THE BIOLOGY OF THE ONION MAGGOT, *HYLEMYA ANTIQUA* (MEIGEN), UNDER FIELD AND GREENHOUSE CONDITIONS

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INTRODUCTION

Hylemya antiqua (Meigen) is one of the most important pests attacking onions. In most onion growing areas it causes damage to the crop nearly every year and some years, almost complete destruction is produced. In the United States losses occur only in the northern areas, the onion maggot being of little or no importance in the south. The current literature concerning the onion maggot is, mainly, from the United States, Canada, England, Germany, and Russia.

A survey of the literature disclosed a large number of references on control of the onion maggot with a lesser number on its biology. Biological data were chiefly descriptive, rather than explanatory, and generally concerned observable factors such as emergence in the spring, length of the various stages, preoviposition period, number of eggs laid per female and so on. These data were very similar in most of the papers examined. Many reports concerned a heavy infestation of onion maggots which occurred unexpectedly.

The onion maggot was first described in Europe by Meigen in 1826. It reached North America shortly afterwards. Some of the first records of injury are from the eastern coast of the United States. Harris (14, p.495) reported severe damage caused by the insect in Massachusetts in 1841. Couper (3, p.9) stated from Canada in 1875 that the onion maggot was a "terrible pest throughout the extent of the Dominion". About 1910, the onion maggot was introduced into the Lake Labish area near Salem, which is the major onion growing region in western Oregon (34, p.140).

Control of H. antiqua in the Lake Labish area was difficult from the beginning. Lovett (21, p.1-2) in 1923, reported over 70 different treatments had been tried against the insect up to that time with only partial success. Testing of insecticides by various workers was continued through the years with varying results.

Calomel was used with good results for a number of years but was expensive, caused planter clogging, and was somewhat phytotoxic. From 1946 to 1949, tests by Thompson (40, p.1) showed that DDT applied as a drench into the furrow at planting time gave good control. DDT was replaced by chlordane in 1951 and used until 1953.

In 1953, a very heavy infestation of the onion maggot occurred. All treatments failed and onion losses ranged from 50 to 100 percent. In 1954, DDT dusts applied in the onion fields to kill the adults were found to give satisfactory control. Growers dusted whenever they saw onion flies in the field and little damage was experienced after June 19. The large number of treatments (as high as 12) required in this method of control was expensive. Experiments were initiated in 1955 using onion seed treated with insecticides, a treatment which was proving successful in several parts of the country. At this time it was decided that a study of the biology of the onion maggot under Oregon conditions might produce some new ideas which would lead to better control.

Biological work on H. antiqua was initiated in the summer of 1955 and was terminated in the spring of 1958. As the numerous reports which had been made of the onion maggot life cycle in the literature were very similar, this phase was not examined intensively. The primary purpose of the study was the further investigation of the basic aspects of the problem.

DESCRIPTIONS OF STAGES

The following descriptions of stages of Hylemya antiqua (Meigen) were modified from the descriptions of various authors including Miles (26, p.583-586), Eyer (8, p.4-9), and Smith (39, p.178-180).

The Egg

Eggs are 1.2 mm. long by 0.5 mm. wide, white, allantoid, truncate at the anterior end, and rounded at the posterior end. The surface of the chorion is marked by numerous fine longitudinal striae which run into one another at irregular intervals producing a reticulate appearance. A ring-like ridge at the anterior end of the egg divides into a number of fine ridges which continue in a narrow ventral band to the posterior end, forming a suture which splits open at larval emergence (Fig. 1).

The Larva

Onion maggot larvae are muscidiform, white, 9-10 mm. long when full grown, tapering towards the cephalic end. Mouth parts are protrusible, hook-like structures embedded in the anterior segments. The prothoracic spiracles are inconspicuous, fan-shaped, and composed of 11 to 12 digits. The posterior end is broadly flattened, containing two raised, yellowish, caudal spiracles each with three oval openings. Eight pairs of caudal tubercles distinguish the onion maggot from other species of the genus by their form and arrangement.

The three larval instars are very similar except in size and are most easily distinguished from one another by the structure of the mouth hooks. First instar mouth hooks are small and delicate, second instar mouth hooks are somewhat heavier, while third instar mouth hooks are very stout and distinctive (Fig. 2).

The Puparium

The puparium is elongate-oval, rounded at the ends, whitish when first formed, later turning yellow-brown to dark red-brown. As the puparium consists of the last larval cuticle, it can generally be identified by larval characteristics. In the formation of the puparium, the cephalic end is drawn inwards with the prothoracic spiracles assuming a terminal position (Fig. 3).

The Adult

Onion flies (Fig. 4) are similar in size to the house fly, *Musca domestica* Linne. The wings of the onion maggot fly appear longer and narrower and are more rounded at the outer ends. The body is less robust in size and lighter in color than that of the housefly. The following description of the adult *H. antiqua* (Meigen) is from the annotated list of British *Anthomyiidae* of Meade (24, p.218-9) who identified the insect as *Phorbia cepetorum*, Meade.

> "*Head*: face slightly prominent; epistome flat; eyes of male contiguous; antennae of moderate length, with arista thickened and pubescent at its base, but nearly bare in the middle and at the extremity.
> *Thorax*: with the scutellum of a light yellowish-grey colour; the former marked with four indistinct pale brown stripes, and with four rows of black bristles.
> *Abdomen*: oblong and rather narrow, cinereous,

clothed with black hairs, and showing silvery-white reflections when viewed from behind; it is marked down the dorsum with a row of elongated, narrow, triangular black spots, which form a subcontinuous stripe; the end segment is grey, small and rather pointed; the subanal male appendages are large and hairy.
Wings: hyaline, with the third and fourth longitudinal veins nearly papallel to each other, and the external transverse ones straight, and a little oblique; Calyptera and Halteres both pale yellow; Legs sometimes piceous; hind femora almost bare of hairs or bristles at the base of their under-surfaces; hind tibiae of the males furnished with a few short bristles along the middle and upper part of their inner sides. The female is very similar in colour to the male; the eyes are widely separated, the intervening space being red at its front part; the abdomen is dull grey, mostly immaculate, conical and pointed at the apex; the calyptera are white, and the halteres yellow."

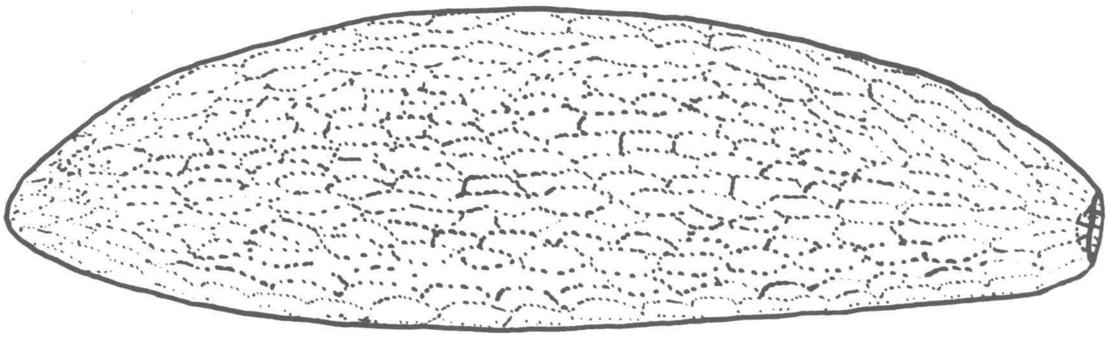

Figure 1. *Hylemya antiqua* egg (x120).

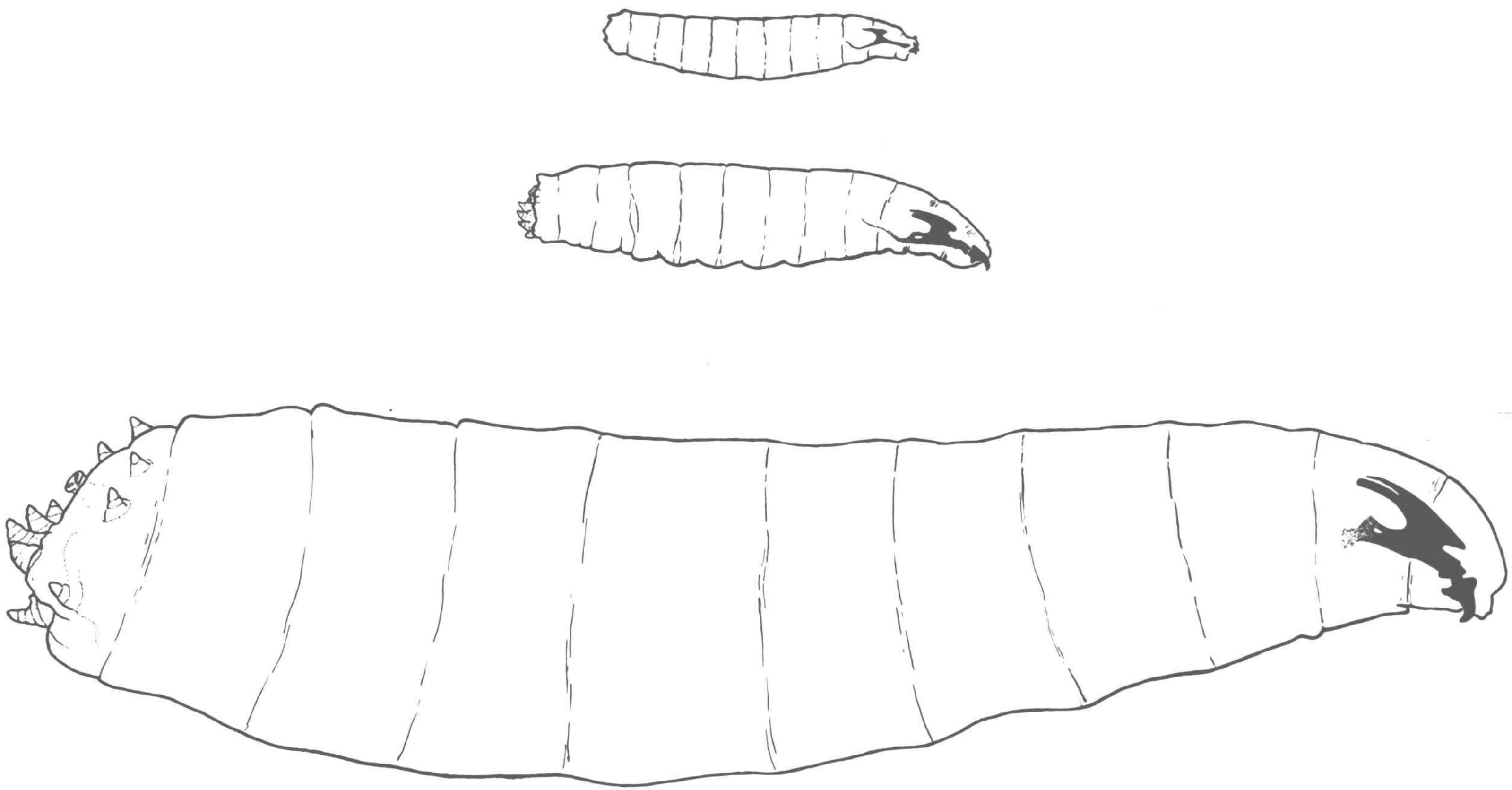

Figure 2. Hylemya antiqua larvae (x21).

