THE LIFE HISTORY AND BEHAVIOR OF THE FLEA BEETLE *Phyllotreta pusilla* Horn IN MANITOBA

A Thesis

Presented to

the Faculty of the Department of Zoology

University of Manitoba

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

---

by

Paul Harold A. N. Westdal

March 1950

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

THE PROBLEM AND DEFINITIONS OF TERMS USED

Flea beetles are represented in Manitoba by several species.* Of those which attack cruciferae, Phyllotreta pusilla Horn** is the most abundant, widespread and destructive. The life history and behavior of the various species are known in general from studies in other localities, but no records of similar studies in Manitoba have been found. The economic importance of P. pusilla in Manitoba makes a biological study particularly important.

I. THE PROBLEM

Statement of the problem. It was the purpose of this study (1) to present an illustrated description of the different life stages; (2) to determine the life cycle of the insect in Manitoba; and (3) to study the behavior and habits of the insect.

Importance of the study. The flea beetle, P. pusilla is one of the most destructive insects attacking

---

* Phyllotreta pusilla Horn
P. vittata (Fab.)
P. robusta Lec.
Psylliodes punctulata Melsh
Epitrix cucumeris Har.

** Phyllotreta pusilla Horn; Chrysomelidae, Coleoptera.

cultivated cruciferous crops in Manitoba. It is a major pest of radish, turnip, and cabbage. In years when the beetles are present in very large numbers, all cruciferous vegetables are damaged and, in addition, non-cruciferous vegetables such as beets may be attacked. Field crops, such as Argentine rape and sugar beets, are often severely damaged when the flea beetle is particularly abundant.

The greatest damage occurs in the spring due to the feeding of the adult on the cotyledons of seedling plants. In addition to this early spring damage, injury to foliage throughout the season causes a reduction in yield and quality of the crops.

The insect is a persistent pest and requires control every year, at a considerable cost to the producer, if high quality crop yields are to be obtained. Large losses have been sustained in the past. For example, in 1948, a commercial planting of twenty acres of cabbage, in the Winnipeg area, was reported totally destroyed by flea beetles. This serves to indicate the importance of basic studies on this pest.

II. DEFINITIONS OF TERMS USED

Flea beetle(s) or beetle(s). Unless otherwise specified, the terms flea beetle(s) or beetle(s), as used in

the text of this thesis, refer to the species Phyllotreta pusilla Horn.

III. ORGANIZATION OF REMAINDER OF THE THESIS

The remainder of the thesis is divided into five chapters. In Chapter II a review of the literature pertaining to the subject is presented. Chapter III deals with the materials and methods used in conducting the study. The description of the life stages of the insect, including a detailed technical description of the mature larvae, is presented in Chapter IV. In Chapter V the life history and habits of the insect are considered. Chapter VI is a summary of the thesis and is followed by a bibliography.

CHAPTER II

REVIEW OF THE LITERATURE

Literature on the genus Phyllotreta. Chittenden (1927)[2] presents a review of the literature on the genus Phyllotreta and in an account of the history of the genus, states that, "The genus Phyllotreta was defined by Foudras in 1859, but was evidently used, presumably as a manuscript name, by Chevrolat much earlier."*

The work of Chevrolat was apparently published by Dejean in his catalogue of Coleoptera and it was Chittenden's[2] view that, "Following the law of priority of publication, Dejean should be credited with the generic name."

In 1889, Dr. Horn[5] in his revision of the genus published the original description of the species P. pusilla Horn.

The taxonomic position of the species within the genus Phyllotreta is uncertain and systematists have been loath to make specific determinations. Chittenden,[2] in discussing the species of Phyllotreta states that:

> . . . The unicolorous species . . . are difficult of definition and of separation by means of tables. Where

---

* Chevrolat, In Catalogue Coleopter Dejean, 1833 (1836), p. 391.

> the antennal joints are so nearly uniform in length some individual difference must be expected, and in small series some difficulty may be experienced in the detection of such characters as the minute apical tubercles in the last ventral segment. While many of these species are quite distinct, at least an equal number are very closely related to some similar one. . . .
>
> In writing of the Halticini in 1889*, Dr. Horn remarked, "The entire tribe is one which presents many difficulties in its study. The characters of taxonomic importance are few, and these are so often interlinked as to make it almost impossible to decide to which priority of importance should be given." Dr. Horn might have gone much further in the discussion of some of the genera and especially of Phyllotreta. Great difficulty is experienced in separating the females of some species from related ones, and even in separating the males from the females of a given species, and there is an almost utter lack of uniformity in the case of the structure of the fifth ventral segment in the males of such common species as pusilla, while the equally common vittata presents characters which are almost baffling without minute study of a large series. . . .

Recently, Mr. W. J. Brown, Systematic Division, Department of Agriculture, Ottawa, has reviewed material from the Prairie Provinces and is of the opinion that the specimens correspond to the published description of Phyllotreta pusilla Horn. Dr. A. P. Arnason, Division of Entomology, Saskatoon, who is familiar with this insect in Saskatchewan also believes the species to be P. pusilla. The author has examined specimens from British Columbia,

---

* Trans. Amer. Ent. Soc., Vol. XVI, 1889, p. 165.

Alberta, Saskatchewan, and Manitoba and in all cases the insects correspond very closely.

Literature on the biology of the species Phyllotreta pusilla Horn. A search of the literature* revealed only one paper, by Chittenden and Marsh (1920),[1] dealing with the biology of this species. In this paper, based on studies conducted in Colorado, various aspects of the biology of P. pusilla are discussed. The work deals with the nature of injury, description of the life stages, distribution of the species in the United States, reports of injury, food plants, seasonal history, life history and habits, natural enemies and control.

No attempt will be made to review the paper at this point. Instead, the results and observations of Chittenden and Marsh[1] will be discussed or compared separately under the appropriate sections of the present study.

---

* Banks, N. Index of Amer. Econ. Ent. 1905-1914.

Colcord, M. Index II-VI of Amer. Econ. Ent. 1915-1939.

Hawes, I. L. Index VII of Amer. Econ. Ent. 1940-1944.

Review of Applied Entomology, Series A. Vol. 1-36: 1914-1949.

Jour. of Econ. Ent. Vol. 4-42: 1911-1949.

U.S.D.A. Bibliography of Agriculture. Vol. 4-13: 1944-1949.

Limitations of previous studies. The previous work on the biology of P. pusilla is limited to a single paper by Chittenden and Marsh (1920).[1] The scope of the study leaves many aspects of the biology of the insect untouched and in some cases, the phases considered are not complete.

There are important similarities and differences in the biology of this species, as reported for Colorado and that found in Manitoba. The variations may be attributable to a difference of response of the species to the different climatic conditions. However, there may also be two races represented. These variations are of sufficient importance from the standpoint of economic control to warrant investigations under Manitoba conditions.

CHAPTER III

THE MATERIALS AND METHODS

Two methods were employed in the study of the life history of the insect. In method I, rearing from egg to adult was carried out in successive steps entirely under laboratory conditions, whereas, in method II, the rearing was done in outdoor cages.

I. METHOD I

Oviposition cages. Two-quart glass sealers were employed as oviposition cages. The open end of each sealer was covered with fine mesh cheese cloth, held in place by an elastic band. Radish and turnip seedlings were transplanted into salve tins containing soil and these were placed in the sealers to provide a suitable place for oviposition as well as an adequate food supply. In addition, 1-inch lengths of glass tubing, stoppered at one end with a cork and at the other with absorbent cotton, were filled with water and placed in the sealers to provide a source of water for the beetles.

The flea beetles used were collected from a field plot of radishes, etherized just sufficiently to permit identification and ease of handling, and twenty introduced into each sealer.

This type of cage proved satisfactory for the purpose of obtaining sufficient eggs for the study.

Incubation. Considerable difficulty was encountered in obtaining a satisfactory method for the incubation of the eggs. During the first trials, eggs were placed in petri dishes, on blotting paper moistened with iodine water.* The petri dishes were placed in a rearing cabinet held at constant humidity of 65 per cent and at a temperature of 86°F. Under these conditions the eggs dessicated and mold formed. However, satisfactory results were obtained with each of the following three methods.

1. Eggs recovered by floatation (see page 14) from soil which had been exposed to flea beetles eleven days previously in outdoor rearing cages, were placed on moist blotting paper in a petri dish. These were kept at room temperature until they hatched.

2. The salve tins used for oviposition were removed from the sealers and the soil kept moist but otherwise left undisturbed for nine days. At the end of this period, eggs were recovered by floatation and placed on moist blotting paper in petri dishes. As in the first method, these also were kept at room temperature until the eggs hatched.

---

* Two drops of 5 per cent iodine solution per quart of water.

