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The biology of the blueberry fleabeetle, Altica sylvia Malloch, with preliminary investigations on its control.

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THE BIOLOGY OF THE BLUEBERRY FLEABEETLE, ALTICA SYLVIA MALLOCH, WITH PRELIMINARY INVESTIGATIONS ON ITS CONTROL

WEIDHAAS, JR. - 1952

THE BIOLOGY OF THE BLUEBERRY FLEABEETLE, ALTICA SYLVIA MALLOCH, WITH PRELIMINARY INVESTIGATIONS ON ITS CONTROL

by

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INTRODUCTION

In 1947, an outbreak of the blueberry fleabeetle, Altica sylvia Mall. was brought to the attention of state entomologists in Massachusetts. Acres of blueberries were found to be completely defoliated in both of the two regions of low-bush blueberry production; namely, the Ashby-Ashburnham area and the Granville-Blandford area. The need for investigation on blueberry pests was clearly demonstrated by the depredation in the fields and the concern voiced by the growers (Shaw et al., 1950). A survey of blueberry pests with preliminary studies on the biology and control of the fleabeetle was undertaken in 1949 by Loeber (1950). Those investigations and continued damage in the field indicated that a detailed study of the biology and control of the A. sylvia was necessary.

It is fortunate that Maine investigators had studied similar problems. Research conducted there has enabled the Massachusetts Extension Service to formulate tentative control recommendations until the problems have been studied in this state. It is the purpose of these investigations to provide data which may serve as a basis for fleabeetle control recommendations under the

environmental conditions which prevail in Massachusetts.

The blueberry fleabeetle, Altica sylvia Malloch

The blueberry fleabeetle, A. sylvia, is a coleopteran of the family Chrysomelidae and belongs to the tribe Alticini. It is a typical fleabeetle with greatly enlarged hind femora and has a coppery to bronze metallic luster. The four stages of development are represented by an orange-yellow reticulated egg, a typical chrysomelid larva, a yellowish to orange pupa, and an adult. The distribution is limited to hortheastern North America, so far as known, in areas where lowbush blueberry, Vaccinium angustifolium Ait., grows naturally and has been developed by man as a crop. A. sylvia is native, reportedly, and host specific.

Economic importance of the blueberry fleabeetle

It has been said that the most important pest of the blueberry is the blueberry maggot, Rhagoletis pomonella Walsh. That the maggot is an important pest cannot be denied; it is present every year as compared with sporadic outbreaks of the fleabeetle. Furthermore, berries with high maggot count are rejected after the cost of growing and harvesting has been paid. The losses incurred are quite apparent and a definite monetary value

can be established by adding the costs of growing, protection, harvesting and materials. They are further emphasized since they occur at harvest time. However, in a long term analysis the maggot is not necessarily the most important pest. The fleabeetle does much less manifest but just as serious a type of damage. The complete defoliation of vines for more than one year not only causes the loss of a crop but indirectly affects future yields and seriously jeopardizes the existence of the vines. Establishing the degree of importance of these two pests is of less significance, however, than understanding that they are not exactly comparable. Since the effects of fleabeetle damage are not so discernible, its importance should be emphasized. Both pests are serious problems to a grower who attempts to produce a profitable crop of high quality.

Culture of the lowbush blueberry in Massachusetts

Lowbush blueberries have been picked in the wild throughout New England for centuries, probably being used by the Indians in the preparation of pemmican (McDannald, 1948). In Maine they have been grown as a commercial crop since about 1900. It was not until the First World War that blueberries became commercially important in Massachusetts. After woodlands had been cut over and pastures were abandoned, blueberries came in to carpet acres of land. Follow-

ing the lead of Maine producers, Massachusetts growers instigated burning at irregular intervals, thus applying the first cultural practice to the growing of blueberries in this state. The chief advantages of burning are: 1, the natural plant succession is prevented and a level of blueberries is maintained; 2, pruning is effected which produces a crop of high quality and quantity the following year; 3, weed plants are effectively controlled at least temporarily; and 4, a partial control of some pests is achieved. There are two important disadvantages: 1, certain insects seem to be favored by burning in that the new vines invite heavier infestation; and 2, very little organic matter builds up in the soil.

The second step toward culture and increased blueberry production was to decrease the interval between periods of burn to a minimum of three years. Hay and waste straw were added to the mowed vines and weed plants to increase the effectiveness of the burn. At the same time, the fields were enlarged by clearing woodland and scrubby tree growth. Such was the extent of care given to a substantial annual crop.

During the Second World War labor conditions forced the growers to find faster methods of harvesting. The practice of harvesting with scoops was initiated.

Growers were deeply disturbed over the defoliation of acres of vines by the blueberry fleabeetle from 1947 through 1950. In 1949 a major part of the crop was condemned and destroyed because of a high count of blueberry maggots (Rhagoletis pomonella Walsh). Control of insect pests automatically became another phase of blueberry culture.

During post-war years, the impetus of Maine studies on weed killers, fertilizers, and varietal selection was being felt in Massachusetts, and investigations were begun in this area. Much progress has been made in experimental work with types of weed killers and fertilizer applications. Research is being continued along these lines and holds promise of further development for the growers.

As the commercial growing of blueberries rapidly approaches a true plant culture, the present outlook includes three main aspects: 1, the fruit is highly desirable in the market; 2, there are many areas of waste land in the state where lowbush blueberries could be developed; and 3, production can be increased, provided that definite cultural practices and pest control measures can be worked out and followed carefully.

At the present time, the blueberries grown in Massachusetts are chiefly lowbush types. Highbush blueberries play a minor but increasing role, since some commercial

areas, particularly in eastern Massachusetts, produce substantial quantities of cultivated fruit. Loeber (1950) states that the probable acreage of commercial lowbush blueberries is 2500-3000, while the annual crop value is about $200,000. The blueberries are used primarily in the fresh fruit market. Some are canned while an increasing amount is frozen, particularly for the baking industry.

REVIEW OF THE LITERATURE

Taxonomy

The taxonomic status of the blueberry fleabeetle is in a highly confused state, but is being studied by L.G. Gentner of the Oregon Experiment Station. He is revising the genus Altica. One point which will be resolved is whether A. sylvia Malloch is a synonym of A. cuprascens Blatchley, or a separate species. There have been several opinions since Woods published a paper, "The Biology of Maine Species of Altica" in 1918, wherein the blueberry fleabeetle was called A. torquata Leconte. J.R. Malloch (1919) stated that the species described and recorded as torquata by Woods was undoubtedly not that species, and proposed the name sylvia, stating that the true torquata is more coarsely punctured with a much shallower pronotal transverse incision. In 1920, H.C. Fall likewise commented that Woods' specimens identified as torquata were not the torquata of Leconte and further that Mr. Leng admitted misidentification. However, Fall thought Malloch's action on proposing a new name premature and supposedly implied that sylvia is a synonym of cuprascens Blatchley. Such a conclusion has been drawn by subsequent workers. However, Fall

stated only that he had compared with cuprascens specimens collected by him from new localities. He did not state that he compared them also with what was called sylvia. He probably assumed that the specimens he had found were sylvia. Therefore, if synonymy does exist, it was not demonstrated conclusively in Fall's paper.

In 1924, Charles Schaeffer published an opinion that the specimens which Fall called cuprascens were not the same as Blatchley's type, but were what Woods called torquata and Malloch subsequently named sylvia. Schaeffer also indicated that purpurea, which Fall described as a new species, is closer to cuprascens Blatch. and therefore put purpurea as a synonym of cuprascens.

Since 1924, no opinions of taxonomic status of these species have been published. However, in the past four years, correspondence with workers on this group has provided some information that is worth recording. Both C.A. Frost and H.S. Barber* (through C.F.W. Muesebeck) have alluded to the synonymy of cuprascens and sylvia. Barber was said to have expressed uncertainty of that synonymy, however. More recently, L.G. Gentner, the best authority on this part of the genus, suggested that the range of low blueberry probably extends into northern Indiana where Blatchley obtained his type of cuprascens. If such were

*deceased

the case, cuprascens would stand, since it was named in 1910. He further stated that he knows purpurea is different from both cuprascens and sylvia. Since he has been unable to obtain Blatchley's type for study, he will not say whether or not it is a separate species from sylvia.

Specimen data in the National Museum, the Academy of Natural Sciences of Philadelphia, and the American Museum were examined. Many of the data were incomplete, especially host records. In view of what is known of the biology and host preference of A. sylvia as it has been determined by Woods, it is felt that the taxonomy of this species must be correlated very closely with host and locality data. This has not been done in most cases; for example, only three specimens in the National Museum contained host records.

It will be necessary to study the distribution and host preference in relation to the taxonomy in order to thoroughly understand the status of the Altica complex. Until the synonymy of sylvia and cuprascens is established, or until the entire genus Altica is revised, sylvia should be used to designate the blueberry fleabeetle. There is no valid evidence to the contrary at the present time.

Distribution

Distribution of A. sylvia.

A. sylvia has been collected to a limited extent from scattered wild low blueberry according to L.G. Gentner and C.A. Frost. However the fleabeetle has been reported in the literature only from the extensive areas of commercial blueberry production; Canada (Maxwell and Pickett, 1949), Maine (Woods, 1918 and Phipps, 1930), New Hampshire (Smith, 1946), Massachusetts (Shaw et al., 1950), and Connecticut (Britton, 1933).

The most serious outbreaks of the fleabeetle have occurred in Maine, Canada, and Massachusetts in that order. Infestation is sporadic and builds up about every ten years. After approximately three years it begins to drop off and A. sylvia becomes endemic. The buildup apparently would not occur if there were not large commercial blueberry areas. Also, the presence of the fleabeetles in any area is dependent on the presence of the host. Therefore a detailed survey of the general and commercial distribution of the low blueberry, V. angustifolium, was made from the literature. It was found that A. sylvia has been found only on V. angustifolium, and that it is restricted in numbers at least to the commercial areas. In view of the small amount of literature pertaining to A. sylvia, it is felt

that the distribution of the fleabeetle is insufficiently known.

General distribution of the lowbush blueberry.

According to Darrow (1946), the lowbush blueberry is native to northeastern United States and eastern parts of Canada. It is a common part of the ground cover in wooded areas and can be found, particularly in Vermont and Massachusetts, along edges of meadows and woods, and in woods where openings in the overstory have occurred. Very often, V. angustifolium is present in the understory of young trees where it has survived since it was dominant; blueberry invades abandoned pastures, and occurs between the grass and tree stages of plant succession.

Great difficulty is experienced in attempting to determine which species is involved in the references to distribution and biology of the lowbush blueberry. Gray's Manual (Fernald, 1950) refers to V. angustifolium as occupying dry open barrens, peats, and rocks in Labrador and Eastern Quebec to Minnesota, and mountains of eastern New York and New England. However, the fruiting dates given do not correspond with those observed in Maine and Massachusetts. The fruiting takes place from July to September, but is given as from August to September

in Gray's Manual. Many other species and varieties are listed, but the distribution is different from angustifolium. Other references in the literature pertaining to angustifolium have agreed with the distribution given in Gray's Manual. According to Eaton (1949) and Phipps (1930), the commercial fields are comprised chiefly of angustifolium with other species present in limited numbers. Therefore it seems apparent that although the term lowbush blueberry may refer to one, many, or all species and varieties of lowbush blueberries, the commercial species (as defined in the following section) in Massachusetts and Maine is V. angustifolium. The 1951 edition of Gray's Manual has adopted that name in place of V. pennsylvanicum, var. angustifolium (Ait.) Gray. In the literature on the blueberry fleabeetle, Woods (1918), Patch and Woods (1922), Phipps (1930), and Loeber (1950) use pennsylvanicum; whereas Darrow and Wilcox (1946), Smith (1946), Eaton (1949), Hitz (1949), and Hilborn (1950) use the name angustifolium. The writer prefers to follow the terminology in the most recent edition of Gray's Manual.

Commercial distribution of the lowbush blueberry (see Fig. 1).

Only one reference, that of Darrow and Wilcox

Fig. 1 Commercial Distribution of lowbush blueberry, Vaccinium angustifolium Ait.

(1946), indicates that lowbush blueberries are gathered commercially outside of New England and eastern Canada. Perhaps shades of interpretation of the word "commercial" may explain such an indeterminate statement. In this paper, commercial shall be referred to in the sense of providing for local markets, distant markets, canneries, and freezing. A commercial area is primarily determined from the abundance of blueberries in terms of the number of tons of berries marketed, the numbers of growers, or the annual monetary value of the crop. Since different states and two countries are involved, all three categories must be used. A discussion of the two main regions, and an evaluation of the subregions within follows.

Canada. Although many lowbush yields are attributed to even the midwestern provinces of Canada (Eaton, 1949), the species angustifolium is commercially important only in the vicinity of New Brunswick. New Brunswick is by far the greatest producer with an average of from 1500 to 2000 tons of blueberries per year, while Nova Scotia is second, Cumberland county alone canning 35 tons of berries in 1940. Prince Edward Island did not develop blueberries as early as the first two areas mentioned, but in 1940 shipped over 300 tons of frozen berries. Much is said of the lowbush production in Quebec in the Lake

St. John and Charlevoix county areas and even Ontario and the prairie provinces. A communication from E.R. Hall, Assistant Superintendent of the Experimental Station in Saanichton, B.C., stated that, "there may be limited plantings (of angustifolium) in the Fraser Valley but all of the plantings we are familiar with are of V. corymbosum". Eaton (1949) referred to V. myrtilloides throughout Canada but angustifolium only in the east.

New England. Maine is the chief blueberry growing area. It produced 83% of the acreage harvested in New England in 1940 with an estimated value of $1 million. The distribution of commercial growers by counties is as follows:

County	No. of growers
Washington	870
Hancock	604
Knox and Lincoln	417
Waldo	131
Oxford	57
Cumberland	29
York	Potential as a result of the 1947 forest fire

New Hampshire has important areas in Hillsborough, Belknap, Strafford, and Carroll counties which produce about 250 tons of berries annually. Massachusetts has two main areas which occupy parts of three counties; Worcester and Middlesex along the New Hampshire line, and Hampden county just north of the Connecticut line in the southern Berkshire mountains. Connecticut has a few fields in the area bordering Hampden county, but not of sufficient extent to be considered from a commercial standpoint. Vermont has no commercial areas as such (Blasberg, 1948), but wild blueberries are harvested by the public from the wild and used for private sales as well as for personal consumption. Thus the commercial production of lowbush blueberries is confined to New England and southeastern Canada. The growing of lowbush blueberries in other parts of North America is confined to certain related species.

In the Northeast, the Canada blueberry (V. myrtilloides), Lamarcks sugar blueberry (V. lamarckii), and V. vacillans occur with angustifolium. However, one species predominates in one given area usually. In Canada, according to Eaton (1949), V. myrtilloides is most widespread, occurring throughout the whole of Canada, while

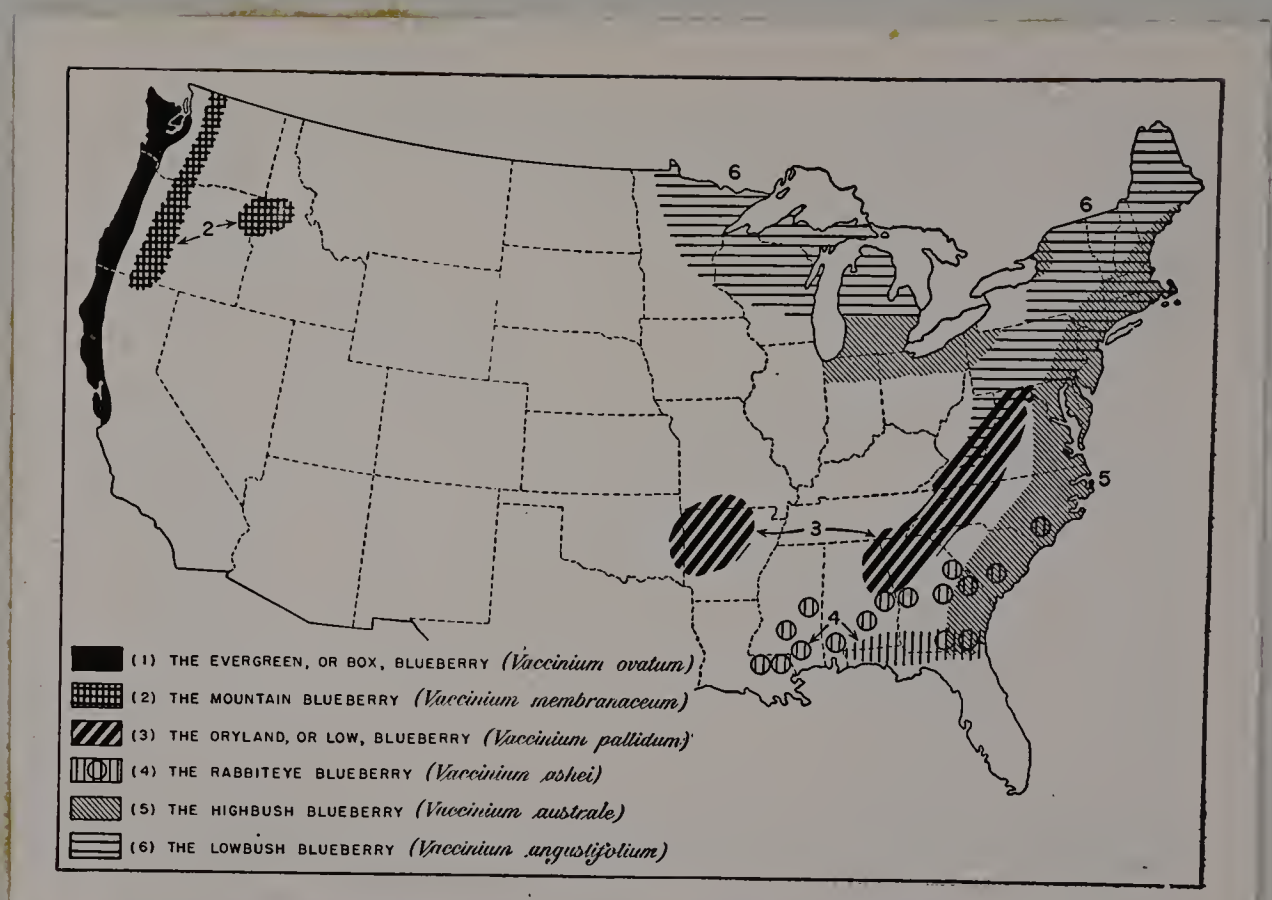


Fig. 2 Distribution of species of lowbush blueberries in the United States. (From Darrow and Wilcox, 1951)

V. angustifolium is of the greatest importance in the east. The distribution of important related species of Vaccinium is shown in Fig. 2, adapted from Darrow and Wilcox (1946).

METHODS AND PROCEDURE

Field work and field observations were considered most important in these investigations. Laboratory studies were carried on when possible, but were not given preference when field observations demanded attention. This procedure was followed because of the immediate need for as full a knowledge as possible of the life history of the pest in the Massachusetts area. The need for immediate control measures was obvious from the defoliation which occurred throughout the area. Since the experimental area was located some 45 miles from the laboratory, it was necessary to plan the field work so as to include travel time and weather variation. Tri-weekly trips were planned with provisions for more frequent visits during the period of larval development and transformation. In this way it was possible to follow the development of the life history very closely and apply timely control tests.

The work was begun with plans for two seasons' studies. Because of circumstances which disallowed financial support the second season, the investigations

were terminated in the fall of 1950. Since A. sylvia has only one generation a year with the immature stages developing in a little more than a month, many phases of the biology and control could not be thoroughly investigated.

Rearing

Various types of rearing cages previously experimented with were unsatisfactory. Petri dishes were found to be suitable containers for rearing and behavior studies. The dishes were washed with soap and water then rinsed with distilled water. Paper toweling was put in the bottom of the dishes and moistened with distilled water. The petri dishes were then placed in constant temperature cabinets at various temperatures and used as cages. The most effective temperature for rearing was found to be 78° F. The relative humidity was considered to be approximately 100% since the dishes were closed and the paper toweling kept moist. Each day a twig of blueberry leaves was placed in the dish as food. Cages containing earth were unsatisfactory since fungal growths produced mortality. Cages with low relative humidity prevented survival, particularly of the larvae, and caused the blueberry sprig to lose its succulence and become inedible.

The petri dishes were satisfactory for rearing all

stages of A. sylvia. Normally, pupation occurs in cells in the ground. In laboratory tests at room temperature, the pupae developed without any soil being present. Loeber (1950) reported failure to obtain eggs in cages which he used. The writer found that the petri dishes prevented neither copulation nor oviposition.

Field studies

During field trips, visits were made to four lots in one section of the blueberry growing area. Two more lots were added in a different section when an infested lot was found on June 5. The respective lots from which observations were made are summarized and described in Table 1. Observations plots were set out in each of the lots. Biological records were taken throughout the season and quantities of larvae were collected for later study. Observations were made frequently on the activity of the fleabeetle in its natural environment.

Control plots, 10' x 10', were set out in lots 1 and 2. The first plots were treated prior to the hatching of the eggs, while adjacent plots were treated when the larvae were in the early first instar. Others in lot 5 were treated in the late third larval instar. Control plots, 25' x 12.5', were set out in lot 2 for control tests on the adults. Fleabeetle adults are more active

Table 1. Summary and Description of Blueberry Lots Studied in 1950

Lot	Altitude	Exposure	Beetle Infestation	Year of burn
1	1150'	So.	heavy	1948
2a	1200'	No.	heavy	1947
2b	1200'	No. ea.	light	1947
3	1300'	Ea.	none	1948
4	1300'	So. W.	none	1950
5	1350'	General	heavy	1948
6	1350'	No. ea.	light	1947

and consequently had to be treated over a larger area. All plots were chosen with consideration toward the most uniform plant cover and degree of infestation as possible. In order to compensate for natural variation, one check plot was used for every two treated plots.

The biology and control investigations were hindered and in many cases fully disrupted by sprays and dusts applied by the growers. Most serious of these was an application of insecticides in July. Apparently the adult fleabeetles were killed before oviposition occurred. Consequently, studies of the adults were limited, and only bi-weekly trips were made to the area from the middle of July to the end of September. During this time, observations were made on the blueberry maggot (Rhagoletis pomonella Walsh) and a noctuid moth (Drasteria graphica atlantica).

In 1951, although the project had been terminated, the writer visited the area in an attempt to determine when the eggs of A. sylvia hatched. This was determined to within a few days and observations were made as to the degree and location of current infestations. No further studies were carried out in the field in 1951.

DESCRIPTION OF STAGES

Egg

Blueberry fleabeetle eggs are pale orange, about 1 mm. long, subcylindrical, and heavily reticulated. They are about 1/3 as wide as long. Fig. 3 illustrates the shape and reticulation of the egg. When the egg hatches, the shell splits longitudinally in three places at the cephalic end to almost 1/3 the length of the egg. Eggs, as they occur naturally in the duff, are sometimes attached to pieces of litter.

Larva

The larva, a typical chrysomelid (Fig. 4), is externally indistinguishable from larvae of other species of Altica and a few other genera of the Alticini. The larvae are variable in color from light brown to almost jet black. The variation is in direct proportion to the distention of the body wall, being darkest in the undistended condition. The tubercles and sclerotized areas covering the body are pigmented; the degree of coloration is controlled by their proximity. The head, prothorax, and anal shield are dark brown to black, and add to the dark aspect of the larvae.

Fig. 3 Eggs of the blueberry fleabeetle enlarged 20 times. (Photo by Robert L. Coffin)

The larva is structurally the same as A. corni which Woods (1918) describes in detail. Further, as shown in Woods' key to the larvae of Altica, there are no characters with which to separate sylvia from chalybea, corni, and ulmi as alcoholic specimens. It is felt that the detailed description which Woods gives of A. corni should be consulted for specific characters. Consideration here will be devoted to a general description of the larva and the analysis of the application of Dyar's Law (1890) (Imms, 1948) to the larval head capsule.

The head is very strongly sclerotized and is divided into three parts dorsally by the epicranial suture. Head hairs are conspicuous and characteristic. The antennae consist of three segments and are shorter than the maxillary palpi.

