate 10%																					36	5	10	8		
Butyric Acid 0.1%																						3	8	1	2	
Butyric Acid 0.3%																						2	13	4	1	
Butyric Acid 0.5%																						8	17	2	3	
Formic Acid 0.1%																								0	0	5
Formic Acid 0.3%																								2	0	1
Formic Acid 0.5%																								4	0	0

Oil of
Spruce
Oil of
Hemlock
Oil of
Sedar
Oil of
Sedar
Oil of
Citron

[illegible]

ATTRACTIVENESS OF VARIOUS BAITS TOWARDS MISCELLANEOUS FLIES

Baits	Aug.										September																				Oct.					
	28	29	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2		
Sodium Arsenite	33	42	39	52	15	22	24	15	12	4	12						37	24	29	52	50	42	43	63	11	13	4	22	8	53	30	24	31	97		
Sodium Cyanide	234	86	548	47	40	36	108	175	43	106	39						60	20	26	28	39	37	47	35	55	37	7	202	92	104	490	137	105	59		
Water + Molasses	214	219	919	240	128	225	232	359	200	189	191						112	95	105	225	180	148	107	55	98	101	8	330	221	348	341	187	168	261		
Water	0	0	0	0	0	0	0	0	0	0	0						0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0			
Crushed Onion				0	7	7	7	19	13	11	16						5	0	1	1	2	0	1	0	0	2	0	0	0	2	5	0	0	0		
Leaves + Water												58	70																							
Molasses + Onion																																				
Leaves													24				270	68	45	152	190	164	196	86	110	103	30	260	212	112	156	261	147	115		
Crushed Onion																																				
Bulbs + Water				31	16	43	39	43	12	23	45	84	99				13	0	3	4	6	5	5	5	8	4	0	8	3	5	21	43	13	0		
Molasses + Onion																																				
Bulbs													160				261	120	89	99	61	42	86	35	71	29	14	76	53	63	115	169	91	97		
Sodium Cyanide																																				
+ Onion Bulbs																																				
Sodium Arsenite																																				
+ Onion Bulbs																																				
Oil of Anise	9	10	209																																	
Kerosene	11	2	4	5	6																															
Oil of Cloves	6	4	17	15																																
Oil of Sassafras				13	5	8																														
Oil of Cinnamon				2	4	2																														
Oil of Rose																																				
Oil of Geranium				2	4	4																														
Oil of Lemon					0	0	3	0																												
Oil of Mustard					7	18	19	12																												
Oil of Origanum					2	2	7	3																												
Oil of Camphor						2	0	1	1																											
Oil of Pulegii								0	0	6	1																									
Oil of Nutmeg								0	0	1	0																									
Oil of Spruce								0	1	3	1																									
Oil of Hemlock									0	0	0	0																								
Oil of Cedarwood											0	5	0	1																						
Oil of Cedarleaf											0	1	0	0																						
Oil of Citronella												1	1	2	4																					

Dead Onion Maggot Flies Found at Traps.

BAITS	August																												
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29			
Sodium Arsenite	4	2	1	0	2		11	8	6	4	5	4	3	2	1	0					1	3	8	0	5	2			
Ferric Chloride	2	0	0	0	4		10	7	3	2	4	0	1	1	0	1													
Sodium Fluoride	3	0	1	3	0		12	1	6	3	8	1	1	2	0	1													
Sodium Cyanide	2	1	1	2	4		14	26	25	10	3	2	12	7	8	7					2	2	12	5	10	9			
Mercuric Chloride	1	0	0	0	1		3	1	12	9	2	0	1	1	0	1													
Molasses + Water	1	1	0	1	1		12	22	34	8	3	2	3	3	2	4					0	0	8	0	0	7			
Water	0	0	0	0	0		0	0	6	3	1	1	1	1	0	0					0	0	0	0	0	0			
Ethyl Alcohol 3%	5	0	0	0	0		6	3	2																				
Ethyl Alcohol 5%	3	0	0	1	0		7	4	3																				
Ethyl Alcohol 7%	5	1	0	1	0		5	4	3																				
Ethyl Alcohol 10%	4	0	0	0	0		6	3	0																				

BAITS	September																										
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	
Sodium Arsenite	2	2	1	7	1	2	0	0						8	4	3	1	0	2	2	0	0	1	0	0	0	
Sodium Cyanide	5	2	4	2	10	10	6	1						6	3	4	0	0	0	0	0	1	0	0	1		
Molasses + Water	3	1	6	3	0	8	3	5						1	2	1	1	3	1	3	0	3	0	0	0	0	
Water	0	0	0	0	0	0	0	0						0	0	0	0	0	0	0	0	0	0	0	0	0	

Dead Miscellaneous Flies Found at Traps

[illegible][illegible]

FIGURE 1

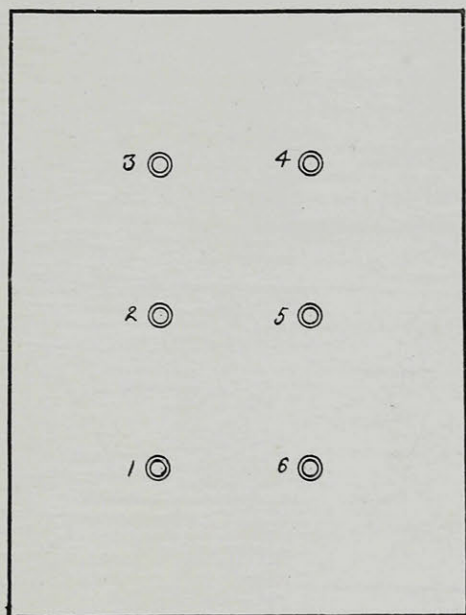


FIGURE 3

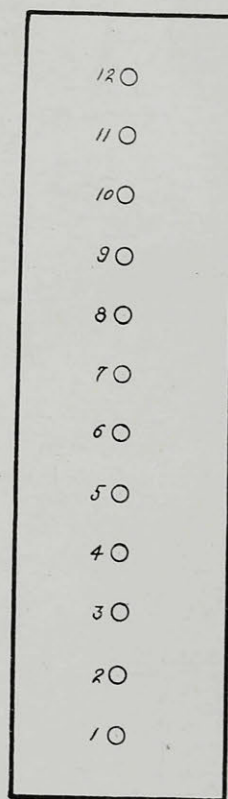


FIGURE 2

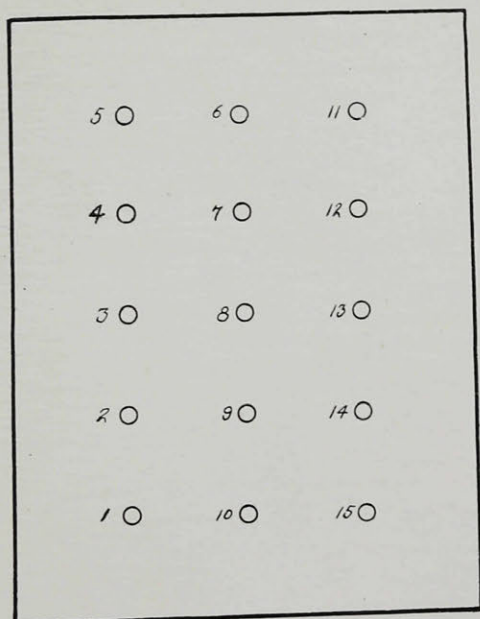


FIGURE 4



FIGURE 5



FIGURE 6



FIGURE 7



FIGURE 8