3. The method of Searls (1928)[6] was also employed. This involved the use of cells made from celluloid tubing 1-inch in diameter cut in 1-inch lengths. These were stoppered at one end with a 1/8-inch thickness of plaster of paris. Freshly oviposited eggs obtained from the surface of the soil in the salve tins were placed in these cells and the cells in turn placed, open end upward, in moist sand to maintain a fairly constant moisture content. Incubation was carried out at room temperature. (Fig. 1, page 13.)

Methods 1 and 2 were essentially the same, except for the source of the eggs, and involved leaving the eggs in the moist soil during the greater part of the incubation period. This overcame the previous difficulties. The problem of dessication was overcome in method 3 but mold formation was not entirely avoided.

All three methods of incubation proved workable. Method 1 simulated natural conditions more closely than methods 2 and 3, but method 3 was simpler and rendered possible daily observation of the eggs.

Larval, prepupal, and pupal rearing. The method for larval rearing, in the laboratory, was also taken from Searls.[6] Plaster of paris was poured into petri dishes to form a thin layer over the bottom of the dish. Seedling cabbage, radish, or turnip plants were placed in the dishes, allowing the leaves to protrude over the side of the dish.

This was covered with blotting paper cut to fit inside the dish and the whole thoroughly moistened. To avoid excessive evaporation, pieces of glass were placed over the dishes. The food supply was changed daily or as required. The larvae were placed on the roots of the seedling plants and held at room temperature. (Fig. 2, page 13.)

The chief difficulty encountered, in rearing the larvae on the roots of seedling plants in petri dishes, was that newly-hatched or first instar larvae failed to establish themselves under these conditions. No difficulty was experienced in rearing larvae which had attained the second instar before being placed in the rearing dishes. These larvae were obtained from the outdoor rearing cages.

As the larvae approached the prepupal stage, they entered small holes formed by air bubbles in the plaster of paris, where they remained throughout the prepupal and pupal periods. Upon completion of the pupal period, the adults emerged from these holes or depressions.

II. METHOD II

This method was conducted under outdoor conditions. Flea beetles were confined in cages forced into soil to a depth of 4 inches over cruciferous plants, grown in flats. The cages were of original design constructed of tin, celloglass screen and wood. The base of the cage, 4 inches

square and 4 1/2 inches in depth, was made of tin. A 7 inch length of celloglass screen was attached to this base. A 4"x4"x1" piece of wood, containing a central hole 1-inch in diameter fitted with a cork stopper, formed the top of the cage. Holes were punched in appropriate areas of the celloglass screen to permit air circulation. (Fig. 3, page 13.)

The initiation of this method of rearing was delayed until June 12, due to the inadequate growth of the host plants, namely, cabbage, radish, and turnip. When the plants had attained an appropriate size, the cages were forced into the soil over the growing plants in a way such that the three varieties of plants were represented in each cage. Twenty beetles were introduced into each cage and allowed to remain for a period of 24 hours. The development of the insect was then followed by examining the soil from successive cages at intervals. The larvae recovered during these examinations were preserved in KAAD* for subsequent studies.

---

* KAAD - Kerosene 1 part
Alcohol (ethyl) 9 parts
Acetic acid (glacial) 1 part
Dioxane 1 part

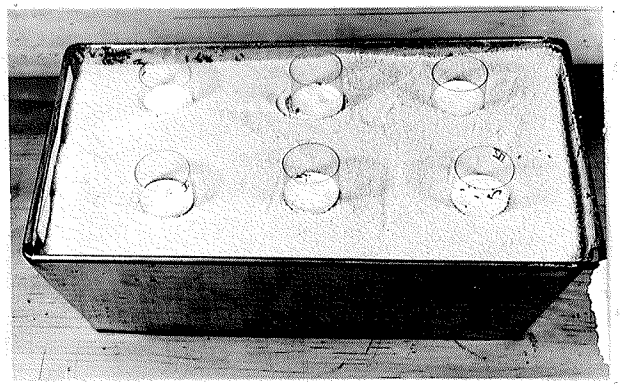


FIGURE 1. INCUBATION CELLS

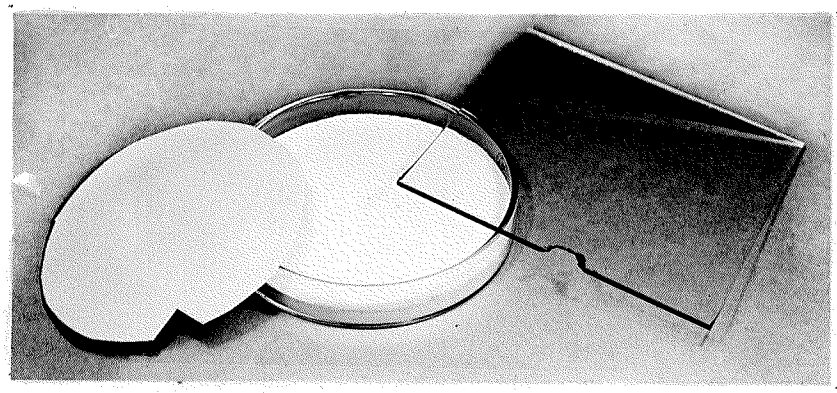


FIGURE 2. LARVAL REARING DISH

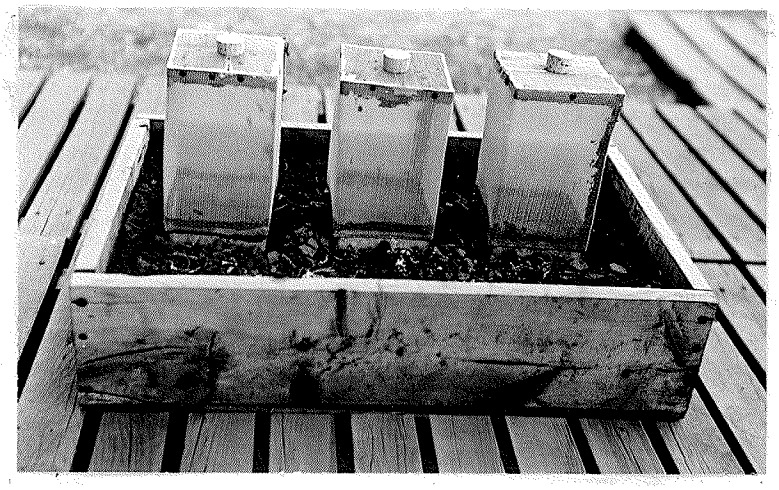


FIGURE 3. OUTDOOR REARING CAGES

III. SOIL SAMPLING METHODS

Microscopic method. Soil and plants, taken from the field, were examined for eggs under a low power dissecting microscope in the laboratory. Due to the minute size of the egg, all the soil as well as the plants had to be carefully examined. This proved to be too time-consuming to render the method practicable and hence it was discarded.

Floatation method. A floatation method was employed with good results to recover eggs from soil samples. Two solutions were used: one was a saturated solution of sugar in water, the other was a salt solution made up to a specific gravity of 1.2.

The method was as follows: a quantity of soil was added to the solution; the mixture agitated; the soil particles allowed to settle out; the solution together with the floating organic material decanted into a Buechner funnel; and the solution filtered. The filter paper was then examined for eggs under a low power dissecting microscope.

Both solutions were effective. The sugar solution floated out eggs and larvae without apparent detriment to either, since the eggs remained viable and the larvae survived. The sugar solution was later discarded in favor of a salt solution because of the greater ease of handling

and the lower cost of the latter. In three tests using a known number of flea beetle eggs, an average of 92 per cent recovery was obtained with the salt solution. No check was made to determine whether it affected the viability of eggs or the survival of larvae.

The floatation method was considerably more rapid and probably more accurate than searching through the soil directly, but was, nevertheless, slow and limited the number of samples which could be examined.

Method for recovering larvae, prepupae, and pupae from soil. To recover larvae, prepupae, and pupae the soil was examined directly with a probe.

CHAPTER IV

DESCRIPTION OF THE LIFE STAGES

I. THE EGG

The egg (Fig. 4) is elongate oval, circular in cross section, quadrate in vertical section. It measures 0.38 mm. to 0.46 mm. in length and 0.18 mm. to 0.25 mm. in diameter, and is yellow in color. The chorion has no reticulation.

II. THE LARVA

Larval instars. The first instar larva averages 0.90 mm. in length by 0.12 mm. in width on emergence from the egg; the head capsule width is from 0.12 mm. to 0.13 mm. The newly hatched larva is dirty white in color, the head and anal plate turning brown within a short time. Following the first molt the larva becomes white in color except for the head and anal plate. The second instar larva is about 4.5 mm. in length and the average head capsule width is 0.175 mm. The third or last instar larva (Fig. 5) averages 6.68 mm. in length by 0.56 mm. in width, and the average head capsule width is 0.264 mm.