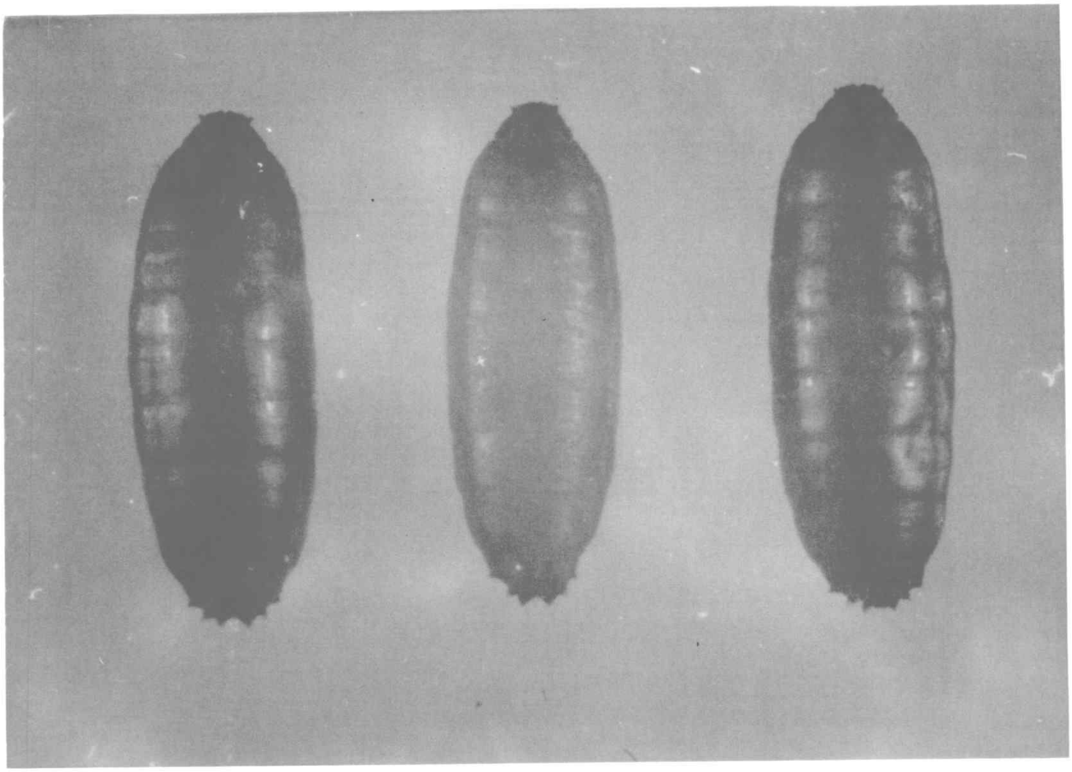

Figure 3. *Hylemya antiqua* pupae (x10).

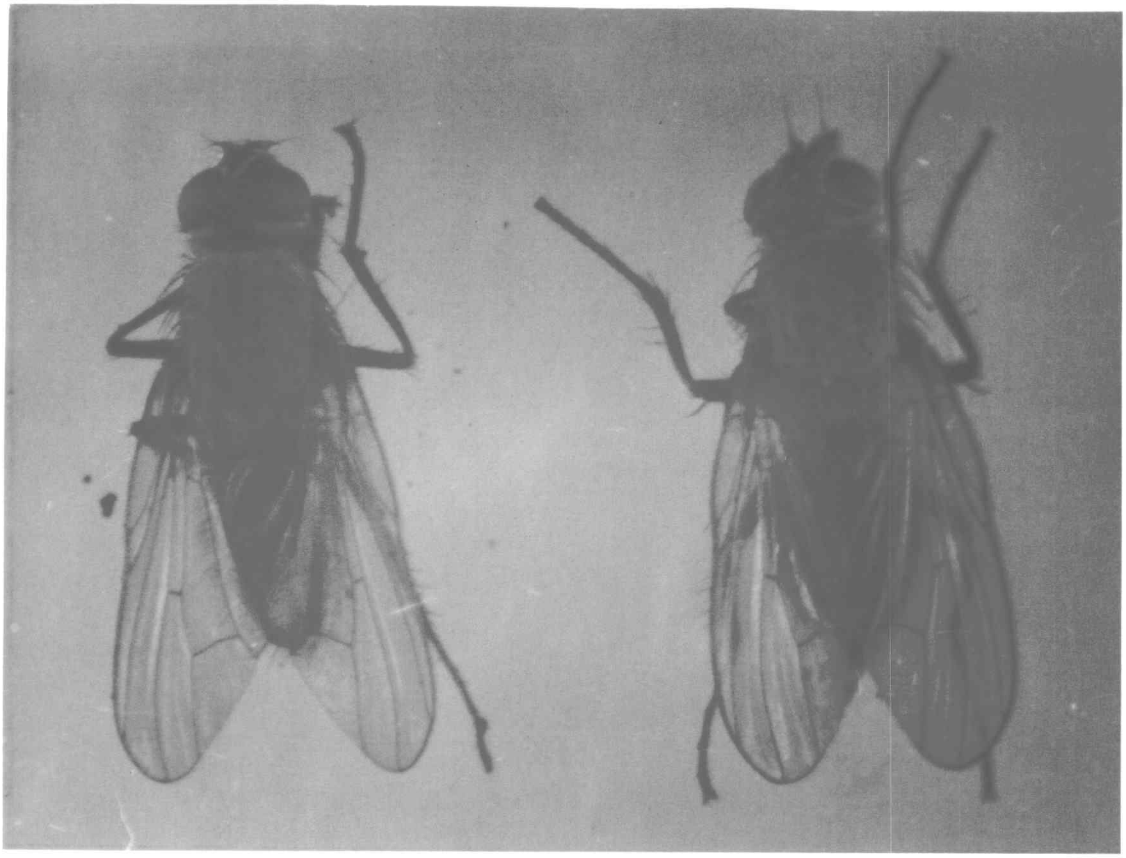

Figure 4. Hylemya antiqua adults (x10).

BIOLOGICAL STUDIES

Rearing Methods

It was determined at the beginning of the problem to rear the onion maggot in the greenhouse so that all stages of the insect would be available for experimentation throughout the year.

There were few references in the literature concerning successful rearing techniques for H. antiqua. Miles (27, p.12) reared onion flies on sugar solution and water containing fish meal (poultry food). She suggested that a temperature of approximately 80° F. was necessary for caged flies to oviposit freely. Rawlins (33, p.1101) reared onion maggot adults on a diet of undiluted honey and brewers yeast. The food was placed in open vessels and renewed at weekly intervals. Rawlins reported that "copious egg production followed." Perron, Lafrance, and Hudon (30, p.145-146) used equal parts of molasses and evaporated milk placed on bread. Broken yeast cake slightly moistened with water, was also placed in the rearing cages. These authors stated that sudden changes in temperature and humidity were essential and that temperature should vary between 70-90° F.

Modifications of the latter two methods were tried with poor success. After some experimentation it was found that greenhouse temperatures over 80° F. caused increased adult mortality and low egg production. Rearing was carried on after this time at day temperatures of 70-75° F. and night temperatures of 60-65° F.

Heating in the greenhouse was by steam. An evaporative type cooler, with a capacity of 5500 cubic feet of air per minute, kept the temperatures below 77° F. even on the hottest days. Temperature regulation was by means of thermostats.

Cages 2x2x2 feet were used for rearing the onion flies as they afforded room for a number of greenhouse pots, yet took up little bench space. One cage 3x3x3 feet, permitting the introduction of flats, and several cages 1x1x1 feet were also used. The cages were covered with 1/16 inch mesh lumite screen with a sleeve type opening at the front (Fig. 5).

Cultures were started by collecting large numbers of maggot-infested onions from the field and placing them in large greenhouse pots with soil until pupation. The puparia were collected by breaking up the contents of the pots in a deep pan of water. The puparia floated to the surface where they were skimmed off with a small screen.

The puparia were placed, slightly moistened, into empty salve tins which were labeled as to area and date collected and stored at a temperature of 35-40° F. When adults were desired, the puparia were removed from cold storage and placed on a moistened filter paper in a petri dish at 70-73° F. If diapause was terminated by this time (see page 40), adult emergence from the puparia and production of eggs could be expected within 22 to 24 days.

Very few flies emerged at storage temperatures and losses due to death of pupae were low except after long storage periods. After storage periods of 12 months at 35-40° F., approximately 30 percent of the pupae were nonviable. Doane (6, p.79) stored onion maggot pupae at 41.0 to 42.8° F. with a viability of 95 percent after 16 months.

Adult cultures were started with about 200 onion flies which emerged within five to six days of each other. No additional flies were introduced after this time so that the age of the flies in each cage was known at all times. Four-inch greenhouse pots of onion seedlings, three to five inches in height, were placed in the cages for oviposition. If eggs were desired for an experiment the seedlings were placed in the cages for a short time during the egg laying period which usually occurred in the late afternoon. Otherwise, they were left in the cage until several hundred eggs had been deposited. The pots were then removed and watered lightly. Half of an onion bulb, 1.5-2.5 inches in diameter, was placed, cut surface down, on the seedlings. Soil was added around the edges of the bulb to prevent drying (Fig. 6). Maggots emerging from the eggs fed on the seedlings and the onion bulb. Onion bulbs which were nearly consumed were soft and yielded to the touch, making it very easy to check the condition of a number of pots in a short time. Fresh bulbs were added where needed. Pupae from maggots raised in the greenhouse were labeled as to origin and number of generations reared and placed in cold storage until used. Frequent examinations were made during the rearing to see that only _H_. _antiqua_ was present.

_H_. _antiqua_ which had been reared over two generations in the greenhouse were not used in the test work. This was done to reduce the possibility of using insects which might have differed from field strains. Smith (38, p. 187-190) reared the plum curculio, _Conotrachelus_ _nenuphar_ (Hbst.), through 40 generations in the laboratory. After the fortieth generation he found that egg production had doubled due to a longer period of oviposition and an increased rate of egg laying. Adults were 25 percent larger than specimens collected in the field.

At first the diet for the adults consisted of honey and brewers yeast in tablet form. A six inch greenhouse platter of water was also placed in the cage. Egg production was satisfactory. When the supply of brewers yeast was exhausted, it was found that the brand had been discontinued. Three different brands were substituted but were not attractive to the onion flies. Little feeding was observed. Periods of egg production were erratic and few eggs were laid.

The diet was then changed to milk (with formaldehyde, two parts per thousand, to retard spoilage) and honey. To 25 parts of honey was mixed one part of a liquid vitamin concentrate containing vitamins A, D, B_1, B_2, B_6, C, E, niacinamide, pantothenic acid, choline chloride, and inositol. Milk was supplied to the onion flies in small jars inverted on the screen on top of the cage with cheese cloth placed over the jar opening to prevent spillage. The honey was placed on top of the cage in small droplets. Very good egg production resulted from this diet throughout the year.

In colonies started with approximately 200 onion flies, from 100 to 200 eggs per day were obtained during the first two to three weeks of egg production. As the age of the culture increased and numbers of adults became less, egg production decreased. Most experiments were planned so that large numbers of eggs were available when required. At times, cultures were started about one month apart so that large numbers of eggs were present over an extended period.

Viability of eggs was often 100 percent and ranged from 90 to 100 percent summer and winter. Perron, Lafrance, and Hudon (30, p.145-146), rearing onion flies on evaporated milk and molasses plus moistened yeast cake,

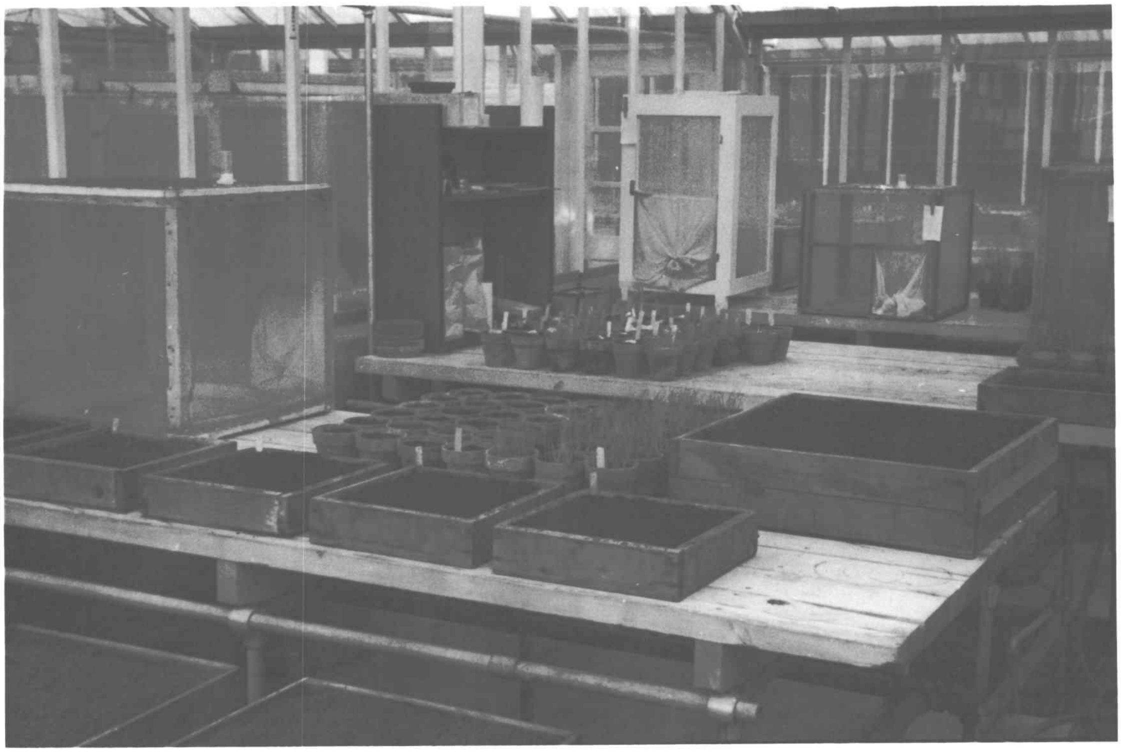

Figure 5. Rearing *Hylemya antiqua* in the greenhouse.

