

THE MEADOW SPITTLEBUG, PHILAEUS LEUCOPHTHALMUS (L.)

IN MARYLAND

by  
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of the University of Maryland in partial  
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## INTRODUCTION

The appearance of white, frothy masses on plants has intrigued laymen and scientists alike for many years. Such colloquial terms as snake spit, cuckoo spit, frog-spittle and toad-spittle have come into use because of various beliefs as to the origin of the spittle-like mass which surrounds certain immature insects. Today the common name for these insects is spittlebug, and they are all members of the family Cercopidae.

Though spittlebugs are not new to Maryland, the meadow spittlebug, in particular, has become increasingly abundant in the last few years. In spite of the accepted importance of the insect as a pest, there seems to be an almost complete lack of knowledge of this insect as it occurs in the state. The studies reported in this paper were made in order to determine the life history in Maryland, the local plant hosts, and the abundance on those hosts.

Field observations began in April, 1950, and were continued on into May, 1951. Specimens were collected from more than half the counties in Maryland, though more intensive observations were made in Montgomery and Prince Georges Counties. After a hayfield survey in Montgomery County, it was estimated that there were close to 1,200,000 spittlebugs per acre.

In the text that follows the biology of the insect will be described particularly as determined by Maryland conditions, and its aspects as an economic pest, as found by the field study, will be discussed.

## REVIEW OF LITERATURE

Spittlebugs are all members of the family Cercopidae (Homoptera) which was first properly described by Leach in 1815. The earliest descriptions of Cercopidae were made by Linnaeus, but he placed them under the genus Cicada. Then in 1775 Fabricius erected the genus Cercopis to cover all the species, but according to Doering (22),

"Leach (1815) and Amyot and Serville (1843) are responsible for giving the characteristics of the family. The six genera occurring in North America north of Mexico are Tomaspis and Lepyronia described by Amyot and Serville in 1843, Anhropera described by Germar in 1821, Clastoptera described by Germar in 1838, Philaenus described by Stal in 1864 and Philaronia described by Ball in 1898."

Apparently the first synopsis of the Cercopidae of North America was written by Goding (31). Another genus was erected by Ball (4) in his review of the family. He had been able to separate the two species of Philaronia from Philaenus where they were formerly grouped. Stearns' (66) key to the species of North American Cercopidae was originally written as a thesis for a Masters Degree in 1917. It was published 5 years later as a part of the Hemiptera of Connecticut. The most recent synopsis of the North American species of this family was written by Doering (22). Since no new species have been described, a more recent revision was hardly been necessary. Following a generic key, the remainder of this comprehensive paper is divided according to genera. Each generic division contains a key to species and varieties, along with a discussion on distribution, host plants, and synonyms. A bibliography is included for the various genera. On pages 95 and 96 the author presents reasons why Philaenus leucophthalmus (L.) is the proper scientific name rather than P. spumarius (L.) used previously by many writers. The current list of approved common and scientific names indicates the acceptance of her arguments (50).



Although there were many taxonomic studies reported on particular genera and species, the papers mentioned above were the only ones known to the writer that reviewed those species of the family which are found in North America.

The sole guide as to the species that occur in Maryland appears to be in a short taxonomic paper by McAtee in 1920 (46) which indicates that of the 6 North American genera, all but Philaenus are to be found in the vicinity of Washington, D. C. However, he lists Philaenus only in his generic key with the footnote, "Has been taken as far south as North Carolina and may be found here" (Washington, D. C.). Evidently they were not present in very great numbers or he would certainly have collected some. This conclusion is borne out by the fact that Deering (22) does not mention Philaenus as having been collected in Virginia, District of Columbia, Maryland, Delaware or Pennsylvania. In addition, the University of Maryland Insect Collection contains only one specimen of Philaenus leucophthalmus which was collected prior to 1946. That one specimen was found by H. S. McConnell in 1936 on a cultivated rose.

The importance of McAtee's paper lies in the fact that it is the only reference which deals with spittlebugs in this region of the East. Although Stearns (66) and Deering (22) provide keys to species and varieties of Philaenus, Deering has this to say, "In as much as these color variations grade into each other and also mate interchangeably, in addition to the similarity of the genitalia there can be no doubt as to their all being the same species." Osborn (53) and Smith (63) are in agreement with Deering regarding the color varieties.