Mature larva. The mature larva is white in color except for the sclerotized parts, i.e., head and anal plate which are brown in color. The head (Fig. 6, page 21) is

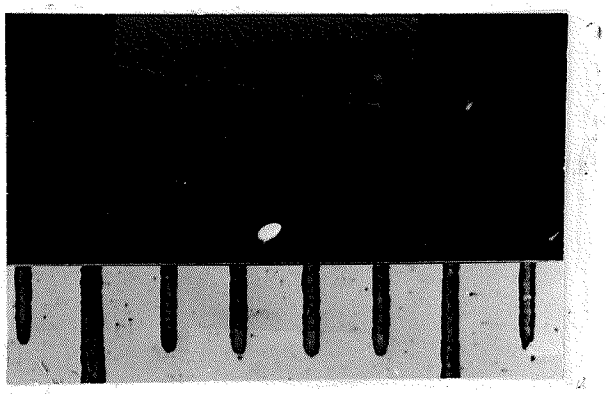


FIGURE 4. FLEA BEETLE EGG

FIGURE 5. FLEA BEETLE LARVA

small and nutant. The labrum (l) is slightly rounded anteriorly with four setae on each side. The lateral setae are long and strong and placed medially. The central setae are somewhat smaller and medially situated. The remaining setae are short and weak and situated on the anterior edge of the labrum. The clypeus (clp.) is transverse with a single row of setae, three on each side. They are uniform in size. The frons (fr.) is distinct from the epicranium (epc.), the two separated by the frontal suture (f.s.) (the ecdysial line and frontogenal sulcus of Duport[4]). The frons has three pairs of setae; anterior, medial, and posterior. The epicranium has a number of setae. Ocelli are absent. The antenna (Fig. 7, page 21) is short and is attached to the cranium by a large membrane (m). It is two-jointed. The basal joint is ring shaped and bears three setae, the posterior one being strong and rounded at the tip. The mandible (Fig. 8, page 22) has five teeth, the median one being larger than the others. The proximal tooth is small and inconspicuous. There are two long setae near the base on the outer margin of the mandible and three setae at the inner margin near the base. Of these latter the two anterior are very strong while the third is short and weak. The maxilla (Fig. 9, page 22) has a large and broad lobe (l) which on the inner margin carries a series of five rather strong stiff setae and at the end six smaller setae in a

ring around a papilla (p). The maxillary palpus is conical and three-jointed and the terminal joint is longer than the two others. The second joint bears a single seta. The labium proper (e) is transverse and is posteriorly limited by a thinly sclerotized arch. It bears one short seta on each side. The labial palpus is short and two-jointed. The basal joint bears a pair of short setae, anteriorly and posteriorly situated. The ligula is lacking. The mentum (mt.) and submentum (smt.) are separated. Together they form a large membranous rounded region between the maxillae. The submentum bears an anterior and posterior pair of setae.

The thoracic segments have a slightly sclerotized tergal shield and dorsally each segment bears four hairs on each side.

The legs (Fig. 10, page 23) are five-jointed, short, and all equal. The fifth joint or "claw" is hook-shaped, moderately curved, and pointed. There is a large membranous empodium (e) present. Segments, one, three, and four each bear several strong setae. The second segment bears a single weak seta.

The first to eleventh abdominal segments (Fig. 11, page 23) are cylindrical and separated by intersegmental membranes (i). Dorsally each segment is divided into three

folds, the anterior (1) bearing three short setae on each side, the second (2), one on each side, and the third (3), three on each side. The pleural area (Fig. 12, page 24) bears two sets of two setae. Ventrally the segment has two transverse folds (v, w). The anterior fold bears one seta on each side and the posterior bears two setae on each side. At the base of all the setae there are very inconspicuous, smooth and shiny, rounded, thinly sclerotized plates. The twelfth abdominal segment (anal plate) (Fig. 13, page 24) is spatulate and posteriorly rounded. The extreme posterior tip continues into a small pointed outgrowth, which is sharply curved dorsally. The segment has two pairs of long setae on its dorsal surface, one pair anteriorly and the other pair posteriorly placed. Laterally and posteriorly there are five shorter but well developed setae on each side. The thirteenth abdominal segment is retractile, cylindrical and long, with the character of a locomotory organ.

The spiracles (s) are small and ring shaped. There is one mesothoracic pair and there are eleven abdominal pairs present.

III. THE PREPUPA

The body is short and thick and averages 3.27 mm. in length by 0.72 mm. in width; it is white in color except for