Figure 6. Rearing Hylemya antiqua larvae in greenhouse pots.

obtained egg production with an egg viability of 85 to 95 percent in the summer and 25 to 35 percent in the winter. They listed some females as living 139 days in the summer and males living 60 to 70 days. In the winter females lived as long as 60 to 70 days, males a month or a little longer.

In Oregon, at temperatures between 65-75° F., males and females in cages lived as long as 60 to 70 days summer and winter with the females generally living a few days longer than the males. Maximum length of life for the females was 101 days and 77 days for the males. In cultures, deaths occurred at a somewhat uniform rate after emergence from the puparia until the last fly was dead.

At times in the rearing of the onion maggot flies, egg production diminished for no apparent reason. Upon examination of the culture, males with torn and broken wings were found among the seedlings placed in the cage for oviposition. After removing these flies and decreasing the numbers of other males in the cage, a normal rate of egg production resulted. It was believed that the males, in attempts at copulation, prevented the females from oviposition. Patterson (29, p.104) reported that the wings of male house flies in rearing cages were characteristically broken by the upward thrusts of the metathoracic legs of the females in repulsing efforts at copulation. Wing damage to the male onion maggot flies appeared similar to that reported by Patterson.

Soils Used In The Study

Three types of soil were used in portions of the experimentation: Lake Labish muck, Oregon State College Horticulture Farm sandy loam, and Oregon State College Entomology Farm clay loam. Onions are grown commercially only in the Lake Labish and Horticulture Farm soil types. Horticulture farm and Entomology farm soils will hereafter be referred to as Hort. soil and Ent. soil. Laboratory analysis performed by the Oregon State College soils department is listed in Table 1.

Table 1. Analysis of soils used in the experimentation. (Performed by the Oregon State College Soils Department).

Soil	Organic material (%)	Sand (%)	Silt (%)	Clay (%)	Field capacity (%)
Lake Labish	18.53	*	*	*	46.62
Hort. farm	1.77	55.62	39.74	4.64	24.26
Ent. farm	4.43	19.08	35.08	45.84	33.25

* unable to make analysis

The Egg

Soil moisture

Soil moisture appeared to be very important in the amount of damage caused by the onion maggot. Numerous references in the literature on maggot infestations reported that damage was most severe during years of increased precipitation. Sleesman (36, p.50-51) found that irrigated onion fields were more heavily damaged by maggots than nonirrigated fields. Kent (19, p.1) reported that the greatest amount of damage occurred where onions were planted next to an irrigated crop. In those places where the sprinkler irrigation overlapped into the onion field it was not uncommon to have as high as 80 percent of the crop killed by maggots. Baker (2, p.65) stated that onion maggot flies oviposited without reference to kind of soil but that larval infestations were usually heavier in sandy soils than in clay soils. Dustan (7, p.22, 27) also described high onion maggot infestations in light soils with low infestations in clay soils. He found the percentage of moisture to be higher in the upper surface of light soils than in clay soil but listed no measurements. In the test plots at Lake Labish the infestation was generally heavier in an area where the soil moisture was highest.

Preliminary field tests were conducted during a warm dry period in July, 1957 at the Entomology Farm. One hundred onion maggot eggs were placed in the soil one-fourth inch deep next to every third onion seedling in each of four thirty foot rows. Water was applied every other day to two of the rows, the others remaining dry. In the wet rows 136 onions were damaged while only seven onions were damaged in the dry rows.

To find out how much soil moisture was required for onion maggot eggs to hatch, 10 grams of air dried soil were placed in salve tins 1 7/8 inches in diameter and 5/8 of an inch deep. Three types of soil were used--Lake Labish muck, Hort. sandy loam, and Ent. clay loam. Graduated amounts of water were added to the different containers and mixed thoroughly with the soil. Ten eggs, less than six hours old, were added and the salve tin covers pressed on firmly. The paper writing-surface on the covers had been removed as it absorbed moisture from the air. The salve tins and contents were then weighed to four decimal points. After two to six days at 71-73° F. they were opened to count numbers of eggs hatched. Unhatched eggs were dissected to see whether they were infertile or whether the larvae had died within the chorion. The checks contained sufficient moisture for the most rapid hatching of eggs (about two days).

Moisture percentage was computed by drying the soil at 221° F. for 24 hours. After drying, salve tin covers were replaced immediately as the dry soil absorbed moisture rapidly from the air. Difference in weights between damp and dry soil gave the percent of water content.

Hatching of onion maggot eggs was delayed under conditions of low soil moisture. If soil moisture was increased during this period, maggot emergence from the eggs usually occurred within two to 30 minutes. Mortality increased with delay in hatching until after three days less than 20 percent of the larvae emerged. Results of over 70 trials indicated that a moisture content of about 10 percent for Lake Labish, 13 percent for Ent., and five percent for Hort. soil was required for optimum emergence (Table 2).

The Larva

Onion maggot damage to onions is caused by the larval stages which feed on the underground stem and bulb of the onion, killing the plant or destroying its market value. Most of the damage occurs in the early part of the year when the onions are in the seedling stage. Little damage is experienced later in the season in most years. However, in some years late season damage may be quite severe.

The onion maggot larva is positioned inside the egg with the mouthparts at the antero-ventral portion. By wetting the egg so that the chorion becomes transparent, the maggot can be observed cutting at this portion. Whether the maggot cuts through the chorion or splits it open by internal pressures is not known. The chorion splits open along the ventral suture about one-half its length with very light external pressure and nearly full length with moderate pressure.

Table 2. Percent of soil moisture required for larval emergence from *H. antiqua* eggs in different soils.

Lake Labish Soil		Ent. Soil		Hort. Soil	
Moisture (%)	Larval emergence (%)	Moisture (%)	Larval emergence (%)	Moisture (%)	Larval emergence (%)
6.71	0	6.36	0	3.51	0
6.90	20.0	6.61	0	3.64	44.0
6.93	0	7.31	0	4.53	70.0
6.99	10.0	7.31	0	4.82	88.9
7.95	100.0	7.71	11.1	5.38	100.0
8.24	60.0	7.92	25.0	5.40	88.9
8.43	66.6	8.25	0	6.44	100.0
8.61	66.6	8.35	25.0	7.12	100.0
8.66	75.0	8.44	60.0	9.60	100.0
8.69	70.0	8.98	14.3		
8.88	77.8	9.20	62.5		
9.25	90.0	9.27	60.0		
9.71	70.0	9.89	30.0		
9.92	90.0	10.20	55.6		
10.28	100.0	10.22	87.5		
10.31	55.6	10.72	44.4		
10.35	90.0	10.95	70.0		
10.36	100.0	11.49	88.9		
10.91	100.0	13.00	75.0		
11.06	80.0	13.67	100.0		
11.85	88.9	14.89	100.0		
12.52	100.0	15.62	100.0		
16.74	100.0	16.64	90.0		
16.98	100.0	18.84	100.0		
20.01	100.0	20.32	100.0		
20.57	100.0	23.28	100.0		

Soil Moisture

Experiments were conducted to find out how much soil moisture was required for onion maggot survival just after hatching from the egg. The experiments were a continuation of the trials on larval emergence from the egg (p.21) and the same techniques were used in both tests.

Results of the experiments showed that larval eclosion from the egg took less than one minute with good soil moisture. In dry soils, emergence took longer and a few larvae carried the egg shell about for some time before it was lost. Newly emerged onion maggot larvae required a moisture of 23 percent or more in Lake Labish and Ent. soils and 10 percent or more in Hort. soil for survival (Table 3). Where there was only enough soil moisture for hatching from the eggs but not enough for survival, the larvae traveled only a short distance from the egg before they were desiccated and killed.

Judging from the results obtained in the preceeding experiments on soil moisture reports of high maggot infestations in light or sandy soils and low infestations in heavy or clay soils may be due to the water retentive ability of the different soils. The moisture present may be in such an amount as to be more available for egg hatching in light soils than in heavy soils. For example, if the soil moisture happens to be between 5-10 percent, there is more likelihood that onion maggot eggs and larvae will survive in Hort. type sandy loams than in muck or clay loam soils.

After emergence from the egg, the larvae penetrated the soil to the base of the onion where they entered just above the basal plate. Onion roots were generally not fed upon although in the greenhouse, maggots tunneled in the larger roots of onion bulbs when food supplies were short. Leaves of infested onions first turned dark green and flaccid, then became yellowed and drooping until finally they fell over. When maggot damaged seedlings were pulled up, only the outer sheath came out of the soil, the basal plate and roots remaining in the ground. The maggots usually stopped feeding at the soil surface and left the onion from the basal portion or cut through the stem sheath near the soil surface and burrowed to a new onion host.

Table 3. Percent of soil moisture required for H. antiqua maggot survival in different soils.

Lake Labish Soil			Ent. Soil			Hort. Soil		
Moisture (%)	Maggots alive (%)* 24 hours	Maggots alive (%)* 48 hours	Moisture (%)	Maggots alive (%)* 24 hours	Maggots alive (%)* 48 hours	Moisture (%)	Maggots alive (%)* 24 hours	Maggots alive (%)* 48 hours
16.7	0	0	15.6	0	0	5.4	0	0
17.0	0	0	16.6	0	0	6.4	0	0
20.1	100	0	18.8	100	0	7.1	0	0
20.6	100	0	20.3	100	0	9.6	100	100
21.3	100	55	23.3	100	100	11.2	100	100
22.3	100	100	23.6	100	100	11.8	100	100
23.4	100	100	23.7	100	100	15.6	100	100

* Ten H. antiqua eggs were used in each test

Phototropic response and feeding

A negative phototropic response appeared to stop maggot feeding in the onion seedlings at, or slightly above, the soil level. When infested seedlings were covered to exclude all light, the maggots continued feeding up into the leaves. In onion seedlings which fell over, the larvae fed outwards to the tip (eight inches) if the diameter of the onion leaf was large enough to accommodate them.

Number of seedlings destroyed per maggot

Many statements have appeared in the literature that onion maggots were most damaging in the spring because each larva consumed a number of seedlings. Later in the season, one onion bulb would support a large number of maggots. Kendall (18, p.83) reported that one larva of the first generation would kill four to five plants when onions were small, while larger onions would sustain 15-20 maggots.

To find out how many onion seedlings one maggot would destroy, tests were set up in the greenhouse involving four to six inch clay pots of seedlings of different sizes. The tests were performed a number of times during the study and over 200 pots of onions were used. Each trial consisted of groups of five to ten replicate pots of seedlings. One onion maggot egg was placed in each pot and the number of onions consumed was recorded every three to four days. Onion seed had been planted one inch deep in all pots so that the length of onion stem consumed by the maggots was the same. Numbers of onions per pot ranged from 35 to 45 in trials involving the smaller seedlings (1-2 mm. in diameter). In tests of the larger seedlings (3-5 mm. in diameter), 5 to 10 plants were grown in six inch pots. Measurements of seedling height and diameter at the soil surface were taken at the start and finish of each experiment.

Several factors complicated the experimentation. From the placement of the egg in each pot until the last onion was destroyed generally took about 20 days. During this time the plants were growing larger. The seedlings also varied slightly in size due to inherent growth factors and spacing of the plants which varied due to seed placement and destruction of seedlings by the maggots. The data in Table 4, therefore, represent the average size of the onion seedlings during the experiments (Fig. 7).

Table 4. Effect of onion seedling size on numbers destroyed by individual onion maggots.