Distribution. Philaenus leucophthalmus is distributed over much of Europe and in North America its range seems to be generally over southern

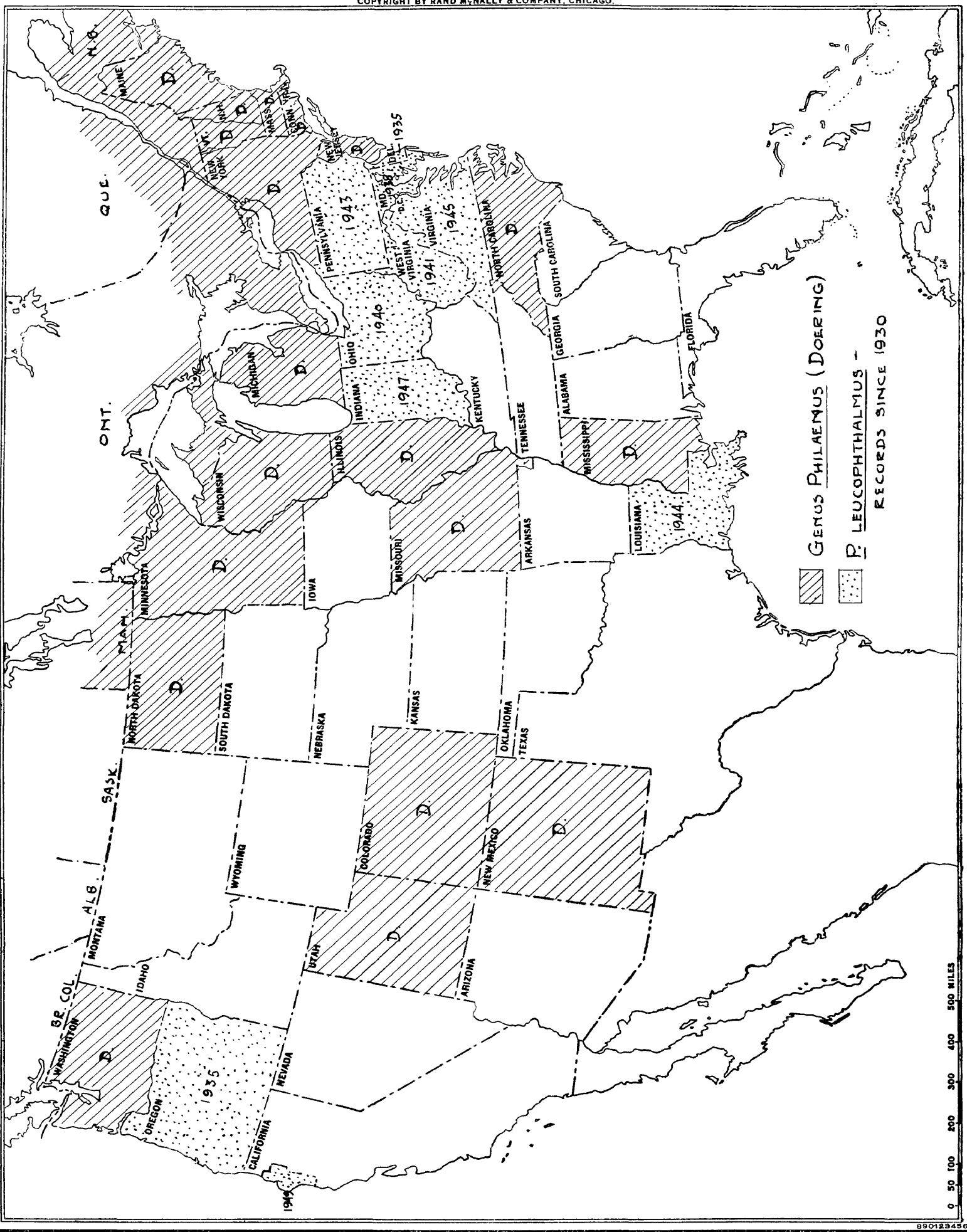
Canada and the northern portion of the United States. Packard in 1898 stated that the insect was generally distributed over North America. It may have been, but other writers of that period did not seem to believe the distribution was as broad as Packard claimed. Distribution data were incomplete and somewhat questionable until Doering (22) assembled her data and wrote,

"The genus has been collected from the following localities: Alaska, Colorado, Connecticut, