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The biology of the meadow spittlebug, Philaenus leucophthalmus (L.), in Massachusetts.

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THE BIOLOGY OF THE MEADOW SPITTLEBUG, *Philaenus leucophthalmus* (L.), IN MASSACHUSETTS

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MEADOW SPITTLEBUG, *Philaenus leucophthalmus* (L.),

IN MASSACHUSETTS

by

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INTRODUCTION

As a contribution to our knowledge of insects affecting forage crops in Massachusetts, a study has been made of the biology of the meadow spittlebug, Philaenus leucophthalmus (L.).

Damage, resulting from nymphal spittlebug feeding, has been reported on a wide range of plants. Such widely diverse crops as alfalfa, celery, strawberries and roses have been subject to attack by this insect.

Relatively little work has been done on the biology of the meadow spittlebug under Massachusetts conditions. Harris (1841) referred briefly to spittlebugs in general in his "Treatise on Insects of Massachusetts Injurious to Vegetation". He listed four species as being of importance as pests in Massachusetts, but the meadow spittlebug was not one of those mentioned. Fernald (1891) presented a general outline of the life history of Philaenus leucophthalmus but reports of later authors indicate that many of Fernald's observations were incorrect. A preliminary study of the seasonal history of this insect was made by Shaw et al. (1953). They indicated that its seasonal history in this state was similar to that reported by previous workers for other states.

In connection with work on control of insects affecting forage crops, it was felt advisable to determine the effect of the meadow spittlebug on legumes especially with reference to distribution, economic importance, type of damage and the stage or stages in which this insect would be most susceptible to control measures.

REVIEW OF THE LITERATURE

Economic Importance

Although the meadow spittlebug has been reported from every continent with the exception of Australia, until recently it has seldom received more than passing interest as an economic pest of forage. The fact that scant attention has been paid to this insect, along with other meadow insects, is probably due to the low value previously placed on meadow crops, the lack of practical insecticidal control measures, and its failure to cause visible destruction to the majority of the crop. Reports of injury to plants by the numphs of spittlebugs began to appear as early as 1684. By 1902, the United States entomologists began to suspect the importance of this insect as a pest of forage. Herbert Osborn, a specialist on meadow and pasture insects, was a voluble exponent of the theory that the masses of nymphs present in legume and grass fields in the spring were causing sufficient damage to be considered economic pests. With the advent of the newer insecticides, such as DDT and Lindane, Osborn's theory was put to test and the destructive effects of this insect on crop yields were shown to be considerable. As a result, fourteen states now recommend the use of chemical measures for the control of this pest.

The abundance and possible economic importance of the spittlebug has been alluded to by various authors since the middle of the 17th century. Sibbald (1684) in England regarded the foam as "an exhalation infecting plants which speedily corrupts and engenders vermiculi and unless wiped off, it burns up the plants." Many sources were quoted by Hardy (1682) as indicating the prevalence of spittlebugs throughout northern Europe. He particularly mentioned that the Swedes believed the froth to be the cause of madness in cattle. Newman (1866) observed the damage caused by the nymphs on fuchsia in England. Cram (1869) in Connecticut reported that one Norwich farmer had been unable to produce a satisfactory grass crop for six years because of infestations of spittlebugs. In another report, Newman (1869) reported that this insect had become unpopular among florists in England due to its abundance.

Lintner (1888) reported that farmers were complaining because of the abundance of spittlebugs in New York. The following year, Lintner declared that spittlebugs caused a one-third reduction in the yields of hay. Buckton (1890) indicated that spittlebugs were the most common insect swept from meadows in Huttersfield, England. Webster (1892) indicates that Ohio farmers were complaining of the abundance of spittlebugs on timothy. Edwards (1896) listed P. leucophthalmus as being very abundant in England. It was claimed by Howard (1902) that spittlebugs damaged pasture crops. Bethune (1906) indicated that spittlebugs were so abundant in Ontario that farmers were fearful that the presence of the frothy masses would be very distasteful to feeding cattle. Spittlebugs were reported by Collinge (1906) to be very troublesome in the midland counties of England. Davis (1910) reported the presence of spittlebugs on imported roses in Illinois. Damage to a number of different plants was attributed to spittlebugs by Schmidt (1914) in northern Europe.

Spittlebugs were so abundant in Ontario according to Caesar (1916) that farmers mowed and burned their hay to prevent poisoning of the cattle. Felt (1916) reported that this insect was very abundant in New York. Doubt was expressed by Osborn (1916) that the extent of the damage done by spittlebugs was really appreciated. In his account, he indicated that they were very abundant on clover. Cameron (1917) noted that in Cheshire, England, the grass hosts of the spittlebug suffered heavy damage. Ashley (1919) indicated that spittlebugs were common on garden plants throughout England as well as on roses. A report by the USDA (1922) showed spittlebugs to be abundant on strawberries in Washington. Osborn and Drake (1922) indicated that a great amount of damage was sustained by clover in the Cranberry Lake region of New York. Murphy (1923) stated in his work on potato diseases that *P. leucophthalmus* var. *spumarius* was a possible carrier of potato leafroll. Hutchings (1928) noted an unusual abundance of this pest on garden plants and grasses in Ontario. Cecil (1930) recorded high level infestations on strawberries in New York indicating that strawberries appeared more susceptible to spittlebugs than to mildew.

During the period 1931-1933, USDA reported that spittlebugs were abundant on strawberries and forage in Oregon. Caesar (1933) indicated that this insect had been very abundant the previous year in Ontario. During the period 1929-1935, Edwards (1935) in Oregon found increasing amounts of damage to strawberries by spittlebugs. Spittlebugs were noted to be abundant in New Jersey and Delaware by USDA (1935). Driggers and Pepper (1935) reported that spittlebugs were unusually damaging to sweet clover in New Jersey and they considered them to be abundant enough for insecticide tests. USDA (1936) recorded the abundance of spittlebugs on legumes and weeds in Maryland. Spittlebug infestation was considered quite serious in Oregon by Aider (1937) who cited that large acreages of strawberries were treated by dusting with Rotenone and Nicotine + hydrated lime for the control of this insect. Besse (1938) recorded as many as 200 spittlebugs per strawberry plant in Oregon. Spittlebugs were recorded to be abundant in Delaware and Oregon and also reported to cause damage to strawberries in Oregon by USDA (1938).

USDA (1939) reported spittlebugs abundant on legumes, celery, and onions in New York, on legumes in Delaware and West Virginia, and on strawberries in Pennsylvania. During the same year, Putman (1939) cited the meadow spittlebug as a possible carrier of the plum nursery mite, *Phyllocoptes fockeui* M. & T. Also, Twinn (1939) reported spittlebugs abundant on strawberries in Ontario. A 30% reduction in yield of strawberries due to this insect was reported by the Canadian Department of Agriculture (1940). The same year, USDA (1940) found spittlebugs to be abundant in Washington and Oregon. The next year, the USDA (1941) indicated an abundance of this pest in Oregon, Delaware, Maryland, and Connecticut. The Delaware Agricultural Experiment Station in 1941 reported that spittlebugs were more abundant on legumes, weeds, and strawberries than in any year since 1935). Also in 1941, Speers indicated that _P. leucophthalmus_ adults were more abundant on Pine in New York than were the pine spittlebug adults _A. parallela_. Manns (1943) refuted his earlier report (Manns 1939) which had implicated _P. leucophthalmus_ as a carrier of the peach yellows disease of peach trees. Spittlebugs were reported by Schuh and Zeller (1944) to have reduced the yield of strawberries in Oregon from one-half to one ton per acre. Krause (1945) recorded the first appearance of _P. leucophthalmus_ in Hawaii in 1944. A report of 15-20 spittlebug adults per wheat head in fields adjoining cut hay fields was recorded by Houser (1945) in Ohio. In the same year, Putman (1945) recorded a tremendous concentration of adults moving into the Niagara Peninsula from newly cut hay fields further up the Peninsula. He reports that buckwheat and other succulent plants were killed, and much of the foliage on more mature herbs wilted and died. He also noted that the leaves on peach nursery stock wilted badly; and while the stock appeared to recover after the insects were killed by DDT, it made little or no subsequent growth.

Since 1946, some 300 reports have been published concerning the meadow spittlebug. Most of these have involved control of this species. It has been consistently recorded as a pest of both legumes and strawberries in most areas where found in the United States. The following references include only those which add to the information already given. Davis and Mitchell (1946) indicated the rapid adaptation of the meadow spittlebug to Hawaiian conditions and included an extensive host list. Fisher and Allen (1946) conclusively demonstrated injury on alfalfa and clover by adults in form of shortened internodes, stunting, rosetting, blossom blast and necrosis. Scholl and Medler (1947) indicated that a direct correlation existed between the percentage of shriveled and blackened alfalfa seed and the extent of adult spittlebug puncturing. A drastic reduction of hay yields was first demonstrated by Weaver (1950) on a field experimental basis. Chamberlin and Medler (1950) showed that under field conditions, spittlebug nymphs reduce seed yields of first cutting alfalfa. The ability of spittlebug adults to act as vectors of Pierce's disease of grape was demonstrated by DeLong and Severin (1950). The spread of the spittlebug over the state of Indiana was reported by Davis (1951) who considered it a major legume pest. Menusan (1951) in Pennsylvania showed yield reductions under field conditions of from 20 to 50 percent at first cutting.

He also indicated that the quality of hay is materially reduced and the presence of froth on the hay makes it difficult to cure. Starnes and Filmer (1952) showed that during wet seasons, plants may tolerate without serious losses a population that would cause severe yield reductions during dry seasons.

Wilson and Davis (1953) showed that there were significant correlations between populations and damage, damage and yield, and yield and stand. They found that some varieties of alfalfa, while supporting high populations of spittlebugs, had a high degree of tolerance in regard to damage. Shenefelt (1952) stated that the spittlebug was a "suspect" as a vector of oak wilt. The numbers of spittlebugs doubled in Illinois from 1948 to 1951 according to White (1952). Rowell and Whiteside (1952) report that injury caused by early nymphal feeding frequently affects the growth of the plants later in the season. Starnes and Filmer (1952) showed that visible injury in form of stunting is directly proportional to the number of spittlebug nymphs present and to seasonal moisture conditions. Wilson and Davis (1953) reported that some varieties of alfalfa show a high degree of tolerance to attack by spittlebug nymphs. Weaver (1953) reported that one adult spittlebug per sweep taken in the fall was indicative of an economic infestation in the field the following spring.

On the basis of data obtained over several years in Ohio, Weaver and King (1954) made the following conclusions:

" (1) Springtime populations in first year meadows are larger than those in second year.

(2) Harvest of the crop brings about an abrupt decline in the number of spittlebugs.

(3) Maturity of the crop brings about a decline in the spittlebug numbers.

(4) Large buildups of spittlebug populations occur in new seedings in September.

(5) August harvest of the alfalfa crop will result in a large buildup of spittlebugs in September.

(6) September harvest of alfalfa brings about low populations of spittlebugs.

(7) May populations of nymphs are correlated with populations of adults in September."

Some of the more recent literature has expanded our knowledge of the extent to which the meadow spittlebug is involved in the economic aspects of legume growing.

Spittlebugs were so numerous on lettuce at Thedford, Ontario, The Canadian Department of Agriculture (1954) reports that control measures were necessary. An unusual infestation of seed spinach in which severe stunting and eventual death occurred was noted in the same area by the Canadian Department of Agriculture (1955). Medler (1955) described a heat-unit method utilizing day degrees for predicting the hatching dates of eggs. It was later modified for use under Ohio conditions by Weaver (1956). A relationship between peach gumosis and adult spittlebugs was conclusively demonstrated by Stearns (1956). Mullett (1958) reports that the meadow spittlebug first appeared on forage crops in Tennessee in 1953). By 1957, it was common on legumes throughout the eastern third of the state and was considered a major forage pest. Wilson and Dorsey (1957) demonstrated that the spittle provided a favorable environment for bacterial growth and isolated several species including two members of the genus *Achromobacter* which are known plant pathogens.

Damage

The symptoms resulting from the feeding of meadow spittlebugs are often readily apparent. Osborn (1939) reported that clover and buttercup seed heads withered and failed to provide seed. Mundinger (1946) indicated that the nymphs stunt and deform strawberry plants. Alfalfa plants in heavily infested fields in Wisconsin were observed by Fisher and Allen (1946) to be dwarfed, rosetted, blossom blasted and necrotic. They also showed that when adults were placed in cylindrical screen cages over uninjured plants that after a month, identical damage was apparent on both caged and uncaged plants. They noted too that adult spittlebug damage on alfalfa in some respects resembled the yellows disease brought on by leafhoppers, but there is the obvious difference that spittlebug feeding shows up in small brown dead spots on the green foliage, while leafhoppers cause a general yellowing.

Scholl and Medler (1947) showed that there is a direct correlation between the percentage of shriveled blackened seed and the extent of adult puncturing, feeding on green seed pods and immature seed. They also showed that the feeding of nymphs and adults caused a characteristic bunchy top condition of alfalfa plants. In California, Severin (1950) showed that the feeding of the nymphs causes leaf curling around the spittle on celery. They observed leaf curling around the spittle masses and dwarfing of the apical leaves was found to be common amoung ornamental flowering plants. Starnes and al. (1952) found that stunting was directly proportional to the number of spittlebugs present and to the seasonal conditions of moisture in connection with alfalfa, clover, and mixed hay.

Pepper (1954) reports that, in addition to stunting and reduction of growth, the vitality of the plants is lowered, hay quality is reduced by the production of fewer and smaller leaves and more and tougher stems, and also that the protein content is reduced. Nymphs are reported to be particularly destructive by Gyrisco (1953) causing a dwarfing, twisting, and crinkling of alfalfa, red clover, ladino, and birdsfoot trefoil. He also noted that adults cause a different type of injury, their feeding often causing a yellowing of the second cutting. Breaky and Brannan (1955) noted that strawberry leaves on which spittlebug nymphs have fed are usually distorted and turn purplish in the feeding area while berries, often developing unevenly, are small and seedy in texture and lack flavor.

Taxonomic Position

The meadow spittlebug belongs to the family Cercopidae of the order Homoptera. At the present time, it is known by the specific name <u>Philaenus</u> <u>leucophthalmus</u> (L.). While it may be easily confused with closely related forms, the characters of differentiation provided by Doering (1930) will suffice to distinguish it. The vertex is twice wider than long. The length of the front is distinctly greater than the length of the vertex on the median line. The ocelli are close to the posterior margin and about equidistant both from each other and from the eyes. The pronotum is rounded and is equal in width to the head. The two-segmented labium extends only as far as the middle coxae. The elytra are broad and have convex costal margins. Their apices are not reticulated. The corium is without a terminal membrane. The apex of the clavus is acute. The hind tibia has two stout spines and a crown of smaller spines encircling the apex. While pubescence is present all over the body, it is not prominent.

The actual scientific name of the meadow spittlebug is surrounded by a certain amount of confusion. The original description by Linnaeus (1758) of <u>Cicada</u> <u>spumaria</u> (L.) has been shown to be readily applicable to *Aphrophora alni* Fallen. Although the markings of the commonly occurring form of the meadow spittlebug are similar to those of *Aphrophora alni*, the latter insect is larger and differs in other fundamental respects. Because size was not mentioned in the original description, later authors have contended that Linnaeus actually described the species later described by Fallen (1805).

The only possible clue as to the actual identity of the specimen before him was given by Linnaeus when he stated that his species was found abundantly on *Salix viminalis* L. Horvath (1898), upon examining the Linnean collection, found it to contain specimens of both *Aphrophora alni* Fallen and *Cicada spumaria* (L.). Therefore, basing his contention upon the Linnean host plant, Horvath showed that the form designated as *spumaria* by Linnaeus should be transferred to *Aphrophora alni* Fallen while the specific name *leucophthalmus* referred to the common *Philaenus* sp. Kirkaldy (1906) followed Horvath's lead and proposed that the name of *spumaria* Fall, be made *leucophthalmus* since this name would be next in availability.

American authors, in the main, accepted Horvath's line of reasoning and called the meadow spittlebug *Philaenus leucophthalmus*, in which form it now appears in the official list of common names of insects of the American Association of Economic Entomologists (1956). Many European writers rejected this course of action and continued to look upon the insect, in question, as spumarius.

Ossiannilsson (1950) reviewed Horvath's opinion and rejected it concluding that the evidence was actually in favor of Fallen's original interpretation. His premise is based, in part, upon actual observation in Sweden where he reports that P. leucophthalmus is more frequently found on Salix sp. than Aphrophora alni Fallen during pre-imaginal stages, whereas the latter is abundant on herbaceous plants. He has requested the International Commission of Zoological Nomenclature to review his argument and make a ruling that Aphrophora spumaria Germar (= A. alni Fallen) be taken as the valid genotype of the genus Aphrophora, Germar. Hence C. spumaria L. would be regarded as identical with Cercopis spumaria Fallen = Cicada leucophthalmus L. = Philaenus spumarius Stal. The actual scientific name would then be P. spumarius (L.) with P. leucophthalmus (L.) as a synonym.

Weaver and King (1954) have accepted Ossiannilsson's arguments. Salmon (1954) has strongly rejected the opinion of Ossiannilsson. He contends that in England and other European countries, only Aphrophora sp. are found on Salix sp., P. leucophthalmus (L.) being with few exceptions confined to herbaceous plants. There is no way of ever knowing just which specimen Linnaeus had before him when he described Cicada spumaria (L.). Therefore, the only recourse is for all to accept the decision of International Commission of Zoological Nomenclature when it is made known.

Early authors tended to describe many of the common varieties as species, thus adding to the confusion. As a result, tracing of the actual synonomy of the meadow spittlebug is very difficult. Weaver and King (1954) have assumed that *Cicada spumaria* (L.) is actually the meadow spittlebug and until an actual decision is rendered, this appears to be the best choice.