The prothorax has a large dorsal shield with characteristic hairs or setae as in Pl. Ia. The membrane of the meso- and metathorax and abdominal segments contain a great number of tiny pigmented areas and many tubercles most of which bear setae. Sanderson (1902) numbered the tubercles of each segment, while Woods (1918) proposed numbers for the setae. Pl. Ib shows the tubercles and setae as they occur on the various body segments as numbered by Woods. The three thoracic segments have differ-

Fig. 4. Dorsal, ventral, and lateral aspect of the larva of A. sylvia. (x20) (Photo by Robert L. Coffin)

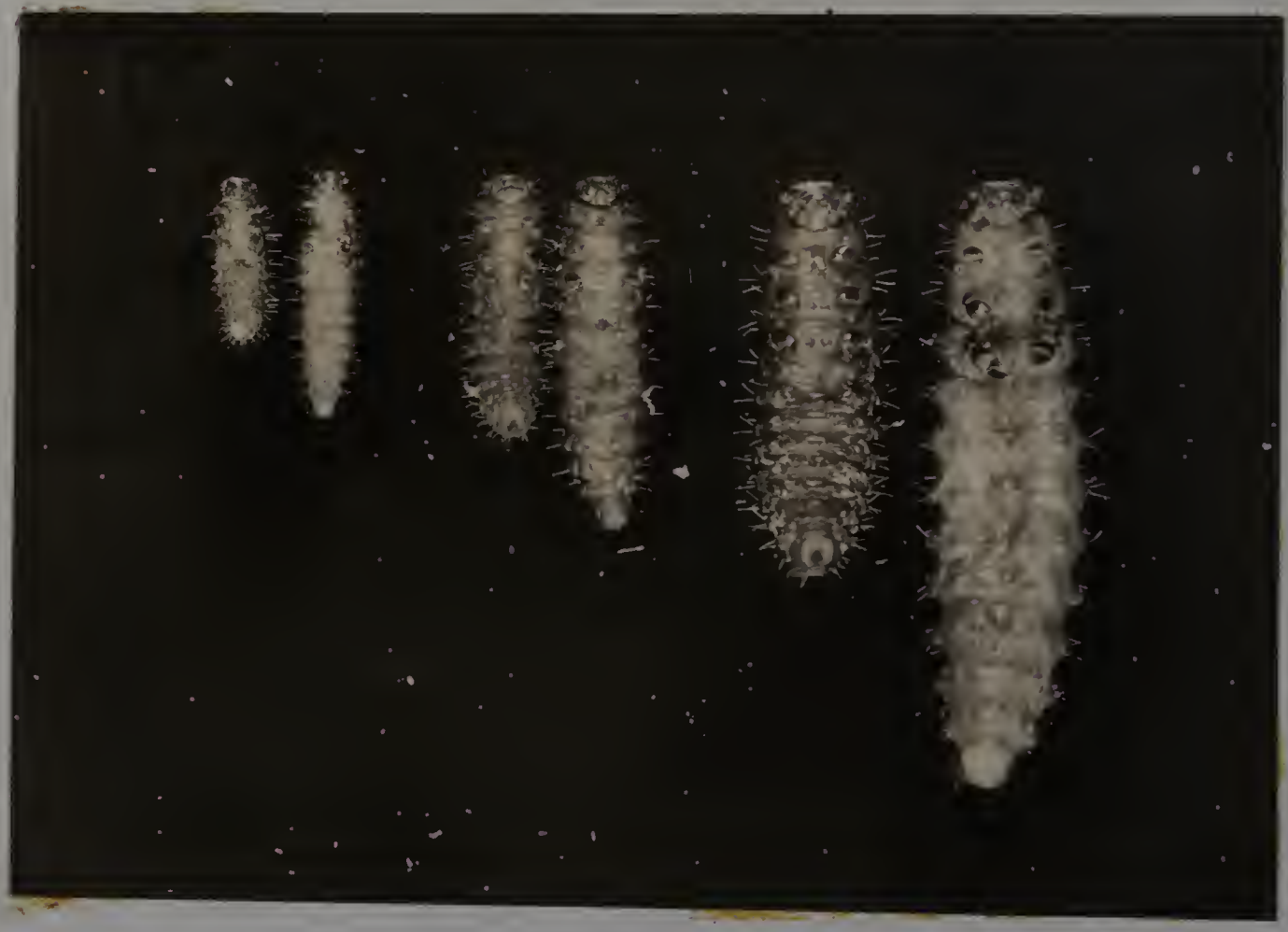


Fig. 5. Comparison of minimum and maximum length of first, second, and third instar larvae of A. sylvia (x20) (Photo by Robert L. Coffin).

Plate I.

a. Lateral view of the larva of A. sylvia

ps - pronotal shield

as - anal shield

b. Drawing showing the location of tubercles and setae. The setae are numbered according to Woods (1918).

p - prothorax

ms - mesothorax

mt - metathorax

1 ab - first abdominal segment

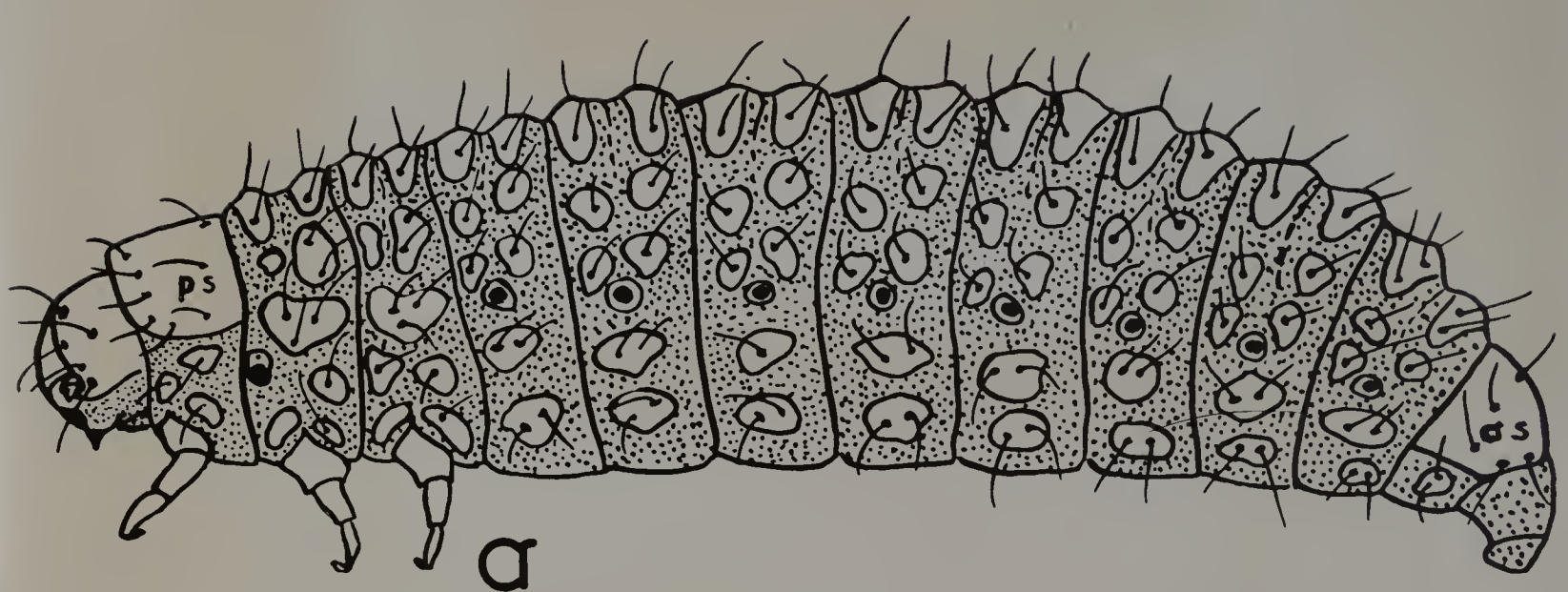
8 ab - eighth abdominal segment

9 ab - ninth abdominal segment

S - spiracle

C - coxa

PLATE I



a

c - coxa
s - spiracle

b

ent arrangements of the tubercles, the most significant difference being that the prothorax has a dorsal plate. Woods suggests that this can be derived from a fusion of several tubercles. The mesothorax contains a spiracle above the coxa, while the metathorax has neither a dorsal plate nor a spiracle. The abdominal segments 1-7 are the same in general appearance. Segment 8 has tubercle ii and iv fused rather than separate. Segment 9 has no spiracle and is reduced to a dorsal, anal shield bearing 10 hairs or setae. Segment 10 bears the anal proleg and the central Y-shaped anal opening.

The larvae have the same structure in all three instars. Length measurements during various stadia are of little value in determining instar, since varying amounts of feeding and defecation probably influence distention of the body. Figure 5 illustrates the variation in length of the three instars, the shorter larvae of the second instar being the same length as the longer of the first, and vica versa, while the longer larvae of the second are the same length as the shorter third instar larvae, and vica versa. There is one constant measurement that can be used effectively in determining instar; that of the width of the head capsule (Woods, 1918). The larvae in the three instars were measured and compared,

showing Dyar's Law to apply quite effectively. These studies were used also to determine when the various instars occurred in field.

Study of the larval head capsule.

In 1890, Dyar established a criterion for determining the number of instars and for comparing different observations on the instars of lepidopterous larvae. He demonstrated that in 28 species of Lepidoptera the width of the head capsule showed a regular geometrical progression in successive stages. This proposition has been accepted and called Dyar's Law. Thus it is possible to calculate whether an instar has been overlooked if at least two successive instars are known.

Woods (1918) applied Dyar's Law to the blueberry fleabeetle. By measuring a number of larval head capsules, he found that there was a definite ratio of increase in width as the instars progressed. Woods drew his conclusions from a total of 48 specimens and worked in one particular area, Maine. The writer studied and analyzed a sample series from the Massachusetts area. Larvae were collected in the field during May and June. After preliminary examination, they were found to fall within 3 distinct groups, based on the width of the head capsule. A total of 105

Table 2. Measurements of Head Widths of the Three Instars of A. sylvia.

First Instar		Second Instar		Third Instar	
width in mm.	no. times observed	width in mm.	no. times observed	width in mm.	no. times observed
.31	1	.45	4	.67	1
.32	5	.46	1	.68	3
.33	14	.47	13	.70	4
.35	12	.49	11	.71	12
.36	1	.50	6	.72	7
.37	2			.74	4
				.75	3
				.76	1

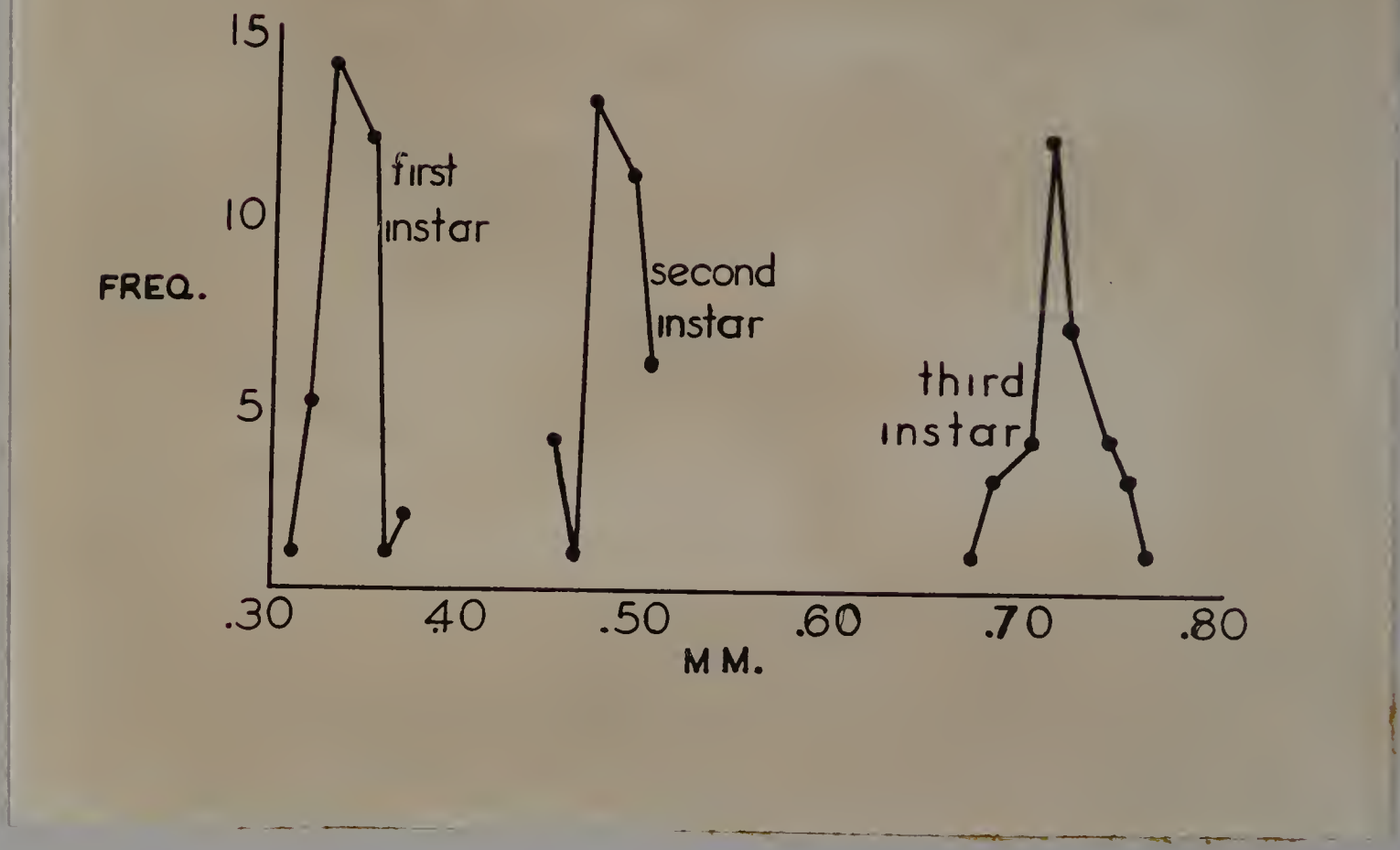


Fig. 6. Distribution curves for the three larval instars of A. sylvia showing the head measurements in millimeters and the frequency of their occurrence.

specimens were studied, 35 selected at random from each group.

The measurements of the head capsule were made with an ocular micrometer in binocular dissecting microscope. The data were recorded to an accuracy of .01 mm, analyzed, and compared with Woods' observations.

The data recorded are summarized in Table 2 and illustrated graphically in Fig. 6. From these data the minimum, maximum, and weighted mean widths were determined for each instar as follows:

Instar	Min. width (mm.)	Max. width (mm.)	Weighted mean
1	.31	.37	.338
2	.45	.50	.480
3	.67	.76	.715

All the measurements fell into three distinct groups. There was some variation within each group, as might be expected, but in no case did the measurements overlap. The weighted mean width of each group was calculated and the ratio of one to another determined. The ratio of the second to the first instar was found to be 1.41, and the third to the second, 1.49. It is apparent, then, that Dyar's Law can be applied to the larvae of A. sylvia and a ratio of increase of the width of the head capsule determined.