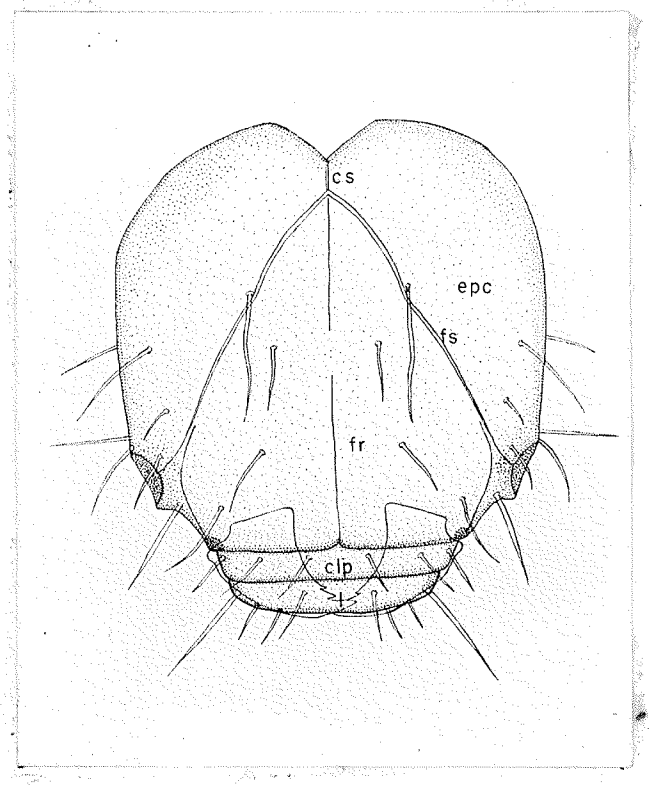


FIGURE 6. HEAD OF MATURE LARVA

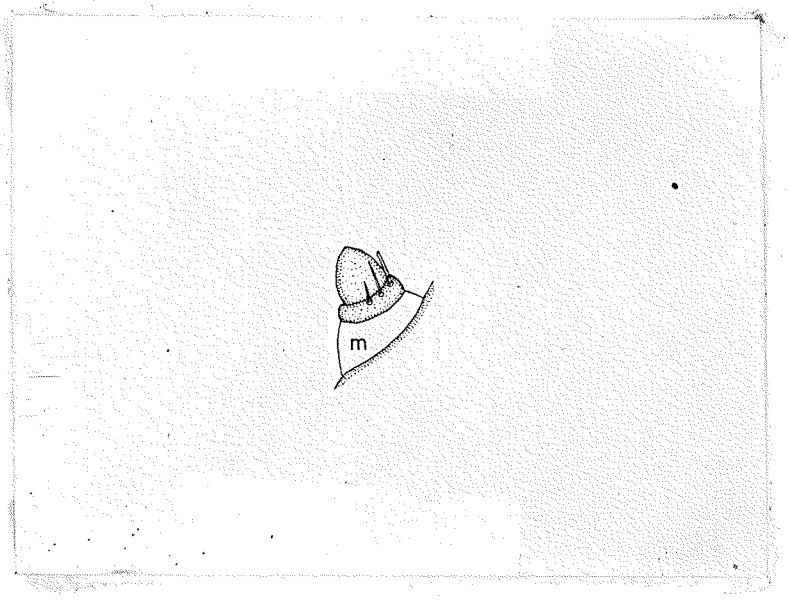


FIGURE 7. THE ANTENNA

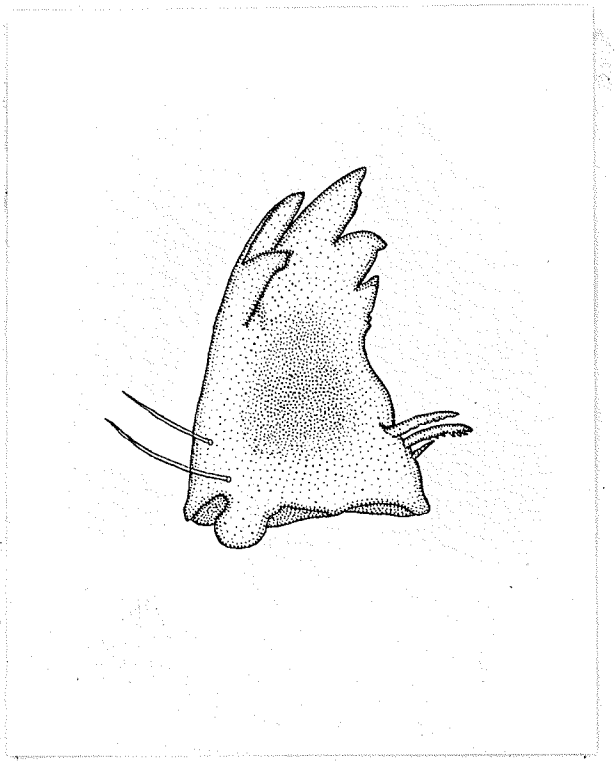


FIGURE 8. THE MANDIBLE

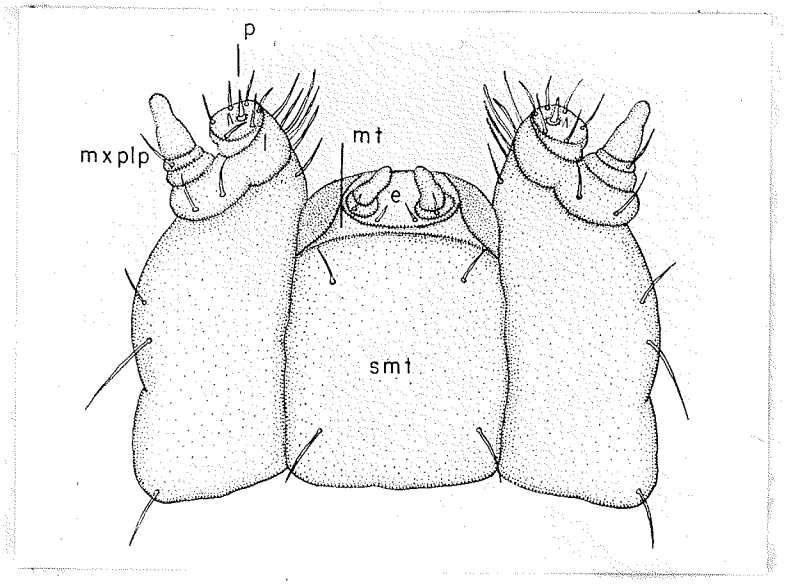


FIGURE 9. THE VENTRAL MOUTH PARTS

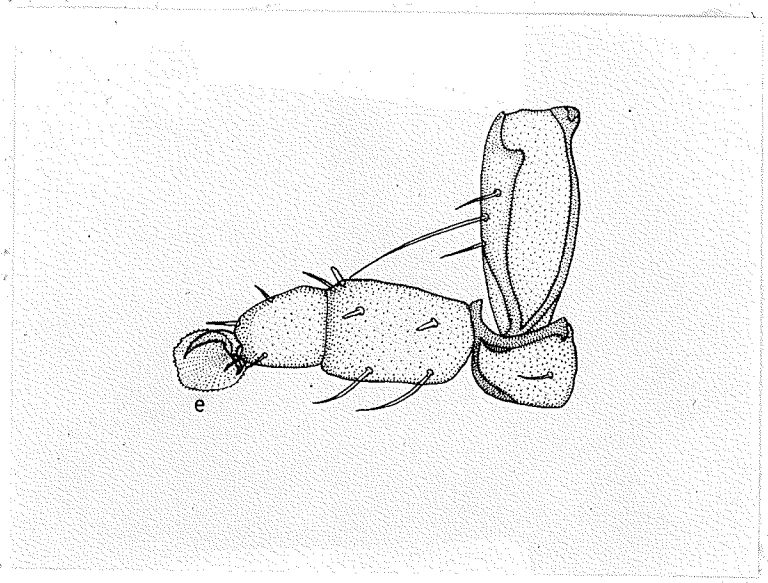


FIGURE 10. THE LEG

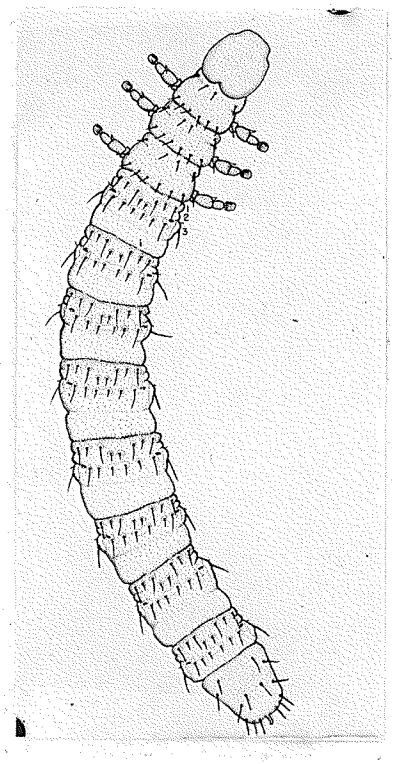


FIGURE 11. DORSAL VIEW OF LARVA

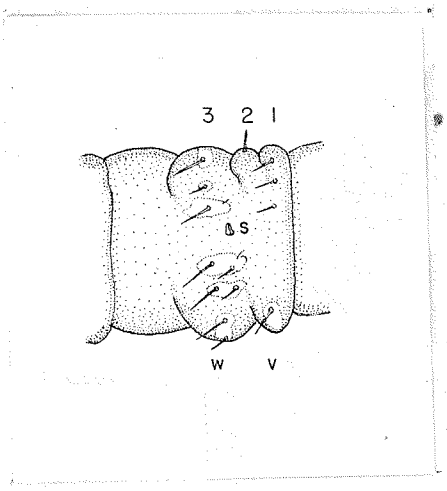


FIGURE 12. ABDOMINAL SEGMENT (LATERAL VIEW)

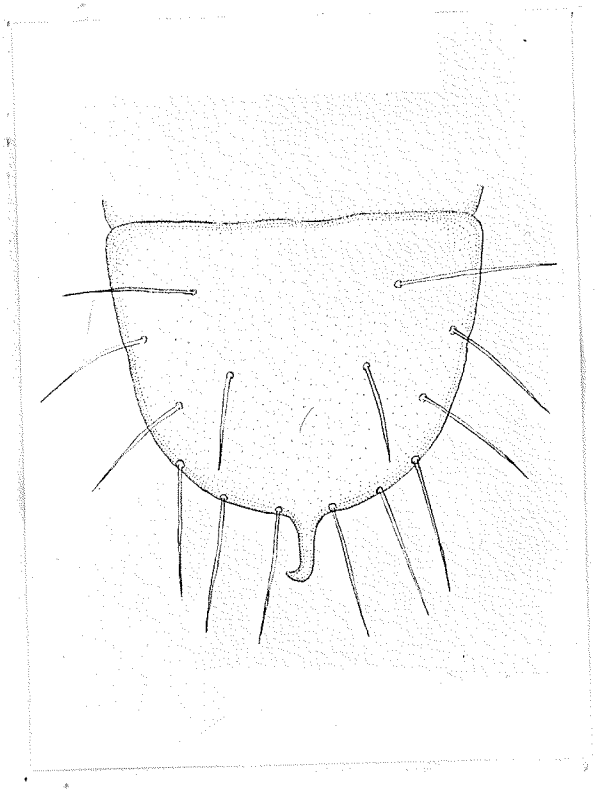


FIGURE 13. TWELFTH ABDOMINAL SEGMENT (DORSAL VIEW)

the head and anal plate (Fig. 14, page 27).

IV. THE PUPA

The pupa (Fig. 15, page 27) measures about 2.41 mm. in length by 0.96 mm. in width; it is uniformly white in color.

V. THE ADULT

The following is the original description of the species by Dr. Horn as taken from Chittenden (1927):[2]

Phyllotreta pusilla Horn

> Elongate ovate, strongly depressed, dorsum distinctly cupreous or aeneous, exceptionally black or nearly so. Antennae slender, half as long as the body, piceous, joints two and three paler. Head scarcely visibly punctate. Prothorax very narrow, less than twice as wide as long, widest at middle, sides arcuate, apex slightly narrower than base; disc moderately convex, punctures fine and closely placed. Elytra wider than the prothorax, humeri obtuse, punctation a little coarser than that of the prothorax, closely placed, very little finer near the apex, but less dense. Pygidium inflexed and visible from ventral surface. Ventral segments black with cupreous or aeneous luster, sparsely punctate, not pilose. Femora black with aeneous luster, tibiae and tarsi dark brown.
>
> ♂ - Antennal joints two, three, four subequal in length; five and six slightly longer, but not much wider; seven to eleven each about twice as wide as two, forming a five jointed club. Fifth ventral segment impressed at the sides, more or less concave at the middle, distinctly linearly impressed at the apex, the impression either very short and narrow or longer and narrowly subdeltoid, with a small rounded, or, exceptionally, a transverse tubercle each side, usually somewhat closely placed together.

♀ - Antennal joints about as in male. Fifth ventral segment impressed at the sides, feebly concave, not linearly impressed at the middle and with a minute tubercle each side, more closely placed together.

Length 1.2 - 1.7 mm.; width 0.6 - 0.8 mm.

A photograph of the adult is shown. (Fig. 16, page 27.)

FIGURE 14. THE PREPUPA

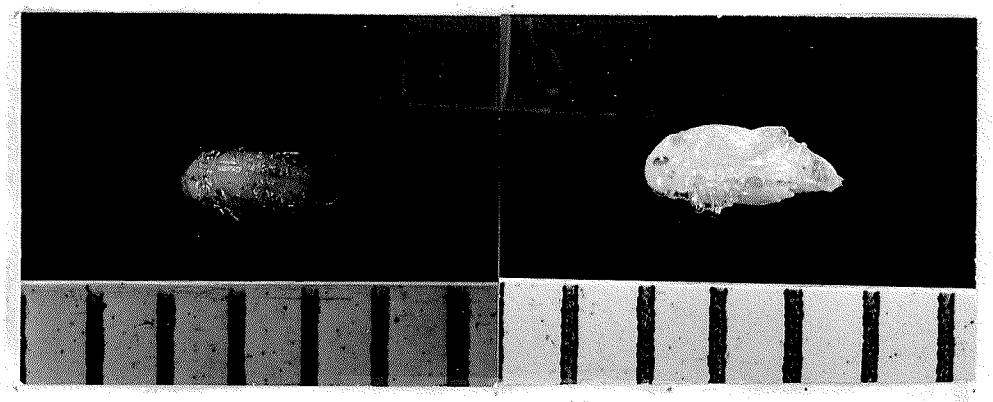


FIGURE 15. THE PUPA

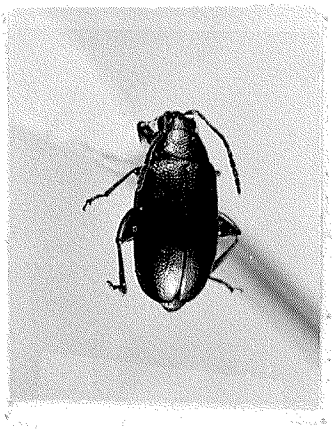


FIGURE 16. THE ADULT

CHAPTER V

LIFE HISTORY AND HABITS

I. LIFE HISTORY SUMMARY

There is only one generation of P. pusilla each year in Manitoba. The flea beetles overwinter in the adult stage under leaves, trash, and debris around gardens or fields, particularly along windbreaks or hedgerows. They begin to emerge with the first extended warm spell of spring, usually in early May in Manitoba, and by the end of the month the spring population has reached its maximum. The beetles mate and begin to lay eggs a short time after emergence. Egg-laying takes place from mid-May to mid-July. The eggs are deposited in the soil near the roots of the host plants and hatch after a period of ten to fifteen days. The adult population remains relatively constant throughout the month of June, but towards the end of July there is a reduction in numbers. The larvae feed on the roots of the host plants and mature in a period of about three to four weeks. There are three larval instars. The prepupal and pupal periods require about two weeks for completion. The new generation adults begin to emerge about the first of August and reach a peak emergence about mid-August. Activity of the new generation continues until about the end of September or until continued cold weather prevails.

In Colorado, Chittenden and Marsh[1] found that there were three generations of the flea beetle annually. They reported that egg laying begins within a few days after the beetles leave their winter quarters -- as early as mid-April -- and continues until early September. In its more northern ranges of the United States they found that the beetles pass the winter months in hibernation under clods of earth, or under heaps of weeds, dead leaves, or other rubbish, whence they come forth with the first warm days of spring. In the extreme south they found that the beetles were active throughout the year but reproduction did not occur throughout the winter. In the Arkansas Valley the beetles are reported to emerge from hibernation in March or early April and in south Texas the beetles are active from February to December.

II. THE EGG

How and where deposited. Under laboratory cage conditions eggs were deposited, either singly or more often in clusters of three or four, in the soil, on the soil surface, and on the leaves and stem of plants. The eggs deposited on the soil surface and on the plants were not laid in any definite pattern or position. The members of a cluster were placed irregularly side by side or partially on top of one another. Similarly, the eggs laid singly were

placed on end, on the side or at an angle, but in all cases the eggs adhered quite firmly to the soil particles or plant surface. Eggs recovered by floatation from outdoor rearing cages were found at a depth of 1/2 to 3/4 inch and within 1/2 inch of the roots of the host plant. In field samples eggs were recovered only from soil samples taken near the roots of the host plant and, with one exception, only in the 1"-2" soil level as is shown in Table I, page 32.

Chittenden and Marsh[1] have records of egg laying only under cage conditions. They observed that the female deposited eggs on the sides of the glass cage, on the soil surface, on the plant leaves, about the crowns of the plants, and in cracks in the soil about the roots of the plants. They considered the latter location probably normal under field conditions. The eggs were not deposited in any particular order or arrangement. They found that the female may lay twenty-one eggs at one time and there may be up to twenty in a mass. They recorded that two beetles, in confinement, laid 193 and 244 eggs respectively and that 32 was the largest number of eggs laid by one female in any one day.

Influence of soil moisture on deposition and incubation of eggs. From studies on the incubation of the eggs it was found that the eggs were extremely susceptible to desiccation and unless they were in direct contact with a

moist surface they soon dried and shrivelled up. In several trials, eggs oviposited on the soil surface desiccated within a few hours after the surface soil particles began to dry. Furthermore, when salve tins containing moist soil on which eggs had been oviposited were placed in a rearing cabinet under artificial (Mazda) lighting, at a constant humidity of 65 per cent, and at a temperature of 86°F., the eggs continued to desiccate. Under natural conditions the average atmospheric humidity is generally considerably lower than 65 per cent. In the field, the top soil is normally very dry and soil surface temperatures, in some cases, reach a maximum of 134°F. Thus, it would seem improbable that eggs could survive if laid on the soil surface.

In field samples (Table I) eggs were recovered from the 0-1" level of soil in only one instance. These were from a single sample taken two days after a heavy rain when the surface soil was still wet. In all other samples the top inch of soil constituted the dry surface layer.

The data suggest that under natural conditions the flea beetle deposits its eggs in the moist soil below the dry surface layer.

The workers in Colorado observed that, under laboratory conditions, if the eggs were allowed to become too wet they did not hatch and if they were not moist enough they dried and shrivelled up. They found that, in general,

TABLE I

RECOVERY OF EGGS FROM FIELD SAMPLES*

Date	Number of samples	Location	Crop	Total no. of eggs	Ave. eggs/sample Depth 0" - 1"	Ave. eggs/sample Depth 1" - 2"
June 1-3	4	Along row	Sweet alyssum	0	0	
	4	Along row	Sweet alyssum	0		0
June 8-24	10	Along row	Radish	7	0.7	
	12	Along row	Radish	31		2.6
June 28	3	Between rows	Radish	0	0	
	3	Between rows	Radish	0		0
July 4-12	4	Along row	Radish	0	0	
	8	Along row	Radish	33		4.1
July 7	4	Between rows	Radish	0		0

* Samples approximately 1/6 square foot in size.

the eggs required soil that was moderately moist. In the present study no difficulty was encountered due to excessive moisture.

Time of day when oviposition occurs. Under laboratory cage conditions, no eggs were found to have been deposited on the soil surface or on the plants during the day. Eggs were found in these locations only after the beetles had been allowed to remain in the cages overnight.

On a radish plot in the field it was found, by measuring the population with a sweep net, and by visual estimates, that large numbers of beetles left the radish plants as dusk approached. They were observed to enter and leave the soil near the base of the plant or to rest on the soil surface. It was not determined whether oviposition occurred at this time or if this was merely a natural evening tendency. With total darkness the beetles returned to the plants in large numbers again.

The fact that the beetles are present on the plants in larger numbers during the day than either in the morning or at night was also observed by Chittenden and Marsh.[1]

Incubation period. As previously described, the incubation period was determined by three different methods. The results are as follows:

Method 1 -- Out of thirty-eight eggs which were recovered from the outdoor rearing cages, 27 hatched. The incubation periods are indicated in Table II.

Method 2 -- Fifteen eggs were recovered from the salve tins and all hatched. The results are shown in Table II.

Method 3 -- Sixty-seven eggs were placed in six incubation cells, and of this number 32 hatched. Mold formation destroyed the eggs in one cell completely. The incubation periods are shown in Table II.

The incubation period varies from ten to fifteen days in Manitoba as shown in Table II.

Chittenden and Marsh[1] found that, in Colorado, the average incubation period was ten, five, and seven days for the first, second, and third generations, respectively.

III. THE LARVA

Feeding habits. Under laboratory cage conditions, the larva has a short quiescent period after emergence, and then becomes active and moves about freely in search of food. Evidence of larval feeding was observed on both the root hairs and the tap root of the seedling plants supplied. In isolated cases, larvae burrowed into the plant at the juncture of the root and stem and tunnelled their way for a

TABLE II

INCUBATION PERIOD

Method	Number of eggs	Date of oviposition	Date hatched	Incubation period in days	Average incubation period
1	1	June 12	June 25	13	
	3	June 12	June 27	15	
	5	June 18	June 30	12	
	16	June 18	July 1	13	
	2	June 18	July 2	14	
					13.4
2	9	June 22	July 5	13	
	6	June 22	July 7	15	
					14.0
3	9	June 25	July 6	11	
	1	June 25	July 6	11	
	11	June 25	July 7	12	
	1	June 26	July 6	10	
	3	June 26	July 7	11	
	7	June 27	July 7	10	
					10.8

considerable distance up the stem. A short time before the prepupal stage is reached the larva ceases to feed.

Chittenden and Marsh[1] observed that, under cage conditions, the young larvae fed on the hair roots of their food plants and the older larvae fed also on the main stalk and branches. [Presumably the authors were referring to the root of the plant.] They reported that on reaching maturity the larvae ceased to feed and crawled restlessly around for a day or so before making a distinct, compact, tightly cemented pupal cell.

Number of larval instars. Exuviae and head capsules were extremely difficult to locate among the root hairs of the food plants during rearing studies because of the minuteness of the larval stages. Hence, progressive observation of instars was impracticable. The number of instars was, however, determined by the application of Dyar's Law (Comstock 1920)[3] to head capsule measurements. According to Dyar's Law, any linear measurement in successive instars of larvae is in geometric progression, and, if the logarithm of the linear measurement is plotted against the number of the instar, a straight line should result.

The head capsule widths of 274 specimens were measured and the results are illustrated in Figure 17, page 38, and Figure 18, page 39.

Figure 17 shows that the head capsule widths fall into three reasonably distinct groups. Applying Dyar's rule and taking the peak of the second last instar at 0.175 mm. and the last at 0.264 mm., the ratio of increase is 0.175:0.264 or 0.66. By using this ratio as a factor, the width of the head capsule of the next smaller instar can be obtained. Calculating, 0.175 x 0.66, the peak of this instar should be, theoretically, 0.116. This calculated value compares reasonably well with the observed value of 0.126 for the first instar.

When these data are plotted (Fig. 18, page 39), the points conform very closely to a straight line. This indicates that the head capsule measurements of successive instars follow a geometric progression as stated in Dyar's Law. It would therefore be reasonable to assume that there are three larval instars with head capsule widths centering at 0.126 mm., 0.175 mm., and 0.264 mm.

Duration of the larval stage. First instar larvae could not be established under the rearing conditions employed. It was therefore necessary to obtain second instar larvae from outdoor cages for rearing to adult. The date of oviposition and the average incubation period under these conditions were known and from studies of the incubation period the date of hatching was deduced.

FIGURE 17

LARVAL HEAD CAPSULE MEASUREMENTS

P. pusilla

FIGURE 17

LARVAL HEAD CAPSULE MEASUREMENTS
P. pusilla

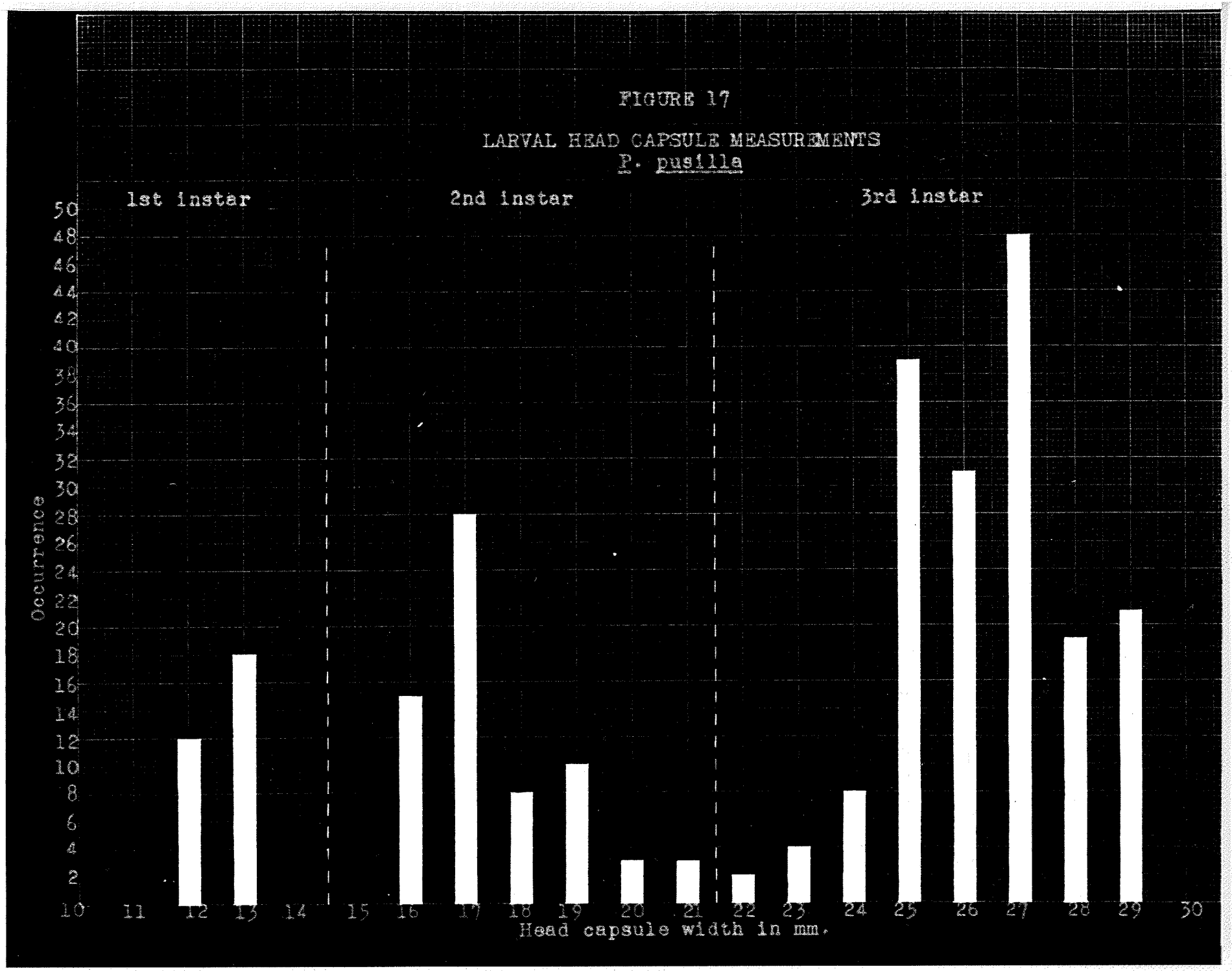


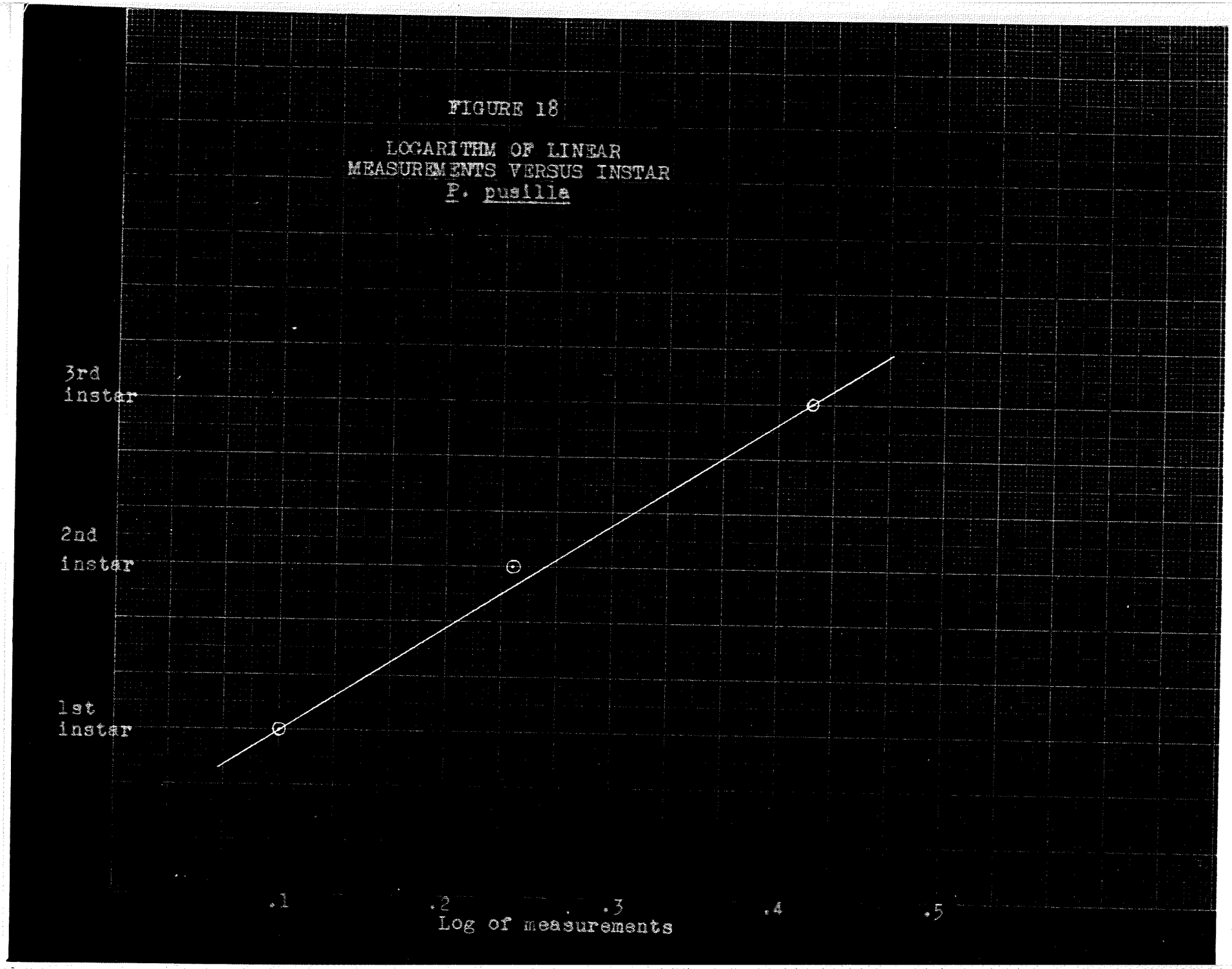
FIGURE 18

LOGARITHM OF LINEAR MEASUREMENTS VERSUS INSTAR

P. pusilla

FIGURE 18

LOGARITHM OF LINEAR MEASUREMENTS VERSUS INSTAR
P. pusilla



The larvae were reared in two series -- one from a cage where oviposition had taken place on June 12, the other from a cage where eggs had been laid on June 18. The average incubation period was thirteen days (Table II, Method 1, page 35). The duration of each life history stage is recorded in Table III. The total larval period is shown to vary from 22 to 28 days.

The same series of specimens were used to establish the prepupal and pupal periods.

Under Colorado conditions the duration of the larval stage was reported to be 29 days, 19 days, and 22 days for the first, second, and third generations, respectively. However, no distinction was made between the larval and prepupal periods, in this case, so it is presumed that the duration of the prepupal stage was included. This would make the larval period four to five days shorter than indicated.

It was observed, by Chittenden and Marsh,[1] that the greatest difficulties, in the life history studies of this species, were encountered in the larval stage. They reported that the larvae were easily killed by excessive moisture especially when accompanied by heat. They found that the most susceptible period was just after the larvae had hatched. A temperature of 70°F. was reported as the optimum temperature for larval development. These workers

TABLE III

DURATION OF LARVAL, PREPUPAL, AND PUPAL PERIODS

No. of specimens	Date of oviposition	Average incubation period	Deduced hatching date	Date larva changed to prepupa	Larval period	Date pupated	Prepupal period	Date adult emerged	Pupal period
9	June 12	13 days	June 26	July 18-23	22-28 days	July 24-27	4-6 days	Aug. 1-4	8-9 days
7	June 18	13 days	July 1	July 23-29	22-28 days	July 29-Aug. 3	3-6 days	Aug. 5-11	7-9 days

suggested that since the eggs and larvae, in the laboratory, seemed to be so susceptible to excessive moisture, the use of irrigation, where practicable, might serve as a control measure.

These workers reported that, at no time were they able to recover larvae or pupae from field soil samples even around the roots of growing turnips or radishes.

IV. THE PREPUPA

Duration of the prepupal stage. The commencement of the prepupal period is marked by a cessation of feeding and a decrease in the activity of the larva followed by a shortening and thickening of the body. At this time the insect forms a small earthen cell in the soil. The prepupal period has a duration of three to six days (Table III, page 41).

The observations reported by Chittenden and Marsh[1] indicate that the contracted prepupal period ordinarily lasts four or five days.

V. THE PUPA

Duration of the pupal stage. Pupation usually occurs in early August in Manitoba and the period lasts seven to nine days (Table III, page 41).

Under Colorado conditions the average pupal period was reported to be eleven, six, and ten days for the first, second, and third generations, respectively.

VI. EMERGENCE OF ADULT FROM PUPA

An opportunity was afforded for limited observations on the change of the pupa to adult, under laboratory cage conditions. At 9:00 a.m., July 21, a pupa was observed at the point of changing to adult. It was pure white in color with the eyes dark and apparently fully developed. The appendages were not yet free. Three hours later, at 12:00 noon, the appendages were free and beginning to darken very slightly at the tips. Except for the eyes, the remainder of the body was a uniform white. The natural punctate appearance was visible on the elytra and thorax. The insect exhibited limited movement of the appendages. At 4:00 p.m., the insect was light grey in color and was beginning to crawl about. At 2:00 p.m., on July 22, the beetle was dark grey in color and moved about freely. Twenty-four hours later the insect was somewhat darker but had not yet attained the characteristic dark metallic adult coloration.

Under field conditions this color change must take place before the beetle leaves the soil or at least before feeding begins, since in no instance, in hundreds of beetles collected and examined, have any been observed that had not developed normal adult coloration.

VII. THE ADULT

Host plants. The known host plants of this insect, in Manitoba, are chiefly those which belong to the family Cruciferae. Flea beetle injury has also been noted on members of the families Chenopodiaceae and Polygonaceae. The specific plants on which the insect has been observed to feed are turnip, radish, cabbage, cauliflower, Brussel's sprouts, broccoli, kohl rabi, horseradish, Argentine rape, table beet, sugar beet, sweet alyssum, hoary cress, green tansy mustard, stinkweed, lamb's quarters, and wild buckwheat.

Chittenden[2] states that the flea beetle feeds on all cruciferae occurring in its habitat and when the beetles occur in great abundance they also injure sugar beets and table beets, mangel-wurzel, lettuce, beans, peas, carrots, tomato, potato, and corn.

In Manitoba, no reports have been received or observations made on flea beetle injury to the plants specifically mentioned by Chittenden,[2] with the exception of sugar and table beets.

Nature of injury. The injury caused by the flea beetle consists of the eating of small holes or pits in the foliage of the plants attacked. With a light infestation,

the injury often occurs first on the edges of the leaves (Fig. 19) and causes the leaf edges to dry and curl. When the population is concentrated, the leaves, petioles, and stem are attacked. Severely damaged leaves take on a "shot-hole" appearance (Fig. 20, and Figure 21, page 47) and usually dry and shrivel.

Distribution of the insect. The flea beetle is known to occur in the four Western Provinces of Canada. It is widely distributed in Manitoba and Saskatchewan and specimens have been collected as far north as The Pas in the former province. In Alberta and British Columbia, the distribution of the insect is probably limited to the more southern regions of the provinces. The specimens examined were collected in the Lethbridge area of Alberta and the Kamloops area of British Columbia.

According to Chittenden and Marsh,[1] the range of the flea beetle in the United States, is from the Dakotas to Mexico and central and southern California. Chittenden[2] states that:

> It is widely distributed in the Rocky Mountain region, especially abundant in Colorado and New Mexico, and occurs eastward and westward in Arizona, California, Washington, Wyoming, Montana, Idaho, Nebraska, Oklahoma, Kansas, and ranges southward through Brownsville, Texas, into Mexico. It frequently occurs at high altitudes and is a permanent inhabitant of lower areas. It is evidently a Sonoran form and common to both the Upper and Lower Sonoran Life Zones, but in some States it has been observed in the Semitropical, Transition and Boreal Zones. . . .

FIGURE 19. FLEA BEETLE INJURY TO CABBAGE

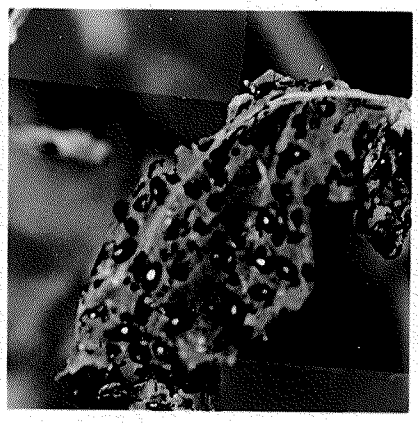


FIGURE 20. FLEA BEETLES FEEDING ON LEAF OF ARGENTINE RAPE

FIGURE 21. FLEA BEETLES FEEDING ON CAULIFLOWER LEAF

Spring emergence. With the first extended period of warm weather in the spring, the adults emerge from hibernation. This is usually in early May in Manitoba. Generally at this time no cultivated cruciferous crops are available and the beetles feed on whatever wild hosts are present. If cold weather recurrs, the beetles return to the debris or go under clods of earth or other shelter.