Synonomy of *Philaenus leucophthalmus* (L.),(Weaver & King 1954)

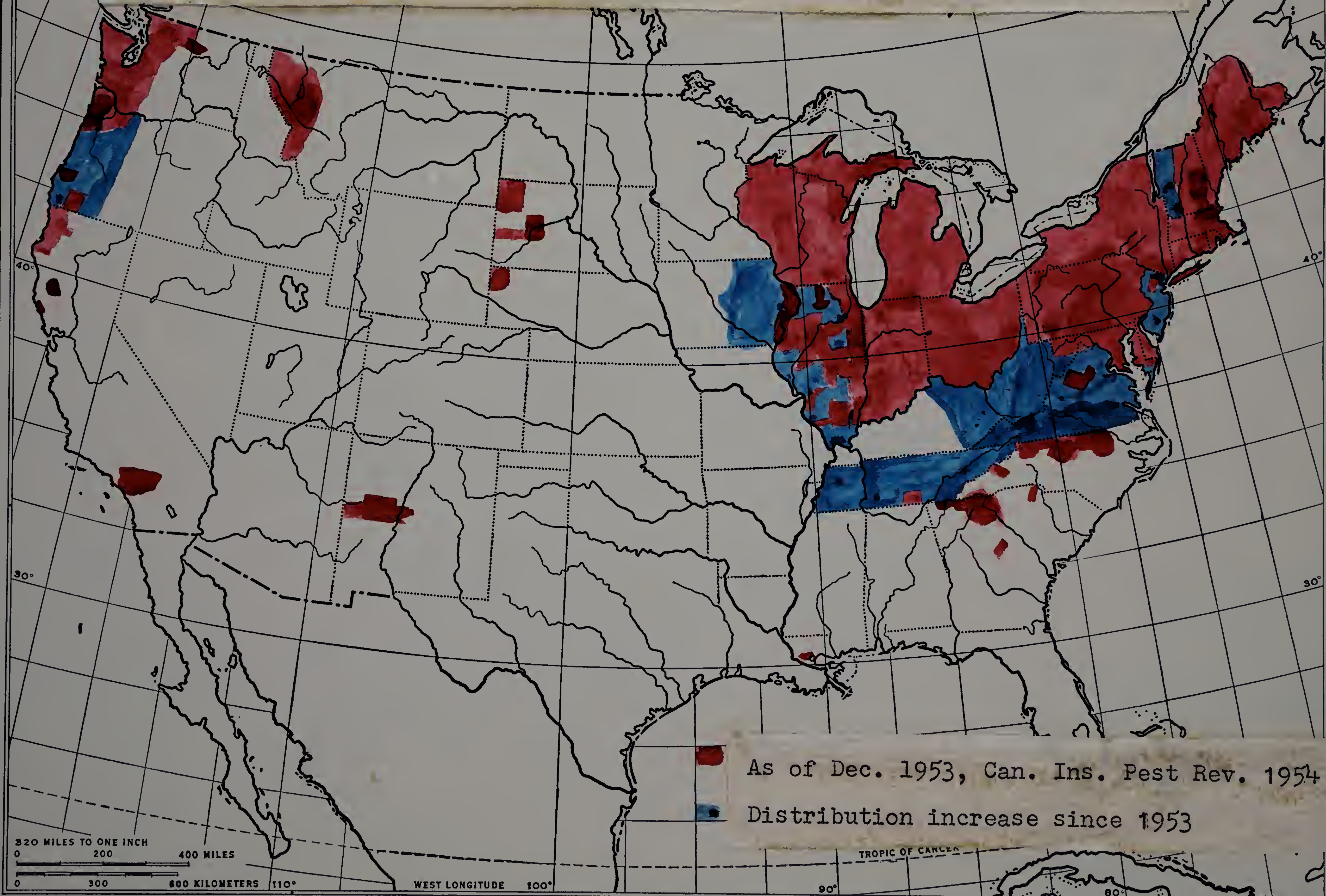
Cicada spumaria L. 1758
Cicada leucophthalma L. 1758
Cicada leucocephala L. 1758
Cicada lateralis L. 1758
Cicada flavicollis L. 1761
Cicada populi L. 1761
Cicada oenotherae Scopoli 1763
Cercopis populi (L.) F. 1775
Cercopis gibba F. 1775
Cicada trilineata Schrank 1776
Cicada albomaculata Schrank 1776
Cicada quadrimaculata Schrank 1776
Cercopis fasciata F. 1787
Cercopis biguttata F. 1787
Cercopis leucophthalma (L.) F. 1794
Cercopis marginella F. 1794
Cercopis leucocephala (L.) F. 1794
Cercopis lineata F. 1794
Cercopis proeusta F. 1794
Cercopis capitata F. 1794
Cicada xanthocephala Schrank 1801
Cercopis lateralis (L.) F. 1803
Cercopis spumaria (L.) Fallen 1805
Tettigonia spumaria (L.) Tigny 1810
Aphrophora leucophthalma (L.) Germ. 1821
Aphrophora apicalis Germ. 1821
Aphrophora oenotherae (Scop.) Germ. 1821
Aphrophora marginella (F.) Germ. 1821
Aphrophora bifasciata (F.) Germ. 1821
Aphrophora leucocephala (L.) Germ. 1821
Aphrophora lineata (F.) Germ. 1821
Aphrophora fasciata (F.) Herr.-Schaff. 1838
Ptyelus bifasciatus (Germ.) Walker 1851
Ptyelus leucophthalmus (L.) Walker 1851
Ptyelus spumarius (L.) Flor 1861

Philaenus spumarius (L.) Stal 1869
Ptyelus albiceps Prov. 1872
Philaenus impictifrons Horvath 1911
Philaenus leucophthalmus (L.) Oshanin 1912
Philaenus graminis (DeGeer) Haupt 1919
Ptyelus graminis (DeGeer) Regnier 1936

Because of the great variability in color shown by *Philaenus leucophthalmus* (L.), several varietal names have appeared in the literature. Haupt (1917) proposed fifteen fairly clear-cut varieties for Europe with four distinctive intergrades. Eight of his generally recognized forms are found in North America according to Doering (1930): *spumarius* (*graminus* of Haupt), *leucophthalmus*, *leucocephalus*, *lateralis*, *fasciatus* (*xanthocephala* of Haupt), *marginellus*, *fabricii* (*vittata* of Haupt), and *pallidus* (*populi* of Haupt).

Doering (1930) dissected the genitalia of the seven color varieties, excluding *marginellus* of which no males have yet been found, and found no structual differences. DeLong and Severin (1950) repeated the procedure and concluded that this would seem to preclude the possibility of any biological significance based on color variation. Personal communication with Doering (1957) indicates that the series of specimens in her collection intergrade from one extreme of color form to the other. She states that "there is really no reliable feature for separating them into varieties, but for convenience sake, where the variety color is typical, it seems useful to use the variety name." DeLong and Severin (1950) described a new variety, *impressus*, on the basis of a row of four impressed dark pigment spots

Plate I. Distribution of the Meadow Spittlebug, Philaenus leucophthalmus (L.) in the United States according to CEIR records and State reports as of December 1957.



arranged transversely across the anterior pale portion of the pronotum. Weaver and King (1954) however, do not consider this character to be significantly different to warrant its being raised to the varietal category, inasmuch as the impressions are present on varieties other than spumarius. Salmon (1954) has divided the European varieties into two general color groupings, viz.: melanistic forms in which the predominant coloration is black or dark brown, and pallid forms in which the coloration is always light. This type of arbitrary breakdown would appear to merely add to the confusion rather than be of any significant value.

Distribution

Distribution of P. leucophthalmus

Philaenus leucophthalmus has been recorded from Europe, Asia, Africa, Japan, and North and South America according to Weaver and King (1954). So common in Europe is the spittlebug that two of its favorite hosts take their common names from its presence. Silene inflatz is known as the spattling poppy, and the Swiss call Cardamine pratense, the meadow foam plant.

For the purposes of this paper, I will confine myself to a discussion of the distribution and spread of this insect in the United States. The map on the opposite page shows the distribution of this insect as of December 1957. The regions within which this insect is considered to be economic importance are expanding consistently year by year.

The map also records the advances made by _P. leucophthalmus_ since 1953, when a survey was made by the Bureau of Entomology and Plant Quarantine (Canad. Ent. 1954). The ensuing records are a compilation of reports received from various state entomologists and the cooperative Economic Insect Report.

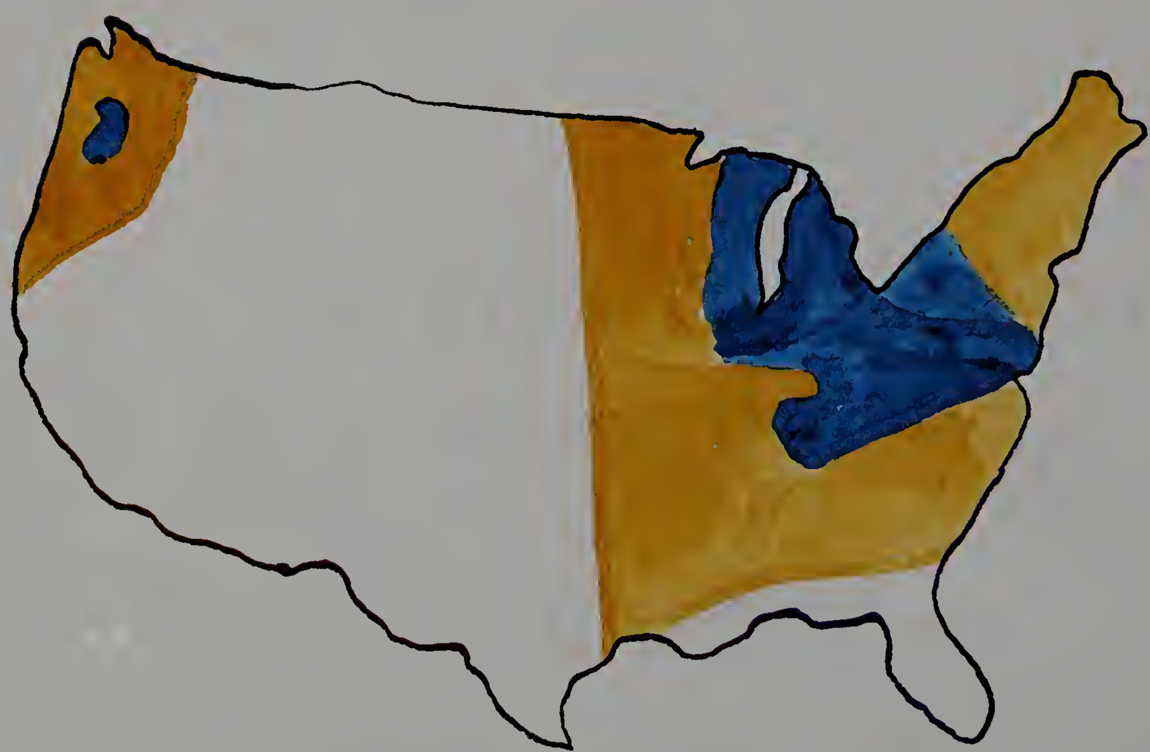
In addition to the presence of satisfactory host plants, the prime factor defining the abundance of the meadow spittlebug is high humidity. There is a direct correlation between the concentrations of spittlebugs and humidity. This is illustrated by the maps on the following page.

One finds that the highest concentrations of spittlebugs are contained within the regions of highest humidity. As the humidity declines, the preponderance of spittlebugs decline also. In all stages, this insect is dependent on high humidity for survival. Weaver and King (1954) has shown that eggs fail to survive under conditions of low humidity. He has also found that first instar nymphs fail to become established if the weather is dry. As the nymphs mature, they are constantly surrounded by a microclimate of their own making, as well as the humid microclimate created by the growth of foliage. Without the necessary rainfall, the plants upon which they feed would be unable to provide the necessary fluid for this operation. Adults are said to be attracted to and apparently survive best on succulent foliage throughout the summer months. Weaver and King (1954)

Plate II Relation of Humidity to Distribution of the Meadow Spittlebug

A.

B.



A. Super Humid — Dry

Humid — Semiarid

Moist — Arid

B. Region where insect is of economic importance.

Region where insect is known to exist.

report that under Ohio conditions, the oviposition site is dependent upon the availability of succulent foliage. Areas in which P. leucophthalmus occurs as an isolated phenomenon are probably interzonal by nature, consisting of spots in which rainfall and humidity are not characteristic of the region in which they are found. The possibility also exists that these may be areas where irrigation is used.

In many of the regions where the meadow spittlebug is considered an economic pest, hay is the principal crop. A second factor must therefore be considered which favors the abundance of this insect, i.e. a specific cropping practice in which the last cutting occurs in August. This has the effect of allowing time for new succulent growth to flourish, thus attracting adults to these fields during the oviposition period. The greater the number of adults ovipositing in a given field, the greater is the infestation the following spring.

Biology

Early accounts of the biology of the meadow spittlebug gave only a very general picture of the seasonal activities of this insect. Swammerdam (1682), Debeer (1741), and Rosel (1749) presented a general outline of the life cycle. In 1912, Licent added some further details stating that the young insects hatch in the spring, spend their nymphal life beneath spittle, and the adults, upon emerging, move around and copulate in August and September. He further observed that egg laying, begun in September, lasted until severe frosts when the adults died. Ahmed (1949) was the first author to make both qualitative and quantitative studies of the meadow spittlebug.

Further studies have been made of the life history of the meadow spittlebug by different authors in various states. Osborn (1916) made a study of the life cycle of this species in Maine. Scholl and Medler (1947) briefly summarized the seasonal history of this insect in Wisconsin. Severin (1950) reported the seasonal history in California. Menusan (1951) gave a brief life history of the meadow spittlebug in Pennsylvania. Teller (1951) made a detailed study of this insect under Maryland conditions. Shaw, Bourne, and Boyd (1953) reported the seasonal history of this pest in Massachusetts. Putman (1953) recorded the life history of the spittlebug in Ontario. Weaver and King (1954) in Ohio have made the most comprehensive study of this insect to date. Quinton (1956) summarized the seasonal history of this insect in Connecticut.

Egg

Rodman (1921), apparently the first to describe the egg outside the female body, also noted the hatching device utilized by the nymph to escape from the egg. Barber and Ellis (1922) observed that eggs are inserted between the stem and leaf sheath of grasses. They also described and figured the eggs of <u>Philaenus</u> <u>leucophthalmus</u> (L.) as well as those of <u>P</u>. <u>lineatus</u> (L.) and <u>Philaronia</u> <u>bilineata</u> (Say).

Nymph

Hatching occurs from late March to late April depending upon the latitude and seasonal variation, and the young nymphs immediately seek out a convenient host. Ahmed (1949) noted that the cycle from egg to adult averaged 34.4 days in Ohio under greenhouse conditions. Weaver and King (1954) in the same State observed that the nymphal period is usually from forty to fifty days under field conditions. They showed that it may be shortened to thirty-five days or lengthened to one-hundred days by temperature manipulations.

There has been some question as to the number of instars *Philaenus leucophthalmus* passes through previous to adult emergence. Osborn (1916) in his study of the species in Maine observed three instars and thought possibly that there was another one. Driggers and Pepper (1935) noted that the nymphs hatch in April and May in New Jersey and complete their growth in from four to eight weeks. They believed that there were four molts during the nymphal stage. Cecil (1930) and Mundinger (1946), who described the life cycle of this insect in New York, stated that there were five nymphal instars but failed to indicate the method used to arrive at this conclusion.

The first qualitative and quantitative study of this problem was made in Ohio by Ahmed (1949) using Dyar's law. While he concluded that there were only four instars, further analysis of his data by Weaver and King (1954) showed that there were actually five. Teller (1951), Marshall (1951), King (1952), and Weaver and King (1954) collected nymphs at regular intervals throughout the season. On the basis of the measurement of the width of the head capsules, they concluded there were five instars.

Production of Foam

Many theories have come down through the centuries to account for the presence and production of foam. Gruner (1901) records that St. Isidore of Seville (Sixth Century) was the first to attribute the spittle masses to the cuckoo. He also cites Bock (Sixteenth Century) who made a list of plants that produced spittle. Other authors, over the years, have attributed the foam to horseflies, to the stars and to exudations from the ground, according to Guilbeau (1908). Another theory advanced by Ray (1710) that the spittle was produced from the animal's beak, was held to be true until recent years. While Fabre (1900) correctly attributed the spittle to an insect, he believed that the liquid welled up from the injury at the point of insertion of the insect's beak. Blankaart (1690) was probably the first to recognize that the fluid was emitted through the anus of the insect. While many of the early investigators agreed with this idea, there was some confusion as to whether it was a clear fluid of foam that issued forth.

Batelli (1891) indicated the presence of glands in the seventh and eighth segments of the abdomen which emitted a waxy secretion. Berlese (1909) believed that the majority of spittle issued from these glands. Working with Aphrophora *parallela*, Guilbeau (1908) demonstrated that the Batelli glands had some connection with foam production by searing the integument in the region of the glands. The foam subsequently produced was no longer stable and Guilbeau concluded that the necessary constituent which allowed the foam to persist so long was secreted by these glands. Licent (1912) had a different theory as to the origin of the material which gives the foam its stability. He demonstrated that the anterior smooth portion of the Malpighian tubules was large and functional in cercopid nymphs but degenerated after the last molt. He concluded that a mucin or mucinoid gave the foam its stable quality. Kershaw (1914), analyzed the constituents of the foam of *Tomaspis saccharina* and showed this to be the case. A third theory is that of Sulc (1912) who maintained that the waxy secretion of the glands of Batelli was acted upon by an intestinal enzyme. Sulc showed that this reaction resulted in the formation of a fatty acid which then combined with the alkaline material discharged by the anus imparting to the froth its soaplike properties. Cecil (1930) believed that the Malpighian tubules did not have the capacity to produce the volume of foam which issued forth. He claimed that no addition was necessary for the production of stable foam as he could find no glands of Batelli in the meadow spittlebug in his study of the alimentary canal. However, the glandular discharge has been described both by Morse (1900) and Osborn (1916) in living insects. That the glands are present can easily be demonstrated according to Putnam (1953) by dropping the nymph in 70% alcohol and observing the waxy secretion which coagulates laterally on the seventh and eighth segments. Wilson and Dorsey (1957) suggest the possibility that the bacteria present in spittle synthesize polysaccharides that stabilize the bubbles formed. While anyone of the above theories may be the correct solution to the problem, there is as yet a lack of confirmation of any one of them. Thus, it appears that adequate proof awaits further study.

Morse (1875) was apparently the first investigator to have a clear conception of the actual mechanism by which the bubbles are introduced into the anal fluid. Sulc (1912) and Ahmed (1949) describe the "air canal" formed by the extensions of the tergites of the fourth to ninth segments. Weber (1930) demonstrated that the tracheae enter this air canal enabling the insect to obtain air even though submerged in the foam. Weaver and King (1954) describe in detail the method by which air and anal fluid are mixed together to form spittle.

The description of this process as given by Weaver and King (1954) is herein cited. Within a few minutes from the commencement of feeding, fluid appears at the anal opening. The liquid adheres to the body of the nymph and as more fluid issues forth, the insect becomes partially submerged. At the same time, the posterior end of the abdomen is elevated with the posterior segments extending and contracting in a telescoping fashion. Outside the fluid, the lateral folds of the tenth segment in conjunction with a posterior flap open to allow air to enter the "air canal". Extensions of tergites of the fourth to ninth segments meet and overlap on the median line to form this canal, thus enclosing a space under the venter of the insect. At the third sternite, a caudally projecting triangular piece splits the canal into a Y. These branches are closed at their anterior end by projections of the first and third tergites which meet the triangular sternal projection. Thus is formed an open channel which extends from the ninth to the third segment where it splits to continue on to the hind margin of the thorax.