Seedling size diameter* (mm.)	Seedling size height** (mm.)	Nos. of plants destroyed (range)	Mean No. seedlings destroyed per maggot
1	40	23-35	28.0
1-1.5	75	17-26	22.0
1.5	125	10-19	13.5
2	180	6-13	9.0
3	225	2-4	3.3
4-5	260	---	1.0

* at soil surface
** from soil surface

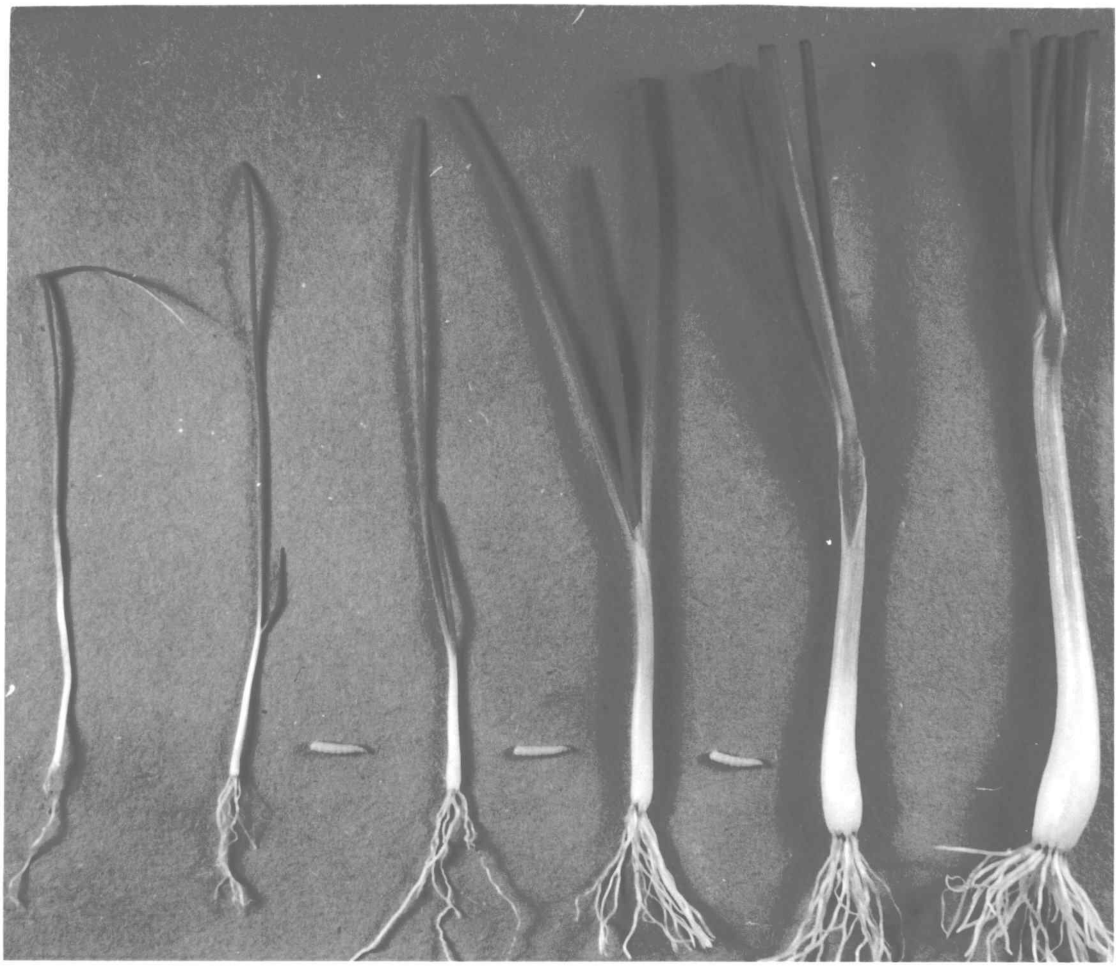

Figure 7. Different sizes of onion seedlings used in tests to determine the number of plants destroyed per onion maggot.

Lovett (21, p.1) and Smith (39, p.178) reported that maggots feeding in mature onions appeared to take longer to complete their development than maggots feeding in younger onions.

In the present study onion maggots were reared in seedlings, 1-2 mm. diameter at the soil surface by 100-200 mm. in height, and onion bulbs, 50-65 mm. in diameter, under greenhouse conditions. Larvae reared in both seedlings and bulbs were found to pupate at nearly identical times (Table 5).

Table 5. Length of larval stages of *H. antiqua* reared in onion seedlings and mature onion bulbs.

Length of larval stages	Days	Mean	No. of larvae
In seedlings	15-21	19.0	100
In bulbs	15-23	19.4	405

Onion maggot survival without food

H. antiqua larvae were found to be able to survive for a considerable time without food. Numbers of maggots of different instars were placed without food in approximately one ounce of moist Ent. soil in salve tins, 3/4 of an inch in height by 1 7/8 inches in diameter, for varying lengths of time. At first the period without food was for 24 hours. All maggots survived. In following tests, the period without food was gradually increased using a fresh group of larvae each time.

In five trials of first instar larvae made just after emergence from the egg, 35 of 40 maggots survived after three days in moist Ent. soil without food. All of 17 first instar larvae survived after four days in moist soil. None of 20 first instar larvae withstood starvation of six days.

Trials of 110 second to young third instar maggots without food for six days resulted in 29 dead and 81 survivors. Forty medium aged third instar larvae were apparently unaffected after six days in moist soil.

At the end of the preceeding experiments and of other trials where the ability of the insect to withstand starvation, submergence, drying and so forth was examined, the individuals tested were placed on a section of lightly chopped onion. Insects which fed and were active three days later were listed as surviving. Many times insects were still moving at the end of a trial but were unable to feed and died 24-48 hours later.

Onion maggot movement in the soil

After an onion maggot has destroyed an onion, it tunnels through the soil in search of another plant. In flats of onion seedlings in the greenhouse, maggots seeking a new host frequently passed by a number of onions and fed on one some distance away. In field plots at Lake Labish, maggots often crossed between the onion rows which were 14 inches apart. Sleesman and Gui (37, p.36) reported on experiments in Ohio in which 12 percent of the onion maggots migrated to adjacent rows of onions in the field while 88 percent remained in the row.

Experiments were performed on onion maggot movement in the greenhouse using flats of soil ranging from 14 to 24 inches square and from three to 12 inches deep. Little work was done with first instar larvae as onion maggot eggs are generally placed very close to the host and the larvae have usually reached the second instar before leaving the onion. However, it was found in tests performed in six inch pots that 21 of 25 first instar larvae tunneled, after emergence from the eggs, to an onion cube placed 3 1/2 inches away in moist Ent. soil. No maggots, from 40 eggs, tunneled 5 inches to an onion cube in two separate trials. Late third instar larvae were eliminated from the experiments as they tended to pupate upon being disturbed.

Onion maggot movement was determined in two ways. A number of larvae were placed 1/4 inch under the soil surface in the center of a flat of soil. Several hours later the soil was removed in layers and the location of each larva recorded. In other tests, maggots were placed 1/4 inch under the soil surface with a one-half inch cube of onion located one-half inch deep in the soil some distance away. The onion cube was removed at intervals and the number of maggots feeding in it were counted.

Onion maggot movement varied with soil type and larval size. Second and medium aged third instar larvae were able to tunnel through 12 and 15 inches respectively, of moist Ent., Lake Labish, and Hort. soils to an onion cube within 24 hours. Maggot movement through Lake Labish soil was the most rapid while Hort. soil was quite resistant to passage (Table 6).

Table 6. Movement of second and medium aged third instar onion maggot through Lake Labish, Ent., and Hort. soils.

Instar	Soil	Inches	Maggots in test	Maggots at onion 24 hrs.	48 hrs.	Total
2	Lake Labish	12	30	17	7	24
2	Ent.	12	30	11	10	21
2	Hort.	12	30	4	0	4
3	Lake Labish	15	35	26	5	31
3	Ent.	15	35	20	7	27
3	Hort.	15	35	17	1	18

Thirty-five medium aged third instar larvae which had been held in a pot of Ent. soil for four days without food were placed in a flat of moist Ent. soil. After four hours the maggots had tunneled as below:

Inches traveled	0	1	2	3	4	5	6	7
No. of maggots	3	10	4	2	4	8	3	0

Fourteen of 45 early third instar maggots traveled four inches to an onion cube within 24 hours after five days without food.

On moist soils larval penetration from the surface took place within a minute or slightly longer and movement through the soil was accomplished very easily. Onion maggots placed on loose dry soils had difficulty in moving over or penetrating the surface. If the maggots succeeded in entering the soil through a crack they often reappeared after several minutes. Twenty-five medium aged third instar larvae were placed one-half inch deep in two flats of air-dry Labish soil in July. One hour later the larvae had tunneled as below:

Inches traveled	0	1	2	3	4
No. of maggots	11	5	7	6	0

Twenty-one larvae appeared at the soil surface.

In air dry Lake Labish peat of 4.1 percent moisture content, 40 second instar maggots were dead--shriveled and brown in color--after four hours at a temperature of 74° to 76° F. Sixty medium aged and late third instar larvae survived 6.5 hours under similar conditions. Four of 20 medium aged third instar larvae survived nine hours in Labish soil of 6.5 percent moisture content. Water and an onion slice were added, but the larvae died 24 hours later. One medium aged third instar maggot of 20, exposed to 21 hours in Labish soil of 8.3 percent moisture, was alive three days later.

Onion maggots released in the center of flats of soil migrated outwards in all directions, generally remaining in the upper three inches. Experiments involving moisture of the soil, different soil types, and position of the flat in relation to the sun showed no influence on direction traveled by the maggots.

Onion maggot resistance to high moisture in the soil

Onion maggots were found to be tolerant to soils of high water content. Water was slowly added to six-inch greenhouse pots of soil containing various stages of onion maggots feeding on sections of onion bulbs placed one inch deep. As the water level in the pots rose, the maggots moved upwards keeping the posterior spiracles above the water level until the soil surface was reached.

To find out what onion maggots would do if water was applied to the soil rapidly, ten medium aged third instar larvae were placed on the bottom of four petri dishes 3/4 of an inch deep and 3 1/2 inches in diameter. Wet Ent. soil was added up to the top of the petri dishes and water added to excess immediately. The number of minutes after addition of soil and water until the appearance of the maggots at the surface is listed below:

Minutes	2	2.5	3.5	4	4.5	5	10	20
Maggots	7	7	5	5	6	2	0	5

Three maggots had not reached the soil surface after 30 minutes.

Following this experiment, 40 onion maggots of all instars were placed in a petri dish and covered with one half inch of water. After one hour the maggots were removed and placed on a section of onion. All survived. The period of submergence was gradually increased in further trials using fresh larvae. No mortalities were found after three, four, five, or six hours. Forty second and third instar larvae lived after eight hours under water. Of 82 second and third instar larvae under water for 11-12 hours, 71 survived. In another trial of 40 maggots under water for 12 hours, however, there were no survivors 48 hours following removal from the water.

From the results of the trials above it is questionable whether heavy amounts of precipitation would have much effect in reducing onion maggot populations in the soil. Only where water stood for an appreciable length of time, as in low places or depressions, would mortalities possibly occur.

Detection of onions in the soil

From observations made in the field and greenhouse, onion maggots were apparently unable to sense onions in the soil at any distance. Finding of the host appeared to be a hit or miss process dependent on the maggots ability to move relatively long distances in the soil.

While no substantiating data was obtained, it appeared from observations of the movement of onion maggots in flats of soil, that the insect had a certain pattern of movement by which it found the host.

In effort to find out something of onion maggot movement in relation to onions, 14-inch flats of Ent. soil were set up with 14 one-half inch onion cubes placed one inch deep in four staggered rows so that the distance between the onion cubes was about four inches. Thirty-five to fifty medium aged third instar maggots were released about one-half inch deep in the soil at one side of the flat ("X" in Fig. 8).

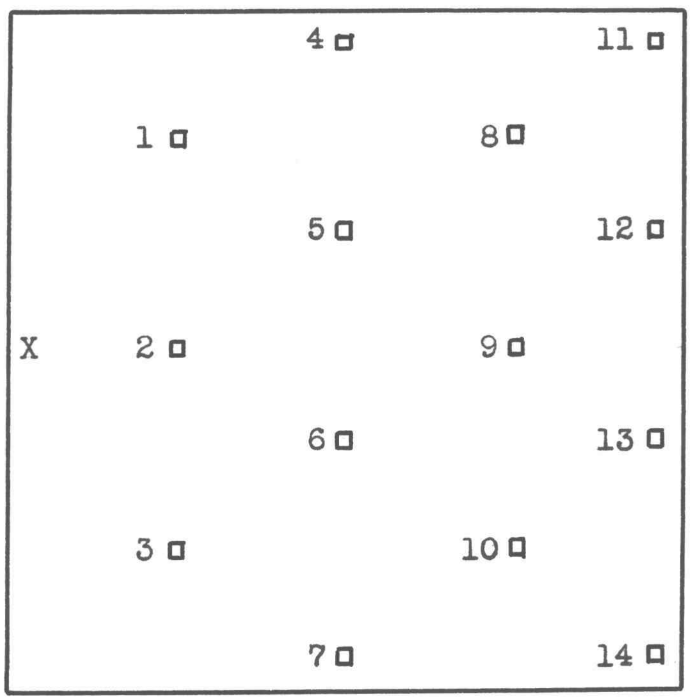

Figure 8. Arrangement of onion cubes in flats of soil to follow onion maggot dispersal.

Examination of onion cubes five to six hours later showed that onions in the row nearest the point of release contained the most maggots. Succeeding rows contained decreasing numbers of larvae. The row farthest from the point of release usually contained one or more maggots (Table 7).

Table 7. Numbers of onion maggots found at onion cubes placed in four rows four inches apart.

Flat no.	Onion cube 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	4	10	5	2	0	4	1	0	1	0	1	0	0	1
2	8	9	9	3	0	2	8	0	1	1	0	1	0	1
3	7	12	6	2	2	4	4	1	1	2	1	0	2	1

Depth of penetration of the soil

Increasing compactness with depth probably limits onion maggot movement to the upper layers of soil. The following test was devised to find out what the maggot would do if confined to a small but deep area of loose soil. A one inch cube of onion was placed at the bottom of a box with sides 12 inches wide and 12 inches high. The box was then filled with moist Ent. soil to the top and lightly compacted by jarring each corner of the box on the concrete floor. Thirty-five medium aged third instar onion maggots were placed 1/4 of an inch under the soil surface. When the soil was removed 24 hours later, the maggots were found dispersed throughout all levels of the soil. The results of three trials are shown in Table 8.

Table 8. Penetration of 35 medium aged third instar onion maggot larvae in lightly compacted Ent. soil.

Test	Depth in inches 1	2	3	4	5	6	7	8	9	10	11	12	Total
1	1	5	3	2	2	3	3	3	2	1	2	4	31
2	1	1	2	5	4	4	6	4	3	1	1	3	35
3	1	3	2	3	5	3	4	2	3	1	2	2	32

Overwintering

To find out whether the onion maggot overwintered as such in the field in Oregon, a number of onions which had been the center of a natural infestation at the Entomology farm in mid October 1957 were examined in late January 1958. No onion maggots were found, although larvae of the lesser bulb fly, Eumerus strigatus (Fallen), were present in large numbers.

In a laboratory test, 60 onion maggots including 15 second, 15 early third, 15 medium third, and 15 late third instar larvae were selected from cultures in the greenhouse and placed on sections of lightly chopped onion. Chopping the onion allowed the maggots to enter very rapidly. After a one hour feeding period, the onions containing the maggots were placed in 3/4 x 3 1/2 inch petri dishes with covers and stored at 34 to 39° F. for 60 days. Six larvae survived--one early third, two medium third, and three late third instar maggots. In a similar group of larvae held at 34 to 39° F. for 90 days, no survivors were found.

Rearing on different hosts

The onion maggot has been reported almost exclusively from members of the genus *Allium* including onion, leeks, shallots, and garlic. Smith (39, p.181) recorded the onion maggot from tulip bulbs and lettuce. Severin and Severin (35, p.343) reared the onion maggot in radish and horse manure. In the present study, eggs were placed on different hosts in the greenhouse. Maggots were reared on radish, turnip, large basal stems of turnip leaves, garlic seedlings, and a moistened mixture of two parts wheat bran to one part alfalfa meal. The larvae pupated and emerged as adults which were identified as *H. antiqua* by R. H. Foote of the Insect Identification Laboratory, U. S. D. A., Washington, D. C. Length of the larval stages was similar to that of maggots reared in onions. It was not possible to rear onion maggots on corn seedlings, bean seedlings, carrot, or potato (Table 9).

Density of the host appeared to be one of the limiting factors in maggot development. Maggot penetration and tunneling appeared to be very difficult in dense tissues such as carrot and mature turnip.

Table 9. *H. antiqua* eggs placed on different hosts and larvae reared to the pupal stage.

Host	No. of eggs	No. of pupae
Alfalfa meal plus bran	250	130
Bean seedlings	100	0
Carrot	50	0
Corn seedlings	474	0
Garlic seedlings	50	39
Potato	100	0
Radish	150	44
Turnip	90	32
Turnip leaf stems	50	27

The Pupa

The onion maggot puparia are usually formed in the soil near the onion host or within the host tissues. In the field the puparia were generally found in the upper three inches of soil. Increased compactness of the soil downwards is probably a limiting factor on puparial depth. In tests where onion maggots penetrated 12 inches of loosely compacted soil to an onion cube, they pupated at that depth also.

Studies on diapause

There are several generations of the onion maggot produced each year depending on the length of the season. Most of the adults from first generation pupae emerge the same season (13, p.39). Later on the majority of the pupae enter a diapause by which the species overwinters. In order to find out the length of the cold period required to break pupal diapause, onions infested with maggots were collected from the field September 25, 1957 and placed in pots with soil in the greenhouse. A large number of pupae were collected October 19 and placed in a refrigerator at 37-41° F. Twenty-five pupae were removed weekly and placed on a layer of moistened filter paper in a petri dish at 71-73° F. Records showed that numbers of adults emerging, increased with longer periods of cold storage until the sixth week when all adults appeared 9 to 14 days after removal from storage. After the sixth week nearly all pupae moved to 71-73° F. transformed to adults within 9 to 14 days (Table 10). This was found in many tests made throughout the study. When pupae were placed at 59-61° F., after six weeks in cold storage, the adults appeared in 20 to 25 days.

Table 10. Emergence of adults from 25 pupae taken from a group collected October 19, 1957 and placed at 37-41° F. for varying periods before removing to 71-73° F.

Storage (weeks)	Period of emergence after removal from storage (days)	Range (days)	Adults emerged (number)
0	16-70	55	5
1	8-48	41	11
2	6-57	52	8
3	7-29	23	18
4	11-31	21	16
5	5-11	7	20
6	9-14	6	25
8	5-14	10	24
11	10-13	4	24

Perron, Lafrance, and Hudon (30, p.146) reported that in rearing the onion maggot during the winter months, the majority of the pupae did not undergo diapause but entered a state of light dormancy that was easily broken, whether or not the puparia were exposed to freezing temperatures. They stated that temperature, humidity, and lighting were controlled in the rearing cages but gave no details.

In the present study two light units were added to the greenhouse rearing set-up in winter for the beneficial effect they might have on the growth of the onion plants. In winter the onions tended to become somewhat spindly with the reduced amount of natural light. The rearing cultures were also observed to see if additional light had any effect on the emergence of the adults from the puparia.

The light units were of the fluorescent type and each contained four, forty watt, white lamps which were four feet long. The lights were suspended two feet above the rearing cages and the onions grown for experimentation. Distance between the two units was about six feet. The units were controlled by a time switch and were in operation from 1 AM until 3 PM, giving 14 hours of additional light each day. The units were turned off at 3 PM so that light conditions at the end of the day would be normal. Under this arrangement, photoperiod during each day was approximately 16 hours. The supplemental lighting was used from October 25 until April 1.

Onion growth under this arrangement was elongated but was much more satisfactory than growth without additional lighting.

The pupal diapause or dormancy entered by maggots reared under the conditions described above was easily broken by a short period of low temperature. A group of 75 pupae collected February 1, 1958 which had developed from eggs deposited January 6, 1958 was placed at 37-41° F. for six hours. They were then removed and placed on a moistened filter paper in a petri dish at 71-73° F. Forty adults emerged within 19 days. In a second group of 75 pupae which did not receive low temperature treatment, four emerged within 19 days. Forty days later no further emergence had occurred and many of the pupae were dead.

Experiments with pupae at 71-73° F. were difficult to conduct over periods of two to three months as they became broken down and rotten under the conditions of increased temperature and moisture.

Emergence of adults from various depths of soil

In April 1957, puparia which had been held overwinter at 37-41° F. were placed under two, four, and six inches of firmly packed Lake Labish soil in the field and sprinkled with water. Emergence cones placed over each group of pupae trapped the adults as they appeared. Onion flies appeared 28-34 days later from all depths (Table 11). Of the 100 puparia placed at each location, four were non-viable at the two inch level, four at four, and five at six inches.

Table 11. Emergence of onion flies from puparia at different depths of Lake Labish soil.

Days	Depth (inches)		
	2	4	6
28	3	1	2
29	7	4	5
30	12	9	11
31	41	55	45
32	25	14	21
33	5	9	6
34	3	4	5

Effect of different soils on size of puparium

When onion maggot larvae were reared in flats of onion seedlings in Hort. soil, fewer seedlings were damaged and the size of the puparia was smaller than those formed by onion maggots feeding on onion seedlings in Lake Labish soil. Twenty-five puparia selected at random from each of the two soils gave the following measurements in Table 12. Differences of length and width between the two groups of pupae were highly significant at the 0.01 level.

It was felt that the difficulty of larval tunneling in the more compact Hort. soil caused the maggots to feed less and to pupate sooner than maggots in the Labish soil, thus accounting for the small puparia.

Table 12. Effect of different soils on the size of the puparia of *H. antiqua*.

Soil	Length (range-mm.)	Mean (mm.)	Width (range-mm.)	Mean (mm.)
Hort.	4.8-5.8	5.2 ± 0.24	1.7-2.0	1.9 ± 0.08
Lake Labish	5.7-6.5	6.2 ± 0.30	2.0-2.5	2.3 ± 0.10

The Adult

Emergence from the puparium

Male onion flies usually preceeded the females by one to three days in emergence from the puparia in the greenhouse. After emergence the adults moved about actively but did not fly until the wings became extended and hardened. This took up to 30 minutes with adults observed in lamp chimney cages. Mortality curves showed a high initial death rate one to five days following appearance of both males and females. Mortality dropped, then increased, to peak at 25 days for the males and 35 days for the females (Fig. 9).

Habits

Onion flies were very scarce in the onion fields on hot days and could usually be found in nearby weeds or other heavy growth. Occasionally adults would be found in dense clumps of large onions. In the early morning