Table 3. The Calculated Standard Deviations from the Mean Head Widths of Three Larval Instars of *A. sylvia*

instar	Standard Deviations		
	1	2	3
1	± .013	± .016	± .021
2	± .026	± .032	± .042
3	± .039	± .048	± .063

The observations of the writer agreed quite closely with those of Woods (1918). Table 4 compares the data of the two studies, showing the measurements made, the average calculated, and the ratio. In general, one set of data supports the other. The measurements are approximately the same in each study. The widths of the head capsules in both cases fell into the same general groups. The greatest differences between the two sets of data involve the maximum and average widths in the first and second instar of each study. The result of this difference is that the ratios are not in close agreement. The only apparent explanation is either that insufficient numbers of specimens were examined or that in the second instar of Woods, and the first instar of Weidhaas, a specimen at wide variation from the normal was included in the sample. Since the individual measurements of Woods are not available, it is not possible to ascertain the basis for his high average for the second instar. Since he used, apparently, an arithmetical average rather than a weighted mean in his calculation, it is highly possible that an abnormal head width influenced the average. No such abnormal variation was observed in the present study (see Table 2). The only possible explanation, then, according to the data observed, is that more specimens should be measured to determine the

Table 4. Comparison of Larval Head Widths of A. sylvia with those Determined by Woods (1918).

Instar	Woods no. larvae used	Woods width in mm. min.	Woods width in mm. max.	Woods width in mm. ave.	ratio	Weidhaas no. larvae used	Weidhaas width in mm. min.	Weidhaas width in mm. max.	Weidhaas width in mm. ave.	ratio
1	9	.31	.35	.33	----1.51	35	.31	.37	.34	----1.41
2	16	.46	.54	.50	----1.44	35	.45	.50	.48	----1.49
3	23	.69	.75	.72		35	.67	.76	.71	

greatest variation that might occur.

Woods (1918) used a ratio of 1.5 to determine the theoretical measurements of the width of the head capsules of A. sylvia. However, he did not state why he chose that ratio. Dyar, in his original paper, gave no method for determining the ratio for a particular species. An approximation can be made. This was probably done by Woods. It is also possible that Woods selected the ratio of the second instar to the first, 1.51. Table 5 shows the theoretical measurements Woods obtained using the ratio of 1.51. It is apparent that the calculated head widths in the third instar do not correspond with the actual measurements. It is also apparent in the writer's data (Table 5), that if the ratio of the second to the first instar were taken, the theoretical head widths would not correspond with the actual widths. Further, in both studies if the ratio of the third to the second instar were chosen, different values would be obtained than those derived from the first ratio. Since Dyar proposed the ratio as a function of the actual widths of the head capsules, then the true ratio for the species should be that which gives theoretical measurements closest to the actual measurements. It is possible to determine such a ratio. In Table 5, if the mean head width of the first and second instar (Woods) is assumed to be correct for the species,

Table 5. Comparison of Theoretical Head Widths of A. sylvia as determined by Woods (1918) and Weidhaas.

Instar	Woods				Weidhaas			
	Mean	Theoretical widths in mm.			Mean	Theoretical widths in mm.		
	in mm.	ratios 1.51	1.44	1.48	in mm.	ratios 1.41	1.49	1.45
1	.33	.330	.334	.330	.34	.340	.322	.340
2	.50	.500	.500	.488	.48	.480	.480	.491
3	.72	.755	.720	.720	.71	.667	.710	.710

then the ratio is 1.5. If the second and third are assumed to be correct; then the ratio is 1.44. If the first and third measurements are assumed to be correct, then 1.48 is the ratio. The same can be done with the writer's figures. However, if a ratio is chosen from each set of figures which gives theoretical measurements closest to the actual measurements, it will be found to be 1.44 in Woods study and 1.45 in that of the writer. Thus it appears that a closer approximation of the true ratio can be made than that offered by Woods. Further, if the measurements made in both studies are significant, the true ratio of the mean widths of the head capsules in the larval instars of A. sylvia is about 1.45.

In order to determine the significance of the head measurements in relation to the total population, the data were treated statistically. The standard deviation of the mean of each instar was calculated by statistical procedure. Standard deviation (SD) is that variation from the mean which theoretically includes 67% of the population. Twice the standard deviation (2SD) includes 95% and three times the standard deviation (3SD), 99% (Arkin and Colton, (1950). 1, 2, and 3 SD for each instar of A. sylvia are listed in Table 3.

Figure 7 graphically illustrates that the data ob-

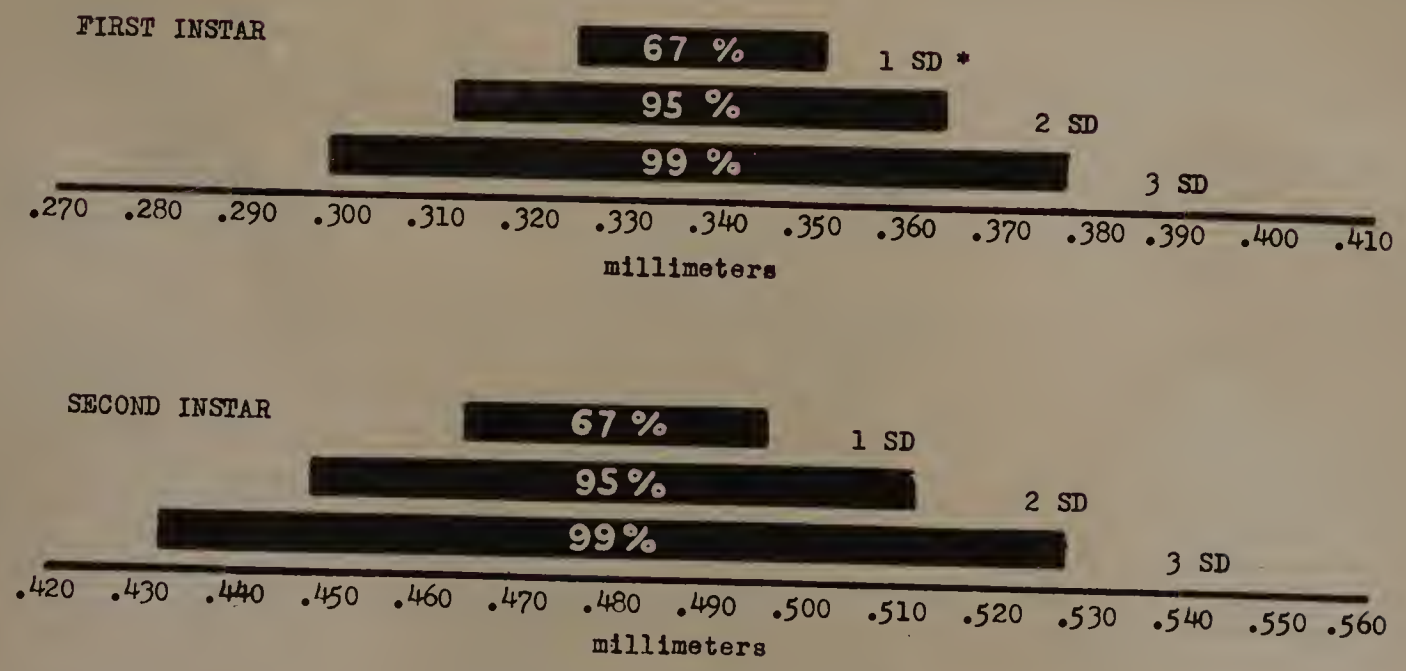


Fig. 7. One, two, and three times the standard deviation of the mean larval head width of the three instars of Altica sylvia, showing the percentage of the total population theoretically included in each.

tained are significant. Theoretically, the measurements made in each instar do not overlap in 99% of the total population. Thus, statistical evidence supports the application of Dyar's Law to the larvae of A. sylvia.

Pupa

The pupa is 4.5 mm. long. At first it is pale yellowish orange, but gradually becomes bright orange. Just before transformation to the adult, however, it appears grayish and darker in color. Variation in pupae of different ages is shown in Fig. 8. The most conspicuous markings throughout the pupal stage are the jet-black eyes and reddish brown mandibles.

Woods (1918) presented a detailed description of the pupae of closely related species of Altica. His description of this stage of A. corni is applicable to A. sylvia. Nine abdominal segments are present, the last bearing a pair of strong black caudal spines. Seven pairs of spiracles are present; one on the mesothorax, and the other six on the first 6 abdominal segments. Woods (1918) states that the setal arrangement is characteristic of the genus Altica. Other than general description, no use has been made of pupal characters.

Fig. 8. Aspects of pupae of various ages of A. sylvia (x10) (Photo by Robert L. Coffin)

Adult

Woods (1918) presented a thorough description of the adult. Should A. sylvia prove to be a valid separate species, that description would be the only detailed treatment of the subject in the literature.

In general, the beetle is from 4.5 - 5.5 mm. long, coppery in color with a strong bronze metallic luster. The entire body surface is lightly punctate, moderately clothed with short white setae. The tibiae and tarsi are similarly clothed except that the ventral side of the segments has extremely dense pads of hairs. The antennae are filiform, twelve-segmented, and moderately hairy toward the tip. The head measures slightly more than two thirds the width of the prothorax. The prothorax is two thirds wider than long, and has the antebasal groove shallow and incomplete. The elytra are three times as wide as long, punctate, and with evenly spaced fine white setae. The legs have the same color and vestiture as the rest of the body. The hind femora are tremendously enlarged (Pl. 2, a), a characteristic of the true fleabeetles. The male and female can be differentiated most easily by the structure of the last ventral segment (Pl. 2, b and c), the male having each side sinuate and the female having the margin entire.

Morphological characters used to classify the adult

are indistinct except for the structure of the male genitalia (Pl. 2, d.). Until the species of Altica have been determined on the basis of genitalic structure, the systematic position of A. sylvia and the importance of its morphological characters cannot be determined accurately.

Plate II.

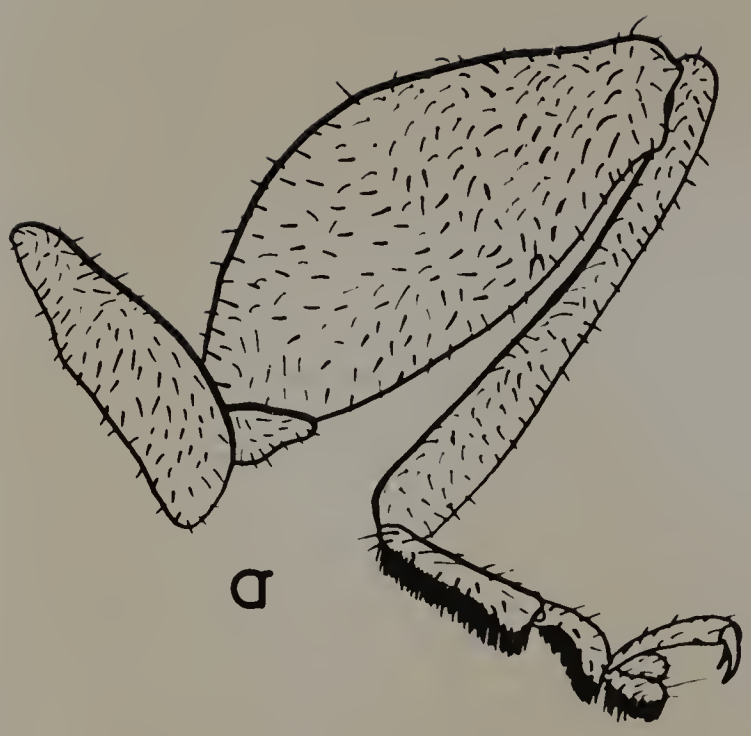
a. The hind leg of the adult of A. sylvia.

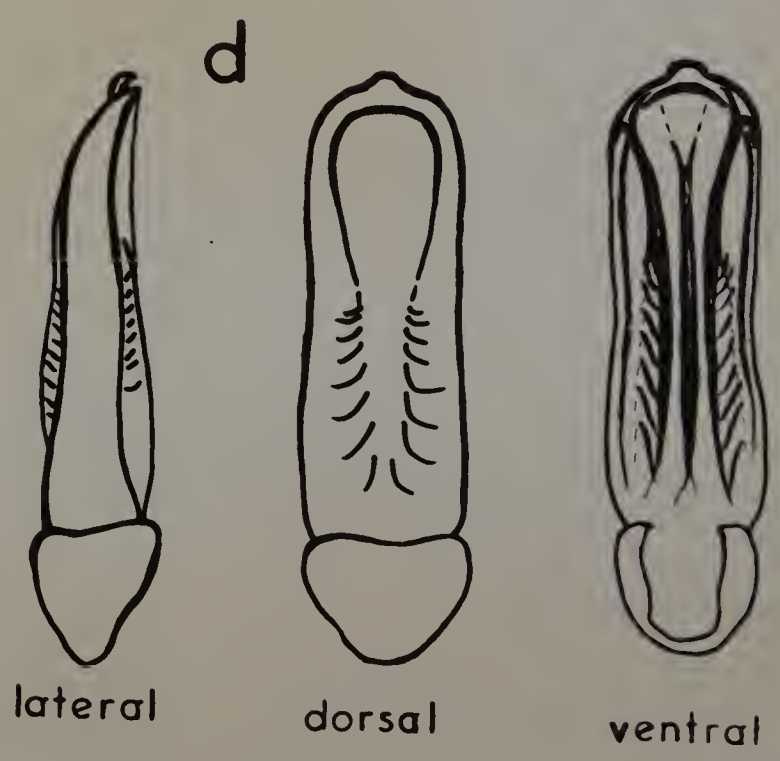
b. The 5th abdominal sternite of the male with the margin sinuate.

c. The 5th abdominal sternite of the female with the margin entire.

d. The lateral, ventral, and dorsal aspect of the male aedeagus.