The air may enter this "air canal" either through the tracheal system of the insect as shown by Weber (1930) when the insect is surrounded by fluid or it may enter naturally when the posterior flap and the lateral folds of the tenth segment are open. When the canal is filled with air, the lateral folds and the posterior flap of the tenth segment are closed and the abdomen is wholly drawn beneath the fluid. The body of the nymph is then contracted and a bubble of air is forced out between plates of the posterior segments into the clear fluid. Continuous repetition of this process several times a minute soon enables the nymph to cover itself with bubbles of foam.

Actual analysis of the contents of the spittle mass has not been attempted until recent years. Early determinations were concerned mainly with the constituents found in plant sap as compared to those found in the spittle. Licent (1912) showed that cercopid spittle contained more water than plant sap (99.44 vs. 94.57%). He also found that there was less organic matter (0.14 vs. 3.83%) and less inorganic matter (0.38 vs. 1.60%) in spittle. Gruner (1901) found the same constituents and also suggested that the spittle probably contained all the substances excreted from the anus. The first comprehensive study of the composition of insect spittle was carried on by Wilson and Dorsey (1957). Using paper chromatography, they demonstrated the presence of certain sugars and amino acids. They further demonstrated that the spittle masses of Philaenus leucophthalmus and Aphrophora parallela contained fewer sugars and amino acids than the plant juices from which each was derived. The pH of the spittle was shown to be more alkaline than that of the sap of the plants upon which the nymphs were collected (7.05 - 7.81 vs. 5.73 - 6.36).

Host Plants

Various authors have made note of the plants upon which the nymphs of the meadow spittlebug feed. The great variety of host plants which have been named would suggest that they are able to survive on almost any plant which can provide them with the necessary succulence. While the majority of host lists contain mostly herbaceous species, some woody plants appear. This is only true, however, when adventitious shoots or the current year's tender growth are still available to the nymphs after the more succulent foliage in the area has become dried or has been cut. The writer observed a number of nymphs feeding on adventitious shoots of slippery elm following the clipping of other plants upon which the insects had been feeding.

Weaver and King (1954) have compiled a list of some 381 host plants based on the records of 26 authors as well as observations of their own. While these species probably do not represent the entire flora upon which this insect feeds, it does give some indication of the ability of this insect to survive in almost any locality in which climatic conditions are favorable.

Adult

Following its emergence from the nymphal state, the callow adult is nearly white with a slight greenish cast. Within a few minutes, it begins to assume its characteristic color pattern. Unless disturbed, it remains inside the spittlemass until its wings have dried.

Adult spittlebugs are relatively active insects and when alarmed may hop over a considerable distance. Weaver and King (1954) have observed them traveling for more than 100 feet in a single flight. Using marked adults, they showed that spittlebugs may travel as much as 300 feet from the point of release within twenty-four hours. They also found by using tangle foot bands at various heights, that the majority of adults travel no higher than four feet.

When the plants upon which the spittlebugs are feeding begin to decline in succulence or if the crop is cut, the adults migrate to new locations. Shaw and al. (1953) found that adults may migrate from mature fields of alfalfa to newly seeded pieces nearby previous to cutting. Weaver and King (1954) indicate that the direction of movement from the field is determined largely by wind since the adults are not strong fliers. They also report that the adults can survive in a large variety of ecological habitats, ie. corn, oats, wheat, wastelands, bluegrass pasture, and legume pastures. Stearns (1956), in Illinois, showed that there was a definite migration of <u>Philaenus leucophthalmus</u> adults to peach orchards by the use of "sticky board traps".

Due to the prolonged period between emergence and egg laying, adults must feed in order to survive. Weaver and King (1954), in tests using radioactive phosphorus as a tracer, proved that adults will feed upon almost any plant which offers a plentiful supply of moisture. They noted also that while reports of crop damage by adult spittlebugs have been substantiated, damage has been slight despite the large numbers of adults which congregate there.

There is a gradual decline in the adult population during the summer season. Weaver and King (1954) state that this reduction results both from death by natural causes and the dissemination of the population over wide areas. They further found that the onset of cold weather will reduce the population through the effect of cold on the insects and by starvation due to the elimination of host plants. Individuals can still be found until the onset of severe freezes. Edwards (1935) reported a rare case of finding a female on the twenty-fifth of January in Oregon.

According to Weaver and King (1954), copulation may be observed from early June until late in the fall. Driggers and Pepper (1935) stated that copulation began in July. Doering (1930) noted that the different varieties mate interchangeably. Smith (1940) noted that individuals paired indiscriminately, sometimes remaining "in coitu" for five days. Eggs are normally developed in the female in late summer. DeGeer (1773), Harris (1842), and Newman (1870) stated that in autumn, the females have their abdomen full of eggs. Osborn (1916), working in Maine, found eggs within the female in late August. Weaver (1951) noted that the development of eggs in the female body is coincident with the lessening of nomadic activity.

With the advent of autumn, the adults, having been widely scattered during the summer, select certain favorable oviposition sites where they appear in great numbers. Teller (1951) indicates that eggs are laid in certain favored fields for many years in succession. Weaver (1951) observed that grain stubble appeared to be the most attractive oviposition site.

Cecil (1930) reported that oviposition took place in September and October. Weaver and King (1954) substantiated Cecil's observations. Mundiger (1946) states that eggs are commonly placed in the axil of grass between leaf and stem, and the leaf is cemented over it. Severin (1950) reported that eggs were deposited diagonally in packets firmly attached to the stems of Sacramento barley. Although adults were found to live for some time on alfalfa, no egg masses were found on these plants. Weaver (1951) found that the eggs are inserted in packets between the dead leaf sheath and the stems of various grains. Recent accounts of the life history of the meadow spittlebug are in agreement with a single exception. Chamberlin (1949) found that in Southeastern Alaska, the adults emerge in late summer and fall, overwinter and deposit their eggs in early spring.

Parasites and Predators

Previous to 1954, there was no published record of any natural enemies attacking the eggs of the meadow spittlebug. In that year, Weaver and King recorded five species of Hymenopterous parasites from eggs collected in the field. They indicate that fewer than ten percent of the eggs are parasitized.

Few natural enemies of the nymphs of Philaenus leucophthalmus are known. While Stirrett (Can. Dept. Agric. 1947) reported that a large number of strepsipterous larvae were found in nymphal cercopids in Ontario, he failed to mention whether the meadow spittlebug was the cercopid involved. Westwood (1840) reports seeing a wasp dragging a nymph from its spittle mass. Weaver and King (1954) indicate that some authors have noted spiders, harvestmen and various predaceous Hemiptera feeding upon nymphs. Nolan (1956) in Indiana reports that the prairie warbler, Dendroica discolor Vieillot, systematically searches for and feeds on nymphs, within the spittle masses. Although the species was not identified, the meadow spittlebug was the commonest species in the area.

The work carried on by Weaver and King (1954) is the only published record of natural enemies of the adult spittlebug. They found the orthopterous parasite, Agamermis decaudata C.S. and C., common in both male and female specimens. Some internal dipterous parasites were recovered in the course of dissecting females for eggs, but these were immature specimens and could only be identified to family (Larvaevoridae).

Undoubtedly adults are commonly attacked by any parasite or predator which attacks free flying insects. Weaver and King (1954) have observed swallows following the mowers at harvest time presumably to feed on the clouds of spittlebugs which arise as the plants are cut.

METHODS AND PROCEDURES

Studies were carried on both in the laboratory and in the field to determine the life history and habits of the meadow spittlebug P. leucophthalmus under Massachusetts conditions. Laboratory studies were confined to the spring of 1956, due to the lack of available equipment for the study of the effect of temperature and humidity. It was felt that a great deal more might be gained by studying the insect in its natural environment. Field surveys for this insect were carried on weekly over a period of two years in conjunction with surveys for other insects attacking forage crops.

Rearing Techniques

Attempts were made for two years in succession to obtain an adequate supply of eggs for laboratory rearing by confining adults in a cage 4' x 3' x 3', placed on the ground outside the greenhouse at the side of Fernald Hall. Both rye and wheat were planted within the enclosure for the adults to feed on. Rye was planted on one side and wheat on the other to indicate whether the adults would show any oviposition preference. Weaver and King (1954) indicated in their work that the addition of straw would incite a greater amount of oviposition. Following this lead, straw was placed on the ground between the two grains. Approximately three hundred adults were placed in the enclosure the autumn of 1956 and about one hundred the

the autumn of 1957. Inasmuch as eggs are laid in packets between the stem and leaf sheath of dead stems mostly, it is unfortunate that both years the maintenance crew raked out the plots in question. That the eggs were removed was apparent in the spring of 1957 when only a single nymph was noted in the new growth of rye.

Over the two-year period, many attempts were made to discover eggs in the field. These attempts were unsuccessful with the exception of two packets of eggs found in the fall of 1957 on some dead stems of rye. Eggs could be obtained fairly easily by confining a number of females in a large wide-mouthed glass jar with moist paper towels and freshly cut stems of alfalfa. This procedure was followed in the fall of 1956 but the eggs did not survive the winter due to the lack of equipment to provide the necessary humidity. At the time of peak egg laying in 1957, the author was making a State survey and could not carry on this experiment.

As a consequence of the above and because of the inability of the author to obtain eggs in the field due to the small number present, specimens of nymphs had to be obtained following hatching and established on plants in the greenhouse.

In the spring of 1956, nymphs were obtained in the field and established on plants in the greenhouse. Twenty-four plants of <u>Silene vulgaris</u> (bladder campion) were potted separately and one nymph was placed on each plant. The plants were placed within an enclosure covered with cotton muslin to prevent sunlight from shining directly on the spittle masses, thereby, possibly reducing their chances for survival.

The flower pots were kept sufficiently far apart so that the nymphs could not crawl from one plant to another. The plants were watered once or twice daily by running a small stream of water around the base of each plant. It was felt that if they were sprayed in the same manner as the other plants in the greenhouse, the nymphs might be knocked from their positions by the force of the water. The cloth-covered enclosure was also useful in this respect. The humidity within the greenhouse was maintained by hosing it down two to three times daily. The temperature remained fairly constant, through a range of 70 - 80° F.

Field Studies

During 1956, weekly surveys were made throughout the summer season with the exception of the month of July when work was curtailed due to work being conducted on other problems. During the 1957 season, weekly surveys were made of five alfalfa fields, one grass and alfalfa mixture, one mixed red and white clover, one red clover, and one grass field. With the exception of three weeks in September when the writer made a State survey, the seasonal history was followed in the aforementioned fields, from the first hatch in April until the first snowfall the following December.

All surveys for adults were conducted in the same manner to make results as nearly comparable as possible. Two identical nets with 12" diameters were utilized for all sweepings. One full swing was construed to mean the movement of the net through 180° arc, and this definition was adopted for all collecting. Fifty sweeps were taken in each field. Each field was approached in a characteristic fashion, ten sweeps in each of the four corners and ten sweeps in the middle. Despite the difference in field size from one to another, the average population for a given area will only differ from field to field in comparison to the population density in a given field.

It was found that jars containing a layer of plaster of Paris and saturated with ethyl acetate gave the quickest kill. By using the nets alternately, it was possible to have at least one net resting in a killing jar at all times. Thus, it was possible to collect in one field and place net and insects in the killing jar and still have a net available even though the time consumned in reaching the next field was not long enough to kill the insects. The insects were then transferred to plain wide-mouth jars until the return to the laboratory. This method has the advantage of speeding up collection and also enabling the collector to be sure of retaining all the insects collected.

The insects were sorted, counted, and recorded immediately upon return to the laboratory. Specimens of the meadow spittlebug were removed, sexed, identified as to variety and then placed in glascine envelopes for possible future reference. Biological observations were begun too late on the nymphal populations in 1956 to get adequate field data as to the relative abundance of different instars over the period of nymphal development. This situation was remedied the following spring. Nymphal development was followed by examining nymphs collected at approximately weekly intervals. The nymphs were collected in a random fashion from three fields, the results being taken collectively.

While several different methods have been used to determine the nymphal population in a given field, no attempt has been made to show whether these methods are comparable. For this reason, it was felt advisable in 1957 to attempt to determine if there was any correlation between the different methods. Four methods were utilized in the study: (1) the use of a three-foot rod which was thrown into the field at random, (2) the use of a square foot wooden frame which was treated in the same manner as the above, (3) the 100 stem count method, and (4) the 125 sweep method. The last method was devised to determine whether nymphs swept up in the net during the spring gave an accurate picture of the population in a given field.

BIOLOGICAL OBSERVATIONS

Description of Stages

Egg

Rodman (1921) was probably the first to describe the eggs of the meadow spittlebug as found outside the body of the female. Previously, Osborn (1916) had dissected the eggs from fertilized females. Barber and Ellis (1922) also described the eggs and included illustrations in their paper.

The eggs of Philaenus leucophthalmus are creamy white, shiny, elongate ovoid structures lacking ornamentation. They are broadly rounded at one end, tapering slightly towards the opposite end. Measurements made by the author show that eggs range from .79 mm. to 1.16 mm. in length with an average of .98 mm. They range from .30 mm. to .43 mm. in width with an average of .34 mm.

The eggs are usually laid in masses held together by a hardened frothy cement. Captive females, however, often laid eggs singly on moistened paper toweling. No single eggs have been found by the author in the field, although it is probable that they are also deposited in this fashion. Plate (III) illustrates the shape of the eggs and the frothy cement by which they are attached between the leaf sheath and the stem on grain stubble.

Nymph

Various workers have studied the nymphal stages of the meadow spittlebug. Osborn (1916) found three instars but

Plate III. Eggs of <u>Philaenus leucophthalmus</u> cemented to a stem of rye.

believed that there was one more. Cecil (1930) described the life cycle of this insect in New York, indicating that there were five instars. Driggers and Pepper (1935) disagreed stating that there were only four. Mundinger (1946) believed that there were five instars. None of the above indicated the method by which they reached their conclusions.

Ahmed and Davidson (1949) were the first to make a systematic study of the nymphal stages. They measured the duration of each instar under greenhouse conditions and came to the conclusion that there were four instars. An incidental part of their work was the measurement of the width of the head capsules. Teller (1951) and Weaver and King (1954), measuring the head capsules of randomly selected nymphs, concluded there were five instars. Systematic collections by Marshall (1951) and King (1952) and subsequent head capsule measurement indicated five instars. Upon this basis, Weaver and King (1954) rechecked Ahmed's Thesis and separated his fourth instar nymphs into fourth and fifth, showing that Ahmed's figures were closely correlated to those of later workers.

All previous workers have taken head measurements of randomly selected nymphs. Because of the possible variability which might arise due to the growth process during a particular instar, the author felt it would be more logical to measure the width of the head capsules of the molted skins. While the size of the insect increases within each instar, it can only increase to the limits of its exoskeleton.

The exoskeleton should therefore provide a reliable index to the actual number of instars. On this basis, the author obtained results which definitely indicate the existence of five instars. As can be seen in Table 1, there is a definite gap which delimits each instar.

Workers, previously mentioned, obtained a fairly constant ratio between instars with the slight exception of that between the first and second instars. Weaver and King (1954) averaged the data of other workers as well as their own and concluded that Dyar's "Law" was probably applicable to the meadow spittlebug. The ratio between instars obtained by the author is somewhat at variance with that of other workers. The possibility exists that the number of specimens measured by the author is not of sufficient size to be statistically significant. See Table 2.

Table 2 is also a comparison of the mean width of nymphal head capsules obtained by various investigators. As can be noted, the head capsule measurements of the fifth instar exuviae are slightly less than those of other workers and the measurements of the head capsules of the adults are slightly more. It is probable that an insufficient number of fifth instar exuviae were measured.

During nymphal development, other morphological changes accompany the increase in head capsule width. Through successive instars, the length of the legs increases in proportion to the length of the body. The tarsi become less bulbous and the abdomen becomes flattened dorso-ventrally.

Table 1. Figures in millimeters obtained by the measurement of the width of the head capsules of molted nymphal skins using 3X ocular with a micrometer reading of .033 mm/unit

First Instar

.33	.41	.45
.40	.43	.46

Average = .41

Second Instar

.53	.56	.63	.66	.69
.53	.56	.63	.66	.69
.53	.56	.63	.66	.73
.53	.59	.63	.66	.73
.56	.59	.63	.66	.73
.56	.59			

Average = .61

Third Instar

.83	.88	.92	.96	1.02
.86	.88	.92	.96	1.02
.86	.88	.92	.96	1.02
.86	.88	.92	.96	1.02
.86	.92	.92	.96	1.05
.86	.92	.96	.96	1.09
.88	.92	.96	.99	1.09
.88	.92	.96	.99	1.09
.88	.92	.96	.99	1.16
.88	.92	.96	.99	1.16

Average=.95

Fourth Instar

1.22	1.29	1.32	1.39	1.45
1.22	1.29	1.32	1.39	1.45
1.22	1.29	1.35	1.39	1.49
1.22	1.29	1.35	1.39	1.49
1.25	1.29	1.35	1.39	1.49
1.25	1.32	1.35	1.39	1.52
1.25	1.32	1.35	1.39	1.52
1.29	1.32	1.35	1.39	1.52
1.29	1.32	1.35	1.42	1.52
1.29	1.32	1.35	1.42	1.52
1.29	1.32	1.35	1.42	1.55
1.29	1.32	1.39	1.45	

Average 1.36

Fifth Instar

1.62	1.72	1.75	1.82	1.85
1.65	1.75	1.78	1.82	1.95
1.65	1.75	1.82	1.82	
1.68	1.75	1.82	1.85	

Average 1.77

Adult

2.37	2.31	2.21	2.08	2.31
2.11	2.05	2.15	2.28	2.28
1.98	2.21	2.15	2.21	2.18
2.24	2.11	2.15	2.15	2.14
1.98	2.11	2.21	1.95	2.31
2.11	2.21	2.17	2.21	2.21
2.08	2.15	2.24	2.37	2.40
2.34	2.15	1.98	2.34	2.05
2.24	2.01	2.11	2.21	2.14
2.24	2.21	2.15	2.08	2.15

Average = 2.17 mm.

Table 2. Mean width of nymphal head capsules in millimeters obtained by various investigators.

Source	Total Number Measured (All Instars)	1	2	3	4	5	Adult
Ahmed (corrected)	453	0.35	0.67	0.89	1.21	1.87	2.0
Teller	105	0.42	0.64	0.91	1.34	1.97	
Weaver	122	0.40	0.67	0.95	1.39	1.99	
King	1160	0.40	0.64	0.89	1.31	1.88	2.03
Average (unweighted)		0.39	0.65	0.91	1.31	1.93	
Ratio, adjacent instars		1.67	1.40	1.44	1.47		
Lavigne	210	0.41	0.61	0.95	1.36	1.77	2.17
Ratio, adjacent instars		1.48	1.55	1.45	1.30		

The first and second instars are difficult to separate, both being orange in color. In the third instar, the wing pads begin to appear making differentiation relatively easy even in the field. The fourth instar is characterized by a change in color from light yellow to light green and the wing pads overlap the first abdominal segment. The fifth instar nymph is green in color and the wing pads have developed distinguishable venation. The variability existing between the body lengths of various instars dependent upon feeding activity, makes this an unreliable characteristic.