Length of oviposition period of overwintering brood. In cages, in the laboratory, flea beetles have oviposited throughout the entire month of June, and in field samples eggs have been recovered from June 8 to July 12. A pupa was recovered from a field sample on June 23, and taking the average period (43 days) from oviposition to pupation, as determined under laboratory rearing conditions, the egg would have been deposited about May 11. The peak emergence of new generation adults usually takes place about mid-August. The total period from egg to adult ranges from 42 to 58 days, i.e., about six to eight weeks. Thus, peak oviposition would occur from about the middle to the end of June.

The oviposition period is, therefore, roughly from mid-May to mid-July and peak oviposition occurs during the latter part of June.

Chittenden and Marsh[1] found that of two overwintering females, held in cages, one began egg laying on March 26 and continued ovipositing until July 26. The specimen died on July 30. The second female began oviposition on April 3 and ceased on June 13. The specimen died on June 20 and an overwintering male confined with this female died on July 31.

Factors affecting activity of the adult. The factors which appear to have marked influence on the activity of the flea beetle are temperature, humidity, sunlight, and wind velocity.

The closely related temperature-humidity factor is probably one of the most important. The beetle population on the host plant varies directly with the temperature and inversely with the humidity (Fig. 22). In the morning and evening when the temperature is low and the humidity high there is less beetle activity than during the middle of the day when the temperature-humidity ratio is reversed.

The absence or presence of direct sunlight also has a bearing on the activity. The beetles feed in a relatively quiet manner in direct sunlight during the heat of the day but when the sun becomes obscured by clouds feeding is interrupted and the beetles begin to move about. The same effect may be achieved by shading the host plant.

FIGURE 22

P. pusilla POPULATION TRENDS THROUGHOUT A SINGLE DAY IN JUNE

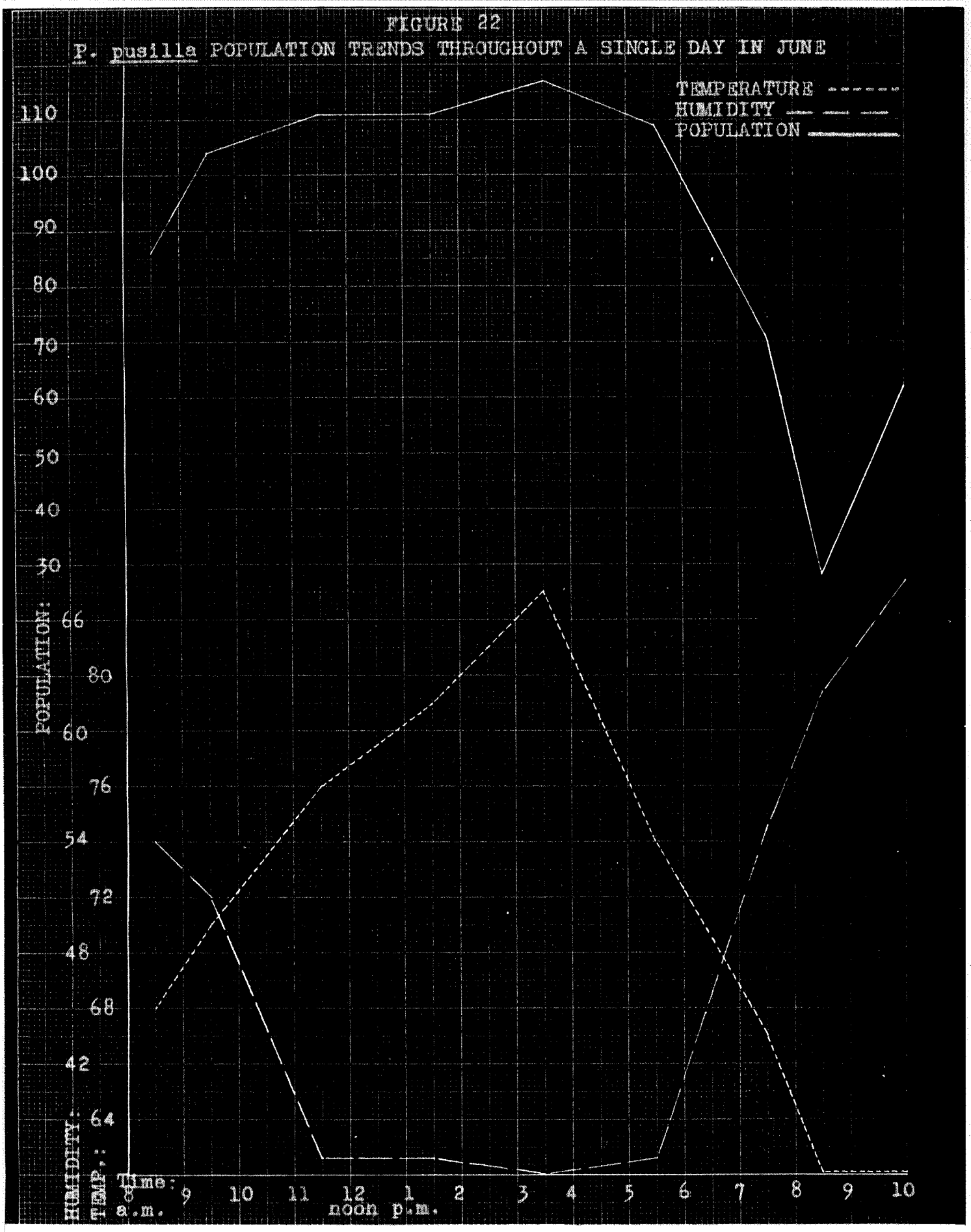


FIGURE 22

P. pusilla POPULATION TRENDS

THROUGHOUT A SINGLE DAY IN JUNE

Wind velocity over 15 miles per hour confines the feeding of the beetles to the more dense and sheltered foliage, usually about the heart of the plant, and appears to be the only factor causing the beetles to choose the more succulent heart leaves.

Hibernation. Hibernation studies were conducted in the late fall (November) and early spring (April) while the flea beetles were in hibernation. Samples of soil and trash cover were taken from gardens or fields in which cruciferous crops had been grown and also along hedgerows in the near vicinity of some of these crops. The number of flea beetles recovered from these samples is indicated in Table IV.

TABLE IV

RECOVERY OF FLEA BEETLES FROM HIBERNATION

No. of samples	Total area of samples (square feet)	Location	No. of beetles recovered	Average per sq. ft.
14	17	Hedgerow	69	4.05
9	13	Field or garden debris	2	0.15

Table IV shows that trash cover along hedgerows is the favored place for hibernation.

Four of the samples of garden debris representing an area of 8 square feet were taken from the centre of a large field. The nearest hedgerow or band of trees was about 440 yards distant. The flea beetles must, therefore, travel considerable distances to seek favorable hibernation quarters.

CHAPTER VI

SUMMARY

The life history and behavior of the flea beetle Phyllotreta pusilla Horn have been studied in Manitoba. There is one generation each year. The insect overwinters as an adult and usually emerges from hibernation in early May. Oviposition commences shortly after emergence and continues for a period of about two months. The eggs, which are extremely susceptible to desiccation, are deposited in moist soil near the roots of the host plants. They hatch in 10 to 15 days. The larvae feed on the roots of the plant and mature in 22 to 28 days. There are three larval instars. The insect has a prepupal stage which lasts 3 to 6 days. The duration of the pupal period is 7 to 9 days. The period from egg to adult is, therefore, from 42 to 58 days. The overwintering adult population decreases toward the end of July and the peak emergence of the new generation is about mid-August. The beetles go into hibernation with the onset of continued cold weather.

The insect feeds chiefly on cruciferous plants but may also feed on members of the families Chenopodiaceae and Polygonaceae.

In Canada, the flea beetle is limited in distribution to the four western provinces. It is widely distributed in Manitoba and Saskatchewan and is present in Alberta and British Columbia.

B I B L I O G R A P H Y

1. Chittenden, F.H., and H.O. Marsh, The Western Cabbage Flea Beetle. United States Department of Agriculture Bulletin No. 902. October 1920.

2. Chittenden, F.H., "The Species of Phyllotreta North of Mexico," Entomologica Americana, Vol. 8 (n.s.), No. 1, June 1927.

3. Comstock, J.H., An Introduction to Entomology. First complete edition, third edition of Part I; Ithaca, New York: The Comstock Publishing Co. 1920. 1044 pp.

4. DuPorte, E.M., "Observations on the Morphology of the Face in Insects," Journal of Morphology, Vol. 79, No. 3, November 1946.

5. Horn, G.H., "A Synopsis of the Halticini of Boreal America," Transactions of the American Entomological Society, Vol. 16, 1889.

6. Searls, E.M., "A Simple Method for Life-history Studies of Root-feeding Arthropods," Journal of Agricultural Research, Vol. 36, No. 7, April 1928.