PLATE II





BIOLOGY

Host Plants

Woods (1918) reported that low blueberry was the only host plant fed upon readily by both larvae and adults. In the laboratory, he found that the larvae ate red oak and wild plum indifferently and refused 44 other plants, including the velvet-leaf blueberry, V. canadense (myrtilloides). The adults ate only red oak indifferently and rejected wild plum and the velvet-leaf blueberry as well as those which the larvae refused. In the field he found that the fleabeetle fed only on low blueberry, V. angustifolium (pennsylvanicum of Woods). In the field the writer found no evidence which disagreed with Woods' observations. Laboratory tests on host preference were not conducted.

The fleabeetle attacks the buds, leaves, and flowers but not the roots and stem. The parts are injured in the sequence of appearance on the plants. Buds are injured only during the time when they are unfolding and exposing leaf growth. The leaves suffer damage both from the larva and the adult. The flowers are chewed by the larvae and become riddled.

Loeber (1950) stated that larvae were not found

feeding more than 6 inches above the ground. Such was found to be the case in the present study. Loeber proposed that leaves above 6 inches were too tough and so were undesirable to the larvae. However, the upper terminal leaves of most plants, including blueberry, are of new succulent growth and much more tender than the older lower leaves. A more reasonable postulation can be submitted on the basis of field observation. V. angustifolium does not grow taller than 6 inches. The clons which are more than 6 inches high are believed to be hybrids which do not suffer such attacks as do the lower forms.

In the laboratory larvae fed upon blueberry leaves from plants 12 - 15 inches tall which were picked in Amherst. These were probably from a hybrid of V. angustifolium. However, no fleabeetles have been found on those plants in the field.

Life History

The blueberry fleabeetle overwinters as an egg in the litter beneath the blueberry vines. The eggs hatch in the spring as soon as the earliest plant buds begin to swell. The time of hatching varies with the weather conditions that occur. In 1950 larvae were not present until two weeks later than in 1951. Since there is an annual

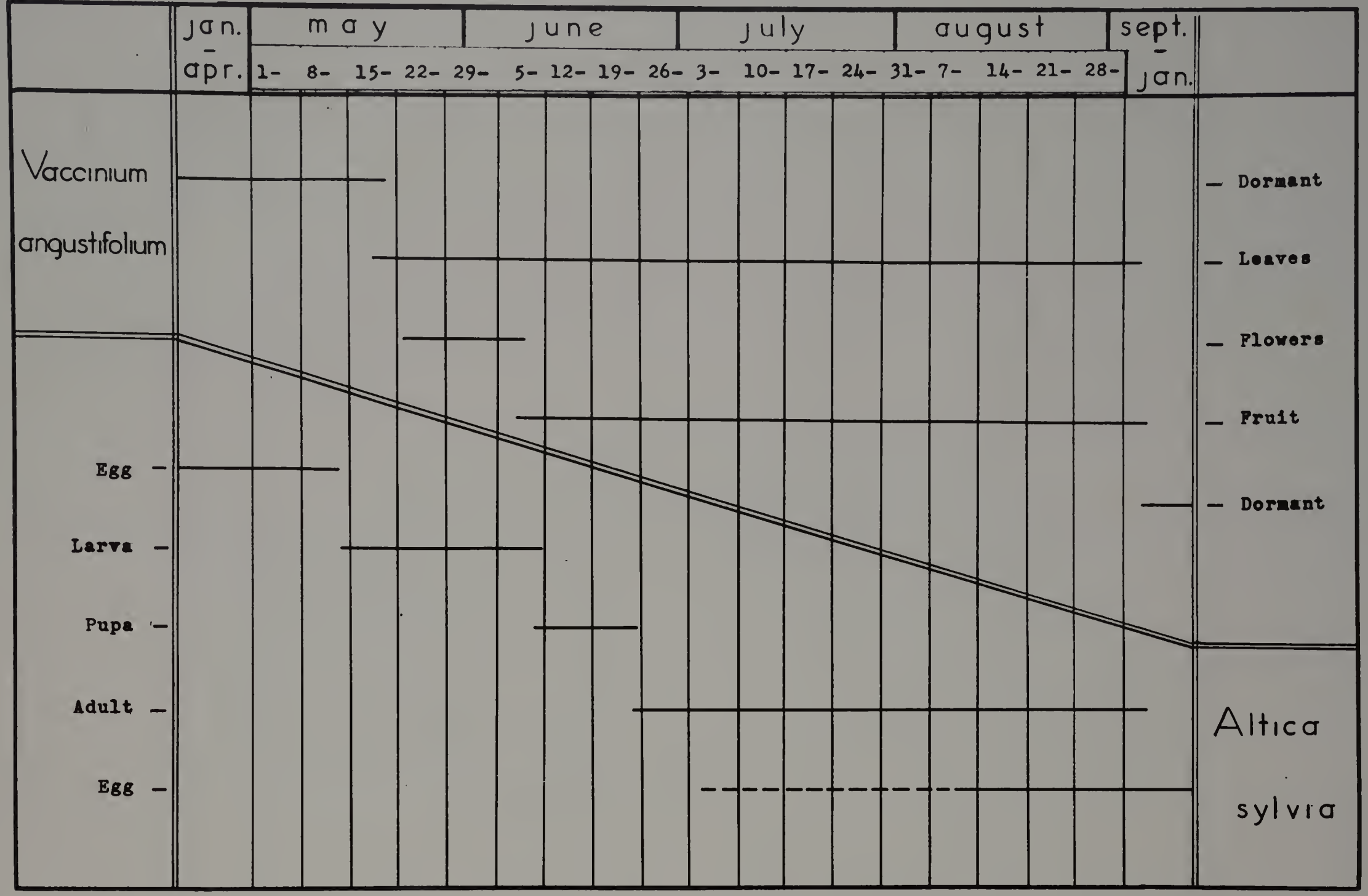
variation, calendar dates are only generally indicative of future hatching dates. Since the whole process of fleabeetle development is correlated with environment, the relationship between A. sylvia and its host was determined as in Fig. 9. Further correlation was made with surrounding vegetation. At the time the eggs were about to hatch in 1950, red maple (Acer rubrum) and shadbush (Amelanchier canadensis) had greatly swollen flower buds. Sugar maple (Acer saccharum), white ash (Fraxinus americanus), beech (Fagus grandifolia), and birch (Betula spp.) had no swelling of the buds to any great extent.

When the eggs hatch, the larvae crawl around in the litter until they find the stems of the vines which they ascend in search of food. In 1950, this was two or three days before the buds began to open. The opening buds are attacked by the larvae. As the leaves and flowers grow they are injured severely. The larval feeding period lasted from May 15 to June 6 in 1950, a total of 23 days. By June 6 practically all the larvae had entered the soil to a depth of not more than 1/2" where the prepupal stage lasted some 5 days. The last molt occurred and the pupae were present until the end of June. The first adult was collected in the field on June 24, while the most numerous collections were made beginning about three days later.

Figure 9.

DIAGRAMMATIC LIFE HISTORY OF A. SYLVIA AND V. ANGUSTIFOLIUM

MASSACHUSETTS - 1950



The adults usually persist for the remainder of the summer (Woods, 1918). Observation of the adults and determination of the time of oviposition was prevented by insecticide applications which the growers used in the first part of July.

Copulation was observed only a few times in the field and not until the 7th of July. No eggs could be found at any time during the summer. Woods found that fleabeetle eggs are laid 10 - 14 days after the emergence of the adults. Apparently the insecticides killed the beetles before they oviposited. Until determinations on the egg-laying habit are made, Woods' observations will be applied to Massachusetts.

Apparently no adults survive the winter. Shaw et al. (1950) reported finding an adult on June 10, 1948 when larvae were present in numbers. Since no aberrant development was noted by the writer, it seems unlikely that one or just a few individuals would mature as early as that. However, it is less likely that one or a few individuals would overwinter as adults when the habit of the species is to survive the winter as an egg.

Biological Observations

The egg.

Until 1950, eggs of the fleabeetle had been obtained only in laboratory cultures by Woods (1918), Hatched eggs, presumably of the fleabeetle, had been found by Shaw (1950) in 1947. They had never been observed in the field as far as could be determined from the literature or by inquiry with workers in the field. From observations in the laboratory, Maine workers suggested that the eggs were probably laid on or near the base of the vines. By very close scrutiny of the litter at the base of the vines, the eggs were found. Some were lightly attached to pieces of brown dried up leaf, while others were loosely mingled with the litter. The slightest jarring of the litter caused most of the eggs to fall through and be lost. The only way that the eggs could be collected satisfactorily was to wet the point of a dissecting needle and touch it to the eggs which had been exposed by teasing aside leaf particles in the litter. The eggs occurred singly or in groups of 2 to 4. Those eggs which could be collected were brought into the laboratory where they hatched. The larvae were reared.

Having discovered the actual location of the eggs and observing their appearance, it is felt that two white

eggs observed by Shaw on July 23, 1948 were not those of the blueberry fleabeetle. Other hatched eggs found by Shaw in the fall were undoubtedly those of A. sylvia which had hatched the previous spring. Many hatched eggs were found by the writer under similar circumstances in the fall of 1950. They were found where unhatched eggs had been that spring and where no eggs were known to have been laid that summer. Thus, it is assumed that they were the same eggs which hatched that spring. Such a conclusion is substantiated by the knowledge that the overwintering stage is the egg and that one generation a year occurs.

Fleabeetle eggs are extremely difficult to locate. It is almost impossible to find infested areas unless the infestation is extremely heavy. Only 21 eggs per sq. ft. were found where later an average of from 80 to 100 larvae were present. Thus it follows that if the population were reduced to where only few eggs were deposited per square foot, there would be only a slight chance of finding them.

Hatching

When hatching occurs, three slits are produced at the cephalic end of the egg extending about one third the length. The egg remained orange colored after hatching, indicating that the chorion contains the pigment. Eggs collected in the field at intervals preceding hatching

gave interesting results when brought into the laboratory and exposed to constant temperatures. An indication of the approximate time of hatching was obtained by comparing when hatching took place in the laboratory to when the eggs were collected in the field. Table 6 shows the data collected. As the date of hatching in the field was approached, the eggs took less time to hatch under constant warm temperatures. The data indicates that if 3-4 days of 80° temperature had prevailed about the 24th of April hatching might have taken place. It is further suggested that as the eggs accumulated degree days the time that the eggs took to hatch in constant warm temperature decreased. The fact that eggs hatched in cold storage, which were collected on May 10, suggests that once that process has begun it continues to completion. It should be noted, however, that eggs which were collected on the 24th of April and kept in cold storage took nearly as long to hatch after a week of storage. There must be a time, then, in the embryonic development of the egg in the spring when hatching is not slowed down by a change to colder temperature. This, however, may not influence survival, since the larvae and not the eggs would be slowed down but not necessarily killed. Larvae which hatched in cold storage were alive 24 hours after hatching, but no data was taken on the effects of prolonged exposure

Table 6. Time required for hatching of A. sylvia at 80° F. in relation to the date collected in the field.

Date collected	No. eggs used	No. days to hatch at 80° F.
4-24-50	8	3 - 4
4-24-50*	7	2 1/2
4-27-50	16	1 - 2
5-6 -50	8	1/4-1
5-10-50	12	hatched on same day while in cold storage

*Kept in cold storage (40° F.) for one week after collecting.

to storage temperatures.

Woods (1918) and Phipps (1930) were the only workers to study the blueberry fleabeetle up to the time of Loeber's and the writer's studies. The results of the present investigation were for the most part in agreement with the observations of previous workers concerning the egg. The great difference occurred in the approximate date of hatching of the eggs. In Maine, May 24 was given as an early date and the end of May as an average. In Massachusetts, the end of April or first of May is an average, the eggs having hatched about April 25 in 1949 and 1951, and on May 10 in 1950.

Effect of burning on the fleabeetle eggs.

Burning over of the blueberry lots is usually done when there is still either some snow, or at least moisture from recently melted snow, present in the top soil layers. Thus burning is carried out before the eggs hatch. Although the eggs receive protection where there are spots of moisture or snow, workers generally agree that the eggs are killed where burning takes place. For the most part, a field which had an infestation of fleabeetles the summer before burn usually has little damage on the new vines after the burn. Observations in Lot 6 shed some light on this problem. The lot had been burned in the spring of

1950. On June 5, when the area was discovered, there was no vegetative growth present except a few succulent new shoots that were probably only a week old. It was obvious that although small areas had been incompletely burned, fire had apparently scortched and killed all the buds. It was found that burning had killed the eggs everywhere in the field but those incompletely burned places. Further, those eggs hatched and the larvae survived until shoots broke through the ground. However, larvae which had been collected in lot 6 on June 5 did not pupate in the laboratory although they recovered from a shrunken state of starvation and developed normally as larvae when fed. Insufficient data was obtained to thoroughly understand what happened, since the grower applied a parathion spray to the lot on June 6.

Burning does kill the eggs of the fleabeetle, but elimination of the population in a field is dependent on a complete, thorough burning of the entire lot.

The larva.

Following hatching the larvae crawl through the surface litter beneath the blueberry vines for as long as one to two days, a factor which may be of great importance when considering possible control measures. The larvae are quite small and do not move very rapidly. Within one or two

days they begin to ascend the plant stems. Feeding starts as soon as the leaves unroll from the bud. The larvae then crawl inside the buds, where they feed on the developing leaves. Usually, all the buds on the plant are infested. When the leaves have entirely unfolded, the larvae feed mostly on the leaves of the lower part of the plant. Indications are that weather variation may have an effect on the position of the larvae. On cloudy, dark days the larvae can be found on all parts of the plants, even on the upper sides of the leaves. When the sun is out, the larvae are not so conspicuous and remain on the lower part of the plant and on the under-side of leaves.

As the season advances and the lower leaves are devoured, the larvae become more noticeable in the field. Unless complete defoliation occurs, the larvae usually do not move about to any extent on the leaves. However, if disturbed they fall to the ground and do not necessarily return to the same plant. Rain will bring about the same effect.

Occurrence of molts in A. sylvia.

Collection of larvae by sweeping was made in observation lots 1 and 2. In each lot, 10 sweeps with a 12" net were made on May 12, 15, 17, 22, 27 and June 5. The contents of the net from each sample were put into a waxed

pint container and taken back to the laboratory. The captured organisms were then killed in boiling water. All the material was then transferred to alcohol vials for preservation. At a later time it was analyzed to determine how many larvae were present and which instars were predominant at a given time. A comparison was also made between the development of larvae of the two lots.

Table 7 shows the total number of larvae collected in each sample. There are two apparent reasons for the gradual increase in the number collected over the period: 1, the larvae feed inside the leaves and on the lower part of the plant in early spring; and 2, hatching period may be somewhat extended. The small number collected from Lot 1 on June 5 resulted from the larvae having entered the ground.

The larvae in each sample were compared by measuring the width of the head capsule to determine which instars were present and in what proportion. Figure 10 shows the percent of each instar present in each sample in relation to the number of days after hatching (May 10). In every sample, the development in Lot 1 was more advanced than in Lot 2. Table 7 indicates clearly that the larvae in Lot 1 went into the ground to pupate earlier than in Lot 2.

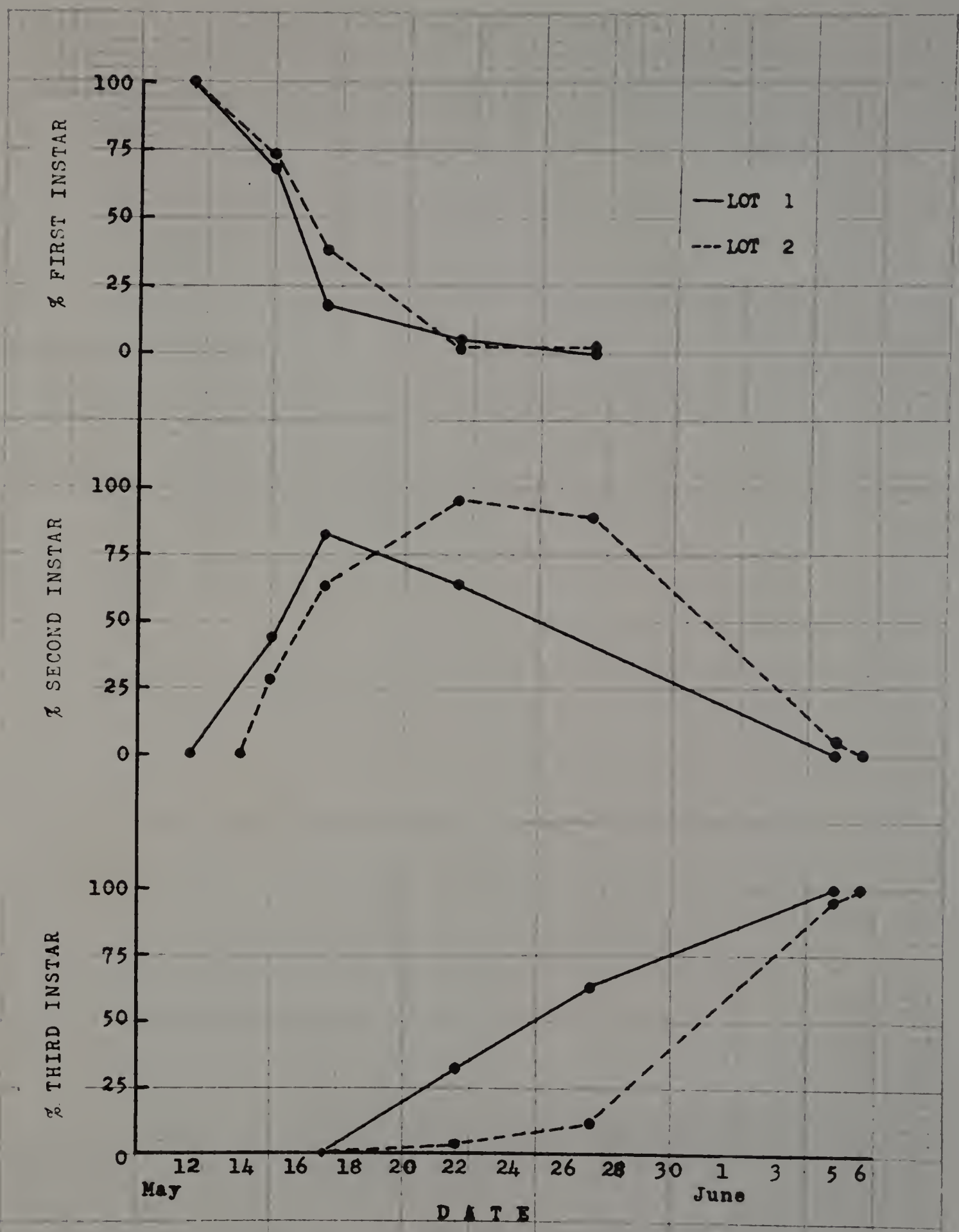


Figure 10. Comparison of larval development in Lots 1 and 2 based upon the percentage of each of the three larval instars present in field samples collected during May and June.

The more rapid development in Lot 1 cannot be attributed to any one factor. Several factors are involved; such as exposure, degree of shelter by surrounding vegetation, altitude, and others probably not recognized. It appears that exposure to the sun and shelter from winds, which blow away the ground-warmed air near the surface, are the most important factors.

The Pre-pupa

After an average of 5 days following the second molt (Woods 1918), larvae crawl into the ground. Very crude, simple cells are made not more than 1/2" in the ground beneath the top litter. Here, the larvae remain without molting or changing form for approximately 7 days (Woods 1918). The third and final molt then occurs and the pale yellowish-orange pupa occupies the cell, while the shed skin sometimes adhers to the caudal tip of the pupa.

The Pupa

According to Woods, the average time spent as pupae is 11 days. The most noticeable change in the pupa is a progressive darkening from yellow-orange to bright deep orange to a grayish caste. Woods states that the order of color changes of the eyes, mandibles, and appendages is

constant as is the time at which the changes occur.

The Adult

The adults of A. sylvia were first collected on June 24 in 1950. By June 28th the adults were extremely numerous. Observations were made of the habits in the field and in the laboratory. Problems of movement and migration, feeding, and reproduction were investigated.

Movement and migration

Fleabeetles were observed to determine the nature of their normal activity. When the temperature is above 75° F., they are extremely active, walking rapidly up and down the vines and over the leaves. Frequent pauses are made for sporadic feeding. Quite often the fleabeetles jump aimlessly from vine to vine, vine to ground, and vice versa. Loeber (1950) stated that fleabeetles do not fly. The writer observed that the fleabeetles use their legs to jump from their position, but carry themselves the last third of the distance by flying. It was noted, however, that rarely did the distance exceed 10 inches. Further, most of the movement was in a vertical plane.

In order to study migration, an attempt was made to mark the adults. Adults were collected and marked with aluminum paint on the thorax in one case and on the elytra in another. Aluminum paint was found to be entirely un-

satisfactory, since it did not persist and became unnoticeable. Due to the elimination of the adults by control applications, further attempts were impossible. Loeber (1950) suggested sweeping an area clean and recording reinvasion. The writer found this extremely difficult. The habit of the fleabeetles of falling to the ground when disturbed made clean sweeping practically impossible. A general indication can be drawn from collections made in Lot 2 when the adults were present. When emerging from the pupal stage, they occupied a localized area about 45 feet long and 20 feet wide. In 12-14 days they had become evenly spread over an area twice as large. Migration was slow at first and later speeded up as defoliation occurred forcing the beetles to search for food.

Feeding

Larvae and adults are the only stages which injure the plants. The larvae feed for 23 days causing partial defoliation of fields except in heavy infestations where complete defoliation sometimes occurs.

The adults begin feeding where the larvae ceased. In areas where larvae caused partial defoliation the adults effect complete defoliation. The type of damage of the adults is the same as that of the larvae, a scalloping of the margins of the leaves. Because of the lack of food and the increased power of movement the adults move

over a wider area than do the larvae. The adults appeared to feed less voraciously. The little amount of feeding observed in the field brought up a question of whether feeding was done at night. No data was obtained to settle the question.

The adults are much less active during cloudy, rainy spells, but contrary to Loeber's observation, the beetles were more conspicuous on the plants. At that time, they were found more often on the upper surfaces of the leaves and near the tops of the plants. Very little feeding was done and the beetles remained in one place for long periods.

Reproduction

Beetles were brought into the laboratory and kept in moist petri dishes containing sprigs of blueberry leaves. Copulation was observed only a few times. Those were for short periods only. No long periods were observed as Woods had observed and suggested as normal. Oviposition was effected in cultures, a total of 78 eggs having been laid in two tests. The beetles had been collected July 6 in the field and began laying eggs 6 days after the start of observations. Five females were in one dish and layed an average of 13 eggs each. The other dish contained 4 females and one male, the females layed

an average of 3 eggs each. The dish with five females proves that copulation took place in the field prior to July 6.

Observations of the adults in the field were carried on but were prevented after July 8. The growers applied effective sprays on that date which killed all but a few scattered adults. The total length of the adult feeding period as well as the length of life of the adults could not be determined definitely. The time of oviposition was not established. According to Woods (1918), the adults lay eggs 10 - 14 days after emergence. The facts that the adults were killed about 14 days after emergence and that no eggs were found indicate that Woods' data is correct. It is possible that a few eggs may have been laid and not found, but copulation was observed only as late as July 7, and no oviposition was observed whatsoever. Scattered individuals were collected feeding later in the summer but no eggs could be found during the remainder of the season.

CONTROL INVESTIGATIONS

Chemical Control

Review of work in other areas.

Early workers (Woods, 1918 and Phipps, 1930) recommended lead arsenate at a rate of 5-6 lbs./100 gal. in two applications; one in June for larvae, and one in July for adults. With the advent of the new synthetic organic insecticides, lead arsenate was outmoded as in many other insect control programs. The Maine Experiment Station (Anon. 1947, 1949) recommended an early application of DDT dust (3-5%) at the rate of 10-15 lbs. per acre just before the blossoms open. A later application of a calcium arsenate (50%), monohydrated copper sulfate (10%), hydrated lime (40%) dust, recommended primarily for blueberry maggot, was felt to be sufficient for controlling the adults. Maxwell and Pickett (1949) gave essentially the same recommendations to growers in Canada. Shaw et al., (1950), following an opinion of Lathrop in Maine, did not recommend DDT after the blossoming period. However, after conducting limited tests on adults with DDT (5%), parathion (1%), and tetraethyl pyrophosphate (1-2500 dilution), they did find that from the standpoint

of cost and residual toxicity DDT would be preferable to the other materials.

In recommendations to Massachusetts growers (Shaw and Wheeler 1949) E.H. Wheeler, extension entomologist, advocated use of either a 5% DDT dust or 2lbs. of DDT wettable powder per 100 gals. of water for larval control before blossom time. He suggested using a rotenone dust for adult control in later applications if the residue of calcium arsenate was a problem. Eastern States Farmers' Exchange (Anon. 1952), using recommendations of local extension workers, suggest in their spray schedule that a 5% DDT dust be used against larvae and either the 50-10-40 calcium arsenate, mono-copper, lime mixture or a 5% DDT dust be used against adults.

Control Problems.

A. sylvia appears to be relatively easy to control. Lead arsenate, calcium arsenate, DDT, parathion, and TEPP have been used effectively in spray and dust treatments. If the eradication of the fleabeetle were the sole objective of control studies, these insecticides would be sufficient. However, certain problems must be considered. First, DDT and arsenicals, if applied too near harvest, leave on the leaves toxic residues which are hazardous to human health. Second, applications to control one insect

have a profound effect on other insects which is undesirable, the outstanding example of which is the buildup of serious new pests where new organic materials have been used. Third, in the extensive and extremely rough blueberry areas, water supplies are limited and applications of materials are difficult. Fourth, insecticides may produce plant injury.

Consequently, control of the fleabeetle must be studied with several objectives in view: 1, control of the pest; 2, minimum injury to the plant; 3, toxicity of materials to organisms other than the fleabeetle, especially beneficial types; and 4, practicality of materials from the grower's standpoint of availability and application.

Methods.

Designation of Plots.

A part of Lot 2 was selected as a site for control tests because it had an extensive infestation. Individual plots were laid out where conditions of plant cover and infestation were most uniform. In order to determine the location of infested areas before selecting the plots for pre-hatching tests, counts of eggs were taken at random. Although the counts were difficult and tedious to make, they proved to be accurate indications. If more than 15

eggs were counted per square foot, the area was considered to be heavily infested. Only the plots for pre-hatching applications were selected in this way. The other plots were laid out after the larvae were present.

The pre-hatching and early larval test plots were 10 x 10 feet, the late larval plots were 10 x 20 feet, and the adult test plots were 12.5 x 25 feet. They were not made larger for three reasons. First, since variation in plant cover and infestation is great, it was most desirable to have the plots all in the same area. Second, the infested area was not extensive enough to include the same number of larger plots. Third, the water supply for spray mixtures was not readily available and the area was inaccessable to the extent of limiting the type of applicator to a 2 1/2 gallon compressed air sprayer.

Treatments and Dosages.

Tables 8, 9, 10, and 11 list the materials used with the concentrations, rates, and dosages. In all cases where possible, dusts were given preference for treatments, and as many dust formulations as possible were included. Other materials such as wettable powders, suspensions, emulsions, and solutions were included for comparison and for testing where no other formulation was available.

Commercial concentrations of the insecticides were

taken at rates most commonly used by growers in control of similar types of pests.

Application

The dusts were applied with a plunger-type hand duster of one quart capacity. An even coverage was applied and the dosage determined by weighing the duster and its contents before and after application. The amount of dust used in each plot was found to be much greater than that which the growers might apply. 50 to 60 lbs. per acre were applied in the tests while growers might use 10-20 lbs.

The sprays were applied with a compressed air-type sprayer of 2 1/2 gallon capacity. Best coverage was obtained by using 2 gallons per 100 square feet, a dosage of 800 gallons per acre. The material was applied to the point of runoff in leaf sprays and to the point of saturation in ground sprays. It was found that good coverage could not be obtained with less than 400 gallons per acre, which seemed to be the absolute minimum. This was indicated in the late larval and adult tests where only 1 gallon of spray mixture was applied to 321 sq. ft. a dosage of 135 gallons per acre.

Treatments were applied so that there would be little or no contamination by drift to adjacent plots. Record was made in cases where drift occurred. The dusts,

particularly, were applied in the early morning when the plants were wet and the wind was at a minimum.

Collection of data.

The effects of various larval treatments were measured by making counts of the larvae in the plots before and after application. Six sweeps with a twelve inch net were made across the plot but avoiding marginal areas. The larvae or adults were then counted and deposited back in the plot at the center. Counts were made at intervals of several days, since daily sweepings would overly disturb the activities. Check plots were swept and counted to determine the effects of factors other than the treatments. Observations were made and recorded on plant injury, although no measurement was made in terms of yield or growth.

Results.

The results of the following tests are indicative rather than conclusive since replicates of treatments were not included. Further studies are necessary, in the laboratory and in the field.

Pre-hatching tests.

A di-nitro material, DN-289, an Eastern States emulsifiable oil, and two concentrations of DDT 50% wettable powder were applied to the ground litter and dormant vines on May 3 before any eggs had hatched. Table 8 shows the

results of larval collections which were made at intervals after application. The first larvae were collected on May 14.

DN-289 gave good control but caused severe injury to the buds and subsequently the leaves were in poor condition. However, the vines apparently recovered in about three weeks and produced some fruit. Eastern States emulsifiable oil gave no control whatsoever. Neither did it injure the vines.

No larvae were found at any time in the two plots treated with DDT and no damage was observed on the foliage. Apparently the larvae were killed while crawling through the litter after eclosion. Figures 11 and 12 illustrate the lack of damage in DDT-treated plots and the extent of feeding in the untreated plots respectively. Observations during the test period indicated that many other insects were normally active in the treated plots, especially the pollinating insects and other flying insects. Loopers (Geometridae) and certain other crawling forms were not as abundant in the treated plots, however.

Controlling the fleabeetle with DDT in pre-hatching applications has several advantages. First, a completely effective control may be achieved. Second, residual action prevents reinfestation throughout the entire lerval

Table 8. The effect of DDT, DN-289, and Eastern States Emulsifiable Oil on *A. sylvia* when applied before the eggs hatch.

Treatment	Rate*	No. larvae per 6 sweeps					
		May 13	May 14	May 17	May 22	May 26	June 5
DDT 50%	2 lb./100	0	0	0	0	0	0
DDT 50%	4 lb./100	0	0	0	0	0	0
Check	---	0	60	75	80	100	100
DN-289	2 qt./100	0	0	20	0	0	0
E.S.E.O.	2 qt./100	0	40	100	150	150	200
Check	---	-	80	100	150	150	150

*Dosage in all spray treatments was 800 gal. per acre.

Fig. 11. Condition of the foliage on July 1 in a plot treated with DDT before the eggs of A. sylvia hatched. (Photo by Robert L. Coffin)

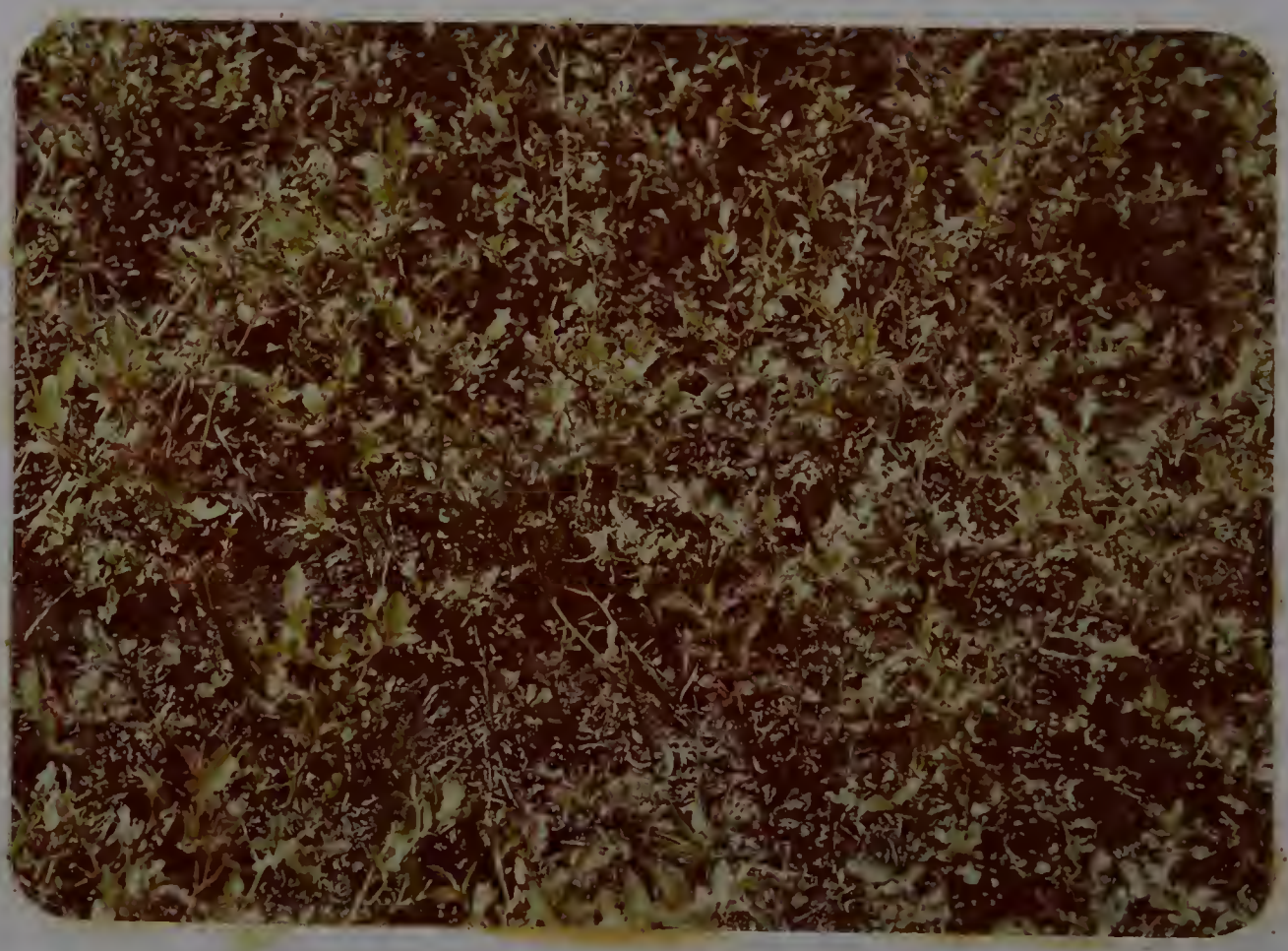


Fig. 12. Condition of the foliage on July 1 in an untreated plot. (Photo by Robert L. Coffin)

period and possibly into the adult period. Third, the leaves are not covered with toxic materials which interfere with physiological processes of the leaf or other insects which may be beneficial or noninjurious. Fourth, danger to pollinating insects is avoided. Fifth, a minimum amount of damage is effected by drawing spray machinery over dormant vines; tractors and spray rigs used in later operations caused severe injury to the vines which were overrun.

The outstanding disadvantage of late dormant applications is that the location of infestation cannot be determined readily. The eggs are not easily found by untrained persons. However, observation of damage during harvest of the previous year indicates general areas which need treatment. Records taken at that time could save the grower extra field trips in determining the extent of infestation.

Some leaf injury developed about three weeks after breaking of dormancy in the plot treated with DDT at 16 lbs. actual per acre. None was observed in the other DDT plot. The cause of the damage could not be determined definitely. Only very general effects on yield could be determined since the lot was in the third year after burn and relatively unproductive. Some berries were produced

in the DDT plots, but none were produced in the check plots, since the larvae damaged all of the blossoms.

Early larval tests.

A series of wettable powder and dust formulations of certain new organic insecticides were applied to plots containing first and early second instar larvae. Lead arsenate was also included. The materials were applied on May 17, less than a week after hatching occurred.

The larvae were counted before application of the insecticides and at several intervals thereafter. The results are shown in Table 9. Check plots were observed throughout the test period.

DDT dust (3%), Toxaphene dust (10%), and lead arsenate suspension gave the poorest control. In general, the wettable powders gave better control than did the dusts. Methoxychlor and DDT wettable powder apparently gave better control than parathion wettable powder.

In Table 9, the reduction in numbers of larvae in Check 1 and 2 on the 19th day after treatment can be accounted for. The grower treated a part of his lot with a DDT dust, and drift occurred on all those test plots except lead arsenate, toxaphene, and check 3.

Table 9. Effect of insecticidal treatments on A. sylvia when applied one week after the eggs hatch.

Treatment	Material	Rate	No. larvae per 6 sweeps before application	No. larvae per 6 sweeps after application 5 days	9 days	19 days
Check 1	--	--	50	80	120	30
Methoxychlor 50%	WP	2 lb/100	50	0	0	0
Methoxychlor 10%	Dust	30 lb/acre	25	1	0	0
DDT 50%	WP	2 lb/100	20	0	0	0
DDT 3%	Dust	30 lb/acre	50	3	4	5
Chlordane 40%	WP	2 1/2 lb/100	40	0	1	0
Chlordane 5%	Dust	27 lb/acre	20	6	0	0
Toxaphene 10%	Dust	27 lb/acre	35	3	14	2
Parathion 15%	WP	1 lb/100	20	4	0	0
Check 2	--	--	25	30	25	10
Check 3	--	--	100	150	100	200
Toxaphene 25%	Emuls.	2 qt/100	75	0	2	0
Lead Arsenate	Suspen.	3 lb/100	100	25	35	40

Table 10. Effect of insecticidal treatment on A. sylvia when applied while larvae are entering the ground.

Treatment	Material	Rate*	No. larvae /8 sweeps before application	No. adults** per 8 sweeps after application 19 days	23 days
Parathion	1% Dust	50 lb/acre	40	7	70
Parathion	15% WP	1 1/2 lb/100	45	20	150
Lindane	1% Dust	60 lb/acre	75	10	40
Methoxychlor	50% WP	2 lb/100	40	1	4
DDT	50% WP	2 lb/100	35	2	10
Lead Arsenate	Susp.	4 lb/100	45	7	18
Check 1	--	--	60	1	22
Check 2	--	--	35	2	50
Check 3	--	--	80	60	100

*Dosage in all spray treatments was 170 gal. per acre.

**Since the larvae went into the ground at the time the applications were made, no larval counts could be made. Counts were made when the adults emerged.

Late Larval Tests

Since the applications for this test were made after most of the larvae had entered the ground to pupate, the treatments probably only contacted a part of the number present and no counts could be made in the plots until the adults emerged. Table 10 shows the counts made. Apparently, residual materials such as DDT, methoxychlor, and lead arsenate gave partial control of the beetles which emerged. One important conclusion indicated by the test is that insecticidal applications applied after the larvae begin to enter the ground are practically of no value whatsoever. This was demonstrated further by an application of parathion applied by the grower in this area on June 6. There was no apparent effect on the abundance of adults when they emerged three weeks later, and an treatment had to be applied at that time to achieve control.

Adult tests

The adults were treated over an area three times as large as that used for the early larvae. Infestation in all the areas was fairly uniform and conditions were ideal for application when the plots were treated. Good coverage was obtained with the dusts. Although the dosage was considerably higher than that which the grower might apply, Only fair coverage was obtained with the sprays. The

Table 11. Effect of insecticidal treatment on A. sylvia when applied within one week after emergence of adults.

Treatment	Material	Rate*	No. Adults per 6 sweeps			
			Before application	After application 1 day	5 days	8 days
Chlordane	40% WP	5 lb/100	100	20	3	5
Parathion	15% WP	1 1/2 lb/100	100	0	1	1
Check	--	--	100	100	60	25
Methoxychlor	50% WP	2 lb/100	200	0	0	1
DDT	50% WP	2 lb/100	200	0	2	1
Check	--	--	250	150	45	100
Methoxychlor	10% Dust	50 lb/acre	200	0	0	1
DDT	3% Dust	50 lb/acre	200	0	0	1
Check	--	--	250	200	100	150

*Dosage in all spray treatments was 135 gal. per acre.

dosage was found to be much too low for thorough coverage. 1 gallon of spray mixture was applied to 321 sq. ft. The material was spread over the plots as evenly as possible when it became obvious that there was only a small amount. Table 11 shows that very few or no larvae were found even in the plots with a low dosage. However, the indication that smaller dosages may be just as effective as the larger minimum recommended is more apparent than real. It is not likely that the grower could get even coverage, since it is more difficult to apply a small amount over a large area with larger equipment.

Immediately after spray applications, inch worms or loopers (Geometridae) which had been inconspicuous crawled to the tips of the vines and appeared to try to crawl higher. In dusted plots where DDT and methoxychlor had been used, loopers and fleabeetles were on the ground within 1 hour of treatment. 30 - 40 fleabeetle were counted in 1 sq. ft. area. The beetles fell to the ground and were kicking their feet in the air sooner in the methoxychlor treatment than in the DDT treatment. In the parathion-treated plot, no adults were seen on the vines, while in the chlordane-treated plots, the beetles were normally active on the vines. Table 11 shows the counts obtained after 1, 5, and 8 days following treatment. The presence

of a few beetles after 5 days was probably from reinfestation since these were mostly collected near the margins of the plots.

In general, methoxychlor gave the best control and chlordane the least. Wettable powders were not noticeably more effective than dusts. This may be explained by the fact that greater amounts of dust and lesser amounts of wettable powders were used than in the other tests.

Effect of DDT and methoxychlor dusts on berry size.

Reports in Maine indicated that applications of DDT dust during fruiting season reduced berry size. Berries were collected on July 20 from plots treated on July 1 with DDT and methoxychlor dust applied for the adult tests. Measurements of the diameters of the berries were made and compared with those from untreated plots.

Table 12 shows the measurements that were made for each treatment. The differences in the average of the treatments are almost negligible. The results obtained were based on berries with an extremely wide variation in diameter. It was found that berries from a lot in the first year after burn appear to be more uniform. In order to obtain a definite conclusion as to the influence of DDT on berry size, more tests will have to be conducted and in a lot where the berries are more uniform.

Table 12. Measurements of the diameter of blueberry fruit from plots treated July 1, 1950 with DDT and methoxychlor dust.

	DDT	methoxychlor	check
# berries studied	455	461	494
max. diameter	10.5	12.0	11.0
min. diameter	4.5	4.0	3.5
average diameter	7.59	7.56	7.63

Biological control

Observations were made on biological control during the season. In the latter part of May, two pentatomid bugs were found feeding on larvae of A. sylvia. Many tiny chalcid wasps of at least three species were taken in larval collections in the observation plots. Two small dipterans were also numerous where larval collections were heavy. Although no rearing was done, it is possible that these were parasites of the fleabeetle.

A fungus which was not identified accounted for great mortality among A. sylvia larvae and pupae. Shrunken, hardened, deformed larvae, which were obviously infected with fungus, were found throughout May. In one sample of

812 larvae, there were 132, or 16%, dead. It is probable that a higher percentage of mortality occurred since many dead larvae were probably on the ground and not collected by sweeping.

Woods (1918) attributed the fungal growth in larvae of A. sylvia and A. corni to Sporotrichum globuliferum Speng. He also found that the prepupae and pupae were susceptible to a wilt disease. The writer did not observe the wilt diseases but fungus-killed prepupa were numerous.

The natural enemies of A. sylvia apparently are an exceedingly important factor in natural regulation of infestations, since outbreaks are sporadic and last only a few years. It might be expected that natural enemies could be used in control if their relationships were studied in detail.

Cultural control

Burning is an important factor in control of the blueberry fleabeetle. In every lot examined, where infestations had occurred, burning eliminated the fleabeetle completely, except for small areas where burning was incomplete or absent. In one lot, where small spots had not been burned, larvae were found feeding upon new succulent shoots. The larvae had survived, apparently without

food, from the time that eggs hatched in early May until three weeks later when new shoots broke through the ground. Thus it is of prime importance that thorough and complete burning be affected, in order to prevent carry over of beetle infestation and damage to new vines.

Following burning, adult fleabeetles reinfest the area during July and August, laying eggs which create a serious infestation the following year. If the adults of that brood lay eggs the next year in the same location, the infestation in the third year after burn is devastating. However, when the field is burned the next spring, most all of the eggs are destroyed.

Two conclusions are evident: one, thorough burning destroys all of the fleabeetle eggs, effectively eliminating the fleabeetle at that time; and two, burning cannot prevent damage from subsequent reinfestation. Thus, in order to protect the blueberries, chemical controls are needed.

SUMMARY

The blueberry fleabeetle has been found only on the lowbush blueberry, Vaccinium angustifolium Ait. It is abundant only in commercial areas of blueberry production in northeastern North America and rare in other areas. It is a typical chrysomelid beetle with three larval instars readily separated by the width of the head capsule according to Dyar's Law. The ratio of increase of the width of the head capsule between instars was found to be 1.45. On this basis, the mean width of the head in the first instar is .34 mm., in the second instar, .48 mm., and in the third, .715 mm.

The fleabeetle overwinters as an egg. Eggs were discovered in their natural location in the spring of 1950, in litter at, but not on, the base of the vines. A count of more than 15 eggs per square foot was indicative of the presence of heavy infestation.

Plant injury is effected by the larva and the adult. The larvae feed on leaves, buds, and flowers, while the adults feed only on the foliage. They are capable of defoliating acres of blueberry vines and causing a heavy loss in blueberry production.

A typical life history of A. sylvia in Massachusetts was determined to be as follows. The eggs hatched about the end of April or the first of May a few days before the blueberry buds opened. The larvae fed for a period of about 23 days. During early June, they entered the ground where they spent 7 days as a prepupa and 11 days as a pupa. Adults began to emerge as early as June 26, but were most abundant after the last week in June. Apparently the adults feed for the remainder of the summer, laying eggs no earlier than 14 days after emergence. The adults die at the end of the summer. Thus a generation is completed in one year.

Control measures of two types were found to be effective: control by the practice of burning, and chemical control.

The eggs of A. sylvia are destroyed by thorough burning of the fields. Since burning is done only at three year intervals, reinfestation may occur. Chemical control must be used to prevent losses.

Preliminary control tests with chemicals showed that an application of DDT in the first week of April or within about one week before the eggs hatch was the best treatment. The DDT was used at the rate of 2 lbs. of 50% wettable powder per 100 gallons of water with 800 gallons applied to one acre.

In early larval stages, normal concentrations and dosages of methoxychlor wettable powder and dust, DDT wettable powder, parathion dust, and chlordane wettable powder and dust proved to be most effective.

Sprays and dusts applied at the time the larvae were entering the ground were generally ineffective.

Sprays and dusts applied within a week of emergence of the adults gave good control and prevented oviposition, apparently. Methoxychlor, DDT, and parathion dusts were found to be highly effective as applied.

LITERATURE CITED

Anonymous. 1947. Blueberry Dust Program for 1947. Me. Ext. Circ. 231. 4 pp.

_____ 1949. Blueberry Dust Program for 1949. Me. Ext. Circ. 255. 8 pp.

_____ 1952. Protect Your Fruit Crops the Eastern States Way. Schedules for Spraying and Dusting. Publ. Eastern States Farmers' Exchange. 32 pp.

Arkin, Herbert and Raymond R. Colton. 1950. An Outline of Statistical Methods. 224 pp. illus. Barnes and Noble Inc. New York.

Blasberg, Charles H. 1948. Growing Blueberries in Vermont. Vt. Agr. Sta. Pamphlet 19. 4 pp., illus.

Britton, W.E. 1933. Plant Pest Handbook for Connecticut. I. Insects. Conn. Bull. 344: 69-182.

Darrow, Geo. M., R.B. Wilcox, and Charles S. Beckwith. 1951. Blueberry Growing. U.S.D.A. Farmers' Bull. 1951. 38 pp., illus.

Dyar, Harrison G. 1890. The Number of Molts in Lepidopterous Larvae. Psyche 5:420-422.

Eaton, E.L. 1949. Blueberry Culture and Propagation. (in) The Blueberry. Can. Dept. Agr. Farmers' Bull. 120:3-25., illus.

Fall, H.C. 1920. On Certain Species of Haltica, Old and New. Psyche 27:101-107.

Fernald, Merritt Lyndon. 1950. Gray's Manual of Botany, 8th Ed. 1632 pp. American Book Co., New York.

Hilborn, M.T. 1950. Species or Varieties of Blueberries. (in) Producing Blueberries in Maine. Me. Agr. Exp. Sta. Bull. 479:7-8.

Hitz, C.W. 1948. Increasing Plant Stand in Blueberry Fields. Me. Agr. Exp. Sta. Bull. 467. 27 pp., illus.

Imms, A.D. 1948. A General Textbook of Entomology. 727 pp., illus. Methuen and Co., Ltd., London.

Loeber, Thomas S. 1950. A Survey of the Insect Fauna of the Lowbush Blueberry in Massachusetts. Preliminary Studies on the Biology and Control of the Blueberry Fleabeetle (Haltica sylvia Malloch). Unpublished Thesis. University of Massachusetts, Amherst. 64 pp.

Malloch, J.R. 1919. Notes on Some Species of the Chrysomelid Genus Altica (Coleoptera). Bull. Brook. Ent. Soc. 14:123-124.

Maxwell, C.W. and A.D. Pickett. 1949. Blueberry Insects and Their Control in the Maritime Provinces. (in) The Blueberry. Can. Dep. Agr. Farmers' Bull. 120:26-29.

McDannald, A.H. (Ed.). 1948. The Encyclopedia Americana. Vol. 21, 805 pp. The American Book-Stratford Press Inc., New York.

Patch, E.M. and W.C. Woods. 1922. The Blueberry Maggot in Washington County. Me. Agr. Exp. Sta. Bull. 308:77-92, illus.

Phipps, C.R. 1930. Blueberry and Huckleberry Insects. Me. Agr. Exp. Sta. Bull. 356:1-232, illus.

Sanderson, E. Dwight. 1902. Notes upon the Structure and Classification of Chrysomelid larvae. Ent. Soc. Wash. 5:21-31, illus.

Schaeffer, Charles. 1924. On a few new and old Chrysomelidae. Jour. N.Y. Ent. Soc. 32:144.

Shaw, Frank R. and Ellsworth H. Wheeler. 1949. Blueberry Insects - A Summary of their Seasonal Development and Suggestions for Control. Unpublished Extensions Notes (mimeograph). Extension Service, University of Massachusetts, Amherst.

Shaw, Frank R., John S. Bailey, and Ellsworth H. Wheeler. 1950. The Blueberry Fleabeetle. Jour. Ec. Ent. 43:387.

Smith, W.W. 1946. Culture of Lowbush Blueberries. Univ. N.H. Ext. Circ. 275:1-16, illus.

Woods, W.C. 1918. The Biology of Maine Species of Altica. Me. Agr. Exp. Sta. Bull. 273:149-204, illus.

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