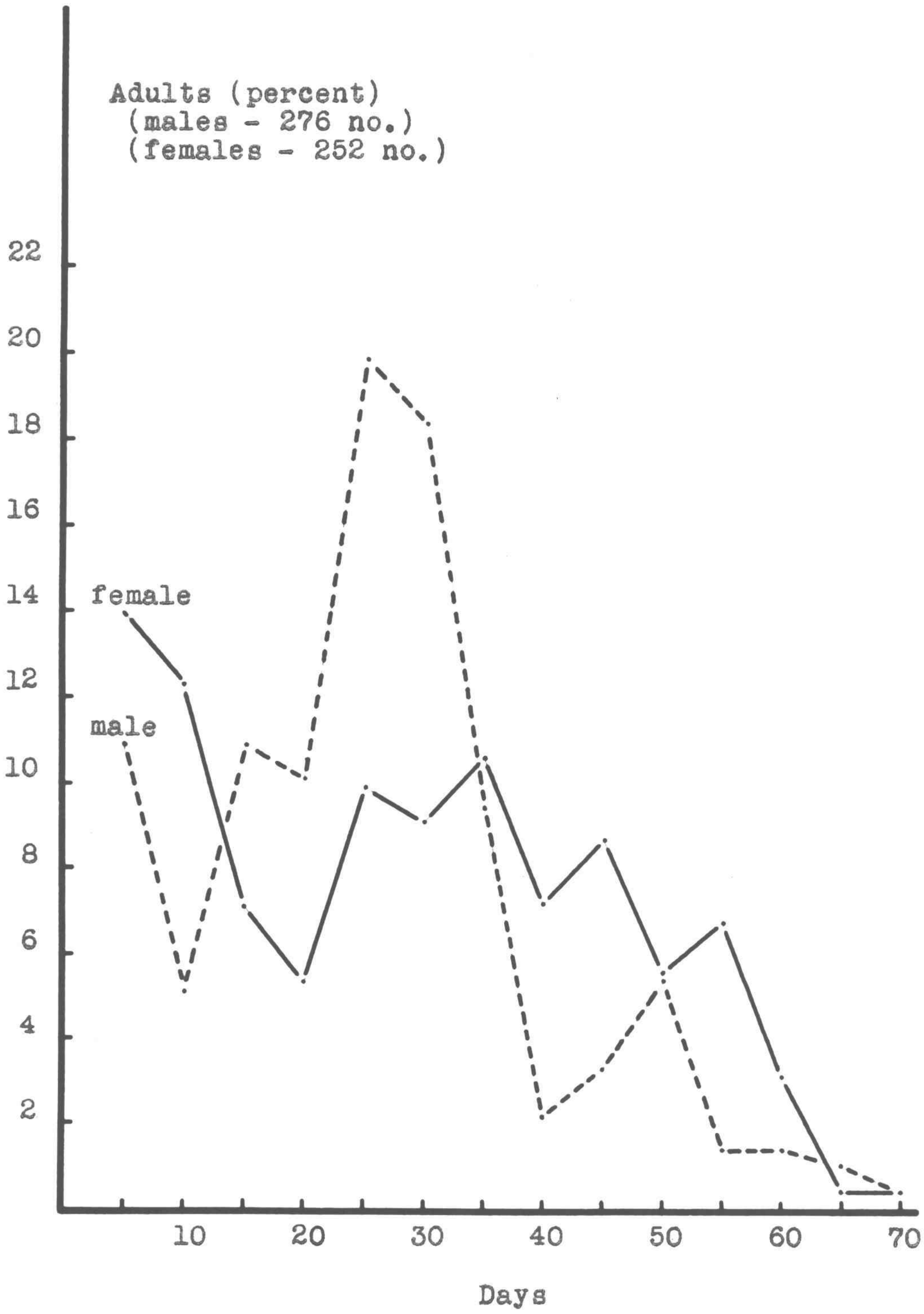

Figure 9. Mortality of <u>Hylemya antiqua</u> adults following emergence from the puparia.

and late afternoon and on cool days, the insects were quite numerous in the field. Adults were readily captured by inverting a 5/8 by inch rimless test tube and placing it over them very slowly. As the insect flew upwards the opening was closed with a finger.

The finding of large numbers of adults in weeds and other protective habitats during the hot part of the day indicates that good control may be obtained by spraying or dusting these areas rather than applying control measures only to the onion fields. Sweeping of weed patches may also give a better estimate of insect populations to growers in the Lake Labish area who rely on finding adults in the field for initiation of control efforts.

Oviposition

Onion maggot eggs in the greenhouse and in the field were nearly always deposited next to the onion plant at a depth of 1/8 to 1/4 inch. If cracks in the soil near the onion were wide enough, the female would enter to oviposit. During a wet period in October, eggs were placed on the leaves and in the leaf axils of large onions growing at the Entomology farm. Very few eggs were found on the smaller onions apparently because of the few numbers of leaves and the tight axils.

Hammond (13, p.39) reported that onion maggot eggs were usually deposited in the soil but on days immediately after a heavy rain, 95 percent of the eggs were laid on the foliage of the onion plants. Doane (6, p.40-43) stated that in Wisconsin in 1951 wet, cool weather prevailed and onion maggot eggs were laid on the plants rather than in the more usual location at or below the soil level. Miles (26, p.584) found that few *H. antiqua* eggs were laid in the soil, most being deposited on the plants. Smith (39, p.182) reported that onion maggot eggs were laid on the leaf sheaths or in the axils of onions, occasionally in cracks in the soil.

Soil Moisture

In order to clarify the problem of oviposition on the plant or in the soil, several experiments were conducted in greenhouse to study the effect of moisture as influencing egg deposition. Onions were grown in four-inch pots from sets which produced plants with a number of large leaves with open axils. Three levels of soil moisture were selected for examination of oviposition preference --wet, damp, and dry. Wet pots were watered to excess and then placed in pans of water so that a film of water covered the soil surface throughout the test. Damp pots contained soil moisture suitable for good plant growth. Dry soil had been without water for several days. Onions in the latter pots were usually beginning to wilt. Size, number, and spacing of plants in the pots of each experiment were very similar. The pots were set in cages with onion flies for two to three days. During this time the moisture of each pot was maintained as when placed in the cage. Six trials of wet versus dry soils and five trials of wet, damp, and dry soils gave the results in Table 13.

Table 13. Numbers of eggs deposited by H. antiqua in wet, damp, and dry soils.

Soil moisture	Eggs in soil	Eggs in axils of leaves	Total eggs
Wet	411	210	621
Dry	893	0	893
Wet	376	139	515
Damp	763	10	773
Dry	749	0	749

In the wet pots females were observed to hold on to the onion just above the water level and thrust the eggs between the stem and the soil. Many eggs were deposited about projections above the water film such as small clods or rocks. Onion maggot eggs placed under water in salve tins hatched but those placed in leaf axils did not unless the plants were sprayed daily with a fine mist of water.

Soil type

Dustan (7, p.27) using different amounts of humus and sand found that H. antiqua females preferred a 50-50 mixture for oviposition. Pure humus was chosen over pure sand, and acid soils over alkaline soils. Five trials replicated 3 to 5 times were performed in the present study to examine the oviposition preference of onion maggot females between seedlings grown in Lake Labish, Hort., and Ent. soils. Seedling number and spacing, and soil moisture and texture were selected to be as similar as possible in each trial. A total of 858 eggs were deposited in Lake Labish soil, 812 eggs in Hort. soil, and 779 eggs in Ent. soil (Table 14).

Table 14. Number of eggs deposited by _H. antiqua_ among onion seedlings grown in different soils.

Trial	Lake Labish Soil No. of eggs	Hort. Soil No. of eggs	Ent. Soil No. of eggs
1	144	133	153
2	96	87	82
3	222	174	186
4	147	174	139
5	249	244	219
Total	858	812	779

Oviposition on different hosts

Onion maggot larvae have been found on a number of hosts and have been reared on several others (page 39) but no references were found in the literature concerning oviposition on different hosts. Various kinds of plants were grown in the greenhouse in four-inch pots and placed together in cages with onion flies. Several days later they were removed and examined for eggs. Results are given in Table 15.

Table 15. Oviposition by H. antiqua on various hosts.

Experiment I

Host	Height (inches)	Stage	No. plants per pot	Eggs (No.)	Eggs (%)
Onion (from sets	8		9	76	36.9
Onion cube	1/2		4	71	34.5
Corn	3		2	26	12.6
Onion	2		10	15	7.3
Bean	6	2 leaf	3	8	3.9
Carrot	2	2 "	25	4	1.9
Radish	2	4 "	20	3	1.5
Beet, red	1 1/2	2 "	14	3	1.5
Garlic	4		15	0	
Turnip	3	4 "	40	0	

Experiment II

Host	Height (inches)	Stage	No. plants per pot	Eggs (No.)	Eggs (%)
Onion cube	1/2		4	159	32.6
Onion (from sets)	8		9	152	31.2
Corn	8		2	71	14.6
Onion	4		10	43	8.8
Radish	4	4 leaf	26	31	6.4
Garlic	7		15	15	3.1
Bean	10	4 "	3	10	2.1
Beet, red	2	4 "	14	6	1.2
Carrot	3	4 "	25	0	
Turnip	4	4 "	40	0	

Experiment III

Host	Height (inches)	Stage	No. plants per pot	Eggs (No.)	Eggs (%)
Onion	5-6		12	2452	52.3
Onion	1-3		28	1137	24.3
Corn	5		6	914	19.5
Radish	3	4 leaf	20	104	2.2
Turnip	3	4 "	31	67	1.4
Swiss Chard	2		6	11	0.2

Experiment III was performed six times while numbers I and II were tried once. Four similar trials of I and II gave like results. It was interesting to note the large numbers of eggs deposited on corn seedlings in all experiments. The eggs hatched but no apparent feeding was done by the larvae.

Flies tended to congregate in pots where seedling growth was most dense such as turnip and radish, however, comparatively few eggs were found there. Onion cubes were very attractive to adults when freshly cut but not many eggs were deposited. Oviposition was heaviest from the second to the fifth days after which the cube became quite dry.

Oviposition in the absense of onions

Females containing fully formed eggs can be found in the spring, before the seedling onions are up, resting on stakes and clods in the field. Several experiments were performed to learn whether the females would deposit eggs in soil in the absence of onions and if they could detect onions below the soil surface. Four inch pots were set up with Lake Labish soil in which onions had been grown for years but which contained no visible onion residues. All treatments with the exception of No. 5 were watered and placed in the rearing cages for oviposition. The results of six trials after three days gave the following:

No.	Treatment	Eggs (No.)
1.	Soil only.	0
2.	Onion seed placed on soil surface.	0
3.	Three 4 x 5/8 inch wooden pot labels placed vertically one inch deep and arranged in a broken triangle--(△)	0
4.	Onion seed planted 1/2 inch deep.	0
5.	Moistened soil with 10 drops of onion juice added over the surface.	231
6.	Dry onion remains placed 1/2 inch deep.	287

When three trials, replicated two times, of treatments 1 to 4 above were placed in the rearing cage for three days, no eggs were deposited in any of the pots. Numerous eggs (200+) were deposited on onion seedlings placed in the cage for two days before and after the trials.

In the spring many growers take the onion debris--scales of bulbs, leaves, root, etc. from the onion storage barns and plow it under in the onion fields. To find out whether onion maggots from eggs laid in this debris could survive and transfer to the onion seedlings after planting, the following experiment was performed in the greenhouse.

Four treatments, replicated six times, were set up in four-inch greenhouse pots using Lake Labish muck soil. The onion debris used consisted, mainly, of the dry, thin, brown, outer leaf scales from onion bulbs plus some dry roots and leaves. The treatments are listed below:

1. Onion debris, one part by volume, mixed thoroughly with 10 parts of soil.
2. Onion debris, one part by volume, mixed thoroughly with 10 parts of soil plus an onion bulb, one inch in diameter, placed three inches deep.
3. Onion debris placed in a 1 1/2 inch thick layer, 1/2 of an inch below clean soil, to represent small masses of trash which might be found in the field after being plowed under.
4. Soil without any visible onion residues.

After all pots were filled, each was watered well. Two days later the pots were watered lightly and 25 _H. antiqua_ eggs plus 10-15 onion seeds were added to four replicates of each treatment. On the next day, 25 _H. antiqua_ eggs only were added to the remaining two replicates of each treatment. The eggs were placed 1/8-1/4 inch under the soil surface while the onion seeds were planted about 1/2 inch deep. The pots were watered every second day following the addition of eggs. At the end of nine days the onion seedlings had grown about 1/4 inch above the soil surface and the leaves from the onion bulbs were one inch above the soil surface. Fourteen days after addition of eggs the contents of the pots were examined. Table 16 shows the number of maggots found in each pot.

Finding of onion maggots in soil mixed with debris was difficult because of the sticking together of the onion scales and some maggots may have been overlooked. All of the larvae were in the third instar and most of them measured about five mm. long. Maggots in treatments containing an onion bulb were usually found feeding in the basal portion of the bulb. Several of the maggots feeding in bulbs ranged from five up to eight mm. long. Maggots in the treatments involving soil without onion debris, but with onion seeds, fed on the onion seedlings and were from 2-3 mm. long.

Maggots in treatments containing onion debris fed and tunneled in the debris. Where the onion trash was placed in the pots in a 1 1/2 inch layer, the upper scales kept the water from penetrating the mass with the result that only the portion next to the sides of the pot was moist. This moist area was where the maggots were found.

Nearly all of the seedlings in each treatment were damaged by the larvae. Many of the sprouts were consumed as fast as they developed from the seed.

From the results of the preceeding experiments it appears possible for onion maggots to be present in the soil before the onion seed is planted. Insecticidal controls against the adults must therefore be carried out in advance of planting, depending on the presence of the adults and suitable materials in the soil for oviposition and survival of the maggots. Insecticidal seed treatments or treatments in the soil to protect the developing seedlings appear to have an important place in onion maggot control under these conditions. Possibly the simplest method of eliminating this problem is the disposal of onion debris by some other means.

Table 16. Number of onion maggots found after 14 days in pots of soil with and without onion debris.

Treatment	Number of onion maggots* Repl. 1	2	3	4	Total
With onion seeds					
Onion debris 1 to 10	15	24	21	20	80
Debris, 1 to 10 plus onion bulb	17	25	16	19	77
Debris in 1 1/2 inch layer	16	21	19	18	74
Soil without onion debris	12	9	16	4	41
Without onion seeds					
Onion debris 1 to 10	17	20	-	-	37
Debris, 1 to 10 plus onion bulb	19	21	-	-	40
Debris in 1 1/2 inch layer	19	15	-	-	34
Soil without onion debris	0	0	-	-	0

* From 25 H. antiqua eggs placed in each pot.

Oviposition on seedlings of different size

Pots of onion seedlings of different size were placed in the rearing cages for five days to examine their relative attractiveness to ovipositing onion flies. Each experiment was performed separately and consisted of two different sizes of seedlings, each replicated three times. In all three experiments the highest number of eggs was deposited in the pots containing the largest onion seedlings (Table 17).

Table 17. Oviposition preference of *H. antiqua* between onion seedlings of different height.

Experiment I		
Onion seedlings	3/8-3/4 inch high	22 eggs
" "	3 inches high	374 "
Experiment II		
Onion seedlings	1 inch high	112 eggs
" "	3 inches high	307 "
Experiment III		
Onion seedlings	2 inches high	215 eggs
" "	5 " "	537 "

Oviposition on preinfested onions

In the field, onion flies were observed to select preinfested onions for oviposition in preference to healthy plants. This was also reported by Sleesman and Gui (37, p.37). Kendall (18, p.83) found that 96.6 percent of the onions oviposited upon by onion flies of the second brood were preinfested (693 plants out of 717).

In onion plots at the Entomology farm a group of 92 healthy seedlings, 1/8-3/8 inch diameter at the soil level, were artificially infested with one to three third instar maggots. Five days later 90 percent of the plants had eggs deposited about them. Of 200 uninfested seedlings in the immediate vicinity 11 were oviposited upon. In another experiment, 24 seedlings, 1/8-3/8 inch diameter, were infested with one second instar larva per plant. Egg counts made 11 days later showed that all 24 plants had eggs placed about them totaling 280 eggs. Of 72 healthy onions examined in the adjacent area there was a total of 23 eggs found about the base of seven plants. Eggs taken from both trials and reared to third instar maggots were H. antiqua.

In general, the only other eggs encountered about onions were of the lesser bulb fly. These were usually found later in the season near large onions. The bulb fly egg is about one-half the size of the onion maggot egg and tapers more at the posterior end.

The attraction of infested onions to ovipositing onion flies is not known. Odor may be a factor. The mechanism is, perhaps, an advantageous one. Infested onions become broken down and water soaked imparting a dampness to the surrounding soil for an eighth of an inch or more depending on the size of the onion. Chances for larval emergence and survival in this area are much greater than in dry soils.

Life Cycle

The life cycle of H. antiqua has been determined a number of times from various parts of the world and was found to be similar in all reports. Differences are probably caused by environmental factors which are generally not listed. The following life cycle was developed from rearing the onion maggot in the greenhouse under conditions described on page 11 and corresponds with histories described in the literature by a number of authors including Doane (6, p.25-54), Eyer (8, p.4-9), Smith (39, p.178-181) and Tozloski (41, p.11-34) (Table 18).

Table 18. Life cycle of H. antiqua under greenhouse conditions in Oregon.

Preoviposition period	10-25 days
Duration of oviposition period	24-67 "
Hatching of eggs	2-3 "
Duration of first instar larvae	2-3 "
Duration of second instar larvae	4-6 "
Duration of third instar larvae	9-14 "
Total Duration of larval stages	15-23 "
Pupal period-spring	9-14 "
Pupal period-winter	overwinter
Male length of life (max.)	60-70 days
Female length of life (max.)	60-70 "

Adult emergence

Adult emergence in the field occurs over a period of four to nine weeks in the spring. Eyer (8, p.4) from

1918 to 1920 in Pennsylvania found flies emerging from May 4 to June 30, May 29 to July 1, May 1 to June 6, and April 29 to June 30 respectively. In 1955, at the Oregon State College Entomology farm, adults emerged from April 11 to June 16. Infested onions had been placed in the soil in the fall of 1954. An aluminum cone 2 1/2 feet in diameter by 2 1/2 feet high placed over the area April 6 trapped the adults as they emerged.

The long period over which onion maggot flies appear results in considerable overlapping of generations. Most authors have reported two to three generations per year based on peaks of adult collections in the field. All stages of _H. antiqua_ have been found at the Entomology farm as late as November 1, 1957.

Natural Enemies

The only parasite found attacking the onion maggot in Oregon was the braconid, _Aphaereta auripes_ (Prov.), determined by C. R. W. Muesebeck of the Insect Identification Laboratory, U. S. D. A., Washington, D. C. It was obtained in collections of maggots from both eastern and western Oregon. A number of pupae sent by Mr. J. P. Perron of St. Jean, Quebec also contained this parasite. Members of the genus have been reported as parasitizing onion maggot larvae from British Columbia (9, p.460), Ohio (37, p.38), Pennsylvania (8, p.10), England (39, p.182), and Holland (22).

It was suspected that the lesser bulb fly, *Eumerus strigatus* (Fallen), caused some predation of onion maggots in the field. Onions could be found with large numbers of bulb flies present but few or no onion maggots. Other infested onions contained only *H. antiqua*. To examine this possibility, various stages of the two species were counted and placed in pots together with a section of onion. Six trials included 20 maggots of each species while one trial consisted of 20 onion maggot larvae and 100 bulb fly larvae. After several days to two weeks the insects were removed and counted. No predation was evident by either species.

The specimens of *Eumerus strigatus* (Fallen) were identified by W. W. Wirth of the Insect Identification Laboratory, U. S. D. A., Washington, D. C.

ONION MAGGOT RESISTANCE TO INSECTICIDES

In recent years control of the onion maggot in some areas has shifted to the use of seed treatments. Onion seeds are coated with various insecticides usually in combination with a fungicide. Maggots in tunneling to the base of the onion seedlings contact the insecticide and are killed.

A number of insecticides applied as seed treatments have given good control of onion maggots. Some of them worked well in certain areas but not in others. One of these was heptachlor. In a cooperative experiment using identical methods and materials it gave good control in British Columbia and Idaho but poor control in Oregon and Washington (5, p.14). Heptachlor is closely related to chlordane which failed as a maggot control in Oregon in 1953 (4, p.3). As insect resistance to organic insecticides has been reported in numerous papers (15, p.89-122) in recent years, it was decided to examine several strains of _H. antiqua_ for resistance to heptachlor.

Onion maggots from three areas were collected for testing. All three strains were reared through one generation in the greenhouse to increase the numbers of insects. Maggots were from the Portland, Oregon area where heptachlor gave poor control; Ontario, Oregon where little control was directed at the insect until 1957 when it became a serious problem; and St. Jean, Quebec where there was little difficulty in controlling the insect. In the Ontario area, onions are rotated in potato lands which are treated with soil insecticides to control wireworms and flea beetles. Onion maggots may have been exposed to certain chemicals persisting in the soil from year to year.

Onion seed was treated with heptachlor, 50 percent wettable powder, at the rate of 1/2 ounce actual toxicant per pound of seed plus thiram, 75 percent wettable powder, at two ounces actual per pound of seed. Untreated seeds comprised a check. The seeds were planted one inch deep in four-inch pots of Labish soil in such numbers that each pot contained 35-40 plants. When the seedlings were 4-8 inches high, a single *H. antiqua* egg was added to each pot next to an onion and about 1/4 inch below the soil surface. The soil in each pot was kept moist throughout the test for good maggot development. Every three days the onion seedlings were examined for damage.

Two trials in which eggs of each of the three strains were placed in 10 treated and 10 check pots of seedlings showed that the Quebec maggots were very susceptible to heptachlor treated seed. Only one seedling of 20 pots was damaged (Table 19). Preliminary tests of Quebec eggs placed on onion seedlings grown from heptachlor treated seed in flats had given similar results. One hundred and twenty eggs placed on the seedlings produced no damage.

Results between Portland and Ontario maggots were not clear cut and experiments with the two strains were continued. Eggs of each strain were placed in four groups of 10 pots of treated seedlings and 10 pots of untreated onions. The Ontario strain appeared to be more susceptible to heptachlor than maggots from the Portland area but still exhibited resistance (Table 20).

In an experiment where second instar larvae were added to pots of treated seedlings, results were similar to those involving onion maggot eggs. The Portland strain was quite resistant, Ontario maggots less resistant, and the Quebec strain very susceptible to heptachlor at the dosage used (Table 21).

Table 19. Damage produced by adding eggs of different strains of H. antiqua to onion seedlings grown from heptachlor treated seed.

Trial	Repl.	Numbers of seedlings destroyed					
		Portland strain		Ontario strain		Quebec strain	
		treated	ck.	treated	ck.	treated	ck.
I							
	1	1	21	0	11	0	13
	2	14	20	0	11	0	17
	3	16	0	0	0	0	23
	4	8	20	21	17	0	14
	5	0	20	0	19	0	16
	6	7	17	0	0	0	13
	7	0	0	0	32	0	27
	8	2	25	0	0	0	32
	9	11	10	0	17	0	20
	10	5	14	0	15	0	0
	Total	64	157	21	122	0	175
II							
	1	0	17	0	13	0	0
	2	0	18	0	15	0	14
	3	21	0	0	23	0	18
	4	0	26	0	22	1	10
	5	17	0	0	0	0	23
	6	16	21	20	22	0	15
	7	0	21	18	22	0	16
	8	15	24	0	21	0	2
	9	0	23	20	24	0	17
	10	0	21	0	0	0	0
	Total	69	171	58	162	1	115

Table 20. Damage produced by adding eggs of different strains of H. antiqua to onion seedlings grown from heptachlor treated seed.

Portland strain	Numbers of seedlings destroyed				
Repl.	Blocks				Check
	I	II	III	IV	
1	1	13	1	6	18
2	2	0	0	16	20
3	2	0	19	28	0
4	12	12	2	0	24
5	1	14	15	3	21
6	0	0	0	17	20
7	17	12	13	15	0
8	15	16	22	1	18
9	16	12	1	8	20
10	18	11	1	0	18
Total	84	90	73	93	160

Ontario strain	Numbers of seedlings destroyed				
Repl.	Blocks				Check
	I	II	III	IV	
1	2	0	8	3	23
2	18	0	23	0	20
3	0	3	1	0	22
4	1	0	0	14	18
5	35	3	0	17	22
6	16	0	1	0	21
7	0	21	0	0	24
8	1	17	0	14	0
9	24	13	19	3	22
10	20	0	0	0	19
Total	117	57	52	51	191

Table 21. Onion damage produced by adding second instar *H. antiqua* to plants grown from heptachlor treated seed.

Replicate	Numbers of seedlings destroyed			
	Portland	Ontario	Ontario	Quebec
1	11	2	0	0
2	12	2	1	1
3	10	0	11	0
4	21	0	0	0
5	14	1	2	0
6	12	13	7	1
7	11	6	1	0
8	14	17	7	1
9	19	2	7	1
10	14	8	0	0
Total	138	51	36	4

Two trials were made to examine the resistance of young and medium aged third instar larvae to heptachlor treated seed. The Ontario strain was selected for testing as it had shown an intermediate resistance between the Portland and Quebec strains in previous experiments. The larvae were added, one per pot, shortly after the seedlings emerged from the soil. Some plants were still in the loop stage. This was the earliest that maggots or eggs had been tested after planting of seed.

Young third instar larvae were found to be very susceptible to the insecticide. Medium aged third instar larvae were fairly resistant but did not destroy as many seedlings as similar stages in the untreated check (Table 22). Further experiments gave similar results. It appears from this data that onion maggots not killed by the insecticide in the early stages would cause considerable damage in onion plantings.

Table 22. Damage produced by young and medium aged third instar H. antiqua, Ontario strain, to onion seedlings grown from heptachlor treated seed.

	Numbers of seedlings destroyed				
	Trial I		Trial II		
Repl.	Y3*	M3**	Y3	M3	M3 (check)
1	5	7	0	13	14
2	0	7	0	9	15
3	2	11	3	11	8
4	0	5	1	11	18
5	1	3	3	9	20
6	0	13	0	10	17
7	0	13	1	13	17
8	2	18	2	11	16
9	4	10	0	12	19
10	0	12	2	8	12
Total	14	99	12	107	156

Y3* - Young third instar larva
M3** - Medium aged third instar larva

Judging from the results of the experiments, Ontario maggots were more susceptible to heptachlor-treated seed when they were exposed earlier after planting. This may have indicated that the insecticide was washed from the seed in watering the pots approximately every three days or that with older seedlings there was a larger stem area which was not protected by the treated seed coat. Further experiments along these lines were not carried out.

