BIOLOGICAL STUDIES OF THE ONION MAGGOT *Hylemya antiqua* (Meigen) (DIPTERA: ANTHOMYIIDAE) IN THE MUCKLAND AREAS OF SOUTHWESTERN QUEBEC.

by

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A THESIS

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M. Sc. Entomology

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ABSTRACT

BIOLOGICAL STUDIES OF THE ONION MAGGOT *Hylemya antiqua* (MEIGEN) (DIPTERA: ANTHOMYIIDAE) IN THE MUCKLAND AREAS OF SOUTHWESTERN QUEBEC.

Field and laboratory studies of the onion maggot *Hylemya antiqua* (Meigen), its life history, depredations, host range and preference, predators, and importance relative to associated dipterous species, were conducted in a commercial onion growing district, on muck soil, at Ste-Clothilde, Québec, during 1952. The insect went through three generations in the year. It overwintered as a pupa. Egg laying commenced late in May. Comparison with other studies showed the life history to be unaffected by the muck soil habitat. Intensive onion culture and not the soil appears to explain the economically serious infestations. The life history was well synchronized with crop development. Early seeded onions gave the best crop and profit but also attracted the most egg laying females and supported the largest larval populations without high plant mortality or obvious above ground symptoms. Other fly species were secondary. Cultural and natural control are not apt to prove adequate.

I. INTRODUCTION

The onion (*Allium cepa*) has been cultivated for so long that its origin is lost in antiquity though wild species are known. The crop is world wide in distribution, forms a fairly staple item in the diet of many ethnic groups, and a significant staple in world trade. It is an economically important item in the agricultural economy of the Province of Québec, where approximately 2,000 or more acres are planted to onion seed each year. Québec is thus second only to Ontario in the production of onions in Canada. Much of this acreage is grown in southwestern Québec, near the Montréal market. Considerable use is made of muck soil for raising onions. The utilization of this soil type poses new problems in culture and fertilization and may well affect pest control problems. One of the major pests of onion is *Hylemya antiqua* (Meigen) (Diptera: Anthomyiidae) the maggot stage of which attacks developing bulbs. This pest is like its host universal in distribution. Complaints from growers and general observations on the depredations of this insect in muckland areas of Québec led the writer to feel that a study of its biology in the Montréal area could contribute much of use to onion growers. Such a study was therefore carried out during the growing season of 1952, at Ste-Clothilde, Qué. The results are reported herein.

II. HISTORICAL REVIEW

The onion maggot was first described by Meigen in 1826 as *Anthomyia antiqua* (Syst. Beschr. 5(145):166). It has since been redescribed and called

1830. *Anthomyia ceparum* Meigen; Syst. Beschr. 6(217):376.

1844. *Musca liturariae* Ratzeb.; Forstins. 3(1):170.

1851. *Anthomyia caepicola* Rob.-Desv.; Guér.-Mén., Rev. Mag. Zool. ser.2, 3(1):234.

1882-83. *Chortophila cinerea* Meade nec Fall.; Ent. Mo.Mag.19:147.

1882-83. *Phorbia cepetorum* Meade; Ent. Mo. Mag. 19:218.

1893. *Anthomyia angustifrons* Strobl. nec Meigen; Verh. Zool.-Bot. Ges. Wien. 43:259.

1904. *Phorbia ceparum* (Meigen); Howard, Ins. Book, 8:171.

1907. *Pegomya cepetorum* (Meade); Smith & Dickerson, N. Jersey Agric. Expt. Sta. Bull. 200.

The accepted name and taxonomic position today is *Hylemya antiqua* (Meigen). It has long been destructive in Europe (Köllar, 1840, in Austria, Ormerod, cited in Bethune, 1881 and Ormerod, 1881, in England) and as Baker and Stewart (1928) report, it is not exactly known when this insect was introduced into this continent. It is thought to have been brought over in shipments of onion bulbs from Sweden, Holland, Denmark and England, either as larvae feeding during the voyage, or as pupae, since its pupal transformation often takes place within the plant. The onion maggot was first mentioned in North America by Harris (1841, 1852) in a report of injurious insects of Massachusetts and in Canada by Couper (1876) who reported this insect as an important pest to the onion crops throughout Canada. This last announcement suggested that there was evidence of H. antiqua in injurious numbers some years previous to that date, otherwise this insect could not have become so well established in the eastern part of the country. In a little less than a century, it had thus spread over the greater portion of Canada until at the present time, it is always present in high number in any kind of soil where its food plants are grown to any extent. A few years later, Fletcher (1884, 1885) mentions in his first and second Annual Reports as Dominion Entomologist that this pest had been very injurious in many districts in Canada, especially in Ontario and Québec. Fletcher (1892) called attention to this insect when apparently it became, with the cabbage, radish and turnip maggots, one of the most troublesome insect pests of the year 1890. Complaints of root maggot injury to onion crops from almost every Canadian provinces were very numerous in 1908 and Gibson (1910) reported that damage was most noticeable in June, August and September.

The occurence of injury by this insect in widely separated localities in Québec was first noted by Swaine (1910) who mentions it damaging onions at Macdonald College for the first time. A number of plants were killed.

Three years later (1913), it was reported from Ile Perrot (Anonymous, 1924). Serious losses were occasioned in 1920 in the Montréal district, and since that date, attacks by this insect have been recorded almost every year, throughout the Province of Québec. From year to year, the attacks of this insect appear to assume greater proportions.

MacNay (1951) reported that in British Columbia, the damage of H. antiqua was very severe throughout the Province especially where the control measures were not applied. A fairly good protection was obtained in the areas where the very recently recommended seed treatment with 50 per cent wettable DDT was used. The onion maggot was more abundant during 1951 in the Prairie Provinces, than at any other time previously. For instance, at Brandon, Man., 30 per cent of the onions were destroyed by the first generation of the insect, while in certain localities the damage reached 100 per cent. The injury done by the second generation was relatively light. The onion maggot is always present in these Provinces but is not considered as an important pest, since the injury is inclined to be patchy. During the past few years in southwestern Ontario, a general reduction in infestation was noticed, while in the eastern part of the Province (Ottawa and Bradford districts) an increase of injury occurred. The damage to onions by H. antiqua during 1951, in the Maritime Provinces, was light in general, except at Charlottetown, P.E.I., where the insect was more abundant than usual and in a great many gardens, it destroyed about 50 to 75 per cent of the crops. Considerable damage was observed in Québec in all the agricultural regions, especially in the intensive vegetable (onion) growing regions, the Montréal-St-Martin and St-Jean-Ste-Clothilde, Qué. districts. At Ste-Clothilde, the injury varied from field to field, ranging from 20 to sometimes over 45 per cent in seedling mortality, and in a few fields during the season 1952, approximately 75 per cent seedling mortality has been observed.

Several workers have noticed the great damage done by H. antiqua to onion crops grown in muck soil in the United States for many years, but none had studied the life history and habits of this insect in that soil type, although some control measures were recommended.

The life history of H. antiqua has been worked out in many localities of the United States and the Canadian provinces. Fitch (1866), Dodge (1870) and Slingerland (1894) in the United States were fairly well acquainted with the life history of this insect at that time. More recent papers on the subject are those of Eyer (1922) in Pennsylvania, Treherne and Ruhmann (1922) in British Columbia, Gray (1924) in Alberta, Hammond (1924) and Baker (1928) in Ontario. It has also been studied in the Montréal and St-Jean districts in Québec Province by Armstrong (1924), Baker and Stewart (1928) and Perron et al. (1950-51), but not in complete details and no worker has studied it in southwestern Québec with a muck soil medium.

III. LOCALE, METHODS AND MATERIALS OF THIS STUDY

1. LOCALE

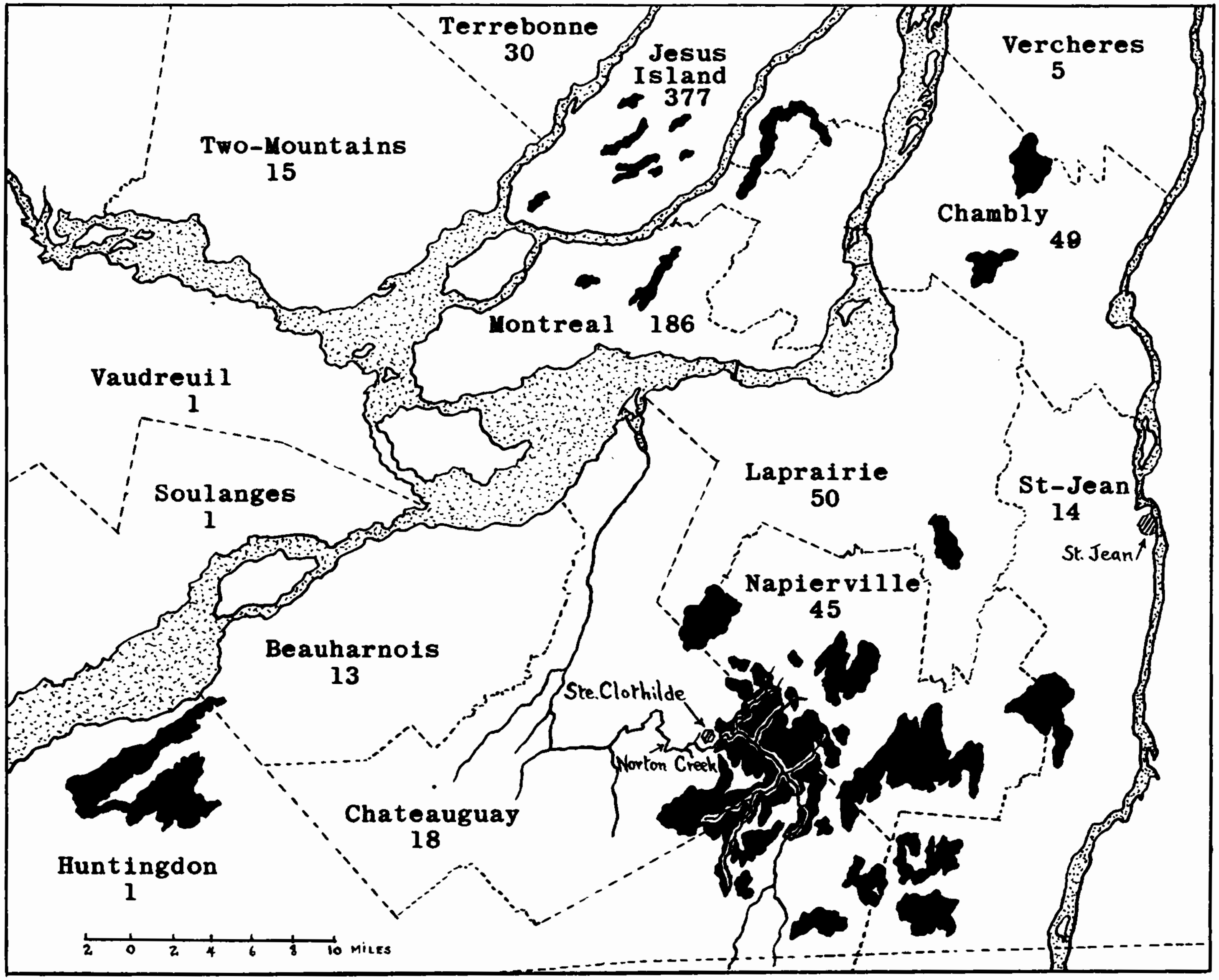
The distribution of onion growing with the 1951 onion acreage by counties for southwestern Québec is shown on the map (Fig. 1) with the distribution of muck soils in the same counties also indicated. Except for the Montréal and Jésus Islands and Laprairie county, most of the onions produced in southwestern Québec come from muck soils (personal communication from the Horticulture Service, Department of Agriculture, Québec).

The actual studies reported here were conducted under laboratory and field conditions, at the Dominion Experimental Substation for mucklands, Ste-Clothilde, Qué.

Muck soil was chosen for these experiments because much of the onion crop in Québec is grown on this soil and because no earlier studies of the pest's biology in this habitat were known.

The substation was established in 1936 by the Dominion Experimental Farms Service to undertake studies of the problems of truck crop production on the muck lands of southwestern Québec, following a survey made by the Québec Soil

Fig. 1. Muck soil areas and onion acreage in southwestern Québec, by counties (dark areas represent muck soil and numbers below the name of the county, onion acreage for 1951).


Terrebonne
30
Jesus
Island
377
Vercheres
5
Two-Mountains
15
Chambly
49
Montreal 186
Vaudreuil
1
Soulanges
1
Laprairie
50
St-Jean
14
St. Jean
Napierville
45
Beauharnois
13
Ste. Clothilde
Norton Creek
Chateauguay
18
Huntingdon
1
2 0 2 4 6 8 10 MILES

Survey Comittee and reported by McKibbin and Stobbe (1936). This survey of the organic soils of the southwestern region of Québec revealed that from a comparatively small area, more than 52,000 acres were of relatively high quality. Browne (1950) reported that of this area, only 27,000 acres were ready for development or under cultivation in 1950. The largest single area, which comprises 17,000 acres is situated in the two counties of Châteauguay and Huntingdon, near the village of Ste-Clothilde, Qué. Another 10,000 acres lie immediately east (see the map, Fig. 1) of the Ste-Clothilde area, in Napierville county near the town of that name. Both areas border streams that have been deepened to provide drainage. Other smaller areas of from 500 to 600 acres are situated in the same general area. There are other larger areas of organic soils in central and eastern Québec which are also largely undeveloped (Browne, 1951).

The substation is located 31 miles south of Montréal on a good highway and comprises a property of approximately 80 acres, 26 of which are rocky mineral soil; 11, marginal muck and the remaining 43 acres a deep muck soil of excellent quality. Twenty-one acres of this deep muck soil had been cleared and for at least ten years had been used for hay production. The other 22 acres were rather sparsely covered with a young scrubby growth of elm, ash, soft maple and several species of native shrubs.

2. MUCK SOILS IN GENERAL

Whatever the origin of organic soils, they can be classed in two groups, according to Browne (1950) so far as immediate value for agriculture is concerned: these are peat and muck. Peat is partly decomposed plant material, while with muck, decomposition is practically complete. There are of course all degrees of decomposition in between the two stages and the point where peat changes to muck is obviously obscure. It is generally conceded that when decomposition has progressed to the extent that definite plant remains are not easily recognized in an organic soil it may be classified as a muck.

Highly organic soils in Québec known as muck and peat have been formed by the decay of plant material in the presence of water. They are of varied origin and differ in value to a very considerable extent. The most common type of muck soil in Eastern Canada had its beginning in water-filled depressions where the movement of water was slow. In south-western Québec, the soil on the deep muck area is characteristic of the predominant type throughout the region. For the most part, these deposits are situated along streams and overlay marl or clay of varying depth to bedrock. In general, these deep mucks are composed of three distinct layers of organic soil: aquatic muck, forest debris and surface layer. The lowest layer of the organic soil is usually an aquatic muck, the beginning of which was apparently formed from plants growing in salt or brackish water. The depth of this aquatic layer varies from a few inches up to over 20 feet in deep depressions. The texture is gelatinous and it absorbs water readily but permits only very small quantities to pass through, forming thus, an almost water-tight bottom to the soil situated above it. The middle layer, from two to four feet in depth, is the forest debris layer. The large quantity of partially decomposed tree trunks, limbs and roots gives it a coarse, open texture which permits water to pass through readily. The surface layer, one to two feet in thickness, was formed after outlets became flooded and the water-table became too high for forest growth. This surface layer is largely decomposed sedge and grass species. The organic material here is in an advanced stage of decomposition, fine in texture, and so can easily be compacted to facilitate the movement of water by capillary action.

The capacity of organic soils to absorb and hold water is very high. At saturation, well decomposed muck will usually hold its own weight and peat soils up to twice their weight. For this reason summer rains seldom penetrate more than an inch or two into the soil and, owing to the loose open texture which permits rather free aeration, such moisture is rapidly lost by evaporation. Therefore, normal summer precipitation cannot be depended upon to supply moisture for maximum crop requirements on these soil types and water control is decidedly a limiting factor. The substation is situated close to Norton Creek, a permanent stream running through the entire bog area. From Norton Creek there is ample water available for irrigation, but at the time the Substation was established the creek bed was not low enough to provide adequate drainage. This condition prevailed until 1948 when the creek was deepened and it was possible to obtain complete water control. However, a system of open ditches was dug and several types of underground drains installed on the deep muck area. Practically all unproductive organic soils are of swampy nature and in their natural state have insufficient drainage; it is only when a good drainage system is installed (as at the Dominion Experimental Substation) that permanent and maximum improvement can be obtained. To provide water for irrigation, a power driven pump was installed and a fibre pipe line laid to carry water to the lightest level on the muckland area. The amount of water made available in this way can be regulated by raising or lowering the water in the main supply ditch, for very little water is lost by sinking to lower levels since the lower layer of aquatic muck acts as a nearby water-tight bottom. When the surface layer is too dry for crop requirements and the forest layer is moist, the lateral seepage from newly filled ditches is 180 feet in 12 hours and up to 200 feet in 15 hours. This means that for the soil conditions on the deep muckland area at Ste-Clothilde, Qué., ditches or drains from 300 to 400 feet apart are adequate for both drainage and irrigation.

The muck soils of southwestern Québec contain a high percentage of organic matter and nitrogen and are relatively low in minerals. A chemical analysis of this soil made from samples taken on the deep muck area at the Substation and reported by McKibbin and Stobbe (1936) is as follows:

Table 1. Chemical analysis of muck soil from the Ste-Clothilde Substation, Qué.

	0" - 12" deep	12" - 24" deep
pH value	6.32	6.36
Total ash	12.27%	10.34%
Calcium oxide CaO	4.42%	4.12%
Magnesium oxide MgO	0.62%	0.49%
Manganese oxide Mn_3O_4	0.040%	0.020%
Potassium oxide K_2O	0.109%	0.101%
Phosphoric acid P_2O_5	0.231%	0.128%
Sulphur trioxide SO_3	1.63%	2.94%
Nitrogen N_2	2.69%	2.62%

In these soils organic matter, which is the portion other than ash, is often 90 per cent or more of the whole. The analyses indicate a soil very low in mineral matter but relatively well supplied with calcium and phosphorus. Sulphur and nitrogen are unusually high while potassium and manganese are decidedly low. The pH value is satisfactory and is ideal for many kinds of vegetable crops. Potash is required in relatively large quantities by most crops and its scarcity in most organic soils is one of the chief limiting factors in crop production. Following a complete soil survey of the Substation farm area, a preliminary trial of all available plant nutrients necessary on this soil type for optimum results with the onion crop was started in 1940 and revealed that phosphorus and potassium are about equal in importance and are required in nearly equal amounts by the onion crop. The maturity of the crop will be adversely affected unless the phosphorus is adequate. Nitrogen significantly increased yields when used in combination with phosphoric acid and potash. A 2-12-10 fertilizer (1,200 pounds per acre) along with borax (10 pounds per acre) and copper sulphate (40 pounds per acre) should prove satisfactory for the onion crop on the muckland areas of southwestern Québec. These last two materials can be applied either in the fertilizer mixture or dissolved in water and applied to the land with a row crop sprayer before seeding, but in either case, they must be thoroughly mixed into the soil.

3. THE EXPERIMENTAL FIELD

The experimental field consisted of a piece of land provided by the Substation where the natural conditions seemed the most suitable for such a study (see Figs. 2 and 3). The experiments were conducted on a muck soil having a dark brown surface soil and a black subsoil. This soil type has a rather uniform texture to a depth of three feet or more, is

Fig. 2. Onion experimental field in June 1952, showing the May 5, 12, 19, 26 and June 2 seedings. On the left, appears a strip of dense vegetation for wind protection.

comparatively free from stones, has a level to slightly rolling topography and a fair natural drainage. The drainage of the experimental field was improved by a system of tile drains installed many years before the beginning of the experiments.

During the 17-year period preceding the experiments reported herein, the experimental field was planted to celery or potatoes most of the time. For the two years (1950-51) immediately preceding the beginning of the experiments, potatoes were grown, so that the presence of the onion maggot was new in this part of the Substation ground. The fertilizer treatment considered optimum for the area and crops (see above) was used.

The whole experimental field was protected from wind by a strip of dense vegetation (shrubs, trees) but was nevertheless open to the sun for the greater part of the day throughout the summer (see Fig. 2).

4. ONION VARIETY

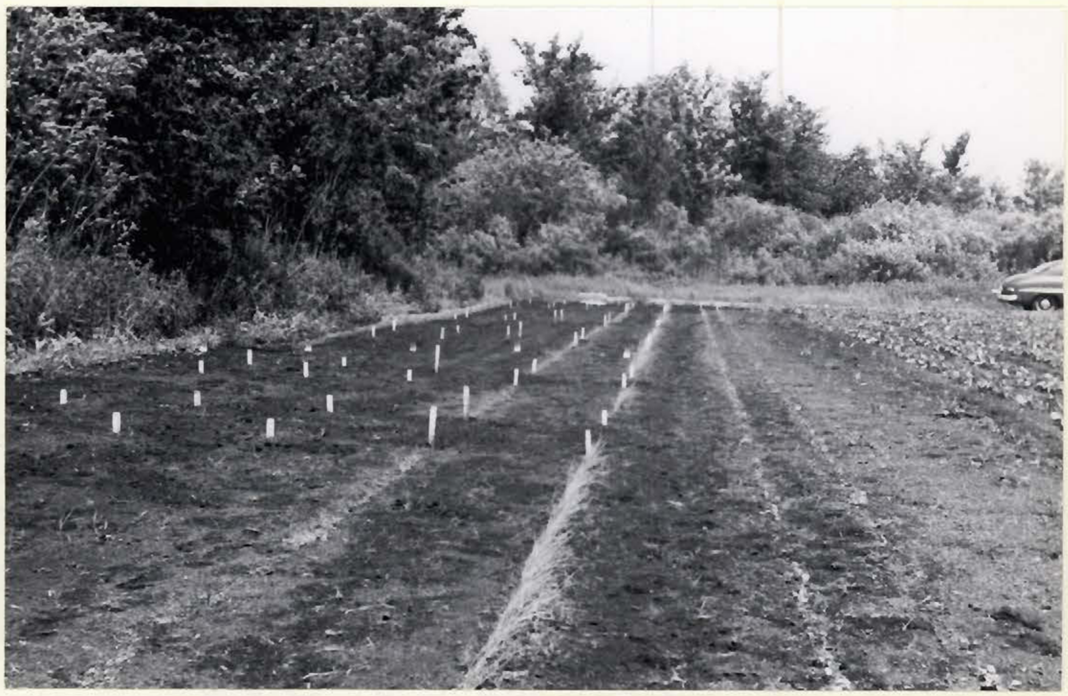
With the exception of a very few localities in which red onions are produced, yellow onions are generally grown. The Early Yellow Globe variety, being most in favor, was chosen for the experimental work, with a seeding rate of three pounds per acre, which is a normal seeding for that soil type.

5. ONION CULTURE

The space between the rows and the germinating power of the seed determine the quantity of seed that should be drilled to the acre. High yields are not obtained by light or heavy seedings. The reason offered by some growers using the heavier quantities was that they hoped that a satisfactory stand would remain when the *H. antiqua* larvae had finished. Unfortunately, the larvae do not thin uniformly and the result is gaps and crowded places with a consequent lower yield of marketable onions. Normally, a final stand of 9 to 12 onion bulbs to a foot of row is not too close, since the bulbs are able to adjust themselves with little injury from crowding because of the loose texture of the muck. An ordinary single-row seed drill was used, and the seed was put at a depth of one inch. In the experimental field, the rather common practice of spacing the rows at 13 to 18 inches was not observed, but the rows were spaced at three feet, in order to be able to carry out the experimental work, which consisted of several egg counts and collection of predators.

Following the usual practice which is that thinning is seldom necessary, the plants were not thinned by hand.

Fig. 3. The onion field in June, showing only the May 5, 12, 26 and June 2 seedings.



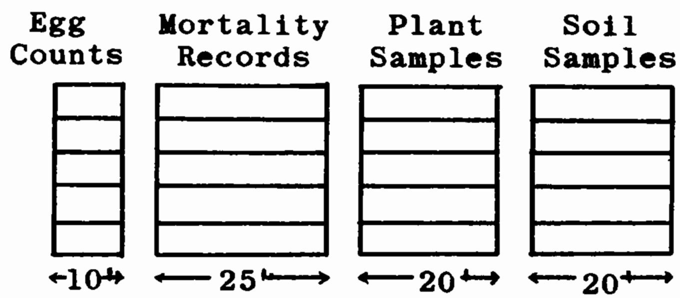
Muck soils which under normal conditions produce excellent onion crops will also produce weeds in almost unbelievable numbers. The crop left a good deal of exposed soil (rows spaced three feet apart) and the rapid growth of weeds involved almost continuous cultivation between the rows. In southwestern Québec, onions are among the most difficult and costly crops to weed, but the most effective control has been obtained with a post-emergence potassium cyanate at one per cent on young plants and at two per cent on plants three or more inches high. No such treatment was used in the experimental field in order not to interfere in the biological experiments.

6. FIELD PLAN

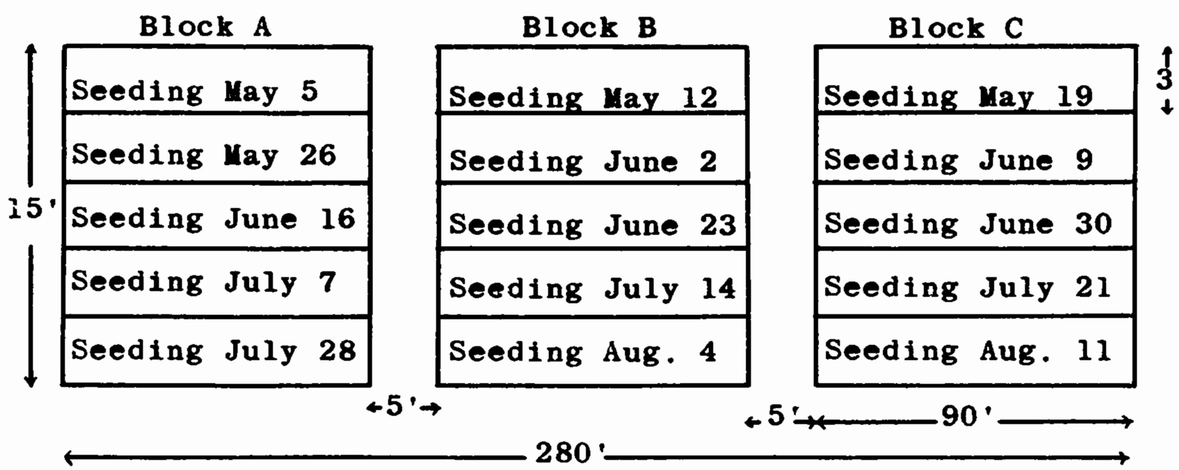
The whole study field was 280 feet long by 15 feet wide and each onion row was 90 feet long. One row was seeded per week for 15 weeks, commencing on May 5 and ending August 11. Each row was marked off into four different sections (see the accompanying map, Fig. 4). Ten feet of row were used for the egg counts made almost every two days. Twenty-five feet served for the seedling mortality records made also almost every two days to find out the various peaks of damage done by the larvae and to see if they corresponded to the peaks found in the egg laying test. Twenty feet were kept for plant samples taken once a week for study of establishment of the

Fig. 4. Field plan showing the experimental onion field (below) and the four sections of one block (above).

BLOCK LAYOUT



ONION EXPERIMENTAL FIELD



different species of root maggots found in the region. Twenty feet were used for soil samples taken also once a week for pupal collections. This last test gave the proportions of pupae of the different generations which remained in the dormancy stage. Five foot spaces were left between the end of each section and the beginning of the next.

7. PLANTING DATES

It has been recognized for some years that extreme differences exist in the susceptibility of onions seeded at different times to the injury done by H. antiqua. The practice in southwestern Québec is to seed onions as early as possible when the weather permits it, although in the localities on Montréal Island, growers make weekly seedings over a period of a month or more. It must be remembered that the onion is a rather cool-season crop. It must make its early growth before the arrival of hot weather, while a long period of daylight is necessary for bulb formation. Thus, the earlier the crop can be planted in the spring, the greater will be the yield. However, the actual date of seeding depends primarily upon the drying of the muck in the spring to a workable condition. In general, the onion crop is ready to harvest when the most of the tops have cured and fallen over.

With early planting, as it is the case in southwestern Québec, this period is generally sufficiently early in the fall (early part of September) so that the weather conditions are generally favorable. It is well known that muck land is 'frosty'; that is, that frosts may injure crops on muck on cool clear nights, even though the days are warm. The onion bulb is very resistant to freezing as long as it is not pulled, but after pulling (as it is usually done before harvesting), it is quite sensitive to frost, especially if the freezing is followed by exposure to the sun's rays. Onion seedings were made on May 5, 12, 19, 26, June 2, 9, 16, 23, 30, July 7, 14, 21, 28, August 4 and 11, fifteen weekly seedings in all. Thus, it will be seen that only some of the experimental seedings were made at the normal time (those made during May and June) and the others so late as to give no hope of maturing a commercial crop; all these different seedings were made to see which ones would escape most *H. antiqua* damages to onions.

8. COLLECTING SPECIMENS

The specimens that served for the various tests indoors and out of doors including eggs and larvae were taken in a commercial onion field close to the laboratory or on cull onions planted early in May. By rearing the larvae, it was possible to obtain the pupal and adult stages for the different tests carried out with the various generations of the insect. The four stages of the onion maggot appear in Fig. 5.

9. REARING AND HANDLING TECHNIQUES

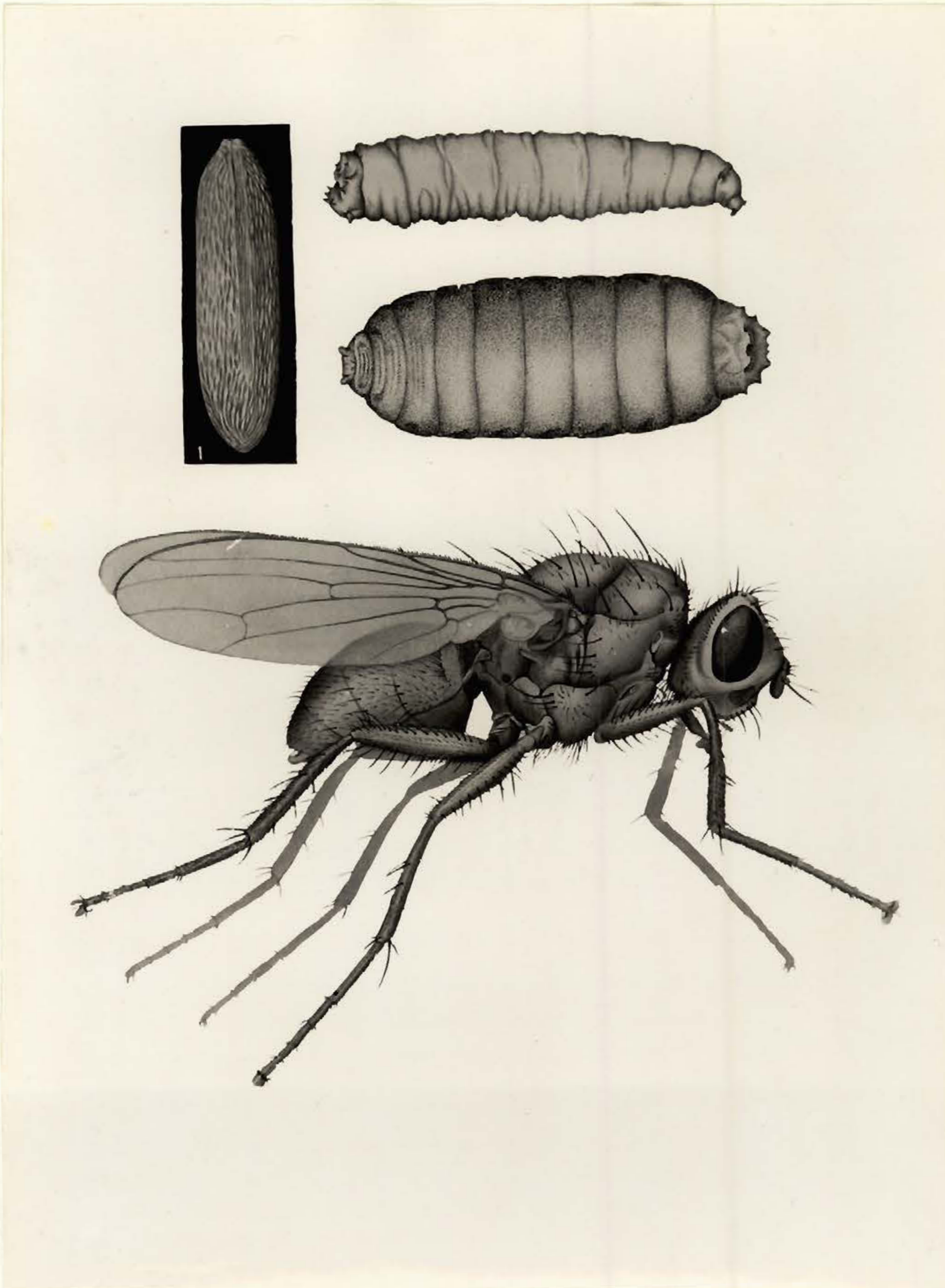
All H. *antiqua* eggs serving in the different laboratory and field tests were hatched in petri dishes containing a filter paper at the bottom and a small portion of onion supporting a squared piece of cardboard on which the eggs were deposited for hatching (Fig. 6). In this way, the newly-emerged larvae could be recovered very easily.

The larvae and pupae were reared in small glass jars covered with a 56-mesh-wire copper screen top (Fig. 7); each jar contained half its volume of muck soil and a small onion bulb on the top of that soil. When the onion was all consumed or badly decayed it was replaced. When the pupae were formed, they were either kept in these jars or placed in petri dishes containing some soil. In the petri dishes, it was easier to determine rapidly the sex of adult flies as each was removed by allowing it to climb up inside a darkened glass funnel (Figs. 8 and 9).

The adult flies were kept in large screen cylinders placed over a few small onions growing in seven inch flower pots filled with muck soil (Fig. 10); the onions

PLATE I

Fig. 5. The four stages of _Hylemya antiqua_: the egg, the larva, the pupa and the adult, all greatly magnified (courtesy of the Science Service, Bio-Graphic Unit, Ottawa, Ont.).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had been carefully examined to insure their freedom from eggs and larvae. The screen cylinders were made of galvanized 14-mesh-wire screen and the tops were covered with fine tulle to avoid parasites and reinfestation and to allow a clear view of the flies confined within. This type of cage was especially used for individual tests, but for mass rearing, wooden boxes (25 inches long, 20 inches wide and four inches high) containing soil and onions and covered with fine tulle were very useful (Fig. 11).

The flies were usually fed with an artificial diet similar to the one described by Perron et al. (1950-51), which consisted of equal parts of molasses and evaporated milk spread on bread, and cellu-cotton pads soaked in a solution of diluted yeast cakes in water. This diet proved very successful source of food for adult specimens.

The temperature in the laboratory during the entire season was fairly constant, being from 65 to 75 degrees Fahrenheit; occasional extremes of 60 and 85 deg. F. were recorded during nights or at noon. No records of air humidity were kept, but in the screen cages and glass jars, the fresh onion bulbs and moist soil supplied adequate moisture.

Each generation was measured from the egg stage, i.e. by the exact time from egg laying until the emergence of the adult fly.

PLATE II

Figs. 6, 7, 8, 9, 10 and 11. Apparatus
for rearing and handling the
different stages of *Hylemya antiqua*.

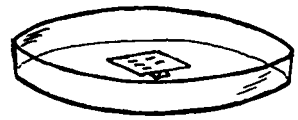


Fig.6

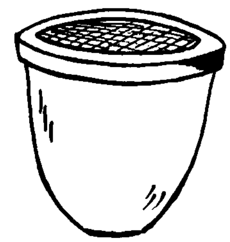


Fig. 7

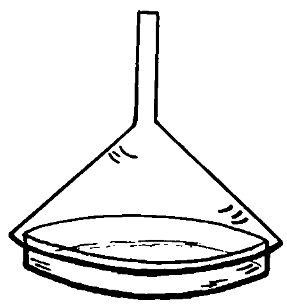


Fig. 8

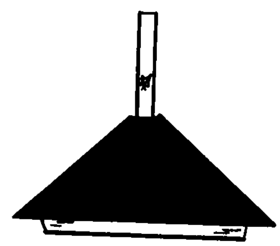


Fig. 9

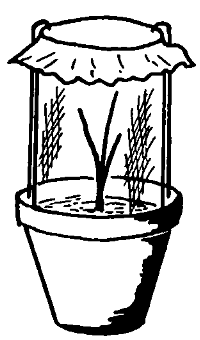


Fig.10

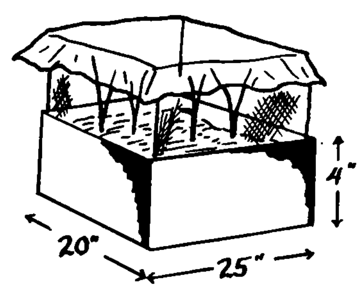


Fig. 11

10. PUPAL RECORDS

Each soil sample, taken for pupal counts and adult emergence of the different generations, contained about five pounds of moist soil; this was obtained by taking twice the volume of soil contained in a metal cylinder (five inches high with a six inch diameter). The pupae were collected by hand-sifting the soil at the laboratory. A few days were allowed between the collection day and the sifting in order that the soil might dry.

11. OVIPOSITION RECORDS

Records of oviposition in the field were taken on ten feet of onion rows (see the map, Fig. 4), 25 plants selected each time, for each seeding and these egg counts were made every two to three days during the entire season. Oviposition studies in the laboratory were made from the time adults were placed in the screen cages until the first eggs were found, by checking the soil around the onion seedlings using a camel hair brush to uncover eggs. Observations on the plants out of doors started when the very first eggs were laid on May 29 and continued until September 27, when the onions were too large and unwieldy for accurate observations.

12. MORTALITY RECORDS

The seedling mortality records were also taken every two to three days during the entire summer, on 25 feet of onion row, for each seeding (see the map, Fig. 4). This consisted of counting all the dead or wilting plants and removing them each time. At the end of the season, all the surviving onion plants were counted and the various percentages of the 15 seedings were calculated.

IV. OBJECTIVES

To determine under the conditions of the study:

1. The preoviposition period
2. The place, time of oviposition and the comparative number of eggs laid by each generation
3. The viability and duration of the egg stage
4. The duration of the larval stage and the distance the larva can travel
5. The duration of the pupal stage and percentage of adult emergence
6. The duration of the adult stage and the sex ratio
7. The number and duration of generations
8. Nature and amount of injury to the host
9. Other species of maggots infesting onions
10. Predators of the onion maggot

V. RESULTS

1. THE PREOVIPOSITION PERIOD

The preoviposition period or that time elapsed between the emergence of adults from overwintering pupae and the deposition of eggs was found to vary greatly with the individuals. One test was carried out with small screen cages out of doors. The length of time was measured from the emergence of the adults to the deposition of the first eggs in the cages, but no dissection was made of the female's abdomen.

Five pairs of flies from overwintering pupae* placed immediately after emergence, one pair per cage, in small screen rearing cages containing small growing onions (Fig. 10) and held out of doors in the shade of trees and without food, lived for a week, but were not observed to copulate and laid no eggs. When similar cages, similarly placed, were supplied with food in the form of wild flowers, yeast and water, evaporated milk and molasses spread on bread, flies were observed mating within four or five days and they oviposited in seven or eight days.

*It should be noted that all flies of the overwintering generation were from pupae collected at St-Jean, Qué., in mineral soils.

Newly-emerged first generation adults confined as pairs along with food, in field, cages behaved as follows:

Table 2. Preoviposition period of 1st generation *H. antiqua* adults Ste-Clothilde, Qué., 1952.

Cage	Location	Placed	First eggs collected	No. of eggs laid	Preoviposition period
A	in sunlight	July 4	July 12	3	8 days
B	in sunlight	July 4	July 14	5	10 days
C	in sunlight	July 8	July 17	6	9 days
D	in shade	July 4	July 19	13	15 days
E	in shade	July 8	July 22	4	14 days
F	in shade	July 8	July 19	11	11 days

It is evident that food is essential to oviposition and under the above conditions, sunlight shortens the preoviposition period.

Other caged pairs of adults fed and kept in the field in sunlight were observed in order to compare the behaviour of the different generations:

Table 3. Preoviposition period of different generations of *H. antiqua*, Ste-Clothilde, Qué., 1952.

Generations	Cage	Placed	First eggs collected	No. of eggs laid	Preoviposition period
Overwintering	A	June 3	June 17	17	14 days
	B	June 3	June 18	4	15 days
1st generation	C	July 21	Aug. 1	8	11 days
	D	July 21	Aug. 4	2	14 days
2nd generation	E	Sept. 4	Sept. 12	5	8 days
	F	Sept. 4	Sept. 14	9	10 days

The preoviposition period seems to shorten with the later generations of the insect.

A similar comparison was made during life history studies in the field in which from two to four pairs of flies were caged together (see section 7). The observed preoviposition periods from emergence of adults to first egg deposition were: overwintering generation 10 days, first generation 9 days and second generation 8 days.

2. THE PLACE, TIME OF OVIPOSITION AND THE COMPARATIVE NUMBER OF EGGS LAID BY EACH GENERATION

a. General observations

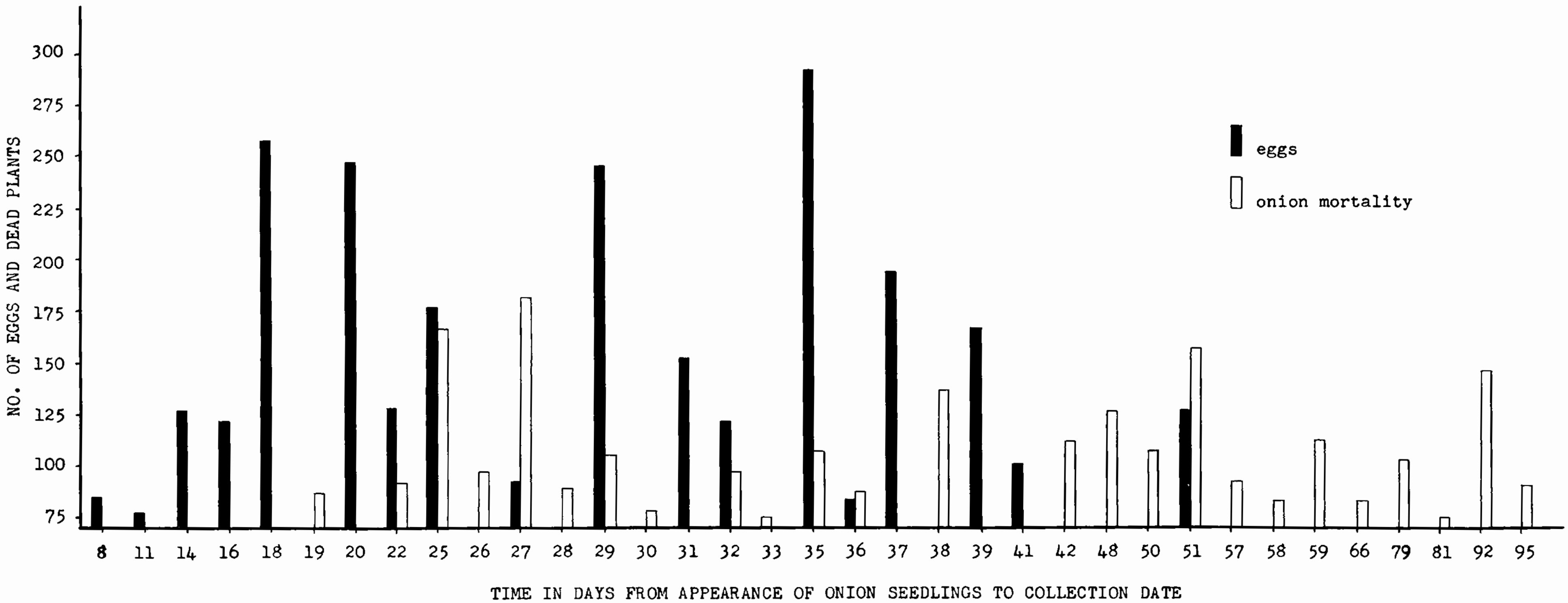
i. Effect of weather

Flies were very active and almost restless in the sunlight, flying very close to the ground, hovering around food plants and settling on the leaves of onion plants and on the ground. On cool and cloudy days, the flies were sluggish, inactive and hard to find. Weather conditions, however, did not seem to affect the rate of oviposition per day. Results in Fig. 13 proved this contention. A great many eggs were collected during rainy days. Direct sunshine was not found especially important for egg laying of adults kept in captivity and fed with the artificial diet.

A temperature of about 75 deg. F. seemed to be the most appropriate for oviposition. Results given in Fig. 13 present a good picture of the oviposition habits of the fly, giving not only the number of eggs laid, but the relation between egg deposition and meteorological conditions.

Laboratory and field observations indicated that copulation occurred for the most part in bright sunlight

Fig. 12. Effect of the age of the onion plant on egg laying by *Hylemya antiqua* and onion mortality due to this pest (data for summer 1952, at Ste-Clothilde, Qué.).



300
275
250
225
200
175
150
125
100
75
NO. OF EGGS AND DEAD PLANTS
eggs
onion mortality
8 11 14 16 18 19 20 22 25 26 27 28 29 30 31 32 33 35 36 37 38 39 41 42 48 50 51 57 58 59 66 79 81 92 95
TIME IN DAYS FROM APPEARANCE OF ONION SEEDLINGS TO COLLECTION DATE

during the heat of the day. Egg laying on sunny days occurred during the cooler part of the day, i.e. late afternoon.

ii. Place of oviposition

Eggs were laid most frequently on the strongest growing seedlings in the early spring (first generation eggs), and at this time of the year, oviposition nearly always occurred at or just above the surface of the soil on or in the vicinity of the plant. Before the end of June, the leaves and leaf sheaths were favored, particularly those of the weaker plants (onions sown during June) or those previously injured by the first generation larvae. Occasionally, eggs were found on the leaves, from two to three inches above the soil surface. Long-leaved plants were preferred during sunny days and fine weather and on windy, cloudy or rainy weather ovipositing females sought shelter between the leaves to oviposit. From Fig. 12, it is evident that the preference was for plants of large size, 18 to 37 days after emergence from the soil surface, i.e. 8 to 18 inches high. After June, in plots containing large onions, the eggs were often laid on the bulbs, or the part of the bulb appearing above the soil (probably second generation eggs). Eggs were rarely laid on those plants with the bulb showing a prominent neck. Late in the season, when the pulled onions were exposed on the ground the female deposited her eggs directly on the bulbs. Eggs were observed deposited on the surface of the soil within a radius of two inches from the plants especially on newly turned moist soil, and sometimes, just below the soil surface, near the plants, singly or in clusters.

During the 1952 investigations in this muckland region, the writer was impressed by a sort of preference of *H. antiqua* flies to oviposit in certain fields or parts of fields. This patchy condition in this muck region, although the damage was not consistent from field to field, does not differ from what has been found during several years with biological and control experiments in a Yamaska sandy loam at St-Césaire, Qué., a St-Jude gravelly sand at Rougemont, Qué., and a Ste-Rosalie clay at St-Jean, Qué.

iii. Numbers of eggs laid

The number of eggs laid in clusters, evidently the product of an individual female's deposition during the height of the spring oviposition period varied from four to 42 on seedling onions and from 14 to 57 on cull onions growing from the remains of the previous year's crop. Solitary eggs were more than common, but clusters of seven to 18 eggs were most usually seen.

Table 4. Number of H. antiqua eggs collected during the summer 1952, on 15 different onion seedings, Ste-Clothilde, Qué.

Dates of seedings	May		June														July													August											September											Total no. of eggs	No. of observations	No. of eggs per observation
	29	30	3	5	7	9	11	13	16	18	20	23	24	26	28	30	1	4	7	8	11	14	17	18	21	23	25	28	30	1	4	6	9	12	14	16	22	25	27	29	3	5	8	9	11	13	15	18	22	25	27			
May 5	4	1	7	65	69	59	193	117	34	51	48	57	22	176	113	81	39	1	5	0	1	0	2	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1148	29	39.5
May 12				3	16	23	11	31	9	29	10	2	27	19	4	27	35	44	14	7	1	0	15	0	1	7	1	0	0	0	2	4	4	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	342	29	11.7
May 19					3	1	9	7	2	14	4	19	76	14	12	41	53	60	21	8	0	2	0	0	13	9	4	3	0	0	0	2	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	378	29	13.0
May 26						3	15	67	26	19	15	17	6	5	5	19	27	49	3	11	0	0	0	0	12	19	3	1	1	0	10	7	4	2	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	344	28	12.2
June 2								14	8	12	9	2	1	8	16	12	19	17	2	39	3	1	14	0	26	26	5	1	0	0	0	1	1	14	11	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	262	28	9.3
June 9														1	0	14	28	18	19	21	0	7	0	4	19	4	1	0	4	0	0	3	0	19	0	0	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	174	26	6.6
June 16															2	7	7	11	5	4	1	4	9	0	13	3	8	6	14	21	14	17	6	47	53	2	9	3	0	0	0	0	0	0	0	0	0	0	0	0	0	266	26	10.2
June 23																				1	2	1	0	1	2	7	0	0	0	8	3	0	0	4	0	1	16	0	0	0	0	1	0	0	0	0	0	0	0	0	0	47	24	1.9
June 30																					1	4	4	1	31	0	0	0	0	0	0	12	1	2	0	2	9	0	0	1	7	7	2	0	1	0	2	1	0	0	0	85	26	3.2
July 7																							2	3	2	5	2	1	0	105	2	0	3	21	2	0	13	31	11	4	22	13	14	0	3	0	4	3	0	0	0	263	25	10.5
July 14																											1	9	2	8	3	21	4	11	4	1	7	16	0	7	13	17	21	12	10	2	18	9	3	0	2	199	24	8.2
July 21																																2	1	2	1	7	8	11	19	9	3	11	37	1	21	4	7	19	41	2	7	213	20	10.6
July 28																																			3	10	11	37	0	18	47	29	14	3	67	11	19	7	5	18	21	320	17	18.8
Aug. 4																																				4	2	0	7	1	5	37	10	5	22	27	8	15	2	7	4	156	16	9.7
Aug. 11																																							2	1	2	5	1	0	0	0	3	2	4	32	2	54	13	4.1

Table 5. Number of dead onion plants collected during the summer 1952, on 15 different onion seedings, Ste-Clothilde, Qué.

Dates of seedings	June												July													August										September										October		Total no. of dead onions	Total no. of healthy onions	Grand total	Per cent of infestation	No. of obser-vations	No. of dead onions per observation
	5	7	10	12	16	17	18	20	23	25	27	30	2	4	7	8	11	14	17	19	21	23	26	28	31	2	5	8	11	14	16	21	25	28	30	1	4	8	10	12	15	18	22	24	26	8	10						
May 5	2	6	17	16	101	44	61	39	19	3	5	7	1	5	4	2	1	0	1	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	336	4	340	98.8	27	12.4
May 12			1	3	13	31	16	9	27	7	22	8	3	20	39	21	6	3	19	2	5	2	0	3	0	3	4	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	267	41	308	86.6	27	9.8
May 19				6	9	15	5	5	4	4	7	3	7	5	19	6	5	2	15	0	3	1	4	6	2	2	4	3	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	143	58	201	71.1	26	5.5
May 26					8	23	21	23	6	6	5	24	49	36	18	0	1	0	8	0	6	4	9	9	4	1	3	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	265	5	270	98.1	27	9.8
June 2								2	1	5	8	2	19	4	23	10	8	4	6	1	17	9	18	13	1	10	9	7	2	0	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	185	87	272	68.0	25	7.4
June 9												5	2	1	4	0	0	2	4	0	2	27	41	2	12	1	0	2	4	2	5	0	0	0	0	0	0	1	2	1	0	0	0	0	0	0	1	116	153	269	43.1	24	4.8
June 16													6	22	27	9	3	3	0	1	37	11	20	29	9	14	16	4	2	7	2	5	0	1	0	2	1	4	3	0	0	0	0	0	0	0	1	230	8	238	96.6	24	9.5
June 23																		2	0	0	10	7	5	43	8	4	10	2	0	1	0	14	16	8	0	16	2	7	10	9	0	0	0	0	0	9	16	174	103	277	62.8	23	7.5
June 30																					1	4	1	4	7	15	18	6	1	3	1	7	4	3	1	7	8	12	5	2	2	1	7	0	0	146	90	113	191	304	37.1	22	5.1
July 7																					1	0	3	0	1	45	37	16	3	1	7	13	4	2	4	5	8	14	25	8	14	5	12	19	4	9	46	216	0	216	100.0	22	9.8
July 14																								1	2	1	0	2	0	0	1	6	41	20	2	30	41	39	52	20	8	12	14	52	7	102	75	351	32	383	91.6	22	15.9
July 21																													1	0	0	1	3	1	0	2	1	6	7	6	9	49	21	75	88	36	55	361	176	537	67.2	19	19.0
July 28																																7	6	7	1	4	5	20	41	35	11	31	79	93	14	61	77	492	79	571	86.1	16	30.7
Aug. 4																																1	17	2	7	6	7	23	65	19	29	47	10	18	19	43	30	343	60	403	85.1	16	21.4
Aug. 11																																					1	2	0	1	5	11	15	25	29	13	35	137	99	236	58.0	11	12.4

b. Experimental evidence

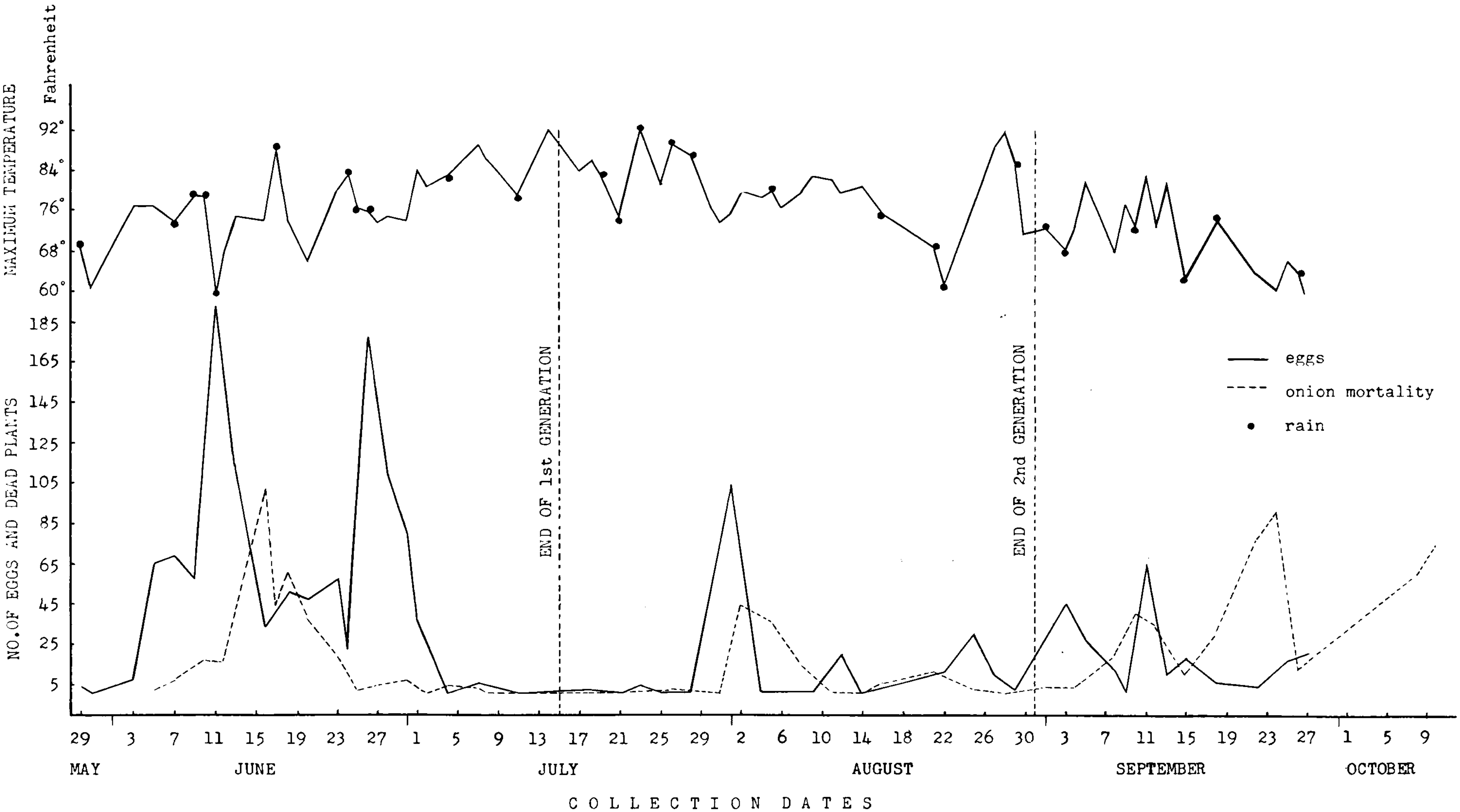
i. Egg laying throughout the season

From May 29 until September 27, all eggs were collected at each collection from 25 onions from each seeding. These eggs were brought in the laboratory, counted and then checked to be sure they were *H. antiqua*. Collections were made each day or twice every three or four days. The number of eggs obtained at each collection on each seeding is given in Table 4. In Fig. 13 are graphed the egg collections made on the May 5, July 7 and July 28 seedings chosen because these three seedings were infested mostly by the first, second and third generation larvae respectively. Comparative data for the three different generations appear in Table 6.

Table 6. Number of eggs collected during the season on three different seedings mostly infested by the 1st, 2nd and 3rd generations respectively, Ste-Clothilde, Qué.

Seedings	No. of eggs collected	No. of collections	No. of eggs per collection	Period of time when the eggs were collected
May 5 1st generation	1143	22	51.9	from May 29 to July 15
July 7 2nd generation	207	18	11.5	from July 15 to Sept. 1
July 28 3rd generation	241	11	21.9	from Sept. 1 to Sept. 27

Fig. 13. *Hylemya antiqua* eggs collected and onion seedling mortality records at Ste-Clothilde, Qué., during the summer 1952. Egg collections were made at intervals of 2 to 3 days from 25 onion plants; mortality records at similar intervals from 25 foot lengths of row. Records from May 29 to July 15 are from onions seeded on May 5. Records from July 15 to September 1 are from onions seeded on July 7. Records from September 1 until the end of the season are from onions seeded on July 28.



MAXIMUM TEMPERATURE Fahrenheit
92°
84°
76°
68°
60°
NO. OF EGGS AND DEAD PLANTS
185
165
145
125
105
85
65
45
25
5
END OF 1st GENERATION
END OF 2nd GENERATION
eggs
onion mortality
rain
29 3 7 11 15 19 23 27 1 5 9 13 17 21 25 29 2 6 10 14 18 22 26 30 3 7 11 15 19 23 27 1 5 9
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
COLLECTION DATES

The various percentages of the total number of eggs laid per month, during the summer, appear in Table 7.

Table 7. Number of eggs collected during the summer 1952, in the onion experimental plots, Ste-Clothilde, Qué.

Months	No. of eggs collected	No. of observations	No. of eggs per observation	Per cent infestation
May	5	2	2.5	4.4
June	1808	64	28.2	49.7
July	920	120	7.6	13.4
August	777	104	7.4	13.0
September	774	70	11.0	19.4
Total	4284	360		99.9
Average			11.9	

ii. <u>Number of eggs laid</u>

In the experimental plots, during two days of egg collection (June 11 and 13) from onions sown May 5 and reported in Table 4, a total of 310 eggs have been taken on 50 plants, giving an average of 6.2 eggs per plant. On 25 onions of the same seeding, a total of 193 eggs were laid on June 11, giving 7.7 eggs per plant for that particular day, the peak of first generation egg deposition.

Based on the biological studies with adults kept in captivity (Table 24), the number of eggs collected during the entire season on the experimental plots (Table 4), the condition of onion growth and the presence of the various onion seedings in the experimental field, it was decided that the first generation egg laying ended around the middle of July and that of the second generation, around September 1. Onions sown on July 7 were about one inch high around the middle of July, thus the most appropriate to receive the second generation egg laying. Therefore, the onion seeding made on July 7 and all the successive ones were said to be infested with second or third generation. Referring to the number of eggs found per collection (Table 4), it was evident that the July 7 onion seeding represented most appropriately the second generation egg laying and the July 28 seeding, that of the third generation egg deposition.

iii. <u>Oviposition by generations</u>

From data reported in Table 4, 1,143 eggs laid by adults coming from overwintering pupae were collected on the May 5 seeding from May 29 until July 15 (presumably the end of first generation egg laying) and only five eggs found in the same seeding might have been laid by first generation adults from July 15 until the rest of the season. A total of 105 eggs (presumably second generation eggs) were collected on 25 onions examined on August 1 on the July 7 seeding.

3. THE VIABILITY AND DURATION OF THE EGG STAGE

The length of time was measured from the moment the egg was laid to the time of hatching, but no dissection was made of the female's abdomen. For a study of the viability and duration of the egg stage, in a first test, 1,696 eggs were collected during the five summer months in a commercial onion field near the experimental plots. These were kept at room temperatures (70 to 80 deg. F.), in petri dishes containing moist soil, in the laboratory (Table 8). Data are for each month and no care was taken for the particular generations. Eggs collected during September and October belong certainly to the second or third generation and even if some of them might come from first generation adults, they must have been a very small number.

In a second test, 1,195 eggs known to be of the first generation were similarly collected, kept and hatched (Table 9). These were collected during a period of time when only the adults from overwintering pupae were active (end of May and early part of June).

It is evident that the viability of the first generation eggs (90.6 per cent) corresponds well with the one (89.9 per cent) that was found for the entire summer. The duration of the egg stage is similar in both cases and may vary

Table 8. Duration of the egg stage and degree of fertility of *Hylemya antiqua* eggs collected during the entire summer (eggs of all three generations), at Ste-Clothilde, Qué., 1952.

Period	No. of eggs studied	No. of eggs hatched	Percent fertility	Number hatching after: 2 days	3 days	4 days	5 days	6 days	7 days	8 days	Average no. of days for hatching
June	523	502	95.9	314	91	78	16	1	2	-	2.61
July	292	256	87.6	10	203	37	-	6	-	-	3.17
August	279	253	90.6	41	1	9	88	79	35	-	5.05
September	410	356	86.8	81	15	-	199	54	7	-	4.42
October	192	157	81.2	13	31	15	93	2	1	2	4.32
Total	1696	1524	89.9	459	341	139	396	142	45	2	3.71
Percentage				27.0	20.1	8.1	23.3	8.3	2.6	0.1	

from two to eight days with an average of approximately three and a half days. This duration has a tendency to lengthen towards the end of the season, with a peak in August.

Table 9. Duration of the egg stage and degree of fertility of 1st generation eggs collected from May 27 to June 18 and kept in laboratory, Ste-Clothilde, Qué., 1952.

No. of eggs studied	No. of eggs hatched	Per cent fertility	Number of eggs requiring: 2 days	3 days	4 days	5 days	6 days	Average no. of days for hatching
1195	1083	90.6%	195	365	399	94	30	3.44
			16.3%	30.5%	33.3%	7.8%	2.5%	

Great variations occurred in the viability and duration of the egg stage when they were submitted to different temperature and soil moisture conditions. In a first test, 320 eggs were placed under supposedly ideal conditions, on slightly moistened blotting paper in petri dishes containing muck soil, at room temperatures (70 to 80 deg. F.). An average of 3.36 days was obtained with 92.8 per cent of hatching. When another group of eggs (519) were submitted to different temperature and soil moisture conditions, different percentages of fertility and durations of this stage were obtained. Only 30 per cent of 195 eggs hatched when they were kept under very high temperatures (90 deg. F.) under dry conditions. It seemed that soil moisture condition was more important in the survival of the eggs than was the temperature factor. Exceptionally high temperatures (90 deg. F.) with a dry medium during a period of at least three days decreased the percentage of hatchability to a remarkably high extent. The duration of the egg stage was longer when the eggs were kept under dry conditions at room temperatures, while at very high temperatures, the length of time for this stage was about the same, whether the eggs were in a dry or moist medium. Results are given in Table 10.

To find out if blotting paper was a factor for diminishing the percentage of hatching when rearing onion maggot eggs, a test was carried out in the laboratory with 610 eggs collected during June on cull onions, 290 were kept under dry condition on blotting paper and onions, while 320 were kept on moist blotting paper and onions during the course of the whole experiment. Here also, the moisture conditions seemed to be important in being able to decrease the percentage of hatchability, whether the medium was blotting paper or onions. Results appear in Table 11.

The <u>H.</u> <u>antiqua</u> eggs which remained uneaten by coleopterous predators to which they were exposed (see Section 10) were retained in each instance and their fertility determined. Approximately 96.3 per cent of 717 eggs salvaged from predator cages kept indoors hatched, and 89.7 per cent of the 39 eggs from the outdoor cages also hatched. The percentages

Table 10. Duration of the egg stage and degree of fertility of 1st generation eggs kept under different temperature and soil moisture conditions, Ste-Clothilde, Qué., 1952.

Condition of medium	No. of eggs examined	No. of eggs hatched	Per cent fertility	Number of eggs hatching after: 2 days	3 days	4 days	5 days	6 days	7 days	8 days	9 days	Average no. of days for hatching
moist condition 70-80 deg.F.	320	297	92.8	78	87	112	3	-	17	-	-	3.36
dry condition 70-80 deg.F.	114	46	40.3	2	4	1	20	12	4	1	2	5.34
dry condition 90 deg. F.	195	57	29.2	29	22	4	1	1	-	-	-	2.64
moist condition 90 deg. F.	210	155	73.6	101	45	4	2	3	-	-	-	2.45

Table 11. Duration of the egg stage and degree of fertility of 1st generation eggs kept under different moisture conditions, at room temperatures (70 - 80 deg. F.), Ste-Clothilde, Qué., 1952.

Condition of medium	No. of eggs examined	No. of eggs hatched	Per cent fertility	Number of eggs hatching after: 2 days	3 days	4 days	5 days	6 days	7 days	8 days	Average no. of days for hatching
dry blotting paper	145	28	19.3	-	-	14	8	4	1	1	4.82
dry onions*	145	64	44.1	-	19	28	10	6	-	1	4.10
moist blotting paper	160	145	90.6	22	89	10	22	2	-	-	3.26
moist onions	160	157	98.1	38	94	23	1	1	-	-	2.95
Total	610	394	64.5	60	202	75	41	13	1	2	

* These onions did not receive any moisture, except their own that they kept during the course of the test.

of fertility of these eggs for each month the test was carried out appear in Table 12.

Table 12. Degree of fertility of *H. antiqua* eggs collected during the season and surviving predation in cages containing predatory beetles under indoor and out of door conditions, Ste-Clothilde, Qué., 1952.

	June	July	August	September	Total
No. of eggs examined	254	140	186	176	756
No. of eggs hatched	230	140	184	172	726
Percent fertility	90.5%	100%	98.9%	97.7%	96.0%

Results reported in Table 2 and obtained on the preoviposition period show that 42 eggs were laid in the six screen cages, and 36 hatched, giving 85.7 percent fertility.

4. THE DURATION OF THE LARVAL STAGE AND THE DISTANCE THE LARVA CAN TRAVEL

The length of the larval stage, as well as that of the egg stage, is of great importance in its practical relation to the injury done by the larva. Three tests were carried out with the larval stage of this insect.

In a first experiment, the length of time of this stage did not seem to vary very much with the generations, but the later generations seemed to require a slightly longer period of time for completion than the first generation did. The percentage of survival decreased slightly with the later generations. Results appear in Table 13. These larvae emerged from eggs collected during May and June in a commercial onion field near the experimental plots for first generation larvae only. The second and third generation larvae were obtained by hatching eggs obtained from adults reared in captivity (Fig. 14). The adults were fed with the artificial diet. Second generation larvae emerged from second generation eggs laid by first generation adults, Table 24.

In a second test with only first generation larvae but kept in two different media under moist and dry conditions, at room temperatures, the larval stage seemed to be affected in its duration, as well as the percentage of survival.

Table 13. Duration of the larval stage and the degree of survival for each generation of *Hylemya antiqua*, Ste-Clothilde, Qué., 1952.

Generation	No. of larvae studied	No. of larvae surviving	Per cent survival	Number of larvae pupating in: 15 days	16 days	17 days	18 days	19 days	20 days	21 days	22 days	23 days	25 days	Average no. of days for larval stage
First	1083	1042	96.2	51	29	231	385	237	79	20	10	-	-	18.05
				4.8%	2.7%	21.9%	36.5%	22.7%	7.5%	1.9%	0.9%			
Second	500	477	95.4	-	21	35	87	71	142	68	41	8	4	19.49
					4.4%	7.5%	18.2%	14.8%	29.7%	14.2%	8.5%	1.6%	0.8%	
Third	200	183	91.6	-	-	6	14	20	28	77	3	31	4	20.71
						3.2%	7.6%	10.9%	15.3%	42%	1.6%	16.9%	2.1%	

Results appear in Table 14. The same technique was followed in each case, except that under moist conditions, the larvae in onion bulbs with muck soil in glass rearing jars received water regularly in order to provide them with the ideal natural conditions, while in the other case, moisture was supplied exclusively by the onion bulbs themselves. As was expected, a longer period of time was required to complete the larval stage under dry conditions.

A third test, this time, with the temperature factor in mind, was carried out with 250 second generation larvae, kept under five different temperatures; the percentage of survival was also checked. These larvae emerged from eggs deposited by first generation adults reported in Table 24. As was expected, at the higher temperatures, the larval period was much shortened and the percentage of survival was relatively small. Results appear in Table 15. The moisture content of the soil in the rearing jars here, remained constant.

Newly-emerged larvae avoid light and the quicker they penetrate the soil seeking the root system of the onions, the more likely they are to survive. Larvae emerged from eggs deposited on soil surface near the plant are first attracted to the soil crevices formed around the plant, passing down through the soil until an onion bulb is reached. A field test was carried out with H. antiqua second and third generation eggs and first generation newly-emerged larvae deposited on the

Table 14. Duration of the larval stage and degree of survival of 1st generation larvae kept under different moisture conditions, at room temperature (70 - 80 deg. F.), Ste-Clothilde, Que.

Condition of medium	No. of larvae examined	No. of larvae surviving	Percent survival	15 days	16 days	17 days	18 days	19 days	20 days	21 days	22 days	Average no. of days for larval stage
moist	60	53	88.3	6	24	20	1	2	-	-	-	16.4
dry	60	56	93.3	-	-	-	2	4	14	31	5	20.6
Total	120	109	90.8	6	24	20	3	6	14	31	5	18.5

Table 15. Duration of the larval period of 250 second generation larvae kept at different temperatures in glass jars, Ste-Clothilde, Qué., 1952.

Temperatures	No. of larvae examined	No. of larvae surviving	Percent survival	Number of larvae maturing in: 11 days	12 days	14 days	15 days	16 days	18 days	19 days	20 days	22 days	24 days	Average no. of days for larval stage
50-60 deg.F.	50	45	90	-	-	-	-	3	4	3	11	10	14	21.1
60-70 deg.F.	50	50	100	-	-	-	2	2	3	24	15	3	1	19.2
70-80 deg.F.	50	48	96	-	-	2	31	12	2	-	1	-	-	15.4
80-90 deg.F.	50	38	76	1	4	5	17	8	1	2	-	-	-	14.9
90 and up	50	12	24	2	3	6	1	-	-	-	-	-	-	13.0
Total	250	193	77.2	3	7	13	51	25	10	29	27	13	15	15.9

soil surface at different distances from an onion plant to find out the number of larvae that would reach the plants. The number of individuals in each case (eggs and newly-emerged larvae) was 300. This test was carried out in small screen cages covered with fine tulle, kept out of doors on muck soil. For the distance of four, six and seven inches, the cage consisted of a wooden box covered also with tulle (Fig. 11) and kept in similar conditions. Eggs for both tests were collected in an adjacent commercial onion field; the experiment with eggs was carried out from September 4 to 22 (18 days) and consisted of the later generations of the insect, and that with first generation newly-emerged larvae, from June 26 to July 14 (18 days). Results appear in Table 16. The percentage of recovery was still important even when the individuals were placed at seven inches from the plants. When dissecting the onions, several pupae were found as well as dead larvae. When the soil was compacted and very dry (after a good rain and several days of dryness), the larvae were apparently able to burrow and work their way through the soil, though probably with more difficulty.

The percentage of recovery of the individuals was directly proportional to the distance they were deposited from the onion plants.

Table 16. Number of eggs and newly-emerged larvae placed at different distances from onions and recovered when fully mature 3rd-instar, Ste-Clothilde, Qué., 1952.

Cage	No. of larvae deposited	Distance	No. of larvae recovered	Percent recovery	Remarks	Percent pupae formed
A	50	1 inch	42	84	2 dead larvae 9 larvae transformed into pupae	21.4
B	50	2 inches	38	76	10 pupae	26.3
C	50	3 inches	39	78	3 dead larvae 21 pupae	53.8
D	50	4 inches	31	62	2 dead larvae 19 pupae	61.2
E	50	6 inches	11	22	8 pupae	72.7
F	50	7 inches	5	10	4 pupae	80.0
Total	300		166		7 dead larvae 61 pupae	

Cage	No. of eggs deposited	Distance	No. of larvae recovered	Percent recovery	Remarks	Percent pupae
A	50	1 inch	41	82	1 dead larva 7 pupae	17.3
B	50	2 inches	36	72	1 dead larva 7 pupae	19.4
C	50	3 inches	31	62	10 pupae	32.2
D	50	4 inches	33	66	7 pupae	21.2
E	50	6 inches	7	14	1 dead larva 2 pupae	28.5
F	50	7 inches	1	2		0.0
Total	300		149		3 dead larvae 33 pupae	

5. THE DURATION OF THE PUPAL STAGE AND PERCENTAGE OF ADULT EMERGENCE

When fully grown, the larva generally leaves the onion and enters the soil to transform into the pupal condition. The exact position in the ground varies but is usually at a depth of two to three inches and may be close up against the onion or a short distance away. On pulling up an attacked plant the pupae may usually be found in the cavity created.

A test with first generation pupae kept at room temperatures (70 to 80 deg. F.) was conducted to obtain data on the length of the pupal stage of the insect, variation of this duration, pupal mortality and presence of possible parasites. These specimens came from larvae collected during early June in a commercial onion field, which larvae were kept in infested onions during their larval stage in glass rearing jars and transferred into petri dishes containing moistened muck soil during the pupal period. During the last part of June and the first half of July, 1,042 newly-formed pupae were then kept at room temperatures (70 to 80 deg. F.), in the laboratory. An average of 17.4 days was obtained for the pupal period. No parasites were noticed at the emergence of the adults, and about 4.7 per cent mortality occurred, or a few pupae may have undergone the resting stage for a longer time than the ordinary pupal period. Results appear in Table 17. It is obvious that over half of the flies emerged on the 16th and 17th days, and all the others in the range of 15 to 22 days, the same as for the larval stage.

A series of tests was planned and conducted to determine the extent to which soil moisture was a factor in pupal development. Newly-formed first generation pupae were placed in glass rearing jars, kept at room temperatures, each jar containing 50 grams of previously oven-dried organic soil. Water was added to the jars each time it was necessary to give the various moisture contents desired. Each jar received 25 pupae collected during the first half of July, and the whole (soil and jar) weighed and replicated once. Weighings were made each day, during 15 days, and water added to make up losses through evaporation. First generation pupae were taken in preference to other generation pupae in order to avoid the unknown percentage of the second or third generation pupae remaining in the hibernating state.

From the data collected and reported in Table 18, the most favorable conditions for pupal development in muck soil existed when 30 to 50 grams of water were added to the soil during the 15-day period, while in the rearing jars that received 40 to 45 grams of water during the same period of time, almost 100 per cent of adult emergence was registered.

Table 17. Duration of the pupal stage and the percentage of adult emergence of <u>Hylemya antiqua</u> from 1st generation pupae kept at room temperatures (70 - 80 deg. F.), Ste-Clothilde, Qué., 1952.

No. of pupae examined	No. of pupae emerged	Percent emergence	Number of adults emerging from pupae after:								Average no. of days for pupal stage
			15 days	16 days	17 days	18 days	19 days	20 days	21 days	22 days	
1042	994	95.3	46	258	294	151	111	78	54	12	17.43
			4.4%	24.7%	27.2%	14.4%	10.6%	7.4%	5.1%	1.1%	

The soil in the jars that received 50 grams of water was almost saturated, while the soil in the jars with 62.5 grams of water was completely saturated. However, it appeared that within a wide range, soil moisture did not affect the pupal development in that soil type. Extremes of moisture content of the soil had a retarding effect on the development of the pupa and severe desiccation arrested development and killed the pupae. Moderate increases in moisture content of the soil under optimum room temperatures 70 to 80 deg. F. hastened development and increased percentage of emergence up to 100 per cent.

Severe or unfavorable conditions affected certain individuals differently, some being able to withstand these conditions better than others. In the following experiment on moisture content of the soil in relation to pupal development, it was noted that with 150 first generation pupae placed in oven-dried organic soil in rearing jars and maintained in this condition for 15 days during July, at room temperatures (at which time of the season most of the emergence of first generation adults occurred in the field), only 18 pupae (12 per cent) were able to withstand the desiccation. Under optimum conditions there probably exists a normal period of development and under abnormal conditions, a disparity in the development appears.

Table 18. Effects of soil moisture on pupal development of 1st generation H. antiqua pupae kept in glass jars containing 50 grams of muck soil, at room temperatures, Ste-Clothilde, Qué., 1952.

Jar no.	No. of pupae tested	No. of grams of water added to the soil	No. of adults emerged	Percent emergence	Proportion of sexes	
					males	females
1	50	0 0	0 0	0	0 0	0 0
2	50	2.5 2.5	0 0	0	0 0	0 0
3	50	5 5	1 2	6	1 2	0 0
4	50	10 10	4 2	12	1 1	3 1
5	50	15 15	7 9	32	2 6	5 3
6	50	20 20	11 15	52	6 8	5 7
7	50	25 25	14 8	44	4 7	10 1
8	50	30 30	20 21	82	14 9	6 12
9	50	35 35	23 23	92	10 7	13 16
10	50	40 40	25 25	100	10 11	15 14
11	50	45 45	25 24	98	11 17	14 7
12	50	50 50	21 23	88	8 8	13 15
13	50	62.5 62.5	12 16	56	5 7	7 9
Total	650		331		155	176

In the test reported in Table 24, from 300 first generation eggs deposited in screen rearing cages, 280 flies were obtained (93.3 per cent), giving only 6.6 per cent mortality for egg, larval and pupal stages altogether, which is a relatively low percentage. About 52.2 per cent were females.

In the test given in Fig. 14, from 225 first generation pupae collected in a commercial onion field, 203 flies emerged (90.2 per cent), giving 108 males (53.2 per cent) and 95 females (46.8 per cent). These pupae were kept at room temperatures (70 to 80 deg. F.) with a normal soil moisture, in petri dishes containing muck soil.

From field captures with two fly traps (similar to the one described by Lafrance (1950-51), and placed at each end of the onion experimental field, the ratio of male and female was fairly evenly divided, with a slight preponderance in favor of the females. Most of the specimens were identified by the writer. Results appear in Table 19.

To find out the number of pupae of each generation remaining in the dormancy stage for overwintering, the following test was carried out and results appear in Table 20. Pupal collections were taken from each seeding, at three different periods of the season (July 15, September 1 and third week of October) which dates corresponded to the approximate end of each generation of the insect. Samples of

Table 19. Sex proportions of *H. antiqua* adults during the season 1952, Ste-Clothilde, Qué.

Period	No. of specimens collected	Males	Females	Per cent of females
June	243	107	136	55.9
July	198	96	102	51.5
August	133	70	63	47.3
September	51	19	32	62.7
Total	625	292	333	Average percentage 53.2

soil were taken each time from the first five inches of the ground, around the plants, sifted by hand and the number of pupae counted. The three first generation pupae collected on July 15 in seedings where plants were supposed to be injured by first generation larvae, emerged. From nine pupae collected on September 1 (corresponding to pupae of second generation) in the 15 different seedings, only four emerged (44.4 per cent) and the others probably would have hibernated. The great number of pupae collected in the third week of October were not kept and checked for their possible emergence, but probably most would have hibernated.

Table 20. Number of *H. antiqua* pupae collected from soil samples, in the 15 onion seedings, at the end of each generation, during the summer 1952, Ste-Clothilde, Qué.

Dates of seeding	Soil sample in lbs.	July 15 No. of pupae	Sept. 1 No. of pupae	Soil sample in lbs.	3rd week Oct. No. of pupae
May 5	5	0	0	50	0
May 12	5	0	0	50	0
May 19	5	0	1	50	0
May 26	5	0	0	50	0
June 2	5	0	2	50	4
June 9	5	2	0	50	595
June 16	5	1	1	50	20
June 23	5	-	0	50	6
June 30	5	-	0	50	84
July 7	5	-	1	50	88
July 14	5	-	0	50	514
July 21	5	-	3	50	190
July 28	5	-	1	50	27
Aug. 4	5	-	0	50	0
Aug. 11	5	-	0	50	1

Another experiment was carried out during the season with the same purpose and the same procedure and technique were followed. The soil samples, however, were taken once a week during 17 weeks (from June 16 to October 4). A total of 382 pupae were collected during the entire summer in the 15 different seedings, and 149 did not emerge (31.1 per cent). Approximately 5.7 per cent of the pupae were lost during the experiment. Results appear in Table 21. Most of the pupae from which no flies emerged were collected among the last seedings (from July 7 to

August 11) and those corresponded with the second and third generations of the insect and were responsible for the population of the following year. Therefore, about 63.2 per cent of all the pupae collected gave rise to the flies of the three generations during the entire season, while 31.1 per cent went into hibernation.

A total of 109 dormant pupae collected in the last six seedings (from July 7 to August 11) represent 97.3 per cent of the 112 pupae found during the same period in the six seedings. In these six seedings, pupal collections started only on August 16, the time at which the second generation must be in the field and these pupae belong certainly to the second or third generation, since they came from eggs that were laid later than the middle of July (the first eggs collected in the seeding July 7 were found on July 17).

Table 21. Number of pupae collected during the summer 1952 in the 15 different seedings with the three generations approximately delimited, Ste-Clothilde, Que.

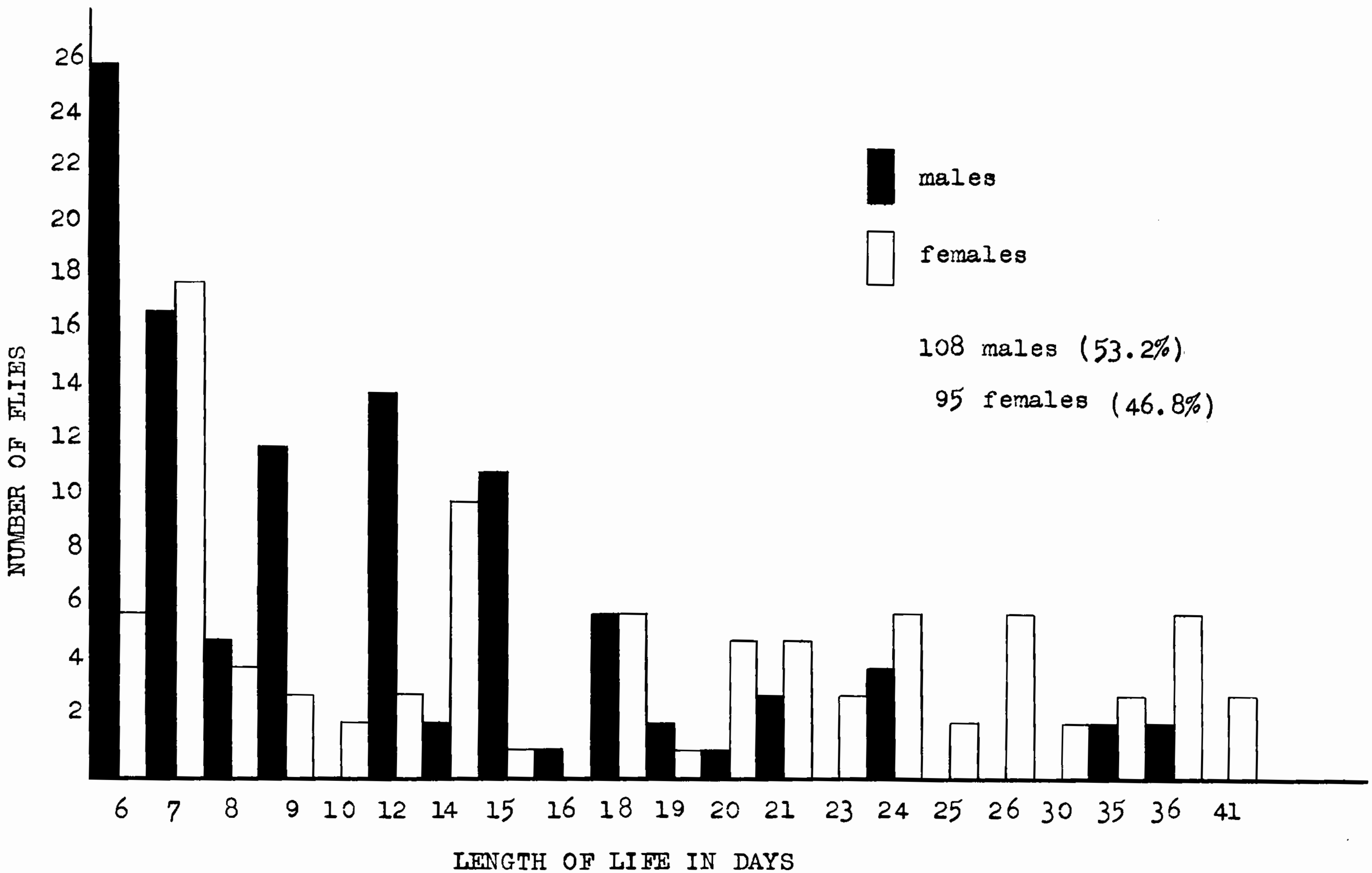
Dates of seedings	June 16	23	30	July 7	14	22	29	August 4	11	16	23	30	September 8	15	22	October 27	4	Total	No. of pupae from which no flies emerged	No. of pupae lost
May 5	6	14	2	4	5	1	0	1	0	0	0	0	0	0	0	0	0	33	0	0
May 12			3	2	17	3	2	0	0	0	0	0	0	0	0	0	0	27	0	0
May 19			1	5	6	8	1	0	0	0	0	0	0	0	0	0	0	21	0	0
May 26				3	1	2	9	1	0	0	1	0	0	2	1	0	0	20	1	0
June 2				1	3	7	5	6	4	0	5	0	3	0	0	0	0	34	0	0
June 9						5	11	5	1	0	0	0	0	1	7	0	0	30	3	0
June 16						1	4	2	3	0	0	3	0	0	0	0	3	16	5	0
June 23							2	1	9	1	4	8	5	0	0	1	0	31	12	8
June 30							1	14	6	3	1	11	4	1	6	0	0	50	19	6
July 7										3	0	7	2	5	5	2	1	25	23	2
July 14											6	0	0	2	4	1	3	16	13	0
July 21												2	1	0	0	6	4	13	10	2
July 28														3	0	7	9	19	16	0
Aug. 4														1	0	14	8	23	23	1
Aug. 11															2	5	17	24	24	3

6. THE DURATION OF THE ADULT STAGE AND THE SEX RATIO

To find out the length of life of the first generation flies under field conditions, a test was carried out with 11 screen rearing cages placed on muck soil out of doors from July 10 to August 23. A total of 225 first generation pupae were collected at the end of June from badly infested onion bulbs and were kept in muck soil in petri dishes. Cages were stocked with flies which emerged during one day, from July 10 to July 18. In the cages, the flies were fed with the artificial diet until their death. The dead specimens were sexed, removed from the cage everyday thereafter to provide more space for the living ones and their respective length of life was noted. In general, death followed several days later. These first generation adults lived from 6 to 41 days. Males lived a shorter time than females. Many eggs were laid during that time and served for the purpose of second generation eggs required in other tests (Table 13). Males and females emerged about the same time, but males were in greater number at the beginning of the emergence. Three females lived as long as 41 days. Results appear in Fig. 14.

The length of life of H. antiqua from egg deposition to death of adult varies from 38 to 96 days under normal moisture and temperature conditions: egg stage two to

Fig. 14. Sex of *Hylemya antiqua* adults reared from field collected larvae and the length of time the adults survived in captivity.



26
24
22
20
18
16
14
12
10
8
6
4
2
NUMBER OF FLIES
males
females
108 males (53.2%)
95 females (46.8%)
6 7 8 9 10 12 14 15 16 18 19 20 21 23 24 25 26 30 35 36 41
LENGTH OF LIFE IN DAYS

eight days (Table 8), larval stage 15 to 25 days (Table 13), pupal stage 15 to 22 days (Table 17) and adult stage 6 to 41 days (Fig. 14). The length of life varies necessarily with the generations of the insect and with the environmental factors.

In the test on the duration of the pupal stage reported in Table 17 with 1042 pupae, 994 adults (95.3 per cent) emerged, giving 471 males (46.9 per cent) and 523 females (53.1 per cent).

Field captures by means of two fly traps similar to the one described by Lafrance (1950-51) and shown in Fig. 15, gave a sex ratio for the entire summer of 53 females to 47 males (Table 19).

Fig. 15. The onion experimental field in June
showing only the May 5 and 26
seedings, with field fly trap.

7. THE NUMBER AND DURATION OF GENERATIONS

To have an approximate idea of the relative lengths of the different generations of *H. antiqua*, a test was carried out with a number of specimens and the data appear in Table 41.

On June 3, one screen rearing cage kept out of doors, received three pairs of adults (three males and three females) for first generation egg laying. These adults had emerged on June 3 from overwintering pupae kept at St-Jean, Qué. during the winter 1951-52 and were brought to Ste-Clothilde, Qué. in order to be sure that they were *H. antiqua* (pure stock) adults and because no overwintering pupae could be found at that time at Ste-Clothilde. The first 17 eggs were found on June 13 and all those eggs hatched on June 17, giving a 100 percent fertility. The eggs had been removed from the screen cage and placed in a petri dish containing a piece of filter paper on which was a small piece of onion. This petri dish received moisture by watering the filter paper and was placed on the soil, out of doors, until all the eggs hatched. After hatching these larvae were removed from the petri dish and were placed on a small onion bulb which was kept in a small glass rearing jar. These larvae were fed with fresh onions, each time it was necessary to renew, in order to rear them in the best natural conditions possible as out of doors, with all the various changes of temperature of days and nights, humidity and precipitation. The glass rearing jar was placed in the soil during the larval stage. The first three pupae were found on July 4, and then 11 other pupae were collected on July 7, and the last three on July 8 and 11. These pupae were removed from the glass rearing jar and transferred into a petri dish containing soil and placed out of doors, on the soil surface. The first generation adults (two males) emerged on July 20, while on July 21, five males and four females appeared. Three days later, three other females emerged, and the rest of pupae were abandoned because the number of adults for the second generation eggs was judged sufficient, and some pupae were found dead of unknown reasons.

This was the first generation from June 3 to July 20, a minimum period of 47 days, giving a preoviposition period of ten days, an egg stage of four days, a larval stage of 17 days and a pupal period of 16 days.

Another screen rearing cage was clear out of everything and muck soil with onion seedlings were put in to rear the second generation of the insect. Data appear in Table 41. On July 21, nine adults known to be of the first generation (four females and five males) were placed in the cage and eight second generation eggs were found on July 30, giving a minimum preoviposition period of nine days. On August 1, 29 eggs were found and seven larvae emerged on August 4, followed by 24 other larvae on August 6. The same procedure of rearing was followed here, as with the first generation. The first three pupae were collected on August 19 and 15 other pupae were found on August 20 and 22. The first adults (one male and two females) of this second generation emerged on September 4; two other males emerged on September 5 and two males and six females on September 8. This was the second generation from July 21 to September 4, a minimum period of 45 days, giving a minimum preoviposition period of nine days, an egg stage of five days, a larval period of 15 days and a pupal stage of 16 days.

Another screen rearing cage was taken to find out if a third generation of the insect existed in that region. From September 4 and 5, five adults (two females and three males) known to be of the second generation were brought together in the cage and fed with the usual artificial diet. Five third generation eggs were collected on September 12, and the next day, seven more eggs were found on the onion plants. On September 15, four eggs hatched and on September 18, six other eggs hatched. When the writer left the Substation on October 5, three pupae were just forming. This was the partial third generation from September 4 to October 4, a minimum period of 30 days to the pupal stage, giving a minimum preoviposition period of eight days, an egg stage of three days and a larval period of 19 days. These pupae would presumably have overwintered.

It will be noted that these duration of generation studies began with eggs collected on June 13. Eggs actually appeared in the field on May 27. Thus, in the field, third generation overwintering pupae may well appear by mid-September (Table 41 for comparison). In the test described above, with cages placed out of doors, the minimal periods for each stage of each generation were taken each time. Then, the minimal time necessary for each generation to complete itself may be as follows: first generation 47 days; second generation 45 days and third generation 30 days (from egg deposition to the formation of first pupae). A comparison of the length of the individual stages of each generation appears below in Table 22.

Table 22. Duration of the individual stages of each generation, Ste-Clothilde, Qué., 1952.

Stages	1st generation	2nd generation	3rd generation
Preoviposition period	10 days	9 days	8 days
Egg stage	4 days	5 days	3 days
Larval stage	17 days	15 days	19 days
Pupal stage	16 days	16 days	8 months
Total	47 days	45 days	30 days - 8 months of over-wintering

The length of the adult stage is not included in these various periods because it was found to vary too much among individuals (see Fig. 14).

From the widely divergent statements mentioned by many workers concerning the various stages of _H. antiqua_ it was thought that results might be unduly influenced by artificial or unnatural laboratory conditions. Therefore, the following experiment was carried in an attempt to keep the insects as nearly as possible under the same conditions as those in the field. The writer was unable, however, to determine exactly the length of life of the adult flies under natural field conditions for the entire summer.

The test consisted of four screen rearing cages that were placed out of doors, on the muck soil where it was believed that the soil moisture and temperature conditions were about the same as in the surrounding earth. Each cage received 75 first generation eggs, collected in a commercial onion field near the experimental plots and placed on the soil of the cages, near the small onions. These onions were renewed periodically and the insects upon hatching were permitted to feed, pupate and emerge without interference. The period of time from egg deposition to appearance of the first generation adults ranged from 32 to 53 days, with an average of 36.3 days. Approximately 93.3 per cent of the individuals emerged; 52.2 per cent were females and 47.8 per cent were males. Results appear in Table 23. From all the specimens emerged, 92.5 per cent emerged within 40 days. Twenty individuals (6.6 per cent) did not reach maturity and were abandoned after the experiment, representing the percentage of mortality.

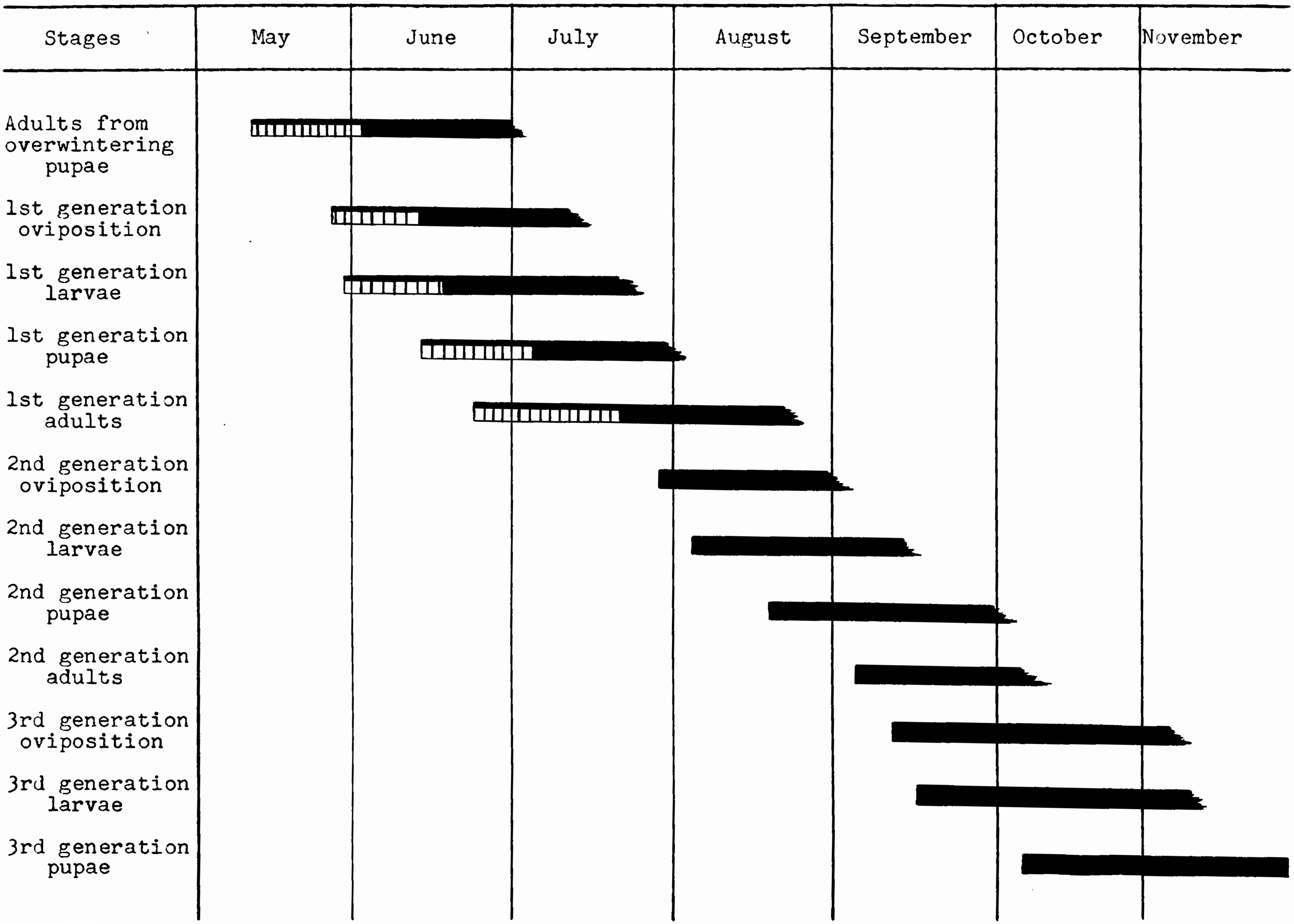
Results obtained during the summer 1952 at Ste-Clothilde, Qué., made possible the life history chart of _H. antiqua_ for southwestern Québec given in Fig. 16. The unbroken dark lines in the chart indicate the duration of the various _H. antiqua_ stages actually recorded in the screen cages in 1952; the dashed lines indicate the possible presence or extension of these stages for the periods included in the field.

Table 23. Number of days required from egg deposition to appearance of 1st generation adults, in screen rearing cages. Ste-Clothilde, Que., 1952.

Cage A			Cage B			Cage C			Cage D		
Eggs deposited on June 11						Eggs deposited on June 13					
Dates flies emerged	No. of flies	No. of days	Dates flies emerged	No. of flies	No. of days	Dates flies emerged	No. of flies	No. of days	Dates flies emerged	No. of flies	No. of days
July 19	48	38	July 13	8	32	July 16	18	33	July 15	3	32
July 20	17	39	July 14	7	33	July 17	41	34	July 18	47	35
July 22	2	41	July 16	45	35	July 21	10	38	July 19	6	36
July 24	1	43	July 18	4	37	July 22	1	39	July 22	4	39
July 31	1	50	July 24	2	43	July 25	2	42	July 24	6	41
Aug. 2	2	52	July 29	1	48	July 30	1	47	Aug. 1	1	49
Aug. 3	1	53							Aug. 2	1	50
Total	72		Total	67		Total	73		Total	68	
	33 males			40 males			30 males			31 males	
	39 females			27 females			43 females			37 females	

Average number of days required for emergence of 1st generation adults: 36.3 days

Fig. 16. Onion maggot life history, at
Ste-Clothilde, Qué., 1952.


Stages
May
June
July
August
September
October
November
Adults from overwintering pupae
1st generation oviposition
1st generation larvae
1st generation pupae
1st generation adults
2nd generation oviposition
2nd generation larvae
2nd generation pupae
2nd generation adults
3rd generation oviposition
3rd generation larvae
3rd generation pupae

8. NATURE AND AMOUNT OF INJURY TO THE HOST

a. Primary injury to healthy onion plants

The appearance of symptoms in infested onion plants depends almost entirely upon the size, number of larvae at work, amount of quickly available fertility in the soil with which the plant can repair damages and finally, the condition of the weather, especially the amount of rainfall. The first symptom of maggot injury to the onion plants is a noticeable checking of their growth and a tendency of the leaves to wilt badly under a hot sun. Soon, the leaves have a sickly bluish color and a few days later, the whole plant becomes yellowish, droops, wilts and dies (see Figs. 17, 18, 19).

Injury by the onion maggot is largely confined to the bulb of the plants it attacks (see Figs. 20 and 21), although occasionally, the maggot will bore into the stem above the ground. Generally, in the seedling onions, damage may occur in the entire plant (Fig. 22) and this is the type of damage caused by first generation larvae early in the growing season. When the eggs of the insect hatch, the young larvae usually enter the leaf near the axil and may feed for some time, the larvae proceed downward, seek immediately the bulb, enter it, tear and injure the tissues with their hook-like mandibles to such an extent, that they mine it out completely and leave only

Fig. 17. Plants showing injury due to onion maggot damage in the experimental plots.

the sheath. This sort of work is readily detected in an onion field for the plants turn yellow and when pulled out, reveal the bulb almost entirely destroyed by the larva. Maggots live on the sap and soon reduce the plant to a rotten mass. They can eat the bulb because the tissue of the onion is rather soft and is still further softened by the decay caused by the larval injury.

It was commonly observed, however, that if the onions once get thoroughly established before the larvae attack them, the plants may show scarcely any indication of the presence of the pest, unless the infestation is outstandingly severe. This is the type of damage caused by second generation larvae which enter the bulb at its period of maximum growth and do of course, the least damage of the three generations of larvae. Infestation of this sort usually occurs in July and August. Owing to the rapid growth of internal bulb tissue, unless in very large numbers, these larvae are not likely to kill the bulb. They may weaken the vitality of the plant and facilitate therefore the infestation of other insects and saprophytic fungi so that the bulb eventually dies as a result of the complication, as was the case with many powdery-mildewed onion bulbs in the experimental plots at the end of the season (see Fig. 23). But very often, when the onions are about 10 to 12 inches high, quite a number of maggots may attain their growth in the large fleshy bulb without indicating their presence by any very noticeable change in the visible portion of the plant. In one bulb, as many as 89 larvae were found. Sometimes, one to 18 larvae have been taken within the hollow stem of a single onion leaf at one to six inches above the soil surface, in big onions, but these larvae may have been forced up by the decomposition of the onion bulb below ground. They did not hatch and develop in the leaves. Under favorable condition of growth, especially at the time the second or third generation larvae are active, if only a few maggots are in the stem, no serious injury results. This has been attributed to the fact that the onion is usually grown in a rich soil from which it quickly repairs the injuries and this is particularly true if the soil contains a high percentage of moisture, as muck soil does. This power of the plant to overcome the ravages of a few larvae is an important factor in the control of this insect. This might be the reason why onion crops in these soils for many years appeared to be less infested by this insect than those in the mineral soils.

The third generation larvae enter the mature bulbs just previous to harvest and storage. They infest the onion at a time when growth has almost stopped and when the larvae of phytosaprophagous insects and the spores of saprophytic fungi are most abundant. The onion powdery mildew follows insect infestation very easily and some of the bulbs are soon reduced to a filmy mass of decay. It has also been observed that the third generation larvae may not emerge until

PLATE III

Figs. 18 and 19. Onion injury on mineral soil
(courtesy of the Science Service,
Bio-Graphic Unit, Ottawa, Ont.)

the onions are ready for storage, and being quite small, do very little damage while the onions are in the field. After the onions are placed in storage these larvae complete their life cycle and together with the above mentioned secondary organisms, destroy the bulb, or reduce greatly its marketable value.

So far as it was observed in this region, H. antiqua begins its activities early enough in the spring to catch the very tender plants, which soon succomb to the attacks of the larvae. This is true when onion seedlings are attacked at any time during the season. A grower may find that on certain hot days the majority of his onions have wilted due to the injury caused by the numerous larvae at work but unnoticed for several days. When this happens, the plants are beyond help even if the maggots are killed at once.

b. Secondary injury to weak or diseased onion plants

To discover if egg laying H. antiqua flies had a preference for diseased (downy mildew) or healthy plants, a test was carried out on September 10 and 11 with the later generations of the insect, since the disease was present in the onion field from mid-August to the end of the season. Approximately 40 plants (healthy and diseased onions) of each seeding were examined for H. antiqua eggs and larvae. Results appear in Table 24. Egg laying flies definitely preferred

PLATE IV

Figs. 20 and 21. Onion bulbs damaged by the onion maggot (courtesy of the Science Service, Bio-Graphic Unit, Ottawa, Ont.).

healthy onions to deposit their eggs on, although they occasionally attacked diseased onions, as it is shown in the Table, where 27 eggs were found on the 109 diseased onions that were infested. The number of healthy onions attacked by *H. antiqua* larvae was about twice as great as the number of diseased onions and the reason seems to be the better growth made by the healthy plants which offered a greater area of plant tissue for egg laying.

Table 24. Number of healthy and diseased onions attacked by *H. antiqua* larvae at the end of the season, in 15 different onion seedings, Ste-Clothilde, Qué., 1952.

Dates of seedings	No. of plants examined	Healthy onions		Diseased onions		No. of eggs found on the bulbs
		Plants attacked	Plants not attacked	Plants attacked	Plants not attacked	
May 5	13	10	0	1	2	0
May 12	40	20	0	12	8	0
May 19	40	17	3	11	9	0
May 26	17	9	1	3	4	0
June 2	40	15	5	10	10	0
June 9	40	19	1	19	1	2
June 16	13	8	2	1	2	1
June 23	40	18	2	17	3	2
June 30	40	17	3	15	5	1
July 7	16	10	0	0	6	0
July 14	40	19	1	7	13	13
July 21	40	16	4	5	15	3
July 28	27	19	1	0	7	0
Aug. 4	40	18	2	0	20	0
Aug. 11	40	20	0	8	12	5
Total	486	235	25	109	117	27
Percentage		48.3		22.4		

Another experiment was carried out during August and September when the disease was present in the onion experimental field and a great many bulbs had started to rot, to investigate damage intensity (number of eggs and larvae present in the onions) in three groups of plants: healthy, rotting and diseased onions. Each observation consisted of examining ten onions of each category and counting the number of eggs and larvae present. To escape the possible attractiveness of egg laying flies for plants offering a greater area of plant tissue, all the onion plants chosen for observation had about the same height (18 inches high). Results appear in Table 25. Flies may oviposit on rotting, diseased or healthy onions, but the latter are by far the most commonly chosen. From such a small number of samples (360 onion plants examined in each category), it becomes dangerous to draw percentage conclusions, but about 54 per cent of H. antiqua eggs and 89 per cent of H. antiqua larvae were found in healthy onion plants. Out of a total of 695 larvae collected during the test in the three categories of onions, 94.5 per cent were H. antiqua. Two other species Eumerus strigatus Fall. (4.1 per cent) and Hylemya brassicae Bouché (1.3 per cent) were occasionally present. The number of individuals of the last two species present in the various categories of onions were not taken into consideration apart from their total number for comparison with H. antiqua.

Table 25. Number of *Hylemya antiqua* eggs and larvae found in healthy, rotting and diseased onions, at the end of the season, Ste-Clothilde, Qué., 1952.

Dates of observations	No. of observations for each category for eggs and for larvae	No. of plants examined	Healthy onions		Rotting onions		Diseased onions	
			eggs	larvae	eggs	larvae	eggs	larvae
August	8	480	85	171	40	16	9	26
September	10	600	143	414	121	12	23	18
Total	18	1080	228	585	161	28	32	44
Percentage			54.1	89.0	38.2	4.2	7.6	6.6

Fig. 22. _Hylemya_ _antiqua_ larvae at work on an onion bulb (courtesy of the Science Service, Bio-Graphic Unit, Ottawa, Ont.).

9. OTHER SPECIES OF MAGGOTS INFESTING ONIONS

To establish what insects were causing damage to onions in this region, a study of the fly species present in onions in the experimental field was carried out by making a series of larval collections (each collection consisted of 25 onions per seeding) about once every week, from June 10 to September 25. The obviously different habits of various species could account for variations in degree of infestation and in the failure of control practices. Results appear in Tables 26 and 27. In addition to larval collections, supplementary collections were made by netting and trapping adults in the onion experimental field. More than 93 individual larval collections were made during the growing season, involving almost 5,000 specimens.

Tables 26 and 27 indicate that at least 39 dipterous species were collected in the experimental onion field, either from growing onions or from captures in two fly traps (Fig. 15), but of these 39 species, only three were actually important in damaging onion plantings in their larval stage (*Hylemya antiqua*, *Eumerus strigatus* Fall. and *Hylemya cilicrura* Rond.). At least 11 of these 39 species were taken as maggots in growing onions (Table 26). The onion maggot *H. antiqua* was by far the most numerous species and definitely caused most of the damage to the Ste-Clothilde grown onions. Except for the

Fig. 23. Downy mildew on onions in August
(diseased onion plants on the right).

seed corn maggot _H. cilicrura_ during June, only relatively small numbers of the other species were found living in growing onions. Approximately 88.8 per cent of the total number of larvae collected were _H. antiqua_ (Table 26). _H. cilicrura_ caused a significant part of all maggot damage to onions during May-June period; the earlier collections had a greater proportion of _H. cilicrura_ than later collections. Maggots of the lesser bulb fly _Eumerus strigatus_, widely known as general scavenger, occurred in great numbers from growing onions during July, August and September. This species is usually not a primary invader of healthy onions, but at least a few cases of primary infestation of slightly mildewed onions were observed in September; _Eumerus strigatus_ larvae were found in these onions without any other species present, suggesting that _E. strigatus_ larvae were primary invaders of these few onions.

The number of _H. antiqua_ specimens collected during the growing season in the various larval collections is considered sufficient to show a reliable picture of its importance relative to the other species present in onion fields. The other species were secondary invaders and relatively few in number.

Table 28 shows that maggot collections were made at weekly intervals from the time of the first attack (beginning of June) when the onion plants were only three to four inches high, until the plants attained 20 inches or more in height and wilting had almost ceased. Unfortunately, no large

Table 26. Dipterous larvae associated with Ste-Clothilde onion growing, 1952.

Species	June	July	August	September	Total
H. antiqua	139	753	1373	1701	3966
E. strigatus	-	14	176	146	336
H. cilicrura	37	13	-	-	50
H. fugax	-	9	20	-	29
H. brassicae	3	6	3	7	19
H. trichodactyla	4	2	5	-	11
Muscina spp.	7	8	-	-	15
Musca domestica	-	5	-	4	9
S. calcitrans	-	4	9	-	13
F. canicularis	1	5	-	-	6
F. scalaris	-	4	5	-	9
Total	191	823	1591	1858	4463
% of *H. antiqua*	72.7	91.4	86.3	91.5	88.8
No. of samples of 25 onion plants	9	32	31	21	93
No. of larvae per 25 onion plants	21.2	25.7	51.3	88.4	186.6
% of total no. of larvae found per 25 onions over the 4 month period	11.3	13.7	27.4	47.3	99.7

number of larvae were secured during the first month of damage (June), due to a lack of time. The data in Tables 26 and 27 are complete in themselves and are highly significant. The specimens reported in Table 26 were collected in the larval stage from wilted or dying onions, while those of Table 27 were in the adult stage, captured from two fly traps, one at each end of the experimental field. The maggots collected were actually responsible for the death of the plants or were associated with maggots causing the onion injury. The comparison of the prevalence of the various dipterous species found is based exclusively on the number of specimens (larvae or adults) collected in the experimental field and the data so far obtained after one season, suggest that in this region, several secondary invaders are occasionally present in infested onion fields.

There is a gradual increase in the number of larvae found per 25 onions with the advance of the season, due to the size of the onion plants which can support a greater number of specimens.

Table 27. Dipterous adults associated with Ste-Clothilde onion growing collected in two fly traps, 1952.

Anthomyiidae

- *Coenosia tigrina* (F.)
- *Fannia canicularis* (L.)
- *Fannia scalaris* (F.)
- *Fannia serena* (Fall.)
- *Fannia* spp.
- *Hylemya* sp. nr. *alaba* Wlk.
- *Hylemya antiqua* (Meig.)
- *Hylemya betarum* Lint.
- *Hylemya brassicae* (Bé)
- *Hylemya cilicrura* (Rond.)
- *Hylemya fugax* Mg.
- *Hylemya inaequalis* Mall.
- *Hylemya trichodactyla* (Rond.)
- *Hylemya* spp.
- *Paregle cinerella* (Fall.)
- *Pegomya lipsia* (Wlk.)

Cordyluridae

- *Orthacheta cornuta* Lw.
- *Orthacheta* sp.

Dolichopodidae

- *Diaphorus* sp. nr. *gibbosus* V.D.
- *Diaphorus* or *Chrysotus* sp.

Ephydridae

- *Scatella picea* Wlk.

Metopiidae (Sarcophagidae)

- *Boettcheria cimbicis* (Tns.)
- *Euravinia l'herminieri* (R.-D.)
- *Phaenicia sericata* (Mg.)

Muscidae

- *Limosia nigrescens* Stein
- *Macrorchis ausoba* (Wlk.)
- *Musca domestica* L.
- *Muscina assimilis* (Fall.)
- *Muscina stabulans* (Fall.)
- *Phormia regina* (Mg.)
- *Pollenia rudis* (Fab.)
- *Scopeuma stercoraria* L.

Ortalidae

- *Euxesta notata* (Wied.)

Syrphidae

- *Elophilus latifrons* Lw.
- *Platycheirus peltatus* Mg.

Tabanidae

- *Chrysops carbonaria* Walk.
- *Chrysops inda* O.S.

Tachinidae

- *Ernestia frontalis* Toth.
- *Eutrixa exilis* (Coq.)
- *Gonia* sp.

Table 28. Species of larvae collected from wilted or dead onion plants, Ste-Clothilde, Qué., 1952.

Species	June			July					August				September				Total
	10	16	23	3	11	18	25	31	7	15	22	28	6	12	19	25	
Hylemya antiqua	33	28	78	86	75	74	148	370	423	144	514	292	568	467	190	476	3966
Eumerus strigatus					1	6	7		11	13	140	12	18	105	2	21	336
Hylemya cilicrura	13	13	11	10	2	1											50
Hylemya fugax								9	9	7		4					29
Hylemya brassicae			3	3	2	1			3				7				19
Hylemya trichodactyla			4				2		5								11
Muscina spp.			7	1		2	2	3									15
Musca domestica							5							4			9
Stomoxys calcitrans						4				2	7						13
Fannia scalaris						2	2				5						9
Fannia canicularis			1			4	1										6
Total	46	41	104	100	80	94	167	382	451	166	666	308	593	576	192	497	4463

Two lots of old fully matured onions, a month after harvest which was on September 5, were examined at the beginning of October for larval infestation and only about 10 per cent of the total number of larvae were *H. antiqua*, the remaining population being *E. strigatus* for the most part and a few specimens of *Fannia canicularis* (L.), *Hylemya fugax* Mg. and *Hylemya brassicae* (Bé). This test involved 334 larvae found in two observations and results appear in Table 29.

Table 29. Dipterous larvae associated with Ste-Clothilde onion growing, 1952.

Dates of collection	*Hylemya antiqua*	*Hylemya brassicae*	*Hylemya fugax*	*Fannia canicularis*	*Eumerus strigatus*	Total
October 2	15	2	3	-	138	158
October 4	19	2	-	6	149	176
Total	34	4	3	6	287	334
Percentage	10.1	1.1	0.9	1.7	85.9	99.7

Examination on September 25 of about 450 newly-rotted plants from the remains of an adjacent onion crop, 224 larvae were found and 92.8 per cent were *H. antiqua*; two other species were present, *E. strigatus* (4 per cent) and *H. fugax* (3 per cent).

10. PREDATORS OF THE ONION MAGGOT

Several species of natural enemies of the onion maggot are present in southwestern Québec and have shown some value in partially checking the pest. The predacious insects collected included many species of carabid, pedilid, nitidulid and staphylinid beetles, one anthomyiid fly *Coenosia tigrina* (F.), one mite *Balaustium* sp. (Erythraeidae, Acarina) and some lace wings (chrysopids). Several times, eggs of these last insects were found upon the lower part of onion plants convenient to *H. antiqua* eggs, although chrysopid larvae were not observed actually feeding on any stage of the onion maggot. While the above list undoubtedly does not include all the species that may prey upon the onion maggot, it indicates that several natural enemies of that economic pest are well established and generally distributed throughout this region. Some of these predators have already been found in the St-Jean, Qué. and Rougemont, Qué. districts a few years ago. Unfortunately, their numbers are so insignificant as compared with the maggots that they seem to exert little influence upon the infestation.

A number of predacious species of coleopterous adults have been observed at Ste-Clothilde feeding actively on the eggs of the onion maggot. At least 19 different species (13 genera) of the family Carabidae have been reared in captivity on the eggs of the three generations of *H. antiqua*. Members of three other families (Pedilidae, Nitidulidae and Staphylinidae) were also found, one genus for each family. One member of the family Tenebrionidae served as check. A list of all the species found follows:

Carabidae (Harpalinae)

Agonoderus comma Fabr.
Agonum carbo Lec.
Agonum placidum Say
Anadaptus baltimorensis Say
Anadaptus discoideus Dej.
Bembidion decipiens Dej.
Bembidion quadrimaculatum L.
Bembidion mimus Hayw. (= *versicolor* Csy, not Lec.)
Chlaenius sericeus Forst.
Dysidius mutus Say
Harpalus compar Lec.
Harpalus pennsylvanicus Deg.
Lebia pumila Dej.
Leiocnemis avida Say
Patrobus longicornis Say
Poecilus chalcites Say
Poecilus lucublandus Say
Pseudamphasia sericea Harr.
Tachyura incurva Say

Pedilidae

Pedilus lugubris Say

Pedilus newmani Lec.

Nitidulidae (Nitidulinae)

Glischrochilus quadrisignatus Say

Staphylinidae (Staphylininae)

Gyrohypnus obscurus Er.

Tenebrionidae

Tenebrio molitor L.

A total of 74 beetles (20 different species altogether) were fed exclusively with *H. antiqua* eggs in glass rearing jars until their death. Each meal consisted of 15 eggs given to each individual; some received four or five meals (60 to 75 eggs) during their adult life. During four months (June, July, August and September), a total of 1,575 eggs were given (105 meals at 15 eggs each), and from these 1,575 eggs, 858 (54.4 per cent) have been eaten by the beetles and 717 eggs (45.5 per cent) remained uneaten in the rearing jars. From the 717 eggs uneaten, 691 hatched, giving 96.3 per cent of fertility. All these beetles were caged under laboratory conditions (70 to 80 deg. F.) in moist soil. Data for each beetle species, i.e. number of days alive, number of eggs given for food, number of eggs remained uneaten and the time at which the eggs were eaten are given below, in Table 30. Most of the specimens were identified to the specific name by the Systematic Entomology Unit, Ottawa, Ont.

Many trials of feeding beetles with exclusively H. antiqua eggs in little screen cages (Fig. 24) placed in soil near the onion experimental field were not very successful. Out of many attempts, seven beetles were fed with 105 eggs (15 eggs to each beetle, but here, all the individuals received only one meal each). From those 105 eggs given, only 39 (37.1 per cent) remained uneaten in the cages and 62.8 per cent of the whole stock of eggs were eaten by the beetles under field conditions. Most of the specimens captured for the test, because of their smallness, escaped from the screen cages and this explains why only seven carabid beetles were recovered for this test. Species marked with an asterisk were also tested in the experiment cited previously with specimens kept indoors. Results appear in Table 31. From the 39 eggs uneaten, 35 hatched, giving 89.7 per cent of hatchability. When the percentage of eggs (62.8 per cent) that had been eaten by the seven beetles kept outdoors is compared to the percentage (54.4 per cent) with beetles kept in glass rearing jars in the laboratory, a large proportion of H. antiqua eggs laid in an onion field are destroyed or eaten by many predators. This reduction of egg

Table 30. Predatory coleopterous species found in the experimental plots kept under laboratory conditions and eating *H. antiqua* eggs during the season 1952, Ste-Clothilde, Qué.

Species	No. of eggs given	Percentage of eggs recovered	Length of life of adults in days'	Time when eggs were eaten	No. of individuals tested
Agonum carbo Carabidae	15	0	18	July	1
Bembidion quadrimaculatus Carabidae	45	6.6	42	June	1
Harpalus compar Carabidae	15	6.6	33	September	1
Bembidion decipiens Carabidae	45	8.8	41	2 A'', S	1
Gyrohypnus obscurus Staphylinidae	15	13.3	15	June	1
Chlaenius sericeus Carabidae	15	20	27	September	1
Pedilus lugubris Pedilidae	30	20	26.5	September	2
Agonoderus comma Carabidae	120	28.3	26.3	J, Ju, S	8
Tachyura incurva Carabidae	180	32.7	24.5	J, Ju, A, S	10
Bembidion mimus Carabidae	225	36.4	21.2	J, Ju, A, S	14
Anadaptus baltimorensis Carabidae	15	46.6	13	June	1
Lebia pumila Carabidae	15	46.6	10	June	1
Pedilus newmani Pedilidae	60	46.6	55	3 A, S	1
Poecilus lucublandus Carabidae	390	46.9	36.5	J, Ju, A, S	12
Harpalus pennsylvanicus Carabidae	45	57.7	22.3	A, S	3
Pseudamphasia sericea Carabidae	30	63.3	13.5	June	2
Anadaptus discoideus Carabidae	30	66.6	13	June	2
Agonum placidum Carabidae	135	71.8	25.7	J, Ju, A, S	4
Glischrochilus quadrisignatus Nitidulidae	135	89.6	14.4	A, S	7
Tenebrio molitor Tenebrionidae (check)	15	100	15	June	1
Total	1575				74
Percentage		45.5'''	27.6'''		

' When more than one individual of a species was tested, an average number of days was determined for the specimens concerned.

'' Two meals (30 eggs) were served to the beetle during August; J = June; Ju = July; A = August; S = September

''' Average for the 20 species altogether.

Fig. 24. Field screen cages for feeding predatory Coleoptera with _Hylemya antiqua_ eggs.

numbers must necessarily reduce larval numbers and hence damage. The writer has observed several times during the course of this experiment, very small beetles eating four to five onion maggot eggs in few minutes, in the same manner as a praying mantis does with grasshoppers. It was also observed, while collecting eggs on onion plants, that several small beetles were very active on sunny days, at the soil surface around the plants, looking for eggs and some of them were seen to eat these eggs in the onion experimental field, after a watch sometimes of 30 minutes. From these preliminary experiments during the season 1952, the presence of those beetles in such a number may certainly play an important part in reducing the population of the onion maggot flies in this muckland region.

However, the only predator that would probably have any importance in this region is the anthomyiid fly Coenosia tigrina; this insect may kill in relatively short time several H. antiqua adults and may thus prevent reinfestation by the following generations by reducing numbers of egg laying females. The writer has often observed the process of ingesting the prey tissues, under the binocular, when C. tigrina specimens happened to consume their meal near the glass side of a collecting bottle. The process may take 20 to 30 minutes when the prey is fairly substantial, like a H. antiqua specimen. The prey was held each time between the captor's fore legs and

Table 31. Predatory coleopterous species found in the experimental plots, kept out of doors and eating H. antiqua eggs during the season 1952, Ste-Clothilde, Qué.

Species	No. of eggs given	Percentage of eggs recovered	Length of life of adults in days	Time when eggs were eaten	No. of individuals tested
* Harpalus pennsylvanicus Carabidae	15	6.6	40	September	1
Leiocnemis avida Carabidae	15	13.3	30	September	1
Poecilus chalcites Carabidae	15	20	31	September	1
* Poecilus lucublandus Carabidae	15	40	31	September	1
Dysidius mutus Carabidae	15	46.6	25	September	1
* Anadaptus baltimorensis Carabidae	15	60	33	September	1
Patrobus longicornis Carabidae	15	73.3	26	September	1
Total	105				7
Average		37.1	30.8		

its head was forced downwards. C. tigrina inserted its proboscis into the thorax through the neck and by rapid up-and-down movements of its proboscis, extracted the tissues from the prey. Sometimes, the labella scraped along the inside of the thoracic wall hollowing out the remains of the tissues. The head was attacked through the occipital foramen when the thorax was quite emptied, and lastly the abdomen, an incision being made near its base and the same movements of the proboscis were repeated until the contents were absorbed. The process was much quicker with smaller and more delicate preys (H. cilicrura) requiring only a few minutes. The contents of the thorax and abdomen appeared to be absorbed through the thoracic opening at the same time. Sometimes, the prey was not killed immediately, but seemed to be paralysed, since it did not walk at all or fly when released by C. tigrina. In each observation, the prey was caught almost instantaneously by C. tigrina the moment it was introduced in the bottle.

VI. DISCUSSION AND CONCLUSIONS

A. COMPARISON OF THE WRITER'S DATA WITH THOSE OF OTHER WORKERS WORKING WITH *H. antiqua* IN DIFFERENT LOCALITIES AND ON DIFFERENT SOILS

1. Preoviposition period

The preoviposition period as determined by the writer varied between 8 to 15 days, but this period is rather difficult to determine accurately due to the artificial conditions of captivity upon the development of the flies. Shade definitely prolonged the period, as well as the first generations of the insect. Food (wild flowers and appropriate diet) and sunlight are the two essential factors for mating and egg laying.

Eyer (1922) mentions a peculiar case where with adults coming from overwintering pupae, the eggs ripened in October and were retained overwinter, a period of six months, in the female abdomen. Kendall (1932) found in 1930, one fly with a preoviposition period of only four days and in 1931, of a number of ovaries examined three days after fly emergence, two had eggs in them that were almost mature.

The following Table gives this preoviposition period as reported by other investigators.

Table 32. The duration of the preoviposition period of H. antiqua as determined by different workers.

Author	Locality	Soil	Preoviposition period
Severin & Severin* (1915)	Wisconsin, U.S.A.	?	12 days and over 16 days
Sanders (1915)	Wisconsin, U.S.A.	?	10 - 14 days
Gibson (1918)	Ottawa region	?	10 - 14 days
Lochhead & Tawse (1921-22)	Montréal Island and Macdonald College	presumably mineral	10 days
Eyer (1922)	Erie county, Penn., U.S.A.	presumably organic	7 - 21 days (average 10 days)
Smith (1922)*	Lancashire & Cheshire, England	?	7 - 10 days
Armstrong (1924)	Montréal Island	?	11.2 days
Baker (1928)	Montréal Island	mineral	10 - 14 days
Kendall (1932)	Guelph, Ont.	?	7 - 11 days (average 7 days)
Perron et al. (1950-51)	St-Jean, Qué.	mineral	12-18 days (summer) 15-30 days (winter)

*Period determined by dissection of female ovary.

It can be concluded that the preoviposition period of this species is not greatly changed by a muck soil habitat. The period appears to be shorter in later generations and longer when specimens are shaded. Both appear to be the result of a temperature effect.

The length of the preoviposition period is particularly important in determining the time to begin chemical control measures each spring. At Ste-Clothilde, fly emergence in relation to natural phenomena may be expressed as follows: flies may be expected in the field just before or when the apple trees are beginning to bloom (this was the case for the season 1952). At this time, the dandelions are just passing the height of their bloom and the lilacs are starting to bloom. The most convenient and reliable of these phenomena to act as a guide for the chemical spray program is when the apple trees are in the pink stage. This means that in normal years the treatment for the onion maggot should start about the time apple blossoms have just fallen and the calyx spray is being applied. For onions sown later which are not above the soil surface at this time, treatment should begin as soon as the onions are sufficiently high (one or two inches) that one can see the rows clearly.

2. The place, time of oviposition and the comparative number of eggs laid by each generation

At Ste-Clothilde, it was found that the preference of egg laying H. antiqua flies was for plants of large size, about 8 to 18 inches high (see Fig. 12). Before the end of June, the leaves and leaf sheaths of onion plants were favored, while after that month, eggs were often laid on the bulbs, or the part of the bulb appearing above the soil. Armstrong (1924) mentioned that during the spring and summer until the plants all attained a size of approximately six to eight inches high, practically all of the eggs laid were deposited in the soil within one or two inches of the plants; at the end of the season (August and September), eggs were commonly laid on the leaves, 8 to 15 eggs sometimes being found on a single plant. In mid-summer, onions injured by first generation larvae were frequently chosen by second generation flies for egg laying. According to this author, these selective habits are important in view of the possible use of volunteer onion growth for controlling the onion maggot during the spring months. The same worker reported from egg counts made at regular three to four day intervals throughout the season that the greatest number of eggs were laid in June and August. At Ste-Clothilde, similar egg counts indicated that the numbers laid in June and September, did not differ very much. A comparison of the results obtained in both regions appears in Table 33.

Table 33. Percentages of the total number of eggs collected during the season, per month, at Montréal (1923) and Ste-Clothilde (1952).

Localities	May	June	July	August	September	Total
Montréal (1923)	2.3	36.1	8.9	39.6	13.1	100.0
Ste-Clothilde (1952)	4.4	50.0	13.4	12.7	19.3	99.8

Ormerod (cited in Bethune, 1881) in England reported that *H. antiqua* eggs were first observed on May 21, laid where the onion leaves divide and the soil was mostly light. The same worker (1881) claimed that the eggs of the later generations, instead of being laid on the leaves which by that time were far above the bulb, were laid either on the onion bulb or on the ground close to it; at that growth stage the bulb was much exposed and in the bulbs examined, the maggots appeared to have entered either quite at the base or a little above it. Fletcher (1885a) at Ottawa, mentioned that the eggs, five or six in number, were laid at the base of the lowest leaves, and in one case, more than 100 eggs had been laid high up on the leaves of an attacked onion in August, but these eggs apparently did not hatch. Ormerod (1881) and Bethune (1889) recommended to cover up the onion bulbs with soil and in such conditions, *H. antiqua* eggs were deposited high up on the foliage and they were dropped on the ground or the newly-emerged larvae were unable to get to their proper feeding place and consequently, perished without doing any injury. Smith (1922) in England, claimed that the eggs were laid on the onion plants in clusters of six or more and sometimes as many as 20 or 30, and were deposited usually under the thin sheathing leaf surrounding the stem or in the crotch formed by the outside leaf and the stem, although some might be deposited in cracks of the soil. The egg attachment was very slight and those found on the soil surface beneath the onion leaves had usually been detached by rains or wind.

At Ste-Clothilde, the writer noticed that <u>H. antiqua</u> flies laid their eggs more frequently in moist, freshly turned soil. This had already been observed by Dustan (1932) at Ottawa, who claimed that sandy soils were always more heavily infested than clay soils, and in these sandy soils, the percentage of moisture content was always greater in the top surface than in clay soils which conditions, however, were reversed at a depth of three to four inches. Smith (1925) in England claimed that, apart from the weather conditions and the presence of shade trees, the texture of the soil was the greatest factor influencing <u>H. antiqua</u> attack to onion crops. Onions grown on loose light soil were always more seriously injured than those grown on heavy clay.

Investigations at the Charlottetown, P.E.I. Entomological Laboratory showed a relationship between the amount of damage caused by root maggots <u>Hylemya</u> species and the soil type in which turnips are grown (Anonymous, 1952). The soil moisture-holding capacity is apparently one factor; in the lighter soils of the same locality, flies emerged from over-wintered pupae much earlier (six weeks) than in the heavier soils. The maggot injury can be substantially reduced when planting is timed according to the soil type; early planted turnips in light soils are usually free of injury; the reverse condition appeared with heavy soils. Similar results were obtained by the writer at Ste-Clothilde in muck soil (considered as a light soil) where early seeded onions were more severely injured by <u>H. antiqua</u> larvae than late-seeded onions. Early seeded onions were definitely more attractive for egg laying because of their size (seedling stage) at the time (June) the first generation <u>H. antiqua</u> larvae are mostly active in onion fields.

Sleesman (1931) in Ohio, claimed that the early planted and thickly seeded onions received a heavier egg deposition and were probably more attractive to egg laying <u>H. antiqua</u> flies. The maximum <u>H. antiqua</u> infestation occurred in onions seeded in mid-April. This seeding averaged 48 per cent infestation as compared to 8 per cent in onions seeded three weeks later. Thickly seeded onions showed an average infestation of 46 per cent and thinly seeded onions gave only 16 per cent.

A comparison of the number of eggs laid during a season of the different generations, reported by Armstrong (1924) and the writer (1952) showed a certain difference in the two localities, particularly for the second generation. Results appear in Table 34.

Another test, however, made by the same two workers, under similar conditions, revealed that results in the two localities did not differ very much; the eggs were collected in a ten feet of onion row for the same period of time during the summer, without any attention to the generations. Results are given in Table 35.

The data presented in the above two Tables are taken from the Table 4 and the individual generations of *H. antiqua* were arbitrarily divided; this is particularly the case for the later generations where September 1 separates the second and third generations.

A comparison of the number of eggs laid during the peaks of egg laying of the different generations on a certain number of onion plants, reported by Kendall (1932) at Guelph, Ont. and the writer at Ste-Clothilde, Qué. in 1952, showed a certain difference in the two localities. Results appear in Table 36.

Table 34. Number of eggs laid during the season 1952, at Ste-Clothilde, Qué. and Montréal Island (Armstrong, 1924).

Locality	Period of egg laying	Number of eggs collected				No. of plants examined
		1st generation	2nd generation	3rd generation	Total	
Montréal Island	from May 30 to Sept. 19	1038	1163	249	2450	10 trap onions
Ste-Clothilde, Qué.	from May 29 to Sept. 27	May 5 seeding 1143	July 7 seeding 207	July 28 seeding 241	1591	10 feet of onion row

Table 35. Number of eggs laid during the season 1952, at Ste-Clothilde, Qué. and Montréal Island (Armstrong, 1924).

Locality	Period of egg laying	No. of observations	No. of eggs collected	No. of plants examined
Montréal Island	from June 11 to Sept. 4	23	408	10 feet of onion row
Ste-Clothilde, Qué.	from June 11 to Sept. 4	May 5 seeding 35	943	10 feet of onion row

Table 36. Number of eggs laid on a certain number of onions at Guelph, Ont. and Ste-Clothilde, Qué., 1952.

Locality	No. of onions examined each time	No. of eggs laid during peak of 1st generation egg laying (June)	No. of eggs laid during peak of 2nd generation egg laying	
Guelph	100	176	1688	
		May 5 seeding	May 5 seeding	July 7 seeding
Ste-Clothilde	25	193	5	105

Results reported in Table 4 and in Table 36 show the incidence of H. antiqua infestation at Ste-Clothilde during the peak of first generation egg laying. During the peak of second generation egg laying on the May 5 seeding at Ste-Clothilde, 5 eggs were laid on 75 onions by first generation adults from July 15 to the end of the season, and on the July 7 seeding (representative of the second generation egg laying), 105 eggs were deposited on August 1. It is evident that injury from second generation larvae at Ste-Clothilde, compared to that of first generation damage was not very important in all the seedings usually made in this muck land region (seedings from May 5 to June 9).

Flies, at Ste-Clothilde, have been taken on the wing every month from May to October where great activity existed throughout the growing season and three generations of the insect appeared. Similar observations were made by Merrill (1951) in the Michigan muck soils, Finlayson (1953) in British Columbia and Perron et al. (1950-51) in Québec Province in a Ste-Rosalie clay at St-Jean, a Yamaska sandy loam at St-Césaire and a St-Jude gravelly sand at Rougemont.

Dodge (1870) claimed that H. antiqua flies begin to oviposit when the onion seedlings are an inch or two high, the time varying with the latitude of the place; in the northern States of the United States, egg laying starts late in May or early June and continues through the season, with peaks in June and July. Eyer (1922) in Pennsylvania, reported that eggs may be deposited on May 25 and oviposition occurs from that date until October, a period of approximately five months; each generation was characterized by a period of maximum oviposition: the peaks of first, second and third generation egg laying which lasted from 10 to 14 days, occurred from June 1 to June 10, from July 15 to July 30 and from September 4 to September 15 respectively. The writer found at Ste-Clothilde that the period of maximum oviposition for the three generations occurred approximately as follows: first generation (May 5 seeding) from June 11 to June 28; second generation (July 7 seeding) on August 1; third generation (July 28 seeding) from September 11 to September 15.

Sleesman (1937) in Ohio, claimed that the rate of H. antiqua larval establishment is correlated with the soil moisture content; the greater the amount of soil moisture in the top inch during the peak of first generation larval infestation, the greater are the chances of larval survival. This contention appeared true at Ste-Clothilde under field conditions and significant increases in maggot populations may be expected in wet season. A severe H. antiqua infestation in muck soil is conditioned by a fine warm weather during the day for a maximum egg laying and a high soil moisture content obtained by heavy rains during the nights.

3. Duration of stages

The experiments carried out in the laboratory and out of doors, and reported here show a range of from two to eight days between egg laying and hatching with an average of 3.5 days; a larval stage of from 15 to 22 days (average of 18 days) for first generation, from 16 to 25 days (average of 19.4 days) for second generation, and from 17 to 25 days (average of 17.4 days) for third generation. Some variations occur with different environmental factors (temperature, soil moisture, etc.) (see Sections 3, 4, 5). Table 37 presents comparable data from the literature.

a. egg stage

The writer found from experiments reported in Section 3 that soil moisture is more important in the survival of the eggs than the temperature, i.e. the duration of the egg stage was longer and the fertility lower when the eggs were kept under dry conditions at room temperatures (70 to 80 deg. F.). At very high temperatures (90 deg. F.), the length of time was about the same, whether the eggs were kept in a dry or moist medium, but the fertility was greatly reduced under dry conditions.

Eyer (1922) claimed that the incubation period was directly dependent on temperature relations (shorter at high

Table 37. Duration of the stages of H. antiqua as determined by different workers.

Author	Locality	Soil	Generation	Duration of stages: Egg	Larva	Pupa	Total
Köllar (1840)	Austria	?	?	-	-	10-20 days	
Slade (1866)	Somerset, Mass.	?	1st	7-12 days	6-8 weeks	overwintering	
Dodge (1870)	U.S.A.	?	?	few days	2 weeks	1½ week	4 weeks
Ormerod (1881)	England	?	?	-	15 days	10-20 days	
Lintner (1882)	New York State, U.S.A.	?	?	within 7 d.	-	-	
Fletcher (1885a)	Ottawa, Ont.	?	?	7 days	-	-	
Caffrey (1912)	Connecticut, U.S.A.	?	?	7-10 days	-	-	
Severin & Severin (1915)	Wisconsin, U.S.A.	?	1st	3-4 days	2-3 weeks	9-16 days	26-41 days
			2nd	-	-	11-13 days	
			3rd	-	-	overwintering	
Gibson & Treherne (1916)	Ottawa, Ont.	?	3rd	-	-	overwintering	
Treherne & Ruhmann (1922)	Vernon, B.C.	?	1st	3-8 days	14-29 days	-	
Lochhead & Tawse (1921-22)	Montréal Island & Macdonald College	presumably mineral	?	3-5 days	2-5 weeks	2 weeks	31-70 days
Eyer (1922)	Erie county, Penn.	presumably organic		2-6 days	15-25 days		
			1st	5.5 days	18-19 days	15-19 days	35-49 days
			2nd	2.7 days	-	8-14 days	32-46 days
			3rd	3.5 days	-	5½-6 months	183-208 days
Smith (1922)	Lancashire & Cheshire, England	?	1st	3-7 days	18-27 days	16-19 days	37-53 days
Armstrong (1924)	Montréal Island	?	1st	6 days	13-16 days	15.7 days	
			2nd	-	16.4 days	19.8 days	
Baker & Stewart (1928)	Montréal Island & Macdonald College	mineral	1st	4.5 days	8-19 days	14-18 days	26-42 days
			2nd	-	9-30 days	-	

temperatures) and moisture seemed to affect the fertility of the eggs rather than the incubation period. These findings as well as his incubation period (two to six days) for first generation eggs found in Pennsylvania are quite in harmony with the writer's data found in the muckland region of Ste-Clothilde.

The high egg fertility record was maintained throughout the summer 1952, at Ste-Clothilde, with a tendency to decrease with the advance of the season; but not all the eggs seemed to maintain such an even degree of hatching, especially when submitted to various moisture and temperature conditions to which they are very sensitive. Such conditions are necessarily present in nature and suggest that a certain percentage of *H. antiqua* eggs are killed, reducing thus the population to some extent. This might explain the claims made by the Ste-Clothilde onion growers that some years, a low percentage of infestation occurs. Egg laying does not seem to have very much to do with onion injury, since a great many eggs are killed when after a long period of dryness and warmth, the soil temperature increases remarkably. High soil temperatures of 85 to 90 deg. F. were sometimes registered, about the level the eggs are laid. Muck soil becomes remarkable hot when the sun strikes it during the middle of the afternoon. This sort of temperature condition occurred very often during July 1952 and may explain why only 87.6 per cent of all the eggs collected during this month in a commercial onion field hatched in comparison with 95.9 per cent in June and 90.6 per cent in August. At least 22 days during that month, the maximum temperature went over 80 deg. F. and for over a week (from July 1 to July 8), the maximum temperature remained over 80 deg. F. For the whole month, the average temperature was 68 deg. F., the warmest month of 1952 (data furnished by the Québec Streams Commission, Montréal).

b. larval stage

The writer's data reported in Section 4 show that the duration of the larval stage was slightly lengthened and the degree of survival slightly decreased with the later generations. The length of time of this period was also lengthened under dry conditions, although the degree of survival of first generation larvae was higher than that under moist conditions. A gradual decrease of the larval period and the percentage of survival were noted with an increase of temperature and a constant soil moisture.

Sleesman (1931) has reported that a hot, dry weather during egg laying and larval periods was responsible for the low rate of *H. antiqua* infestation.

Eyer (1922) claimed that the duration of the larval stage was directly influenced by the temperatures and moisture, but the latter was more important. A decrease in temperature and dry conditions lengthened the period to a considerable extent (22.5 to 25 days) while an increase in temperature with a normal soil moisture shortened the period from 14.5 to 18 days. Smith (1922) found that later generation larvae living in larger and more mature onions seemed to take longer over that stage than the first generation. The same appeared true at Ste-Clothilde in muck soil (see Table 13).

In the field, where changing soil temperatures prevailed throughout the growing season, a variation in the length of the larval period of different individuals is to be expected.

The writer found at Ste-Clothilde that newly-emerged H. antiqua larvae were able to survive when placed at seven inches away from onion plants and the percentage of recovery was two and 10 per cent in each test. Kendall (1932) in Ontario reported from tests in bringing H. antiqua maggots of different ages at a depth of three inches and at different distances away from onions that most maggots from 7 to 12 days old were able to reach onions ten inches away inside of 24 hours; maggots younger than seven days perished, while those older than seven days pupated before reaching the onions.

c. pupal stage

Gibson and Treherne (1916) in Canada and Smith (1922) in England claimed that *H. antiqua* had been recorded as overwintering in the larval stage. Smith and Dickerson (1907) and Eyer (1922) reported that *H. antiqua* may hibernate in the adult stage and with the warmer temperatures of spring, these flies would come out from their winter quarters for egg laying. Eyer (1922) reported that early autumn catches of flies from fly traps placed in onion fields consisted almost entirely of female flies, heavily laden with eggs. Based on this observation and the fact that some flies emerged in October and were observed in onion fields on warm days late in November and flies observed again early in April, Eyer concluded that some individuals hibernated as adults. It is now thought that the insect overwinters in the pupal stage. In Canada, the other stages present in onion fields during the winter are probably killed. Only the pupae buried in the soil survive.

Eyer (1922) mentioned that the first generation pupae were formed four to five inches below the soil surface, usually an inch or two away from the plants, and those of the later generations were mostly found closer to the onion bulb, among its roots. At Ste-Clothilde, the writer found several third generation pupae below the soil surface and either away or very close to the plants. Eyer (1922) also claimed that the duration of the pupal stage was directly influenced by temperatures; a decrease in temperature lengthened the period to some extent (seven to eight days at temperatures averaging 73 deg. F. and 12 to 14 days at 65 deg. F.).

At Ste-Clothilde, it was assumed from data obtained and reported in Section 5, that a relatively high soil water content is essential to a high rate of pupal development.

d. adult stage

The writer found that with first generation flies kept in captivity out of doors and fed with an artificial diet, the length of *H. antiqua* adult life may vary from 6 to 41 days (see Fig. 14) and the life of male flies was shorter than that of the female. Both sexes emerged at the same time. Eyer (1922) found for the three *H. antiqua* generations that the male flies emerged two to three days later than the females and the life of males under field conditions was shorter than that of females, the maximum being ten days (at Ste-Clothilde, some male flies lived during 36 days in confinement in screen cages, reported in Fig. 14). The longest life period obtained by Eyer (1922) was 25 days with female flies fed on molasses and onion agar (preoviposition period of 19 to 21 days, an oviposition period of three days and died two days later).

Smith (1922) in England claimed that flies kept at room temperatures and fed on casein, lived for periods ranging from three weeks to two months. Perron et al. (1950-51) found that with flies kept in captivity, females lived from 60 to 70 days in the winter, compared with 139 days in the summer, while males lived a month or a little longer compared with two to three months in the summer. The remarkable length of adult life of some individuals may be partly attributed to the artificial conditions of feeding in the cages and the absence of natural enemies. The same workers reported from similar tests with this insect in sandy soil, at St-Jean, Qué., carried out in the laboratory and out of doors, that the former conditions were more favorable for adult life than field conditions where strong warm winds with high temperatures and frequent heavy rains were unfavorable. They found that the number of eggs laid, the pre-oviposition, egg laying and adult periods varied greatly between individuals. Smith (1922) reported that the flies refused to feed upon sugar and water in captivity but fed readily upon casein; Perron et al. (1950-51) at St-Jean, Qué., and the writer at Ste-Clothilde succeeded in rearing flies with an artificial diet constituted of molasses-evaporated milk on bread and yeast-water.

Baker (1928) claimed, however, from tests carried out at Macdonald College, Qué., that successful rearing of *H. antiqua* flies has been accomplished with cages supplied with fresh dandelion blooms. Apparently, no other food was necessary and the flies laid freely when onions were introduced. This worker thought this flower was a food plant for the flies alone and recommended the control of the blooming of this weed. Perron et al. (1950-51) at St-Jean, Qué. and the writer at Ste-Clothilde found it necessary to introduce an artificial diet in the screen cages for egg laying purposes.

Eyer (1922) reported the ratio of male and female flies emerged in laboratory cages to be approximately one; the number of females having a slight preponderance. The ratio was about three to one in favor of the female flies from field captures with fly traps; the reason for this may be the longer life period of the females. Similar results were obtained by the writer at Ste-Clothilde.

The writer found from experiments carried out at Ste-Clothilde with adult flies kept in captivity that biological studies and habits of H. antiqua in the field were particularly difficult because of their variable preoviposition period and the length of their life in some cases both causing the overlapping of the various generations and stages of the insect.

4. Number and duration of generations

During the past five years (1949-53), the insect was studied in two districts, St-Jean and Rougemont, Qué. and the first H. antiqua flies to develop from overwintered pupae in the field appeared at approximately the same time, i.e. from May 14 to May 26, time at which the onion seedlings were about one to two inches high. During the same five years, egg laying commenced in the field from May 19 to June 6 until the crop was harvested. A comparison of the various dates of fly appearance and egg laying in spring in these two districts with those found at Ste-Clothilde, Qué. is given in Tables 38 and 39.

Table 38. Dates of appearance of first H. antiqua adults in the field or in laboratory, during 5 years (1949-53), at St-Jean, Rougemont and Ste-Clothilde, Qué.

Locality	Soil	1949	1950	1951	1952	1953
St-Jean, Qué.	clay					
laboratory		May 13	May 24	May 20	May 25	May 16
field		May 15	May 26	-	-	May 17
Rougemont, Qué.						
field	gravelly sand	-	-	-	May 20	May 16
Ste-Clothilde, Qué.						
field	muck	-	-	-	May 19	-

Table 39. Dates of appearance of first H. antiqua eggs laid in the field or in laboratory, during 5 years (1949-53), at St-Jean, Rougemont and Ste-Clothilde, Qué.

Locality	1949	1950	1951	1952	1953
St-Jean, Qué.					
laboratory	May 14	June 3	-	June 3	-
field	May 16	June 6	May 22	-	May 21
Rougemont, Qué.					
field	-	-	-	May 27	May 19
Ste-Clothilde, Qué.					
field	-	-	-	May 27	-

First generation:

The first generation arose from eggs deposited by flies that emerged during the first favorable days of spring from overwintered pupae; H. antiqua flies were first observed in the onion experimental field at Ste-Clothilde on May 19 and in much greater numbers during early June. The period of emergence of those flies was dependent on the weather conditions; they were active from mid-May to mid-June and first generation eggs in the field commenced hatching on May 29. Seedling mortality records were first taken on June 5 (see Table 5). The date when the first eggs are laid may vary considerably with the weather and the seasons. It was observed that H. antiqua egg laying may start late in May (see Table 4) and in normal season (such as the summer 1952), oviposition is well under way during June and early July. The first generation larvae had mostly pupated by the end of June and the first generation adults commenced emerging during early July and were on the wing until mid-August.

Second generation:

The first generation flies started second generation egg laying about mid-July and second generation flies appeared around the end of August until the end of the season, being especially active during September. The approximate duration of a H. antiqua generation, reported in Table 22, was established as 45 to 47 days, including a preoviposition period of nine to ten days. Based on these figures, the first generation adults appeared in the field about July 2 (Table 41) with nine to ten days for the preoviposition period and the second generation eggs were laid around the middle of July. Some second generation individuals arising from belated first generation flies may continue to emerge probably until mid-September, therefore, the four stages of the second generation may be found at any time from mid-July to mid-September.

Cole (1953) in Manitoba claimed that second generation maggots caused considerable damage in August and larvae were still active in the onion field on September 27.

Similar conditions were found by the writer at Ste-Clothilde.

<u>Third generation</u>:

The third generation egg laying may be expected in the early part of September and may continue until about mid-October, although Perron et al. (1950-51) at St-Jean mentioned that it may continue until the third week of November. The third generation larvae pupate by the end of September or early October, although in late seasons, it has been observed in southwestern Québec that they may continue to feed until the early part of November. The third generation of the insect always overwinters in the pupal stage and the adult flies emerge the next spring. The 45 or 47 day-period for the duration of a generation is very arbitrary and merely taken for the convenience of illustrating the various <u>H. antiqua</u> generations which overlapped considerably in the field under natural weather conditions. This was particularly observed at Ste-Clothilde, at the end of the growing season. A comparison of the approximate dates for the presence of the three <u>H. antiqua</u> generations in the field mentioned by some workers, appears in Table 40.

The overlapping of the three <u>H. antiqua</u> generations in the field can only be well delimited in studying the different stages of the insect in confinement in screen cages. This was confirmed by Perron et al. (1950-51) who found that some female flies may live 139 days and lay 706 eggs (80 per cent fertility) during 120 days. However, adults present

Table 40. Approximate dates for the presence of the three *H. antiqua* generations in the field in different localities.

Author	Locality	Generations*		
		1st generation	2nd generation	3rd generation
Eyer (1922)	Erie county, Penn.	from April 25 to June 30	from July 10 to Sept. 1	from Sept. 10 to Oct. 30
Armstrong (1924)	Montreal Island	from May 20 to July 19	from July 19 to Sept. 8	from Sept. 1 to Oct. 30
Writer (1952)	Ste-Clothilde, Que.	from May 19 to July 15	from July 15 to Sept. 1	from Sept. 1 to Oct. 15

* The generations mentioned in the above Table are delimited by the duration of the preoviposition and egg laying periods of a particular generation. When the writer mentions the limits May 19 to July 15 for the first generation at Ste-Clothilde, Que., it is possible that after July 15, many first generation larvae, pupae and adults are found in the field, but it is unlikely that any first generation eggs would be laid after that date.

in the field at any one time are mostly of one generation; in Tables 4 and 5, the limits between the first and second generations were placed with some certainty in mid-July, while those between the second and third generations were put around the beginning of September.

The approximate duration of a H. antiqua generation was mentioned in Table 22 as being 45 to 47 days from adult emergence of one generation to adult emergence of the next to it, including a preoviposition, egg, larval and pupal periods. Similar results were found by Smith (1922) in England.

It must be understood that the following Table 41 is entirely artificial and attempts to give approximate dates for the various appearances of the different H. antiqua stages in some localities. The generations are not sharply divided off as they appear in the Table; some first generation adults may still be emerging at the same time as the second generation adults and first and second or second and third generation larvae may be found together in an onion field.

Armstrong (1924) stated that the first generation, from egg laying to the fly emergence, may last in the field from May 30 to August 20, a period of 82 days altogether; the second generation, from July 20 to October 4, a period of 76 days; the third generation, from September 8 to the end of the season. According to this worker, the second generation egg laying started on July 20; based on this contention and from indoors biological studies at Ste-Clothilde, the writer thought it reasonable to establish the beginning of the second generation egg laying about July 15. Armstrong (1924) obtained from July to October 1923, 81.4 per cent of second generation dormant pupae and all these pupae overwintered; the writer found 97.3 per cent in muck soil in similar conditions. Baker and Stewart (1928) reported that some pupae under the same conditions behave differently and do not take the same length of time for emergence. This appeared true at Ste-Clothilde, in 1952.

The beginning of second generation egg laying reported in Table 4 and 5 was located approximately in mid-July. Severin and Severin (1915) in Wisconsin, U.S.A. found from daily dissections of _H. antiqua_ flies when first generation flies were about to oviposit in onion fields that 55 per cent of the females contained almost mature eggs in their ovaries on July 10.

Table 41. Approximate dates for the appearance of the *H. antiqua* generations in different localities.

Stages and generations	Smith (1922) England	Armstrong (1924) Montréal Island	Finlayson (1953) B.C.	Cole (1953) Manitoba	Writer (1952) Ste-Clothilde, Qué.	
					field	laboratory
Adults emerged from overwintered pupae	-	May 20	May 10	-	May 19	June 3
1st generation eggs	May 28	May 30	-	May 19	May 27	June 13
1st generation larvae	June 1	June 5	-	-	May 29	June 17
1st generation pupae	June 19	June 19	-	June 11	June 14	July 4
1st generation adults	July 18	July 4	July 6	June 25	July 2	July 20-21
Preoviposition period	7 days	-	-	-	-	9 days
2nd generation eggs	July 15	July 19	-	-	-	July 30
2nd generation larvae	July 18	-	-	-	-	Aug. 4
2nd generation pupae	Aug. 5	-	-	-	-	Aug. 19
2nd generation adults	Aug. 24	Aug. 21	Aug. 20	-	-	Sept. 4
Preoviposition period	7 days	-	-	-	-	8 days
3rd generation eggs	Sept. 1	-	-	-	-	Sept. 12
3rd generation larvae	Sept. 4	-	-	-	-	Sept. 15
3rd generation pupae	Sept. 22	-	-	-	-	Oct. 4
3rd generation adults	-	-	Sept. 15	-	-	-

5. Nature and amount of injury

It is well known that an attack by this insect takes place immediately after onions have emerged from the soil surface and sometimes, the larvae are fully grown before infestation is discovered by the onion grower. Larvae penetrate the small onion bulbs and feed in the interior of the plant. Tunnels are soon made and become full of wet brownish rotting matter that keep the larvae bathed in moisture.

One onion seedling is often not sufficient food for a larva and since an onion plant may contain several maggots, the onion is quickly devoured and the next to it is immediately attacked. Larvae will feed in this way until a whole row is cut down for several yards if not checked in their progress. This migratory movement of the larvae from dying to living onions is particularly noticed when the onions are small and they are killed easily. A list of several workers that observed this migratory movement appears in the following Table 42.

H. antiqua larvae were present in southwestern Québec onion fields throughout the entire growing season, but the most important damage to the onion plants occurred in early June. Several field surveys made at that time in the Ste-Clothilde district revealed the onion injury to be patchy and uneven, suggesting that *H. antiqua* adults have a certain preference in the selection of soils for egg laying. It was not uncommon to find the onions in 30 to 40 feet of onion row unmarketable and in one instance, an onion crop was almost totally destroyed before mid-June. Smith (1925) in England and Baker (1928) in Montréal Island also noted the patchy nature of infestations.

Table 42. Migratory movement of H. antiqua larvae noticed by several authors.

Authors	Locality	Soil
Fitch (1866)	New York State, U.S.A.	?
Slade (1866)	Somerset, Mass., U.S.A.	?
Parsons (1869)	New York State, U.S.A.	?
Dodge (1870)	U.S.A.	?
Lintner (1882)	New York State, U.S.A.	?
Fletcher (1885a)	Ottawa, Ont.	?
Fyles (1891)	South Québec	?
Harmer (1927)	Michigan, U.S.A.	muck
Brown (1928)	Indiana, U.S.A.	muck

Smith and Dickerson (1907) claimed that the later generations of H. antiqua larvae proved sometimes as injurious as the first generation when the season is long and the warm weather persistent; such weather conditions prevailed at Ste-Clothilde in 1952. Results reported in Tables 4 and 5 show that the number of eggs and dead onion plants collected at each observation were especially important in the beginning and at the end of the season.

Data obtained at Ste-Clothilde from tests reported in Tables 24 and 25 suggest that there is a direct association between the occurrence of egg laying *H. antiqua* flies and the presence of healthy onions, although they may occasionally attack diseased or rotting onions.

Köllar (1840) in Austria claimed that *H. antiqua* larvae fed gregariously on the various sorts of leeks and onions, especially among the white onions, destroying sometimes whole crops. Lintner (1882) claimed that the onion, in all its stages and varieties, was subject to *H. antiqua* attack, although egg laying flies occasionally selected a limited locality and even a particular onion. Such conditions had already been discovered by Fitch (1866) who reported that a yellowish-wilted onion, little more than half an inch thick, with most of its roots being a soft putrid mass and thronged with all sized larvae (newly-emerged, full grown and some transformed into pupae) probably contained 200 of these maggots living in the wet dirt in contact with the roots. Crevices on the bulb above ground, around the leaf bases, were occupied by about 50 eggs and many empty egg shells from which larvae had recently emerged. The writer, in muck soil at Ste-Clothilde, had several times the occasion to see such conditions present in the onion experimental and commercial fields. Slingerland (1894), however, mentioned that this insect had never been recorded on any other food plants other than onions, although it may exceptionally feed on cabbage and radish plants. Armstrong (1924) carried out experiments in the Montréal region, reported that onion plants affected by the disease onion smut proved attractive to egg laying flies in August.

Hodson (1926-27) in England claimed some definite preference of egg laying Eumerus species flies for onion bulbs already damaged and the reverse condition (healthy onion bulbs) with egg laying H. antiqua flies was observed in muck soil at Ste-Clothilde. However, a certain association exists between rotting onions in muck soil and the occurrence of H. antiqua larvae, the egg laying flies of which are sometimes attracted to moist and decaying onions (many eggs were laid on such onion plants).

The following Table 43 presents comparable data from the literature.

Table 43. Food plants of H. antiqua larvae reported by different workers.

Authors	Locality	Soil	Host plants
Köllar (1840)	Austria	?	different sorts of leeks and onions, especially white onions
Slingerland (1894)	New York State, U.S.A.	?	cabbages, radishes
Severin and Severin (1915)	Wisconsin, U.S.A.	?	fresh manure, radishes
Smith and Wadsworth (1922)	Lancashire and Cheshire, England	?	leeks
Smith (1922)	Lancashire and Cheshire, England	?	shallots, leeks, tulip bulbs, lettuce
Armstrong (1924)	Montréal Island	?	onions affected by onion smut

The southwestern Québec onion crops grown on muck are not particularly injured by onion diseases, the only extensive losses, apart from H. antiqua damage, are caused by injuries and rots during the harvest or storage period of certain years. However, two diseases, the onion smut and the onion downy mildew may occasionally be present in some onion fields, at the end of the season. During the summer 1952, the disease found in the experimental plots, was the onion downy mildew caused by the fungus Peronospora schleideni (Fig. 23). The disease occurred in different forms, sometimes in small patches in the axils or in the other parts of the leaves, extending finally to all the leaves, causing them to dry and die. It was first noticed by the writer when the outer leaves of the onion plants became pale and collapsed, with a violet color; the tips of the other leaves also showed similar symptoms soon after, and a few weeks later, whole tops of many plants died with the effect of retarding the growing and maturing of the onion bulbs and thus, producing a fairly small inferior crop. It is especially important in damp weather, as was the case of the 1952 summer, at Ste-Clothilde, Qué.

In mid-August, when the disease appeared, all the seedings were made and onions of the later seedings were just emerging from the soil surface. A few weeks later, the disease was almost general among all the seedings, attacking onions of all sizes (fully mature onions of the first seedings to onions a few inches high of the later seedings); however, the disease was particularly severe among big onions. Its gradual extension over the onion experimental field did not reduce the crop very much, since onion leaves were mostly affected. It was more obvious in the experimental onion field, because all sized onions were present and due to the wilting action of the onion leaves caused by the disease, it retarded and even stopped plant growth in the later seedings. Onions of the commercial crop sown normally in May were almost fully mature when the disease appeared and damage caused by this disease was insignificant. The disease was especially observed in the onion experimental plots because onion seedlings and fully mature plants were particularly present throughout the summer until mid-October, while normally, onion crops are harvested in the early part of September, the time when the disease started to be important.

Doran and Bourne (1931) in Massachusetts stated that this disease occurred in onion fields at the end of July when periods of rain were interrupted or followed by high temperatures, bright sunlight and drying winds, which conditions prevailed at Ste-Clothilde particularly during August and September.

6. Other fly species infesting onions

About 89 per cent of 4,463 maggots collected in the onion experimental plots at Ste-Clothilde were *H. antiqua*.

Recently, an increased interest by Canadian entomologists in root maggots of garden crops resulted in the collection of much material from all parts of Canada for a check of the possible species present. It soon became evident that great many dipterous species belonging to several families, varying both seasonally and geographically, lived in the roots of many garden crops. Some were phytophagous and caused damage, others were saprophagous and caused no actual damage to the onion plants, since they were already injured by the phytophagous insects. Among the phytophagous species, the onion maggot is certainly the most important insect attacking onions. Brooks (1949, 1951) indicated that sometimes an ecological succession of species is involved and many phytosaprophagous insects are attracted to the root first injured by phytophagous species. As the process of decay proceeds, additional saprophagous species, predators and parasites are lured to the roots and establish, though such conditions are not the same for two adjacent plants.

The following Table 44 presents comparable data from the literature.

Table 44. Dipterous species associated with onion growing as reported by different workers.

Authors	Locality	Dipterous species associated with onion growing	Hosts
Fletcher (1885a)	Ottawa, Ont.	2-3 anthomyiid fly spp. including *H. antiqua*	all varieties and stages of onions
Fletcher (1902)	Ottawa, Ont.	*Eumerus strigatus*	onions
Chittenden (1912)	U.S.A.	*H. cilicrura*, *H. brassicae*	onions
Severin & Severin (1915)	Wisconsin, U.S.A.	*Stomoxys calcitrans*	fresh or decayed onions
Chittenden (1916)	U.S.A.	*H. cilicrura*	onions
Cole (1920)	Oregon, U.S.A.	*Eumerus strigatus*	onions
Collin (1920)	England	*E. strigatus*, *E. tuberculatus*	onions
Curran (1924)	Vineland, Ont.	*E. strigatus*	onions
Wilcox (1926)	Oregon, U.S.A.	*E. strigatus*, *E. tuberculatus*	decayed onions
McDaniel (1928)	Michigan, U.S.A.	*E. strigatus*	narcissus, potatoes, parsnips, iris roots
Seamans (1931)	Alberta	*E. strigatus*	unhealthy onions and sound carrots
Miles (1948)	England	*H. cilicrura*	onions
Matthewman et al. (1950)	Ottawa, Ont.	*H. cilicrura*, *E. strigatus*, *Muscina assimilis*, *Muscina stabulans*, saprophytic Phoridae, predacious *Platypalpus* spp. (Empidae)	onions
Merrill (1951)	Michigan, U.S.A.	*H. cilicrura*, *E. strigatus*, *E. tuberculatus* *Muscina assimilis*, *M. stabulans*	onions
MacNay (1951)	Vernon, B.C.	*E. strigatus*	onions
Anonymous (1952)	Canada	*E. strigatus*, *H. cilicrura*	onions
Cole (1953)	Brandon, Man.	*E. strigatus*, *H. cilicrura*	onions
Finlayson (1953)	B.C.	*E. strigatus*	onions
Merrill & Hutson (1953)	Michigan, U.S.A.	*E. strigatus*	onions growing in muck

Matthewman et al. (1950) reported from root maggot collections in onion experimental fields at Ottawa, that 97.1 per cent of about 1,500 maggots responsible for the wilting and death of the onion plants were H. antiqua and 1.3 per cent were H. cilicrura. These workers reported that onion bulbs kept in storage in October, 40 Eumerus strigatus larvae were collected; this species may be responsible for a large proportion of the late season infestation of the bulbs. Since the earliest collection of this insect was on July 14 it may not attack young onion plants. There is considerable discussion in the literature as to whether or not E. strigatus larvae attack healthy onion bulbs; plants infested with this species are usually in a partial or complete state of decay and putrefaction. It is doubtful, according to Wilcox (1926), if E. strigatus larvae attack healthy onions, since egg laying flies select injured or partly decayed bulbs for their egg deposition; larvae do not migrate from one onion bulb to another as do H. antiqua larvae and when food supply becomes insufficient, development is retarded and larvae either perish or develop into undersized flies after a longer pupal period. This insect is always attracted to weakened onion bulbs whether the trouble is due to nematodes, mites, diseases or the onion maggot. At Ste-Clothilde, E. strigatus larvae were always found in onions previously attacked by the onion maggot, since no larval collections reported in Tables 26 and 28 contained only E. strigatus as larvae.

Doucette (1941) claimed that in the absence of the decay organisms necessary for the proper development of the larvae, there is almost no growth of the young larvae, and they are able to enter only bulbs in which decay or rot has already affected the tissue. These associated organisms are especially present in a moist environment and explain why dry bulbs in storage are often found with numerous eggs on the outer scales but perfectly sound and not suffering from any larval attack. This has been observed several times at Ste-Clothilde, after harvest, with onions kept in storage. However, Doucette (1941) reported that on a few occasions, when the infestation occurred in early September, E. strigatus was definitely the primary and only invader, but this primary cause of infestion was attributed to organism of the disease powdery mildew existing at this period of the summer in those few onion bulbs having only E. strigatus as larvae. This disease appeared in the onion experimental plots at Ste-Clothilde on August 9, but some E. strigatus larvae had already been found on July 11 a month before, suggesting that before August 9, egg laying E. strigatus flies were attracted for their egg deposition only by partly decayed onions caused by H. antiqua injury and later by the onion powdery mildew in a few cases.

Merrill and Hutson (1953) claimed that the predominant species in piles of cull onions when these are first placed in the field either in the fall or early spring was H. antiqua. This species does not breed in old cull piles.

According to these workers, to reduce the number of H. antiqua specimens by destruction of infested cull onions, onions should be disposed of preferably at harvest or before the next spring. From data obtained at Ste-Clothilde and reported in Table 29, the writer found that another species E. strigatus was extremely abundant at the end of the season. The destruction of infested cull onions at harvest proposed by Merrill and Hutson (1953) would also be a means of controlling E. strigatus since this species was found in numbers (see Table 29) in old cull onions at the very end of the season.

H. cilicrura larvae appeared relatively numerous in the onion experimental field during early summer (June and July). This suggests that this species may damage germinating onions in this region. Serious damage by H. cilicrura would alter the timing of recommended control measures. But serious injury from this pest has not been established. Most of the damage to onions appears definitely attributable to H. antiqua larvae rather than to H. cilicrura when the actual number of specimens collected for both species are compared. During larval collections at Ste-Clothilde, many H. cilicrura eggs were found on onion plants in the onion experimental plots. Similar observations were made in England by Miles (1948) who claimed that onions were among the food plants of H. cilicrura.

A number of dipterous larvae breed in onions after *H. antiqua* larvae have caused decay (see Table 26). *Muscina* species larvae (probably *M. assimilis* and *M. stabulans*) were found at the beginning of the summer, increasing gradually with the season, but no specimens were found after July. They are reported by Merrill and Hutson (1953) as being never found to be primary invaders. They regard both species as filth infesting.

7. Predators of *Hylemya antiqua*

A total of 23 predacious species of coleopterous adults have been observed at Ste-Clothilde, Qué. feeding actively on the eggs of the three generations of the onion maggot. The Carabidae are by far the most numerous with 19 different species (13 genera). Members of three other families (Pedilidae, Nitidulidae and Staphylinidae) were also found, one genus for each family. One tenebrionid species *Tenebrio molitor* served as check.

Baker and Stewart (1928) claimed that both staphylinid and carabid beetles were the most important natural enemies of *H. antiqua* and contributed materially to a decrease in numbers of this pest. After some morphological studies with flies, Hobby (1934) claimed that superficially the Anthomyiidae do not seem at all well adapted for the capture of prey, although *Coenosia tigrina* mouthparts had several anatomical adaptations for such habit. Several predators associated with root maggots exist in Canada and Cannon and Read (1953) believe that unfortunately, they do not seem to reduce the populations significantly. The same contention appeared true at Ste-Clothilde with the various predators collected in the onion experimental field. None of these predatory species do enough to actually lessen the *H. antiqua* populations in onion fields, from year to year, because they confine their operations largely to individuals or to only one stage of *H. antiqua* and therefore, they cannot be relied upon to relieve onion growers from active control measures against the pest. As mentioned earlier, the only predator that would probably have any importance in this muckland region is the anthomyiid fly *Coenosia tigrina*. Several specimens of this fly, collected in two fly traps placed at each end of the onion experimental field during the summer, were found to be predators of *H. antiqua* adults. *C. tigrina* was first recorded in Canada by Perron and Lafrance (1952) and the first attempts to rear it were made at St-Jean, Qué. by Perron (1953). If this valuable predator were to become numerous in southwestern Québec, it might well be a valuable control factor for the onion maggot.

The following Table presents comparable data from the literature.

Table 45. Predators of the onion maggot as reported by different workers.

Authors	Locality	Predators	Prey
Fitch (1866)	New York State, U.S.A.	*Chrysopa* sp. larvae	*H. antiqua* eggs
Lintner (1882)	New York State, U.S.A.	*Chrysopa* sp. larvae	*H. antiqua* eggs
Fletcher (1885)	Ottawa, Ont.	staphylinid beetle *Aleochara* sp.	*H. antiqua* eggs
Slingerland (1894)	New York State, U.S.A.	staphylinid beetle *Aleochara verna* *Aleochara* sp.	*H. antiqua* eggs
	Michigan, U.S.A.	acarine *Trombidium* sp.	*H. brassicae* eggs
Poulton (1906)	England	anthomyiid fly *Coenosia tigrina* adults	empid fly *Tachista connexa* Mg.
Caffrey (1912)	Connecticut, U.S.A.	staphylinid beetle mite	*H. antiqua* larvae *H. antiqua* eggs
Severin & Severin (1915)	Wisconsin, U.S.A.	nitidulid beetle *Glischrochilus* (*Ips*) *fasciatus* Oliv. adults and larvae	*H. antiqua* larvae in decaying onions
Eyer (1922)	Erie county, Penn.	carabid beetles: *Evarthrus sodalis* Lec. *Pterostichus lucublandus* Say & *P. sayi* Brulle, *Platynus cupripennis* Say;	*H. antiqua* adults and larvae
		staphylinid beetles: *Aleochara* spp. *Xantholinus* spp.	*H. antiqua* larvae and pupae
Baker & Stewart (1928)	Montréal Island	staphylinid & carabid beetles	*H. antiqua* eggs, pupae, larvae
Evans (1930)	England	anthomyiid fly *C. tigrina*	psychodid fly *Psychoda alternata* Say adults
Hobby (1931)	England	*C. tigrina*	50 dipterous species, the anthomyiids predominating
Anonymous (1952)	P.E.I.	staphylinid beetle, *C. tigrina*	root maggots in turnips
Perron and Lafrance (1952)	St-Jean, Qué.	*C. tigrina*	*H. antiqua* adults
Perron (1953)	St-Jean, Qué.	*C. tigrina*	*H. antiqua* adults

B. CORRELATION OF INJURY, INSECT LIFE HISTORY AND HOST STAGE

From the data collected for the first generation (seedings made from May 5 to June 30 inclusively) and reported in Table 4, it is evident that the infestation of onions seeded May 5 was consistently higher than that of onions seeded on any other dates. This is shown by both the number of eggs laid (Table 4) and the seedling mortality records (Table 5).

Throughout the growing season, all the onions sown in May supported the greatest first generation egg deposition at each collection in comparison with the five seedings made during June. The same was true with the seedling mortality records, except for the May 19 seeding where the number of dead plants (5.5) per collection was lower than some of the seedings made in June.

Based on the percentage of seedling mortality (Table 5) and because onions sown later than middle of June cannot normally be marketable (after June 15, the maturing season is relatively too short for normal size of the bulbs), it appears that onions sown on May 19, June 2 and 9 proved to be less susceptible to maggot attack. May 19 was the most appropriate time for onion seeding in this region to escape *H. antiqua* egg laying. The right time for seeding onions and the type of plant growth have both a great deal to do with the abundance of maggots.

In Fig. 13 are graphed the dead onion plants in collections made on the May 5, July 7 and July 28 seedings chosen because these three seedings were infested mostly by the first, second and third generation larvae respectively. Comparative data for the three different generations appear in Table 46. Data presented in Fig. 13 show the periods of greatest abundance of eggs deposited and dead onion plants in the field for the entire summer, with the three generations of the insect. It is probable that our notes do not show the exact date of collection (May 29) of the first eggs laid in the onion fields. The various dates of finding immature stages of H. antiqua show that larvae are active from June to October (Table 5).

Table 46. Number of dead onion plants collected during the season on 3 different seedings mostly infested by the 1st, 2nd and 3rd generations respectively of H. antiqua, Ste-Clothilde, Qué., 1952.

Seedings	No. of dead onions collected	No. of collections	No. of dead onions per collection	Period of time when the dead onions were collected
May 5 1st generation	334	18	18.5	from June 5 to July 18
July 7 2nd generation	142	14	10.1	from July 18 to Sept. 3
July 28 3rd generation	467	11	42.4	from Sept. 3 to Oct. 10

Peak periods of egg laying and larval activity occurred during the middle of June. This peak of larval activity has been widely recognized throughout the region. It corresponds to the damage done by the first generation larvae. The peak of injury given by the egg laying and seedling mortality records for the second generation occurred about August 2 to 5 (with the representative July 7 seeding for that generation). If we confine our attention exclusively to the number of eggs laid on 25 onion plants and the seedling mortality records taken on 25 feet of onion row per plot, in September and October, we note marked fly activity. The lower damage at this date is then due to the presence normally of very few young and susceptible onion seedlings. During the first and part of the second generation, on the May 5 seeding, a total of 1,148 eggs were collected during a period of about 62 days (from May 29 to July 29) on 25 plants, giving an average of almost one egg per plant per day (Table 4), which is relatively important if we consider the length of the period of observation. Onions from about 18 to 37 days after emergence from the soil (see Fig. 12) have the greatest attractiveness to egg laying flies and such plants are about 8 to 18 inches high. These results were obtained from the 15 different onion seedings.

During three seasons (1950-51-52), it was found in a St-Jude gravelly sand at Rougemont, Qué. that onions sown in May suffered most injury from <u>H.</u> <u>antiqua</u>. In muck soil, during the season 1952, similar results were obtained and are presented in Tables 4 and 5.

Adult flies started to lay their eggs during the last week of May and plants started to be damaged during the first week of June. The injury was obviously done by the first generation of the insect. At the time the first egg laying records were taken, onions sown May 5 were measuring from three to five inches high and were the most suitable plants to be attacked. Onions sown later were less damaged during the same period of time (first generation activity) as they were smaller. The time required for the following seedings to emerge from the soil made these onions much smaller than those sown during the first (May 5) seeding. There was a great difference in the size of onions when the peak of seedling mortality of the first generation occurred about June 16 - 20. Onions of the May 5 seeding were about 13 inches high while those sown during the following seedings were less than seven inches.

Any cull onions present in the field attracted the first flies during the May oviposition period. In fact, the very first eggs were collected on May 27 on cull onions, and two days later, some first generation eggs were collected on the onion experimental plots. Egg laying commenced at the end of May when the onions were only one or two inches high (but very few eggs were laid on such onion plants). At that time, the cull onion growth was four to eight times that of the seedlings, or in other words, the cull onion growth of May was equal to the seedling growth of June and both attracted flies for egg laying. Similar graphed results were obtained from seedling mortality records (Fig. 12) and show that onions from about 25 to 51 days after emergence from the soil are the most susceptible to be injured by H. antiqua larvae, no matter what the generation or the date of onion seeding. Fig. 12 shows also that onions as old as 92 to 95 day-emerged from the soil are susceptible to be injured and killed by this insect, a period of time of over three months.

Onions sown during July were mostly injured by first generation adults laying second generation eggs because these onions were the most suitable plants to be attacked at that time (end of July and beginning of August), being about five to ten inches high. The other onions were only slightly injured because they were at that time too small or too big.

Results from biological studies revealed that second generation eggs are usually laid around the middle of July and most workers agree with that date in various localities where similar experiments were carried out. These two reasons were sufficient to delimit the beginning of the second generation egg laying around July 15. Damage done by late generation (second and third generations) larvae (egg laying and seedling mortality records of August and September) proved to be as injurious as that of the first generation larvae (Tables 4 and 5). However, since normally onions are not sown later than mid-June, damage done by these late generations of larvae remains unimportant. The first six seedings (May 5 to June 9) give an approximate idea of the conditions that prevail normally in this region and the small amount of injury done by the second or third generation is principally due to the remarkable size of these onions. Onions sown later than middle June offer, because of their relatively small size, the same sort of attractiveness to flies laying second or third generation eggs than onions sown earlier do to flies depositing first generation eggs.

A single first generation larva will often kill, while the onions are in the seedling stage, from five to six onion plants, and by the middle of July, the onions are so large that they may support 20 to 50 maggots and still be living, with a sort of bluish-green appearance.

From results reported in Table 8 with the egg stage, it appears that due probably to the hot weather and desiccation, fewer eggs hatched in July than in June and this would explain the small amount of injury found during that month. Note the small number of eggs found in July, reported in Table 4.

Tables 4, 5, 20 and 21 and Fig. 13 show peaks of egg laying, seedling mortality and the number of pupae found in the soil. As would be expected these are successive phenomena.

The life history appears well adjusted to that of the onion. Egg laying is at its highest when plants are in an attractive stage. If the onions are sown very early (as is the practice) they are large enough by the time infestation occurs to avoid 100 per cent seedling mortality, which would of course, be fatal to many of the flies.

C. CONCLUSIONS

The duration of the stages of *H. antiqua* and the number of generations do not appear to be greatly influenced by its growth on onions in muck soil. Egg counts and seedling mortality records bear out the statements of growers that the infestation on muck lands in Québec is of comparatively high intensity. This is probably correlated with extensive onion cultivation over the years. Early onions attract more egg laying females, but suffer less seedling mortality, and in muck soils high in moisture content often fail to show visible signs of infestation. Thus, the grower may not suspect the damage until time of harvest. It would appear that cultural methods of controlling this pest are not promising nor are natural control factors apt to prove adequate.

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