The following brief descriptions may be utilized for a more specific determination of the nymphal instars at hand.

First Instar: Head capsule width 0.33 - 0.46; average 0.41 mm.; body orange in color; wing pads undeveloped; legs long in proportion to body.

Second Instar: Head capsule width 0.53 - 0.73; body orange in color; legs longer in proportion to body; wing pads still undeveloped.

Third Instar: Head capsule width 0.83 - 1.16; body orange to yellow in color; wing pads rudimentary, assuming the shape of lateral enlargements of the meso and metathoracic tergites having sharply differentiated distal margins.

Fourth Instar: Head capsule width 1.22 - 1.55; body yellow to light green in color; wing pads expanded laterally and caudally, slightly overlapping the first abdominal segment with distal margins rounded.

Fifth Instar: Head capsule width 1.62 - 1.95; body green in color; wing pads with distinguishable venation, appearing as well developed lobes extending posteriorly beyond the first abdominal segment.

Adult

The features which distinguish the meadow spittlebug from others similar in appearance are as follows. The insect averages 6.24 in length and has a head capsule width averaging 2.17 mm. The head is broad and short, being equal in width to the rounded pronotum. The vertex is half as long as wide and is bluntly angular. The ocelli are separated by a width equal to that between them and the eyes. The eyes are prominent on the side of the head. The antennae are inserted on the genae between the eyes. The two segmented labium extend only as far as the middle coxae. The general body form is short and squat from whence comes the term "froghopper". The elytra, which are held in the form of a tent over the abdomen, are bluntly rounded, meeting beyond the tip of the abdomen. The costal margins of the elytra are convex and the apex is not reticulated. The corium lacks a terminal membrane. The apex of the clavus is acute. The hind tibia have two stout spines and a crown of smaller spines about the apex. The adults of this species are covered with a short pubescence.

The great variability exhibited by the color pattern of this species has created a taxonomic problem. The reader is referred to the discussion on taxonomy in a previous section for information relating to this variable.

Economic Importance in Massachusetts

The importance of *Philaenus leucophthalmus* as a pest depends on the density of the nymphal population on cultivated host plants.

Previous to this study, no attempts had been made to determine the economic significance of the meadow spittlebug in Massachusetts. It was not known whether the infestations, which appeared to be of a general nature, were sufficiently destructive to be termed economically important. Studies in other states, specifically Ohio and Illinois where within the last fifteen years this insect has become a major pest on legumes, indicated the advisability of conducting a survey designed to provide this information.

The preferred cultivated hosts in Massachusetts are alfalfa, red clover, white clover, and strawberries. While small grains are also considered as preferred hosts in other states, those species are seldom grown commercially in this state.

The author has noted many of the damage symptoms reported by previous workers in the course of his study of this problem. Probably stunting and shortened internodes are the most obvious results of nymphal feeding on alfalfa. The entire plant tends to be smaller and have a rosette type of growth. Where the plants have attained the majority of their growth, before being attacked, only the terminal portions of the stems are shrunken and deformed. On clover, no distinct rosette is apparent although plants may be similarly stunted. The meadow spittlebug is one of the first insects to attack legumes in the spring, but they are quickly followed by populations of leafhoppers. Lacking an insecticide which is specific for leafhoppers, it is sometimes difficult to determine if the actual damage is the result of the feeding of one or the other.

Population Densities

Earlier workers have found that when the number of nymphs per stem exceeds one, an infestation may be said to be of economic importance. Petty (CEIR 1955) working in Illinois, has recommended treatment on first year hay crops in those areas where an average of one-half or more nymphs could be found per stem. A survey was made in the spring of 1957 of some of the alfalfa fields in Hampshire and Hamden Counties. The results are shown in Table 3. All those alfalfa fields with nymphal populations exceeding .40 nymphs per stem are first year fields. If we accept the recommendations of Dr. Petty, as indicated above, then it would seem advisable to treat at least those three fields having .50 nymphs per stem or more.

Weaver and King (1954) devised a method, using statistical analysis, whereby they could predict the nymphal infestation in the spring based on the number of adults per sweep recovered in a given field the preceding September. Utiliza-

Table 3. Determination of the reliability of using infested stems as an index to the number of nymphs per stem.

Field	100 Stem Count		
	A No. of Infested Stems	B No. of Nymphs per Stem	C No. of Nymphs Predicted by Proportion Method
Townline 63, #1	.25	.42	.45
Townline 63, #2	.22	.35	.37
McNiff's	.30	.50	.55
Clusters	.10	.08	.14
Scibelli	.16	.22	.25
Tannery Rd.	.26	.50	.46
Southwick Country Club	.20	.29	.33
Fisk	.09	.09	.13
Southampton	.27	.40	.48
Edgewood Motel	.17	.20	.27
Westfield Hill	.29	.51	.52
Townline - Hadley	.16	.19	.25

tion of this method showed that one adult per sweep in the fall was the equivalent of one nymph per stem in the spring. Petty (CEIR 1955) utilized the same general method under Illinois conditions but assumed that for each adult spittlebut per sweep, there would likely be $\frac{1}{4}$ - $\frac{1}{2}$ spittlebug nymph per stem. In making a follow-up in late May after all the eggs had hatched, it was found that nymphal counts based on 100 stem samples gave county averages which did not vary substantially from those predicted.

Both of these methods have the advantage of giving actual figures upon which to base and check predictions. They also make it possible to obtain a quantitative cross section of populations in old and new fields of various mixtures of grasses and legumes as well as straight stands of legumes.

In the fall of 1956, one 50 sweep sample was taken in each of six alfalfa fields. Using both methods above, predictions were formulated as to the infestation to be expected the following spring. In late May of 1957, 100 stem counts were made for nymphs in the above mentioned fields. The results have been tabulated below.

Area	# Adults per sweep	Petty-# expected per stem	Weaver-# expected per stem	Actual # per stem
Amherst	.52	.26	.52	.42
Hadley	.04	.02	.04	.08
Southwick	.08	.04	.08	.29

Area	# Adults per sweep	Petty-# expected per stem	Weaver-# expected per stem	Actual # per stem
Southhampton	.20	.10	.20	.20
Westfield	.10	.05	.10	.51
Westfield	.46	.23	.46	.40

The above data indicates that prediction methods are reliable for this area. Weaver's method more nearly seems to fit our conditions. It should be noted, however, that if we accept Petty's recommendation, an insecticide treatment should be applied when ¼ - ½ nymph per stem is present, then we should consider four of the six fields as being economically infested and recommend control.

During the first three weeks of September 1957, a survey was made of the alfalfa fields throughout the state. The number of adult spittlebugs per 100 sweeps was recorded for each field. Having determined that Weaver's prediction method is applicable to this region, each record was broken down to the number of nymphs which could be expected per stem in the spring of 1958. On the basis of these translated figures, it would appear that none of the fields visited during the fall of 1957 will have an economic infestation of meadow spittlebug during the spring of 1958. See Table 4.

Distribution in Massachusetts

While it has been assumed that Philaenus leucophthalmus is prevalent throughout the state, no systematic survey of legumes on a state wide basis has ever been undertaken.

Table 4. Expected nymphal population in fields of alfalfa throughout the State in the Spring of 1958. Assuming one adult/sweep in the fall is equivalent to $\frac{1}{2}$ nymph/stem in the Spring.

PLYMOUTH COUNTY			MIDDLESEX COUNTY			WORCESTER COUNTY		
Adults/100 Sweeps	Adults/ Sweep	Expected Nymphal pop./stem	Adults/100 Sweeps	Adults/ Sweep	Expected Nymphal pop./stem	Adults/ 100 Sweeps	Adults/ Sweep	Expected Nymphal pop./stem
0	0	0	9	.09	.045	5	.05	.025
2	.02	.01	15	.15	.075	1	.01	.005
0	0	0	1	.01	.005	5	.05	.025
1	.01	.005	2	.02	.01	1	.01	.005
0	0	0	13	.13	.065	6	.06	.03
0	0	0	2	.02	.01	11	.11	.055
4	.04	.02	1	.01	.005	2	.02	.01
0	0	0	3	.03	.015	4	.04	.02
2	.02	.01	2	.02	.01	4	.04	.02
			3	.03	.015	12	.12	.06
Ave. 1	.01		5.1	.05		6.1	.06	

Table 4a. Expected nymphal population in fields of alfalfa throughout the State in the Spring of 1958. Assuming one adult/sweep in the fall is equivalent to $\frac{1}{2}$ nymph/stem in the spring.

BRISTOL COUNTY			BERKSHIRE COUNTY			HAMPDEN COUNTY		
Adults/100 Sweeps	Adults/ Sweep	Expected Nymphal Pop./Stem	Adults/100 Sweeps	Adults/ Sweep	Expected Nymphal Pop./Stem	Adults/100 Sweeps	Adults/ Sweep	Expected Nymphal Pop./Stem
1	.01	.005	7	.07	.035	2	.02	.01
2	.02	.01	2	.02	.01	7	.07	.035
1	.01	.005	16	.16	.08	1	.01	.005
0	0	0	27	.27	.135	28	.28	.14
1	.01	.005	11	.11	.055	20	.20	.10
0	0	0	4	.04	.02	8	.08	.04
2	.02	.01	17	.17	.085	7	.07	.035
6	.06	.03	41	.41	.205	17	.17	.085
0	0	0	1	.01	.005	15	.15	.075
0	0	0	14	.14	.07	10	.10	.05
0	0	0				15	.15	.075
						1	.01	.005
Ave. 1.1	.01		9.3	.09		10.5	.10	

Table 4b. Expected nymphal population in fields of alfalfa throughout the State in the spring of 1958. Assuming one adult/sweep in the fall is equivalent to $\frac{1}{2}$ nymph/stem in the spring.

ESSEX COUNTY			FRANKLIN COUNTY			NORFOLK COUNTY		
Adults/100 Sweeps	Adults/ Sweep	Expected Nymphal Pop./Stem	Adults/100 Sweeps	Adults/ Sweep	Expected Nymphal Pop./Stem	Adults/100 Sweeps	Adults/ Sweep	Expected Nymphal Pop./Stem
2	.02	.01	31	.31	.15	10	.10	.05
1	.01	.005	6	.06	.03	0	0	0
3	.03	.015	18	.18	.09	3	.03	.015
0	0	0	2	.02	.01	6	.06	.03
2	.02	.01	18	.18	.09	0	0	0
2	.02	.01	10	.10	.05	7	.07	.035
5	.05	.025	24	.24	.12	7	.07	.035
0	0	0	2	.02	.01			
0	0	0	29	.29	.145			
Ave. 1.3	.01		15	.15		4.7	.05	

Table 4c. Expected nymphal population in fields of alfalfa throughout the State in the spring of 1958. Assuming one adult/sweep in the fall is equivalent to $\frac{1}{2}$ nymph/stem in the spring.

HAMPSHIRE COUNTY

Adults/100 Sweeps	Adults/ Sweep	Expected Nymphal Pop./Stem
7	.07	.035
4	.04	.02
33	.33	.165
3	.03	.015
15	.15	.075
31	.31	.155
57	.57	.285
60	.60	.30
Ave. 26.2	.26	

BARNSTABLE COUNTY

Adults/100 Sweeps	Adults/ Sweep	Expected Nymphal Pop./Stem
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	

During the first three weeks of September 1957, the writer made a survey of the alfalfa fields in Massachusetts for the purpose of determining the distribution of the meadow spittlebug and other forage crop pests. A complete day was spent in each county in association with the county agent in charge of field crops. An average of 10 fields were visited in each county. A 12" net was used and one pass of the net constituted a sweep. One hundred sweeps were taken in each field.

The results of the survey indicate that this insect is present throughout the state. While specimens were not collected from every field sampled, the overall picture shows a common prevalence. Specimens were not collected from any of the fields visited in Barnstable County, but this may be explained as the result of the severe drought in the southeast section of the state which had just about ruined all the alfalfa fields. The lack of spittlebugs in legume fields in this area may then have been due to the absence of adequate succulent foliage to attract the adults for oviposition. The map on the following page indicates the relative area which was surveyed.

Varietal Distribution

The relative distribution of the different varieties of the meadow spittlebug has been noted by different authors in recent literature. DeLong and Severin (1950) listed _spumarius_, _marginellus_, _fabricii_, _pallidus_, _leucophthalmus_,

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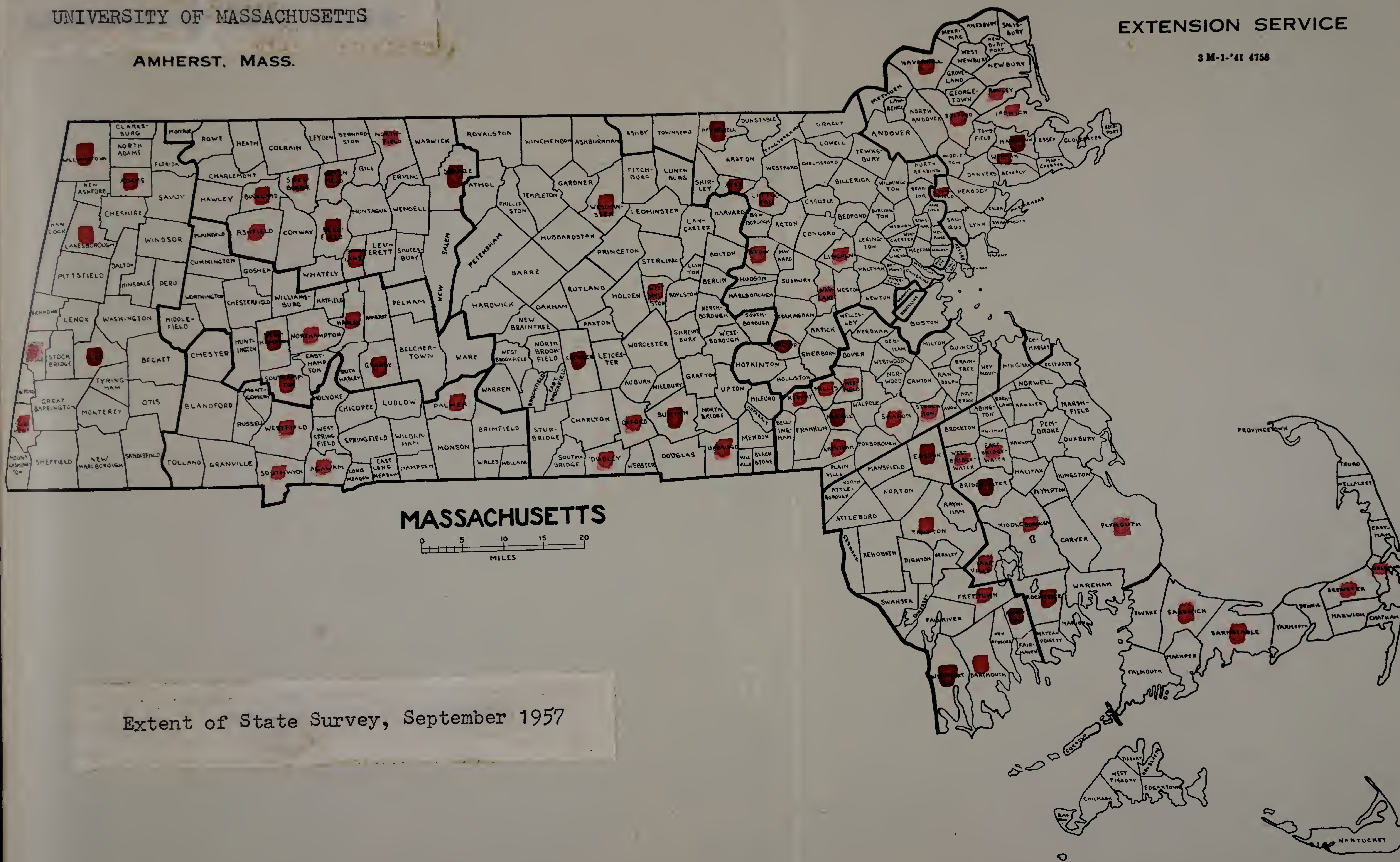


Extent of State Survey, September 1957

Plate IV. Varieties of <u>Philaenus leucophthalmus</u> (L.) in Massachusetts. A. <u>spumarius</u>, B. <u>marginellus</u>, C. <u>fabricii</u>, D. <u>fasciatus</u>, E. <u>leucocephalus</u>, F. <u>pallidus</u>, G. <u>leucophthalmus</u>, H. <u>pallidus</u>

and <u>impressus</u> as occurring in California. Table 5 gives some idea of the varietal distribution as it occurs in North America. The author has taken specimens of all the North American varieties with the exception of <u>lateralis</u> from legumes in Massachusetts. While the two varieties <u>spumarius</u> and <u>pallidus</u> make up 80-95% of the specimens reported in North America, the proportions of the other varieties apparently vary considerably.

Horvath (1898) believed that the color differences were due to geographical location. Regnier (1936) dismissed this theory inasmuch as he found seven of the ten color varieties that occur in Normandy feeding on a single host plant. On this basis, he concluded that the host plant had little or no biological significance.

There appears to be little evidence of biological significance based on varietal differentiation, with the possible exception of the predominence of females in some varieties. Fallen (1805) found this to be the case with <u>lateralis</u>, <u>marginella</u> and <u>leucocephala</u>. Doering (1952 - Weaver and King 1954) stated that in her collection, there were 24 specimens of <u>marginellus</u>, all females; 22 specimens of <u>lateralis</u>, 2 of which were males; and 76 specimens of <u>leucocephalus</u>, 25 of which were males. Weaver and King (1954) examined over 200 specimens of the variety <u>marginellus</u> without discovering a male. Russell (1957) reports that there are no male specimens of <u>marginellus</u> in the U. S. National Museum collection.

Table 5. Varietal Distribution showing percentages of the different forms as they occur in different parts of North America.

Variety	Pielou (1950) Ontario	Marshall (1951) New York	Fisher & Allen (1946) Wisconsin	Scholl & Medler'47 Wisconsin	Weaver & King '54 Ohio	Lavigne Mass.
pallidus	52.6	33-39%	60	30.3-39.8	24	34.6
spumarius	45.0	60-64	21	42.3-50.1	65	56.4
fabricii	—	—	17	11.6-14.2	2.5	3.1
leucophthalmus	—	—	—	1.6-2.1	4.5	1.2
marginellus	2.4	1.5-3.0	—	0-0.1	4	2.5
lateralis	—	—	2	2.3-2.8	rare Ahmed & Davidson (1950)	—
leucocephalus	—	—	—	0-0.1	rare Pruess (1956)	0.5
fasciatus	—	—	—	1.4-1.6	—	1.5

The author examined 3329 adult specimens. Tables 6 and 7 present data showing the seasonal distribution, according to both sex and varieties, during the summers of 1956 and 1957. As can be noted, no males were found among the 87 specimens of the variety marginellus examined. Plate IV shows the different color varieties which were found to be indigenous to Massachusetts.

Seasonal History

A brief summarization of the seasonal history of Philaenus leucophthalmus, as it occurs in Massachusetts, may be recorded as follows. The meadow spittlebug overwinters as an egg affixed to the stem of its host by a frothy cement. The appearance of warm temperatures and high humidities in late April or early May induce hatching. Following eclosion, the nymph leaves the site of egg deposition and crawls to a position where it may pierce suitable succulent foliage. If its search is successful, the nymph will begin to feed, almost immediately forming spittle. During a period lasting from four to six weeks, depending upon temperature, the nymph will molt five times. Molting is usually completed within the spittlemass. At the time of the final molting, the nymph ceases the production of spittle and allows the foam to dry. The drying spittle forms a chamber within which the final molt usually occurs. After its wings have dried, the adult will crawl or if suddenly disturbed may jump from the chamber leaving a neat round hole in the foam.

Table 6. Seasonal Distribution of adults of <u>Philaenus</u> <u>leucophthalmus</u> as to both sex and variety, as collected during the 1956 season.

Variety		June	July	August	Sept.	Oct.
pallidus	♂	24	19	54	7	2
	♀	30	21	24	55	22
fabricii	♂	7	4	6	4	0
	♀	5	2	5	2	2
leucophthalmus	♂	2	0	0	0	0
	♀	0	0	0	0	0
spumarius	♂	158	59	145	43	10
	♀	74	29	79	60	14
marginellus	♂	0	0	0	0	0
	♀	4	2	12	5	1
lateralis	♂	—	—	—	—	—
	♀	—	—	—	—	—
leucocephalus	♂	0	0	1	0	0
	♀	1	0	2	1	1
fasciatus	♂	1	1	0	0	1
	♀	6	1	2	1	3

Table 7. Seasonal Distribution of adults of *Philaenus leucophthalmus* as to both sex and variety, as collected during the 1957 season.

Variety		June	July	August	Sept.	Oct.
pallidus	♂	285	15	39	3	1
	♀	355	34	130	23	10
fabricii	♂	24	3	8	0	0
	♀	25	1	2	1	2
leucophthalmus	♂	0	10	11	0	0
	♀	5	2	11	2	0
spumarius	♂	628	50	113	12	2
	♀	281	20	76	13	13
marginellus	♂	0	0	0	0	0
	♀	39	4	13	3	1
lateralis	♂	—	—	—	—	—
	♀	—	—	—	—	—
leucocephalus	♂	5	0	0	0	0
	♀	5	1	0	0	0
fasciatus	♂	12	1	4	0	0
	♀	9	1	6	1	0

Adult spittlebugs will usually remain in the vicinity of hatching until such time as either the host plant is cut or becomes less succulent. In the former case, the adults will quit a field immediately. In the latter case, however, the exodus from the area of declining succulence is very gradual. Because spittlebugs have not been considered a pest under Massachusetts conditions, cuttings are a more or less dependent on the time of maturity of a crop, usually when 10% of the plants is in blossom. Thus some fields are cut before the majority of adult emergence gets underway, while in other fields, cuttings are delayed thereby forcing almost immediate withdrawal of the newly emerged adults. Subsequent cuttings throughout the season and declining succulence of uncut forage results in a more or less continuous type of migratory activity. Mating occurs almost from the time of adult emergence but it is not until August that fully developed eggs start appearing in the ovaries of the females. Early September marks the period of lessened migratory activity and also the period of most intensive egg-laying. The females continue to lay eggs until they die naturally or are killed by a severe frost. With the coming of the fall months, the number of adults in the fields decline. This population decline occurs more rapidly after the initiation of egg deposition. The majority of eggs are laid close to the ground, usually between two opposed surfaces, such as on grain and forage stubble.

Ecology

Egg

The oviposition site of the female spittlebug apparently remained undiscovered until about 1920 when Rodman (1921) reported on Gahan's finding that eggs were placed between the bark and innerwood of a tree. Barber and Ellis (1922) caged adults on Setaria glauca and described the egg masses which they subsequently found. Later workers have reported a large variety of sites as being adequate for oviposition.

The author spent a great many hours in the field searching for eggs. The average time required for a thorough search of a square foot of alfalfa ranges between an hour and an hour and one-half. During the 1956 season, no eggs were obtained except through the caging of adults in glass jars containing moist paper towels and cut tillers of alfalfa. During 1956 and 1957, adults were confined within a wire mesh cage 4' x 4' x 6' outside Fernald Hall. Unfortunately, this area was raked out by the grounds crew both years despite the presence of signs. That this was effective in completely reducing the egg density in 1956 is indicated by the fact that only one nymph hatched in this area the following spring. The temperature humidity chambers available were not in working order during the two years the study was in progress so that experiments concerned with temperature and humidity studies of all stages had to be omitted.

The eggs are laid in masses held together by a hardened frothy cement-like substance. The author found that the number of eggs per mass laid by females caged in the laboratory varied from one to eleven and averaged about four. One packet of eggs was recovered from grain stubble in the fall of 1957 containing twelve eggs. Weaver and King (1954) report a variance of one to thirty eggs per mass with an average of about seven.

The location of an egg mass ordinarily varies with the type of cover and concealment offered by the host plant, the survival of the eggs being dependent upon insulation against low temperature and concealment from predators and parasites. On grain stubble, the eggs are mostly laid between the sheath and stem at a 45° angle to the axis of the stem. This position is common on alfalfa plants also. The dried petioles of both strawberry leaves and red clover have a well defined longitudinal groove and Teller (1951) reports that egg masses are commonly deposited in these grooves. The stipules of strawberry plants are sometimes utilized for egg deposition. Such a location is ideal for the young nymphs are almost in the crown of the plant when they hatch. Straw is quite generally used by commercial growers as winter cover for strawberry plants. Weaver and King (1954) have indicated that the presence of straw surrounding common hosts is responsible for an increase of 65% in egg deposition.

Prediction of Hatching

A relatively new field of endeavor in relation to spittlebugs is that concerned with the effect of temperature upon the time of egg hatching. Barnard (1948) has reported that heat unit summations are of practical value in the planting and harvesting management of canning crops. Apple (1952) described a method by which the seasonal development of the European corn borer could be followed by utilizing "borer day degrees". These figures were obtained by summing the daily degrees above 50° F. Medler (1955) analyzed 11 years of spittlebug hatching data at two Ohio stations. He found that by beginning on February 1st and summing day degrees above a base of 40° F., that the first nymphal hatch coincides with 200 day degrees under Ohio conditions. Under Wisconsin conditions, it was found that with a 50° F. base, the accumulation of 150 day degrees coincided with the period of first hatch. Weaver (1956) showed that by utilizing a 50° base, the period from April 1 to the date corresponding to the accumulation of 25 day degrees, coincided with the early part of the best time for spraying. This method works well throughout all but the extreme southern part of Ohio.

Table 8, 9, and 10, on the following pages, show temperature data over a period of three consecutive years which compares the relative effectiveness of the three methods described above. The data over the three year period indicates that Medler's method, utilizing a 40° F. base, and Weaver's method, utilizing a 50° F. base, are comparable in effectiveness under Massachusetts conditions. On the basis of the data thus far accumulated, the author feels that the number of accumulative day degrees needs to be extended for the

Table 8. Comparison of three methods used for the prediction of spittlebug hatch during the spring of 1956 under Massachusetts conditions.

February 1956				Day Degrees		Accumulated Day Degrees	
Date	Maximum	Minimum	Mean	40° base	50° base	150 DD 50° base	200 DD 40° base
1	34	13	23.5				
2	33	24	28.5	—	—	—	—
3	36	15	25.5	—	—	—	—
4	21	1	11.0	—	—	—	—
5	39	20	29.5	—	—	—	—
6	34	13	23.5	—	—	—	—
7	39	33	36.0	—	—	—	—
8	46	30	38.0	—	—	—	—
9	40	32	36.0	—	—	—	—
10	36	32	34.0	—	—	—	—
11	37	33	35.0	—	—	—	—
12	40	34	37.0	—	—	—	—
13	39	31	35.0	—	—	—	—
14	43	26	34.5	—	—	—	—
15	38	30	34.0	—	—	—	—
16	33	22	27.5	—	—	—	—
17	26	18	22.0	—	—	—	—
18	31	24	27.5	—	—	—	—
19	39	25	32.0	—	—	—	—
20	42	23	32.5	—	—	—	—
21	27	9	18.0	—	—	—	—
22	23	4	13.5	—	—	—	—
23	25	11	18.0	—	—	—	—
24	34	2	18.0	—	—	—	—
25	47	30	38.5	—	—	—	—
26	35	26	30.5	—	—	—	—
27	42	31	36.5	—	—	—	—
28	35	17	26.0	—	—	—	—
29	28	8	18.0	—	—	—	—
				—	—	—	—

Table 8. (Cont.)

March 1956

Date	Maximum	Minimum	Mean	Day Degrees 40° base	Day Degrees 50° base	Accumulated Day Degrees 150 DD 50° base	Accumulated Day Degrees 200DD 40° base
1	35	12	23.5	—	—	—	—
2	42	30	36.0	—	—	—	—
3	50	36	43.0	3	—	—	3
4	42	30	36.0	—	—	—	—
5	45	28	36.5	—	—	—	—
6	37	32	34.5	—	—	—	—
7	36	32	34.0	—	—	—	—
8	34	26	30.0	—	—	—	—
9	34	24	29.0	—	—	—	—
10	39	25	32.0	—	—	—	—
11	40	26	33.0	—	—	—	—
12	38	32	35.0	—	—	—	—
13	40	30	35.0	—	—	—	—
14	35	31	33	—	—	—	—
15	37	22	29.5	—	—	—	—
16	24	15	19.5	—	—	—	—
17	27	7	17.0	—	—	—	—
18	31	2	14.5	—	—	—	—
19	24	18	21.0	—	—	—	—
20	35	21	28.0	—	—	—	—
21	45	14	29.5	—	—	—	—
22	48	14	31.0	—	—	—	—
23	42	31	36.5	—	—	—	—
24	34	16	25.0	—	—	—	—
25	27	10	18.5	—	—	—	—
26	38	17	27.5	—	—	—	—
27	38	22	30.0	—	—	—	—
28	45	16	30.5	—	—	—	—
29	38	18	28.0	—	—	—	—
30	40	30	35.0	—	—	—	—
31	40	28	34.0	—	—	—	—

Table 8. (Cont.)

April 1956

				Day Degrees		Accumulated Day Degrees		
						150 DD	200 DD	25 DD
Date	Maximum	Minimum	Mean	40° base	50° base	50° base	40° base	50° base
1	45	29	37	---	---	---	---	---
2	47	21	34	---	---	---	---	---
3	44	34	39	---	---	---	---	---
4	44	38	41	1	---	---	4	---
5	54	37	45.5	5.5	---	---	9.5	---
6	64	31	47.5	7.5	---	---	17	---
7	45	38	41.5	1.5	---	---	18.5	---
8	39	30	34.5	---	---	---	---	---
9	45	29	37.0	---	---	---	---	---
10	53	29	41.0	1	---	---	19.5	---
11	54	29	41.5	1.5	---	---	21	---
12	54	28	41.0	1	---	---	22	---
13	55	31	43.0	3	---	---	25	---
14	55	29	42.0	2	---	---	27	---
15	50	37	43.5	3.5	---	---	30.5	---
16	62	40	51.0	11	1	1	41.5	1
17	52	36	44.0	4	---	---	45.5	---
18	52	30	41.0	1	---	---	46.5	---
19	46	34	40.0	---	---	---	---	---
20	45	29	37.0	---	---	---	---	---
21	50	30	40.0	---	---	---	---	---
22	53	38	45.5	5.5	---	---	52	---
23	45	33	39.0	---	---	---	----	---
24	47	30	38.5	---	---	---	---	---
25	57	26	41.5	1.5	---	---	53.5	---
26	42	36	39.0	---	---	---	---	---
27	60	33	46.5	6.5	---	---	59.5	---
28	78	47	62.5	22.5	12.5	13.5	82	13.5
29	57	47	52	12	2	15.5	94	15.5
30	62	40	51	11	1	16.5	105	16.5

Table 8. (Cont.)

May 1956

Date	Maximum	Minimum	Mean	Day Degrees 40° base	Day Degrees 50° base	Accumulated Day Degrees 150 DD 50° base	Accumulated Day Degrees 200 DD 40° base	Accumulated Day Degrees 25 DD 50° base
1	62	34	48	8	---	---	113	---
2	62	34	48	8	---	---	121	---
3	65	40	52.5	12.5	2.5	19	133.5	19
4	68	40	54.0	14	4	23	147.5	23
5	63	33	48.0	8	---	---	155.5	---
6	58	43	50.5	10.5	.5	23.5	166	23.5
7	55	40	47.5	7.5	---	---	173.5	---
8	54	32	43.0	3	---	---	176.5	---
9	64	28	46.0	6	---	---	182.5	---
10	64	44	54.0	14	4	27.5	196.5	27.5
11	65	34	49.5	9.5	---	---	206	---
12	82	46	64.0	24	14	41	230	41
13	84	61	72.5	32.5	22.5	63.5	262.5	63.5
14	64	54	59.0	19	9	72.5	281.5	72.5
15	72	50	61.0	21	11	83.5	302.5	83.5
16	68	38	53.0	13	3	86.5	315.5	86.5
* 17	56	35	45.5	5.5	---	---	321	---
18	52	40	46.0					
19	68	37	52.5					
20	67	43	55.0					
21	70	43	56.5					
22	80	50	65.0					
23	70	39	54.5					
24	55	35	45.0					
25	61	30	45.5					
26	66	35	50.5					
27	60	49	54.5					
28	60	46	53.0					
29	73	36	54.5					
30	68	50	59.0					
31	86	59	72.5					

* 1st nymphal spittlebug found in 1956 in the field.

Table 9. Comparison of three methods used for the prediction of spittlebug hatch during the Spring of 1957 under Massachusetts conditions.

February 1957

				Day Degrees		Accumulated Day Degrees	
Date	Maximum	Minimum	Mean	40° base	50° base	150 DD 50° base	200 DD 40° base
1	31	14	22.5	---	---	---	---
2	42	18	30.0	---	---	---	---
3	35	10	22.5	---	---	---	---
4	42	31	36.5	---	---	---	---
5	39	24	31.5	---	---	---	---
6	42	16	29.0	---	---	---	---
7	44	24	34.0	---	---	---	---
8	43	23	33.0	---	---	---	---
9	37	20	28.5	---	---	---	---
10	42	31	36.5	---	---	---	---
11	31	15	23.0	---	---	---	---
12	29	9	19.0	---	---	---	---
13	30	14	22.0	---	---	---	---
14	33	24	28.5	---	---	---	---
15	40	20	30	---	---	---	---
16	37	19	28.0	---	---	---	---
17	35	24	29.5	---	---	---	---
18	41	30	35.5	---	---	---	---
19	40	26	33.0	---	---	---	---
20	33	22	27.5	---	---	---	---
21	42	17	29.5	---	---	---	---
22	43	20	31.5	---	---	---	---
23	47	29	38.0	---	---	---	---
24	43	29	36.0	---	---	---	---
25	53	35	44.0	4	---	---	4
26	64	44	54.0	14	4	4	18
27	57	20	38.5	---	---	---	---
28	31	14	22.5	---	---	---	---

Table 9. (Cont.)

March 1957

Date	Maximum	Minimum	Mean	Day Degrees 40° base	Day Degrees 50° base	Accumulated Day Degrees 150 DD 50° base	Accumulated Day Degrees 200 DD 40° base
1	32	24	28.0	---	---	---	---
2	42	21	31.5	---	---	---	---
3	34	21	27.5	---	---	---	---
4	32	18	25.0	---	---	---	---
5	40	13	26.5	---	---	---	---
6	45	18	31.5	---	---	---	---
7	44	27	35.5	---	---	---	---
8	37	33	35.0	---	---	---	---
9	40	33	36.5	---	---	---	---
10	37	26	31.5	---	---	---	---
11	47	22	34.5	---	---	---	---
12	45	34	39.5	---	---	---	---
13	64	26	45.0	5	---	---	23
14	68	32	50.0	10	---	---	33
15	55	31	43.0	3	---	---	36
16	57	38	47.5	7.5	---	---	43.5
17	47	32	39.5	---	---	---	---
18	45	30	37.5	---	---	---	---
19	41	29	35.0	---	---	---	---
20	35	31	33.0	---	---	---	---
21	51	30	40.5	.5	---	---	44
22	56	27	41.5	1.5	---	---	45.5
23	59	28	43.5	3.5	---	---	48.5
24	52	26	39.0	---	---	---	---
25	52	27	39.5	---	---	---	---
26	48	36	42.0	2	---	---	50.5
27	50	37	43.5	3.5	---	---	54
28	54	32	43.0	3	---	---	57
29	53	29	41.0	1	---	---	58
30	47	28	37.5	---	---	---	---
31	52	21	36.5	---	---	---	---

Table 9. (Cont.)

April 1957				Day Degrees		Accumulated Day Degrees		
						150 DD	200 DD	25 DD
Date	Maximum	Minimum	Mean	40° base	50° base	50° base	40° base	50° base
1	60	21	40.5	.5	---	---	58.5	---
2	55	37	46.0	6	---	---	64.5	---
3	45	29	37.0	---	---	---	---	---
4	44	29	36.5	---	---	---	---	---
5	36	32	34.0	---	---	---	---	---
6	48	35	41.5	1.5	---	---	66	---
7	47	39	43.0	3	---	---	69	---
8	41	33	37.0	---	---	---	---	---
9	40	30	35.0	---	---	---	---	---
10	58	29	43.5	3.5	---	---	72.5	---
11	56	31	43.5	3.5	---	---	76	---
12	70	34	52.0	12	2	6	88	2
13	47	30	38.5	---	---	---	---	---
14	44	30	37.0	---	---	---	---	---
15	52	23	37.5	---	---	---	---	---
16	62	25	43.5	3.5	---	---	91.5	---
17	60	44	52.0	12	2	8	103.5	4
18	69	35	52.0	12	2	10	115.5	6
19	69	48	58.5	18.5	8.5	18.5	134	14.5
20	71	45	58.0	18	8	26.5	152	22.5
21	85	50	67.5	27.5	17.5	44	179.5	40
22	71	44	57.5	17.5	7.5	51.5	197	47.5
23	78	45	61.5	21.5	11.5	63	218.5	59
* 24	78	51	64.5	24.5	14.5	77.5	243	73.5
25	65	49	57.0					
26	74	48	61.0					
27	84	50	67.0					
28	82	54	68.0					
29	75	56	65.5					
30	65	45	55.0					

* 1st nymphal spittlebug found in 1957 in the field.

Table 10. Comparison of three methods used for the prediction of spittlebug hatch during the Spring of 1958 under Massachusetts conditions.

February 1958

				Day Degrees		Accumulated Day Degrees	
Date	Maximum	Minimum	Mean	40° base	50° base	150 DD 50° base	200 DD 40° base
1	33	16	24.5	---	---	---	---
2	33	23	28.0	---	---	---	---
3	27	13	20.0	---	---	---	---
4	21	9	15.0	---	---	---	---
5	33	17	25.0	---	---	---	---
6	40	18	29.0	---	---	---	---
7	31	17	24.0	---	---	---	---
8	31	14	22.5	---	---	---	---
9	14	11	12.5	---	---	---	---
10	21	4	12.5	---	---	---	---
11	25	-9	8.0	---	---	---	---
12	23	-7	8.0	---	---	---	---
13	20	7	13.5	---	---	---	---
14	21	7	14.0	---	---	---	---
15	27	2	14.5	---	---	---	---
16	18	8	13.0	---	---	---	---
17	8	-7	0.5	---	---	---	---
18	10	-12	-1.0	---	---	---	---
19	23	2	12.5	---	---	---	---
20	30	9	19.5	---	---	---	---
21	33	18	25.5	---	---	---	---
22	41	26	33.5	---	---	---	---
23	28	13	20.5	---	---	---	---
24	45	25	35.0	---	---	---	---
25	43	31	37.0	---	---	---	---
26	43	24	33.5	---	---	---	---
27	38	31	34.5	---	---	---	---
28	38	31	34.5	---	---	---	---

Table 10. (Cont.)

March 1958

				Day Degrees		Accumulated Day Degrees	
Date	Maximum	Minimum	Mean	40° base	50° base	150DD 50° base	200 DD 40° base
1	39	30	34.5	---	---	---	---
2	44	30	37.0	---	---	---	---
3	39	30	34.5	---	---	---	---
4	41	32	36.5	---	---	---	---
5	43	34	38.5	---	---	---	---
6	45	34	39.5	---	---	---	---
7	40	29	34.5	---	---	---	---
8	37	25	31.0	---	---	---	---
9	42	23	32.5	---	---	---	---
10	50	31	40.5	0.5	---	---	0.5
11	51	30	39.5	---	---	---	---
12	43	33	38.0	---	---	---	---
13	49	27	38.0	---	---	---	---
14	38	33	35.5	---	---	---	---
15	40	30	35.0	---	---	---	---
16	37	30	33.5	---	---	---	---
17	38	26	32.0	---	---	---	---
18	44	30	37.0	---	---	---	---
19	45	29	37.0	---	---	---	---
20	41	30	35.5	---	---	---	---
21	35	30	32.5	---	---	---	---
22	43	32	37.5	---	---	---	---
23	43	33	38.0	---	---	---	---
24	50	28	39.0	---	---	---	---
25	45	36	40.5	0.5	---	---	1.0
26	48	36	42.0	2	---	---	3.0
27	48	36	42.0	2	---	---	5.0
28	51	29	40.0	---	---	---	---
29	54	23	38.5	---	---	---	---
30	57	24	40.5	0.5	---	---	5.5
31	49	37	43.0	3	---	---	8.5

Table 10. (Cont.)

April 1958

				Day Degrees		Accumulated Day Degrees		
						150 DD	200 DD	25 DD
Date	Maximum	Minimum	Mean	40° base	50° base	50° base	40° base	50° base
1	45	35	40.0	---	---	---	---	---
2	44	40	42.0	2	---	---	10.5	---
3	51	36	43.5	3.5	---	---	14.0	---
4	57	32	44.5	4.5	---	---	18.5	---
5	62	25	43.5	3.5	---	---	22.0	---
6	44	33	38.5	---	---	---	---	---
7	42	38	40.0	---	---	---	---	---
8	43	34	38.5	---	---	---	---	---
9	46	25	35.5	---	---	---	---	---
10	58	26	42.0	2	---	---	24.0	---
11	45	38	41.5	1.5	---	---	25.5	---
12	45	33	39	---	---	---	---	---
13	60	35	47.5	7.5	---	---	33.0	---
14	63	42	52.5	12.5	2.5	2.5	45.5	2.5
15	69	36	52.5	12.5	2.5	5.0	58.0	5.0
16	68	38	53	13	3.0	8.0	71.0	8.0
17	74	38	56	16	6.0	14.0	87.0	14.0
18	75	40	57.5	17.5	7.5	21.5	104.5	21.5
19	76	42	59	19	9.0	30.5	123.5	30.5
20	74	49	61.5	21.5	11.5	42.0	145.0	42.0
21	76	49	62.5	22.5	12.5	54.5	167.5	54.5
22	67	57	62	22	12	66.5	189.5	66.5
23	62	55	58.5	18.5	8.5	75.0	208.0	75.0

Massachusetts climate. Although, in 1956, first instar nymphs were collected on May 17th, it is probable that hatching had begun a few days earlier. In 1957 and 1958, the author feels certain that the date of collection of first instar nymphs, April 24th in both cases, is within a day of corresponding to the date of initial hatching. On this basis, the author feels that in utilizing a 40° F. base, dating from February 1st, the number of accumulative day degrees can be raised to 215 to correspond to Massachusetts conditions. In the same way, utilizing a 50° F. base, dating from April 1st, the number of accumulative day degrees can be raised to 75 to correspond to the beginning of spittlebug hatching in the vicinity of Amherst, Massachusetts.

Weaver (1956) has presented data which indicates that good control of spittlebug populations can be obtained by the application of a residual granular insecticide just previous to spittlebug hatch. The data presented in Tables 8, 9, and 10 will be useful for relating the time of spittlebug hatch to a control method if a program of forage crop insect control is instituted in the State.

The results of these prediction methods will vary, dependent upon where it is utilized within the State. The author found adults first appearing in 1957 on May 30th in West Springfield whereas adults did not appear in the Amherst area until June 5th. This indicates that hatching probably occurred at an earlier date. Therefore, this prediction method will have to be applied in each locality under consideration according to the particular climatological data at hand.

Nymph

Following hatching, the first instar nymphs seek out a suitable host plant. The proximity of the eggs to tender plant growth is often a condition which determines their survival. Humid conditions are equally necessary at this stage. The nymphs will therefore be found on low rosetting type plants or plants whose leaves and stems are closely apposed. Such a site offers protection from the sun and drying winds. Spittle is produced within a few minutes after feeding commences, enabling the young nymph to surround itself with its own humid microclimate. Their small size and choice of host plants usually enables the first instar nymphs to escape detection despite their bright lemon yellow color. Around Amherst, the nymphs are usually observed first on goldenrod which exhibits a dense upright growth. It seems likely that these nymphs have crawled between the closely apposed newly formed leaves of alfalfa about the same time but are not usually observed in this location. In such plants, a higher humidity exists than when growth is lateral. Weaver and King (1954) have shown experimentally that a planting of alfalfa provides a more humid microclimate, through the restriction of air movement, than a planting of bluegrass, thus resulting in higher survival rates for nymphs in alfalfa plantings.

As the nymphs pass into later instars, they become more active moving to higher positions on the plants. This changing of position corresponds to the elongation of the growing tip of the plant, the nymphs seeking the most tender and succulent plant parts. If deprived of their host plant for more than an hour, they become dessicated and die.

Biology

Host Plants

As mentioned previously, Weaver and King (1954) compiled a list of host plants of the nymphs of the meadow spittlebug based on the works of twenty-six authors as well as their own observations. The present author has found the nymphs on many of these species and is also adding to this group 17 species which have not been previously reported. These latter species are indicated in the following list by asterisks. All botanical specimens were identified by Dr. Robert Livingston of the Department of Botany at the University of Massachusetts.

Achillea millefolium L.	common yarrow, milfoil
**Ambrosia trifidia* L.	great ragweed
**Aster cordifolium* L.	heart-shaped aster
**Aster ericoides* L.	white heath aster
Aster sp.	aster
Barbarea vulgaris R. Br.	common winter cress, yellow rocket
**Bromus secalinus* L.	chest or chess grass
Bromus sp.	brome grass
Chrysanthemum leucanthemum L.	white daisy, ox-eye daisy

*Cirsium vulgare (Savi) Tenore	bull or common thistle
Daucus carota L.	wild carrot, Queen Anne's lace
Fragaria vesca L.	strawberry
*Galium asprellum Michx.	rough bedstraw
*Lactuca scariola L.	prickly lettuce, compass plant
Lotus corniculatus L.	birdsfoot trefoil
Lychnis alba Mill.	white campion
Medicago sativa L.	alfalfa
Melilotus alba Desr.	white melilot, sweet clover
Oenothera biennis L.	evening primrose
*Oxalis stricta L.	sheep sorrel
Phleum pratense L.	timothy, herd's grass
Poa compressa L.	Canada blue grass
*Physalis sp.	Chinese lantern
Plantago rugelii Dene	Rugel's plantain, purple-stemmed plantain
Potentilla simplex Michx.	old field cinquefoil
*Potentilla norvegica L.	rough cinquefoil
*Potentilla recta L.	common cinquefoil
Ranunculus sp.	buttercup
*Rhus typhina L.	staghorn sumac
Rosa sp.	rose
*Rudbeckia hirta L.	yellow daisy, blackeyed susan
Rumex acetosella L.	field or sheep sorrel
Rumex crispis L.	common dock

*_Saponaria vulgaris_	bouncing bet
Solidago altissima L.	tall goldenrod
Solidago canadensis L.	Canada goldenrod
*_Solidago juncea_ Ait.	goldenrod
Spiraea tomentose L.	hardhack, steeple bush
Symphytun officinale L.	Quaker comfrey
Taraxacum officinale Weber	dandelion
Trifolium hybridum L.	alsike clover
Trifolium pratense L.	red clover
Ulmus rubra	slippery elm

It is apparent from the work of both the present and previous authors that the nymphs are able to survive on almost any plant that will provide them with sufficient moisture to maintain their feeding habits.

Habits of Nymphs

Observations on nymphal behavior made by Osborn and later authors have been substantiated by the author. While the nymphal life is spent beneath their foamy masses, they do engage in some migration, as noted previously. Daily weather changes have some effect on local nymphal movement on a plant. Early in the morning, spittle masses may be found near the growing tips of the plants, but as the temperature rises, the nymphs vacate the masses leaving them to dry out, and move down the stem to more shaded areas. In some instances, they move downward from established spittlemasses as was observed following a change in prevailing cool weather to a hot dry windy spell. While unable to fly, the nymphs move rapidly around a stem when disturbed, attempting to remain within the spittlemass. If the disturbance is continuous, they will move up or down the stem. These movements render them susceptible to residual insecticides. More than one nymph may be found in the spittle; a dozen or more is not unusual. The later instars seem to concentrate together at the growing tip of a tiller when infestations are high.

The effect of temperature on the duration of nymphal development may be further shown by the following observations made both in 1956 and 1957. Some distance behind the laboratory, a steam line crosses from the street to a dormitory. Several succulent weed species begin their spring growth here earlier than those same species in nearby habitats. The author observed that the nymphs upon these plants were already in their second instar when first instar nymphs appeared in nearby fields. In the spring of 1956, adults emerged in the area above the steam pipe on June 6th as compaired to the emergence of adults on June 11th in the greenhouse and June 14th in the field.

In the spring of 1957, the same phenomena occurred with adults first appearing in the area above the steam pipe on May 25th as compared with June 3rd in the greenhouse and June 5th in the field.

Moulting is accomplished in a manner similar to that of many other Homoptera. The nymphal skin splits along the ecdesial line across the back of the head and down the thorax. The nymph then pulls itself through this split. Reference as to the number of molts has already been made in a previous section.

The author carried on laboratory studies to determine the length of time spent in each instar. Twenty-four first instar nymphs were recovered from the field and placed upon young plants of *Silene latifolia*, the common bladder campion, in the greenhouse. They were examined daily and the molted skins removed. The plants were moistened once or twice daily by pouring water into the soil at the base of the plant. An average temperature of 25° C. was maintained throughout the experiment. All the plants were closely spaced and enclosed by cotton mesh screening to prevent the sun from creating a humidity deficient condition. Table 11 shows the results of this experiment. The indicated figures are averages for each instar. Those for the first instar are of questionable value as the insects were not collected at the time of hatching.

Table 11. Average length of time spent in each instar by nymphs of *Philaenus leucophthalmus* during the spring of 1956 under laboratory conditions.

Instar	1st	2nd	3rd	4th	5th
Average Length of Time in Days	10.2	6.2	6.3	6.5	8.7

There has been some question as to whether the nymph of the meadow spittlebug remains within the spittle mass while undergoing the final molt. Ball (1928) states that all spittlebugs but Monecphora bicincta Say crawl out of the spittle mass to make their transformation to adults. Doering (1931) disagrees with Ball reporting that Lepyronia quadrangularis (Say) passes the last molt within the spittle. Severin (1950) indicates that Philaenus leucophthalmus (Say) usually crawls out of the spittle to undergo the last molt. Weaver and King (1954) report opposite results stating that the insects cease to make spittle at the time of the last molt. The foam is permitted to dry leaving a chamber in which the adult expands its wings. During frequent observations of this phenomena, the author has never found the final instars molting anywhere but inside the spittle mass. After molting, the adult either crawls or hops through the dried foam leaving behind a neat hole.

Periodical field observations were made to determine the percentage of the total population that each instar constituted in the field at any one time. These percentages are presented in tabular form for 1956 and 1957 in Tables 12 and 13. By noting the peak occurrence of each instar, one can approximate the duration of each. The early instars are of considerably longer duration than those of the later instars. This results from the gradual increase in daily temperatures in the spring. The length of individual instars may vary in either direction from year to year depending upon spring temperatures. Adjustments in either direction may also occur as a result of the influence of variations in temperature during any given instar.

Table 12. Percentage of spittlebug nymphs of various instars from hatch to adult emergence during the Spring of 1956.

Date	Total Number of Nymphs	Percentage of Each Instar					
		1st	2nd	3rd	4th	5th	Adult
May 17	5	100					
June 7	79	6	32	62			
June 14	79		7	24	30	39	1
June 22	35			17	34	49	Few
June 25	5					100	Many

Table 13. Percentage of spittlebug nymphs of various instars from hatch to adult emergence during the Spring of 1957.

		Percentage of Each Instar					
Date	Total Number of Nymphs	1st	2nd	3rd	4th	5th	Adult
May 15	79		31	60	9		
May 22	80		10	58	30	2	
May 29	81		1	19	56	24	
June 5	82			4	13	83	Few
June 12	20				5	95	Many

Methods of Evaluating Nymphal Populations

Weaver and King (1954) have summarized the principal methods by which the extent of nymphal infestations may be measured. These methods fall into five general categories: (1) spittle masses per unit area or per stem, (2) nymphs per square foot, (3) nymphs per stem, (4) percent infested stems, (5) adults per sweep at emergence. To these five, the author has evaluated two more possible methods: (1) use of a three foot rod and (2) nymphs per 125 sweeps. See Plate V.

Measurements involving spittle masses per unit area or per stem would seem to have limited application except in fields where an infestation is extremely light. Where infestations are high, nymphs tend to congregate in a single large mass, thereby making it impossible to distinguish individual masses. Marshal (1951) and MacCreary and Stearns (1953) have utilized this method on legumes.

Wilson (1953) working with the measurements of nymphs per square foot has shown that in fields where a single uniform crop has been grown, a great deal of precision may be obtained by this technique. The author has found that this method gives a fairly accurate picture when it is used for comparison of populations in different stands of alfalfa. Where fields contain significant weed populations or mixed hay crop, large variation may occur.

Counts based on the number of nymphs per stem have the advantage of indicating the degree of infestation on a

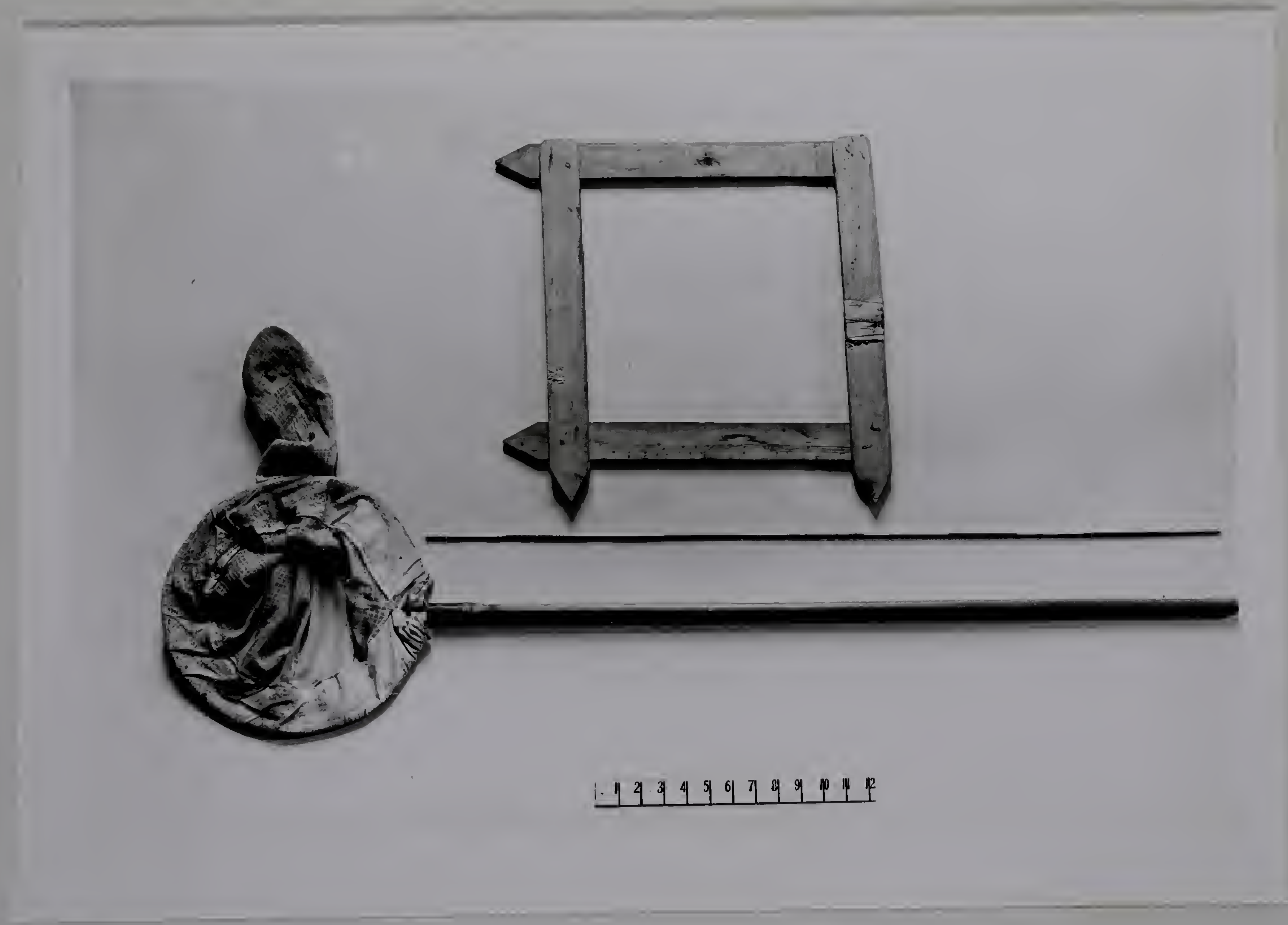


Plate V. Equipment used for evaluating nymphal populations: a squarefoot frame, 3 foot steel rod, 12" diameter net.

legume in a legume-hay mixture. Under such circumstances, estimation of the insects per unit area must still be made if this type of field is to be compared with those in which a single uniform crop is grown. In fields in which alfalfa is the only crop plant, the author has found this method to be satisfactory, but there is a tendency to reach for those stems supporting numerous spittle masses, thereby possibly nullifying the results.

Measurements utilizing the percentage of infested stems is a rapid method for coverage of a large area. Weaver and Whitney (1956) have shown statistically the correlation between this method and that of the method mentioned immediately above. These results were published in a paper entitled "A Proportion Method for Sampling Spittlebug Populations". Tables have been worked out for both alfalfa and red clover by which the number of nymphs per stem may be accurately predicted from a count of the number of infested stems in a given area. The author has found this method to be relatively accurate under Massachusetts conditions. The reader is referred to Table 14 in which data is presented.

It is possible to evaluate a previous nymphal population by sweeping the newly emerged adults. Everly (1951) indicated that a fairly accurate estimate could be obtained by this method. Weaver and King (1954) substantiated Everly's work and found that one nymph per stem in the spring was the equivalent of about nine adults per sweep at the time of peak emergence of the adults. This ratio would vary depending upon the conditions under which sweeps were made.

Table 14. Comparison of 100 stem count and square foot frame count in relation to prediction by Weaver and Whitney's Proportion Method

Field	100 Stem Count			Five (1) Foot Square		
	A	B	C	A	B	C
	No. of Infested Stems	No. of Nymphs per Stem	No. of Nymphs Predicted by Prop. Method	No. of Infested Stems	No. of Nymphs per Stem	No. of Nymphs Predicted by Prop. Method
Townline 63, #1	.25	.42	.45	.27	.42	.48
Townline 63, #2	.22	.35	.37	.17	.17	.27
McNiff's	.30	.50	.55	.24	.36	.42
Clusters	.10	.08	.14	.08	.09	.11
Scibelli	.16	.22	.25	.25	.34	.44
Tannery Rd.	.26	.50	.46	.31	.61	.58
Southwick Country Club	.20	.29	.33	.16	.18	.25
Fisk	.09	.09	.13			
Southampton	.27	.40	.48			
Edgewood Motel	.17	.20	.27			
Westfield Hill	.29	.51	.52			
Townline, Hadley	.16	.19	.25			

The author has found that by counting the number of nymphs found on stems touching the length of a three foot aluminum rod thrown into a field five times in a random fashion, results are obtained which give a rough indication of the degree of infestation present. This method has the advantage of being relatively rapid and indicative of the degree of infestation on only the host plant involved. Here again, however, a preponderance of weeds or hay will upset the results.

Another possibility which was explored by the author was the use of a 12" sweeping net to capture nymphs. The net was passed through the forage twenty-five times in five different localities within the field. The number of nymphs was then totaled and compared with other methods. The results were too eratic to have much value.

Table 15 shows a comparison of four different methods of evaluating nymphal spittlebug populations in fields containing uniform crops of alfalfa. As can be seen in the data, all the methods give a rough indication of the degree of infestation. Inasmuch as Weaver's proportion method has been shown to be applicable to this region, we can assume that the nymph per stem method is fairly accurate. Upon this basis, it can be seen that none of the other methods are uniformly reliable.

Adult

Adults were first observed in the spring of 1956 on June 14th in the field and on June 5th in 1957. Adults, as

Table 15. Comparison of methods of evaluating nymphal spittlebug populations in fields containing a uniform crop of alfalfa.

Field	Sq. Ft. Frame*	3 Ft. Rod**	Nymphs per Stem 100 Stem Count	125 Sweeps
Townline, Rte. 63, #1	42	35	.42	38
Townline, Rte. 63, #2	17	25	.35	17
McNiff's	36	40	.50	30
Cluster's	9	1	.08	9
Scibelli	34	22	.22	31
Tannery Rd. Field	61	25	.50	42
Southwick Country Club	18	13	.29	22

* Square foot frame was thrown five times at random and nymphs enclosed were totaled.

** 3 Ft. rod thrown at random five times and the number of nymphs on stems touching the rod was totaled.

previously stated, emerged earlier under greenhouse conditions. The habits of the adults were observed during both 1956 and 1957. Problems involving seasonal abundance, population comparisons in different legume stands, decline of males through the season, and reproduction were investigated.

Seasonal Abundance

Periodic surveys, at roughly weekly intervals were carried on during the summers of 1956 and 1957. Adults were collected by sweeping with a 12" diameter net. Ten sweeps were made in each of five specific localities within each field. The specimens thus obtained were immediately transferred to ethyl acetate killing jars and then removed to the laboratory for further study.

As indicated by the data in Tables 16 and 17, a sharp decline in population was apparent following mowing. Adults did not move back into these fields until the new shoots began to appear. While Weaver and King (1954) state that adults thus forced out move into adjoining fields of oats, corn, wheat and legume pastures, these habitats were not available in the region studied. Since the adults are not strong fliers, the direction of their movement is dependent largely upon the prevailing wind currents. In all the fields studied, the only sources of succulent foliage were adjoining fence rows and wastelands, and it was in these habitats that the adults appeared.

Weaver and King (1954) indicate that there is a gradual decline in population within the fields as summer progresses

Table 16. A summary of insect counts of the adults of *Philaenus leucophthalmus* taken from 50 net* sweeps at approximately weekly intervals during the 1956 season, comparing the relative population densities in six fields of alfalfa in the vicinity of Amherst, Massachusetts.

FIELDS	June			July	August				September			
	6	14	25	19	1	13	24	27	4	10	18	25
Townline, Rte. 63	0	0	**	--	**	--	4	23	16	27	12	21
McNiff	0	1	8	4	11	16	**	19	11	18	4	5
Cluster's, Field A	--	0	2	1	8	13	--	5	1	2	6	**
Cluster's, Field B	--	--	--	--	**	0	--	7	0	11	5	**
Bay Rd., Town Line	0	0	5	10	0	2	--	**	2	2	5	7
Mill Valley Rd.	--	0	--	6	5	4	--	**	--	7	4	1

FIELDS	October			
	2	9	16	25
Townline, Rte. 63	7	5	**	0
McNiff	2	**	--	--
Cluster's, Field A	--	--	--	--
Cluster's, Field B	--	--	--	--
Bay Rd., Town Line	6	2	1	0
Mill Valley Rd.	7	3	1	0

--No collection on these dates due to other duties or because regrowth was not adequate for sampling purposes.

* 12" diameter beating net.

**Date of cutting.

Table 17. A summary of insect counts of the adults of *Philaenus leucophthalmus* taken from 50 net* sweeps at weekly intervals during the 1957 season, comparing the relative population
(a) densities in nine fields of forage in the vicinity of Amherst, Mass.

FIELDS	May 15	22	29	June 5	12	19	27	July 3	9	16	23	31	August 6	13	21	28
Rte. 63-Alfalfa	0	0	0	0	**	0	1	7	**	0	1	4	1	4	0	8
Mill Valley Rd. Alfalfa-Grass	0	0	0	1	7	43	3	**	11	6	7	3	13	14	11	6
S. Maple St. Mixed Clover	0	0	0	0	**	1	3	4	11	5	**	0	0	4	1	2
S. Maple-Red Clover								4	2	4	**	0	2	4	0	0
Bay Rd.-Alfalfa	0	0	0	0	2	9	3	6	2	4	1	**	0	3	3	9
Clusters-Alfalfa	0	0	0	0	**	1	14	16	11	2	0	**	0	6	0	5
McNiff-Alfalfa	0	0	0	0	**	4	7	9	10	**	0	2	6	7	5	9
McNiff-Alfalfa-Grass	0	0	0	0	**	2	6	4	9	10	9	4	10	7	25	33
Stockbridge Rd. Alfalfa	0	**	0	0	0	0	4	2	3	**	0	6	0	0	**	0

* 12" dia. beating net
** date of cutting

Table 17. A summary of insect counts of the adults of _Philaenus leucophthalmus_ taken from 50 net* sweeps at weekly intervals during the 1957 season, comparing the relative population
(b) densities in nine fields of forage in the vicinity of Amherst, Mass.

FIELDS	Sept.		October					November			December
	3	24	1	9	15	22	29	5	12	20	3
Rte. 63-Alfalfa	18	15	11	2	0	0	0	2	0	1	0
Mill Valley Rd. Alfalfa-Grass	2	0	0	0	0	0	2	0	1	0	0
S. Maple St. Mixed Clover	0	0	0	0	3	0	**	0	0	1	0
S. Maple St. Red Clover	0	1	**	0	0	1	0	0	0	0	0
Bay Rd.-Alfalfa	4	7	5	**	0	2	0	0	1	0	0
Clusters-Alfalfa	3	3	0	0	0	0	0	0	0	0	0
McNiff-Alfalfa	11	10	3	**	1	1	0	0	0	0	0
McNiff-Grass-Alfalfa	20	9	3	**	2	1	0	0	1	0	0
Stockbridge Rd. Alfalfa	1	2	1	**	0	1	0	0	0	0	0

* 12" dia. beating net
** date of cutting

regardless of mowing practices. Because spittlebugs are not abundant in this area, this population decline is not readily apparent from the data presented. If the data is transposed to one-hundred sweep samples, this decline would become more evident.

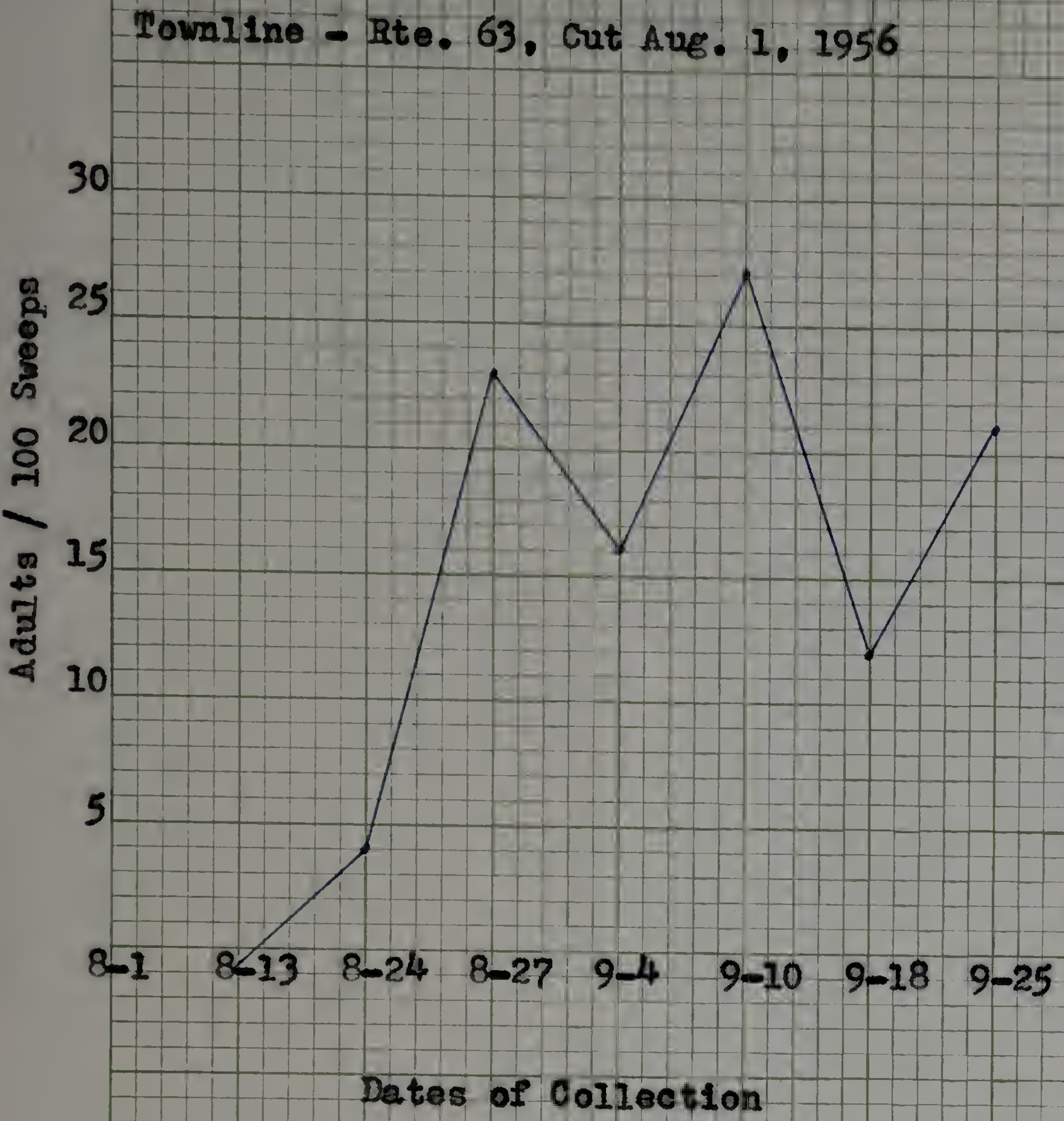
It can be seen in Table 17 that in those fields which were cut on June 12, 1957, just prior to adult emergence, the peak appearance of adults took place at later dates. It is apparent that the nymphs thus deprived of their immediate source of food and exposed to the prevailing winds retreated downward to the crowns of the plants rather than being eliminated by mowing. In these less protected and less succulent locations, the nymphs required a longer time to complete their growth, the adults thus appearing at a later date.

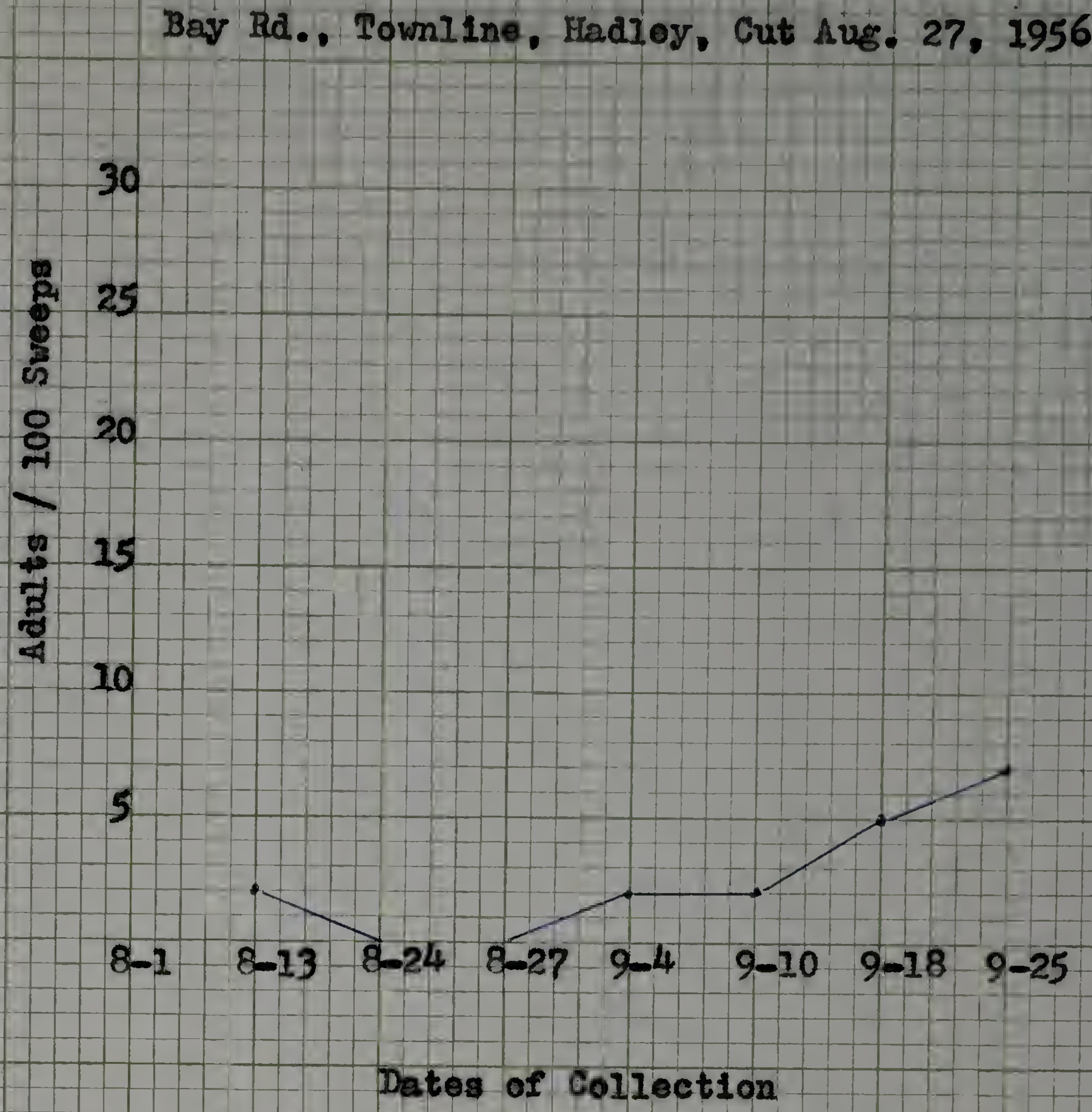
Alfalfa fields in Massachusetts are managed under both two and three cutting systems. In a year such as 1957 where drought conditions prevailed much of the season, plant growth had not reached sufficient height to make cutting economically feasible. This crop was thus allowed to stand through September in order to give the plants sufficient time to store up nutrients which would enable them to overwinter successfully. This procedure provided perfect conditions for the female spittlebugs which return to succulent foliage in the fall for feeding before oviposition. It is in these fields that the majority of egg deposition takes place. As can be seen in the data presented, adults showed up in increasing numbers in alfalfa fields in late August and early September.

This trend is also readily apparent in the data presented for the 1956 season. In the alfalfa field on Stockbridge Road, on the other hand, where a cutting took place on August 21st, there was no build-up of adults during the fall. See Graph I. Inasmuch as the number of nymphs in a field is a direct reflection of the number of eggs deposited the preceding year, the author feels safe in predicting a very light infestation in this field in the spring of 1958. The graph on the following page contrasts the effect of early and late clipping of the last crop on the number of adults appearing in the fields at this time. Therefore, if a system of management is followed which allows for the cutting of alfalfa fields during the last two weeks of August or first week of September, the infestations which occur the following year will be sub-economic. This has proven to be the case also under Ohio conditions.

The data presented for the 1957 season also indicates that mixed clover and red clover are not attractive oviposition sites for adult females under Massachusetts conditions. This finding substantiates that of Weaver and King (1954) who reported that first and second harvest year, red clover meadows did not attract adults in late summer. These crops are usually removed in early August and the plants show slow recovery due to the drier conditions resulting in smaller populations of adult spittlebugs.

Graph I Effect of Late Cutting of Alfalfa Stands on Adult Spittlebug Populations in 1956.





Population Comparisons in Different Legume Stands

A comparison of the seasonal abundance of the meadow spittlebug in four types of legume fields is presented in the following Table 18. Under Massachusetts conditions, clover does not maintain as high a seasonal population of spittlebugs as does alfalfa. As previously indicated, clovers are poor oviposition sites so one would naturally expect a lower initial population. One of two things may be surmised from the data. Either the adults are not especially attracted to clover fields or the fields were too far removed from any source of abundant spittlebugs.

While the alfalfa grass mixture has a higher spittlebug population throughout the early part of the season, it would not seem to be an attractive oviposition site. This conclusion is not altogether warranted because of the effect of cutting dates. As can be seen by the data, the last cutting was made on July 3rd. The natural decline in succulence of the plants over the rest of the season precludes its use as an attractive oviposition site. This conclusion holds equally well for both stands of clover. The reason that the alfalfa field in this case provides an attractive oviposition site is correlated with the method by which growth reoccurs. When an alfalfa plant is cut or the upper portions of the plant allowed to die, new tillers arise from the crown of the plant distinct from the previous shoots or tillers. These new shoots attract the scouting female to their succulent growth providing an ideal place for feeding and deposition.

Table 18. A summary of insect counts of _Philaenus leucophthalmus_ adults taken from 50 net* sweeps at weekly intervals during the 1957 season, comparing the relative population densities in four types of forage crops.

FIELD TYPES	May			June				July					August			
	15	22	29	5	12	19	27	3	9	16	23	31	6	13	21	28
Alfalfa	0	0	0	0	**	4	7	9	10	**	0	2	6	7	5	9
Alfalfa-Grass	0	0	0	1	7	43	3	**	11	6	7	3	13	14	11	6
Mixed Clover	0	0	0	0	**	1	3	4	11	5	**	0	0	4	1	2
Red Clover								4	2	4	**	0	2	4	0	0

FIELD TYPES	Sept.		October					November			December
	3	24	1	9	15	22	29	5	12	20	3
Alfalfa	11	10	3	**	1	1	0	0	0	0	0
Alfalfa-Grass	2	0	0	0	0	0	2	0	1	0	0
Mixed Clover	0	0	0	0	3	0	**	0	0	1	0
Red Clover	0	1	**	0	0	1	0	0	0	0	0

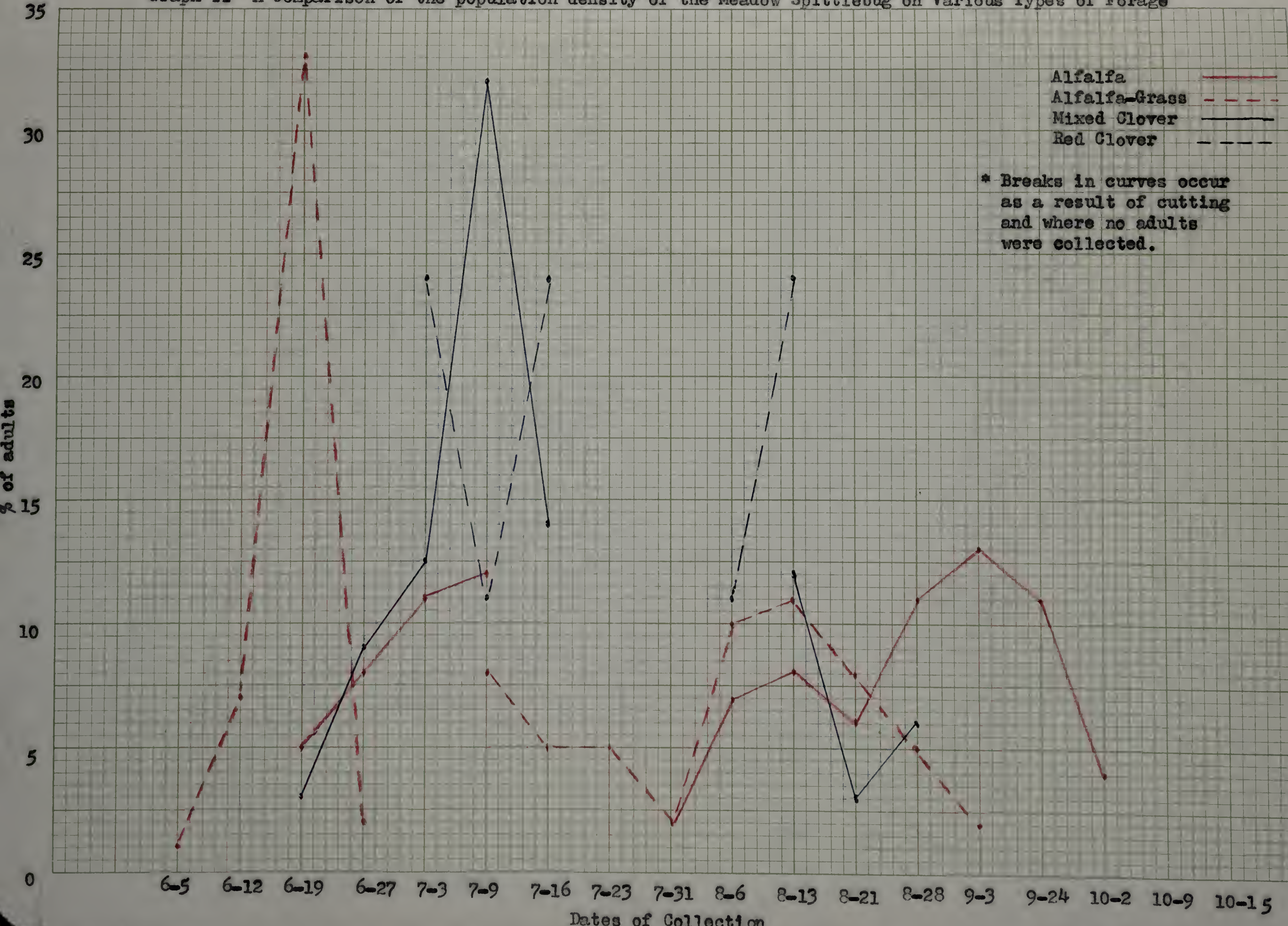
* 12" dia. beating net
** date of cutting

Graph II gives a comparison of spittlebug population in four types of legume stands on a percentage basis. The number of adults in a field at a given time is a percentage of the total number of adults collected throughout the season. This method of presentation has the advantage of equalizing the data thus eliminating the variable of actual numbers collected. It is apparent from the graph that those fields in which a companion grass crop has been grown support a higher initial population. This seems to indicate that the faster growing grasses create a more optimum habitat for the nymphal populations. The effect of cutting of the alfalfa field on June 12th is readily apparent when contrasted to the alfalfa grass mixture which was not cut until July 3rd. The movement of adults from the fields following peak emergence is shown along with the gradual seasonal population decline regardless of the type of field. The unattractiveness of the clovers as opposed to alfalfa as oviposition sites can also easily be seen.

Seasonal Proportion of Sexes

Cecil (1930) in a limited experiment indicated that there might be a gradual decline in the number of males in proportion to females as the season progressed. In Oregon, Edwards (1935) found that the proportion of females to males in Oregon rose from 30% in early spring to 91% in January. Weaver and King (1954) obtained sufficiently large samples

Graph II A Comparison of the population density of the Meadow Spittlebug on Various Types of Forage



of adults to show a definite trend showing that the proportion of males to females is higher in June and decline as the season progresses.

The sex of adult spittlebugs is easily determined and a plentiful supply of adults was available as a result of systematic surveys already completed. The author decided to check Weaver and King's work in this respect. Table 19 shows a comparison between Weaver and King's data and that obtained by the author over two seasons. The results are comparable. The data shows that somewhere between August and September, the proportion of males to females changes completely with the females becoming more prevalent. By early September, mating is largely completed. The females move into the oviposition sites and cease migration. During the autumn, they are easily captured. It is not known whether the males have died off because their function has been completed or whether they have simply not migrated into the same areas as the females.

Mating

Copulation of the meadow spittlebug was first described by Gadeau de Kerville (1902). Driggers and Pepper (1935) thought that copulation began in July. Weaver and King (1954) have observed copulating adults from early June to late fall.

The present author made special note of mating pairs during the 1956 season. The following table shows that

Table 19 Relative abundance of males to females throughout the season for both 1956 and 1957 collected in Amherst, Mass.

		June	July	Aug.	Sept.	Oct.
1956	♂	192	83	206	54	13
	♀	120	55	114	124	43
1957	♂	954	79	175	15	3
	♀	719	63	238	43	26
Weaver	♂	671	302	300	1081	445
	♀	579	300	328	1287	661

adults were observed mating from mid July until November 15th. Fall weather was unusually mild that year, which might explain why mating activity was still occurring as late as November 15th.

Table 20 also indicates that indiscriminate mating occurs among the different color varieties. This lends further evidence to the premise that these variations are not biologically differentiated. While it is rather unusual that no males of the variety marginellus have ever been found, it would appear from the present author's observations that the females of that variety mate with males of other varieties.

The length of time during which mating pairs remained in the copulating position was observed under laboratory conditions. The average length of time appears to be about five hours. It may be that there is a relation between the extended period of copulation and delayed fertilization. Robertson and Gibbs (1937) making a detailed study of spermatogenesis in the meadow spittlebug, showed that the mechanism of spermatogenesis and the release of the sperms in the female spermatheca was designed for delayed fertilization.

Egg Deposition

Most of the entomologists who have investigated reproduction in meadow spittlebugs have indicated that eggs are developed in the fall. Osborn (1916) did not find any eggs

Table 20. Observations on mating behavior of the Meadow Spittlebug during 1956 season.

Varieties Involved	Length of Time in Copulatory Pos.	Date Observed
Both *pallidus* var.	-------	July 18
spumarius and *pallidus*	-------	July 19
spumarius and *pallidus*	-------	Aug. 7
pallidus and *pallidus*	-------	Sept. 6
pallidus and *spumarius*	-------	Sept. 7
spumarius and *marginellus*	-------	Sept. 10
spumarius and *spumarius*	-------	Sept. 25
pallidus and *spumarius*	-------	Sept. 25
pallidus and *spumarius*	-------	Oct. 2
spumarius and *spumarius*	5 hours	Oct. 9
	2 hours *	Oct. 9
pallidus and *spumarius*	6 hours	Oct. 16
	------- **	Oct. 17
pallidus and *spumarius*	8 hours	Oct. 16
pallidus and *pallidus*	5 hours	Nov. 15
spumarius and *spumarius*	3½ hours	Nov. 15

-- Length of time not observed.

* Same pair copulated again same day.

** Same pair remated the following day but the length of time in copulation was not observed.

within the females until late August under Maine conditions. Cecil (1930) indicated that egg deposition did not take place until September and October. Edwards (1935) stated that oviposition did not occur until 80 days following adult emergence. Weaver and King (1954) dissected females found at Wooster in 1950 and concluded that peak development occurs about the second week in September.

The occurrence of peak development probably but does not necessarily establish the time when eggs are actually laid. In three years sampling in New York, Cecil (1930) was unable to find any eggs before September 11. Weaver and King (1954) made tests with caged adults and periodic samples of the number of eggs on straw in legume meadows, but were unable to locate eggs under Ohio conditions prior to September 1.

Field observations made by the present author were unsuccessful in locating eggs with the exception of two packets discovered on rye stubble in early November.

During the fall of 1956, adults were caged in large glass open-mouthed containers. Moist paper towels and freshly cut alfalfa stems were inserted along with the adults in the jars. The material within the jars was examined for eggs following the death of all the adults. The dates on which the containers were examined are recorded below. See Table 21. It should be noted that with the exception of those eggs laid on the moist paper towel, the majority of eggs are deposited in packets of 2-11 between the sheath and stem of the plant.

TABLE 21

Data Showing the Number of Eggs Recovered from Cages During 1956 Season

Date Examined	Total # of Eggs Found	Moist Paper Towel	Packet Size on Plant
Aug. 30	9	---	1, 4, 5
Oct. 8	33	26 singly	1, 1, 1, 2, 2
Oct. 19	29	1	8 singly 4, 2, 2, 3, 2, 4, 3, 3, 3, 2
Oct. 22	11	---	pad of 11

SUMMARY

In the course of this study, a thorough review of the literature disclosed a considerable amount of information relating to the biology of the meadow spittlebug. Very little information, none of it quantitative, was found for Massachusetts.

The foregoing study was initiated to determine the life history of Philaenus leucophthalmus under Massachusetts conditions. It was found that the insect studied has one generation a year. Overwintering occurs in the egg stage. Hatching usually takes place in late April or early May depending on the seasonal temperatures. The nymphs pass through five instars, the length of each being dependent on temperature, moisture, and plant succulence.

Laboratory studies, carried on during the spring of 1956, indicated that the average length of spittlebug instars was 10.2, 6.2, 6.3, 6.5, and 8.7 respectively. The adults emerge in large numbers in mid June and subsequently disperse. Marked reinfestation of alfalfa fields occurs in early September with the appearance of females seeking attractive oviposition sites.

Field studies were conducted in both 1956 and 1957. Surveys were the main tools used. In these surveys, one swing of the net through a 180 degree arc was considered a full sweep. The nets used were identical, all having 12" diameter. Each field was approached in a characteristic

manner, ten sweeps being taken in each of four corners of the field and ten sweeps taken from the middle. This method insures that the difference in the field size is not a variable in evaluating populations.

Distribution studies were carried on to determine the range of the spittlebug within the confines of Massachusetts. It was found to be present in all counties. Note was also taken of the varietal distribution of this insect. The variety pallidus was found to represent 34.6% of the total specimens examined; spumarius, 56.4%; fabricii, 3.1%; leucophthalmus, 1.2%; marginellus, 2.5%; leucocephalus, .5%, and fasciatus, 1.5%. Comparison of this data with that obtained by other workers indicates that the color differences are not due to geographical location.

A comparison was made of several methods used by both the author and other workers to survey nymphal populations. The author found that a technique utilizing the percentage of infested stems gave the most accurate results as well as being the most rapid method for evaluating comparable populations. The work carried on by the author corroborates the conclusions drawn by Weaver and King (1954).

A nymphal host list was prepared and seventeen species of previously unreported host plants were included. While spittlebug nymphs feed on a wide range of plant species, the preferred hosts of economic importance in Massachusetts are alfalfa, red clover, white clover, and strawberries. Feeding by adults represents no serious problem under Massachusetts conditions as legumes are not grown for seed.

Observations were made on nymphal behavior. Nymphal movement is restricted largely because of the necessity of remaining within a self-made microclimate. Migration up and down a stem is far more common than movement from plant to plant. The former type of migration is a response to environmental changes such as the motion of drying winds or the daily increase in the intensity of sunlight as midday approaches. Moulting is accomplished in a manner similar to that of the cicada. The adult emerges from the last nymphal exuviae within the dried spittle mass and then crawls or springs forth.

Studies were carried on relative to the behavior of adult spittlebugs. It was found that a population decline occurs in legume fields as the season progresses. The relative proportion of sexes changes during this period from a preponderance of males following adult emergence to an excess of females in early autumn. A comparison of the population density of spittlebugs in different types of legumes revealed that alfalfa and alfalfa grass mixtures were more heavily infested than the clovers.

Mating habits of <u>Philaenus leucophthalmus</u> were noted. Copulation begins about a month after the emergence of the adults. Different color varieties were observed to mate indiscriminately indicating that these are varieties rather than species. The males mount the backs of the females and may remain in the copulatory position anywhere from two to eight hours.

Oviposition takes place in early September in Massachusetts. The choice of a favorable oviposition site is dependent on the presence of adequate stubble and succulent foliage. First year alfalfa stands which were previously planted to grain are more heavily infested than second or third year stands. Clover fields are unattractive as oviposition sites because of their slow recovery following the final cutting. Eggs are laid in packets cemented between the stems and leaf sheathes of plants. Attempts by the author to locate eggs in the field were largely unsuccessful. Eggs were fairly easily obtained by enclosing adults in large bell jars with suitable substrate for oviposition.

The economic importance of the spittlebug at the present time was determined for Massachusetts. Quantitative population studies in 1956 indicated that certain of the alfalfa fields surveyed could be considered to be economically infested. Weaver and King (1954) devised a method whereby the nymphal spring populations could be predicted on the basis of the population density of adults in the same fields in the fall. This method was shown to be applicable under Massachusetts conditions. On this basis, the prediction was made that none of the fields under observation in the fall of 1957 would have an economic infestation in the spring of 1958.

The type of damage resulting from the feeding by this insect was noted. Probably stunting and shortened internodes are the most obvious results of nymphal feeding.

Rosetting is commonly observed. In addition to the above, hay quality is reduced by the production of fewer and smaller leaves and more and tougher stems.

Field studies were carried on to develop information which might be of practical significance should it become the policy to attempt the control of the meadow spittlebug in Massachusetts. A comparison of heat unit methods based on day degrees indicate that Weaver's method based on a 40 degree base dating from April 1st was best adapted for the prediction of spittlebug hatch under Massachusetts. The author extended the number of accumulative day degrees from 25° to 75°. A comparison was made of several methods of determining the nymphal populations in a field. The author confirmed the practicability of using infested stems as an indication of actual spittlebug populations. Proper timing of cutting in the spring will reduce the initial adult population. Proper timing of cutting in the late summer was shown to have a measurable effect on the populations of nymphs in the field the succeeding spring.

CONCLUSIONS

Several valid conclusions may be reached based on the data presented in the foregoing paper.

1. Under Massachusetts conditions, the meadow spittlebug has one generation a year.

2. The meadow spittlebug is widely distributed throughout the State of Massachusetts.

3. The color differences exhibited by the different varieties are not due to geographical location.

4. A comparison of survey methods for nymphs indicates that measurements utilizing the percentage of infested stems give the most accurate results and this method is more rapid than any of the other methods tested.

5. The preferred hosts of economic importance are alfalfa, red clover, white clover, and strawberries.

6. Following peak emergence, adult populations decline in legume fields as the season progresses until early September when these fields are reinfested for oviposition purposes.

7. Utilizing Weaver's day degree method, as modified by the author, the date of the hatching of spittlebug eggs may be predicted.

8. Weaver's method of predicting spring populations of nymphs based on the population of adults in the field the previous fall is applicable under Massachusetts conditions.

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