The data from the trials using heptachlor-treated onion seed indicate that onion maggots from the three areas tested possess varying degrees of resistance to the insecticide. No attempt was made to determine the degree of resistance exhibited by each strain of maggots nor was their resistance to other insecticides tested.

The differences in susceptibility to heptachlor found in H. antiqua indicate that resistance to various insecticides is probably developing. Some of the control difficulties being experienced in the field at present may be due to this factor.

THE ONION MAGGOT AND WEATHER RECORDS

A number of authors have reported that heavy onion maggot infestations occurred during wet years--Crowell (4, p.4), Doane (6, p.1), Gray (12, p.36), McLeod (23, p.631), Peterson and Noetzel (32, p.852) and others. From these reports and from the data obtained in the present study on moisture requirements for onion maggot emergence from the egg and survival (p.23, 25), it appeared that high populations might be related to precipitation during the onion growing season.

In an effort to find out whether maggot damage could be anticipated through weather reports, a comparison was made of 20 records, taken from the literature, of heavy infestations and climatological data. The amount of moisture and departure from normal was examined for the year of infestation and the two years which preceeded it.

Data was tabulated for the months of May through August, which period covers the main onion growing season (Table 23).

Nothing definite could be established. While the majority of infestations occurred during wet seasons, some also occurred during dry seasons. The critical moisture period, however, may be a very short one during the oviposition period. Increased moisture for one or two weeks during the peak of egg production may be enough to favor the development of a high population. It will be noticed of reported heavy infestations during dry years, there were several areas with months of appreciable precipitation; Racine, Wisconsin--July 1927, June 1929; Kenton, Ohio--June 1928; and Amherst, Massachusetts--May, June, July, Aug. 1951. An examination of weather records for these dates showed that rainfall of 0.1 inch or more per day occurred over an average number of 14 days. At Lake Labish, Oregon in May 1923, there were eight days with rainfall of 0.1 inch or more but measurable amounts of precipitation occurred on 17 days.

While it appears from these findings that heavy onion maggot infestations and wet weather are correlated, accurate records of moisture during the oviposition period, numbers of eggs laid during the oviposition period, and degree of infestation over a number of years are needed for substantiation.

It is the opinion of the author that the very heavy infestations of the onion maggot which occur at intervals in various parts of the country are due largely to weather (moisture) and other environmental factors which, in the right combination, are highly favorable for the development of enormous numbers of the insect. Population pressures become so great that all control methods fail. The development of new effective controls a year or more later may in actuality be a return of environmental conditions which are not favorable to large populations.

Table 23. Moisture data for years of reported heavy onion maggot infestations and for the two years which preceeded them.

Locality		May		June		July		August		Total
Amherst, Mass.	1949	4.76	+1.01	0.72	-3.02	3.41	-0.84	3.64	-0.57	-3.42
	1950	2.77	-0.98	3.65	-0.09	2.83	-1.42	2.93	-1.28	-3.77
	1951*	2.96	-0.79	3.05	-0.69	4.15	-0.10	3.56	-0.65	-2.23
	1952*	4.00	+0.25	4.97	+1.23	4.99	+0.74	3.98	-0.23	+1.99
East Lansing, Mich.	1954		-		-		-		-	-
	1955	1.53	-2.22	3.81	+0.44	3.99	+1.71	4.08	+1.40	+1.33
	1956*	5.60	+1.85	1.80	-1.57	2.69	+0.41	3.20	+0.52	+1.21
	1957*	5.17	+1.42	2.88	-0.49	7.55	+5.27	1.29	-1.39	+4.81
Kenton, Ohio	1926	2.26	-1.38	2.54	-1.54	4.87	+1.31	4.89	+2.04	+0.43
	1927	5.96	+2.17	3.17	-0.94	5.52	+1.96	2.35	-0.53	+2.68
	1928*	1.64	-2.15	7.31	+3.20	3.64	+0.08	1.23	-1.65	-0.52
Nyssa, Ore.	1955	0.51	-0.43	0.76	-0.21	0.20	+0.08	T	-0.30	-0.86
	1956	1.59	+0.65	0.52	-0.45	0	-0.12	0.46	+0.16	+0.24
	1957*	3.79	+2.85	0.30	-0.67	0.02	-0.10	0.03	-0.27	+1.81
Portland, Ore.	1952	0.78	-0.98	2.23	+0.51	T	-0.42	0.18	-0.43	-1.32
	1953	3.45	+1.69	2.04	+0.32	0.03	-0.39	1.79	+1.18	+2.80
	1954*	1.83	+0.07	3.58	+1.80	1.24	+0.82	1.92	+1.31	+4.00
Puyallup, Wash.	1951	0.56	-1.05	2.48	+1.36	0.13	-0.26	0.07	-0.42	-0.36
	1952	1.28	-0.93	1.15	-0.46	0.46	-0.33	0.38	-0.45	-2.17
	1953*	2.65	+0.44	2.52	+0.91	0.41	-0.38	1.72	+0.89	+1.86
	1954*	2.26	+0.05	2.50	+0.89	1.16	+0.37	1.92	+1.09	+2.40

Table 23. Moisture data for years of reported heavy onion maggot infestations and for the two years which preceeded them (cont.).

Locality		May	June	July	August	Total
Racine, Wisc.	1913	-	-	-	-	-
	1914	6.96 +3.91	5.25 +2.43	1.41 -1.93	0.88 +2.19	+2.22
	1915*	8.35 +5.30	3.13 +0.31	3.40 +0.06	1.62 -1.45	+4.22
	1925	2.04 -1.51	3.21 +0.13	5.37 +2.27	1.37 -1.35	-0.44
	1926	3.33 -0.22	3.55 +0.27	3.25 +0.13	1.91 -0.81	-0.63
	1927*	3.92 +0.37	1.41 -1.67	4.13 +1.03	0.54 -2.18	-2.46
	1928	2.20 -1.35	6.76 +3.68	2.58 -0.52	3.19 +0.47	+2.28
	1929*	3.05 -0.50	4.95 +1.87	0.75 -2.35	1.39 -1.33	-2.31
	1949	1.76 -1.70	-	4.62 +1.73	0.72 -2.28	-
	1950	1.36 -2.10	5.83 +2.66	7.41 +4.52	2.92 -0.08	+5.00
	1951*	4.46 +1.00	4.44 +1.27	2.47 -0.42	3.72 +0.72	+2.57
Salem, Ore.	1921	1.62 -0.63	1.05 -0.30	T -0.48	0.13 -0.16	-1.57
	1922	0.93 -1.28	0.03 -1.28	0 -0.46	1.49 +1.07	-1.95
	1923*	1.89 -0.31	0.97 -0.33	1.21 +0.73	1.05 -0.36	-0.27
	1946	1.15 -0.95	1.28 +0.01	1.72 +0.33	0.09 -0.37	-0.98
	1947	0.18 -1.84	3.60 +2.39	1.41 +1.02	0.44 +0.03	+1.60
	1948*	4.15 +2.13	0.38 -0.83	0.61 +0.22	0.52 +0.05	+1.57
	1951	2.49 +0.47	0.01 -1.20	0.17 -0.22	0.65 +0.18	-0.77
	1952	0.20 -1.82	2.64 +1.43	0 -0.39	0.03 -0.44	-1.22
	1953*	3.76 +1.83	1.34 +0.12	T -0.32	1.65 +1.16	+2.79
St. Paul, Minn.	1949	1.06 -2.11	3.87 -0.27	4.78 +1.21	1.27 -1.74	-3.01
	1950	3.47 +0.20	1.54 -2.60	4.06 +0.49	1.86 -1.15	-3.06
	1951*	4.05 +0.78	5.25 +1.11	5.94 +2.37	3.28 +0.27	+4.48
	1952*	3.48 +0.18	4.20 +0.06	4.10 +0.53	4.36 +1.35	+2.12

Table 23. Moisture data for years of reported heavy onion maggot infestations and for the two years which preceeded them (cont.).

Locality		May		June		July		August		Total
Walla Walla, Wash.	1954	0.81	-0.45	1.34	+0.13	0.13	-0.15	0.96	+0.62	+0.15
	1955	1.20	-0.06	0.30	-0.91	0.97	+0.69	T	-0.34	-0.62
	1956*	2.03	+0.77	0.74	-0.47	0.08	-0.20	1.52	+1.18	+1.28
	1957*	4.19	+2.93	1.05	-0.16	T	-0.28	0.15	-0.19	+2.30

* Heavy onion maggot infestation reported

SUMMARY

Biological work on _Hylemya antiqua_ (Meigen) was initiated in the summer of 1955 and terminated in the spring of 1958. The life cycle was not studied intensively as it had been reported in the literature by numerous authors. The primary purpose of the study was the further examination of the basic aspects of the onion maggot biology.

Descriptions of the stages of the insect are presented.

H. antiqua was reared in the greenhouse so that all stages of the insect were available throughout the year. Rearing methods and materials including diet, cages, temperature, pupal storage, number of eggs produced, and other factors are given.

Different types of soil were used in portions of the study--Lake Labish muck, Hort. sandy loam, and Ent. clay loam--to examine larval movement, depth of larval penetration, oviposition preference, and effect on size of the puparium.

Soil moisture was found to be very important in larval eclosion and survival in the soil. A moisture content of about 10 percent in Lake Labish muck, 13 percent in Ent. clay loam, and five percent in Hort. sandy loam was required for optimum emergence. The soil moisture required for survival of the newly-hatched maggots was

23 percent or more in Lake Labish and Ent. soils and 10 percent or more in Hort. soil.

A negative phototropic response appeared to stop maggot feeding in the onion seedlings at, or slightly above, the soil level.

One onion maggot was found to destroy from 23-35 onion seedlings one millimeter in diameter at the soil level by 40 millimeters in height. The number of seedlings destroyed per maggot decreased with increase in size of the plant. One seedling was destroyed per maggot when the plants were 4-5 x 260 mm. in size.

Onion maggot larvae reared in both seedlings and bulbs were found to pupate at nearly identical times.

Onion maggot movement varied with soil type and larval size. Third instar larvae tunnelled further and more rapidly through soil than second instar larvae. Maggot movement was most rapid through Lake Labish muck while Hort. sandy loam was quite resistant to passage.

Onion maggots were found to be tolerant to soils of high water content. Larvae in wet soils generally moved to the soil surface. Some maggots were found to withstand submergence in water for 11-12 hours.

The finding of onions in the soil by the onion maggot appeared to be a hit or miss process dependent on the maggots ability to move relatively long distance in the soil.

Onion maggots were reared to the pupal stage on alfalfa meal plus bran, garlic seedlings, radish, turnip and turnip leaf stems. It was not possible to rear larvae on corn seedlings, bean seedlings, carrot, or potato.

Pupae obtained October 19, 1957 from onion maggot infested onions taken from the field were found to require a storage period at 37-41° F. for six weeks for complete breakage of diapause. Diapause or dormancy entered by pupae from maggots reared during the winter was easily broken by short periods of cold storage.

Puparial size of maggots reared in Hort. sandy loam was highly significantly smaller than that of maggots reared in Lake Labish muck.

Wet soils caused ovipositing H. antiqua to deposit their eggs on the above ground portions of the onion plant.

Onion flies were found to oviposit on bean, beet, carrot, corn, garlic, onion, radish, swiss chard, and turnip seedlings.

Onion flies did not oviposit on clean soil or on onion seed. Eggs were deposited on soil to which onion juice was added and soil with onion remains placed 1/2 inch deep. H. antiqua eggs placed in moist Lake Labish muck containing onion debris developed to third instar maggots, five millimeters long, within 14 days.

In oviposition preference tests between onion seedlings of different height, onion flies deposited the highest numbers of eggs in pots containing the largest seedlings.

In experiments to examine the resistance of three strains of onion maggots to heptachlor insecticide, larvae from Portland, Oregon were found to be fairly resistant. Larvae from Ontario, Oregon were less resistant and maggots from St. Jean, Quebec were found to be quite susceptible to the insecticide.

From reports in the literature on heavy onion maggot infestations and from the data obtained in the present study on moisture requirements for onion maggot emergence from the egg and survival, it appeared that high populations were related to precipitation. A comparison of 20 records of heavy maggot damage and climatological data showed that the infestations occurred during wet periods.

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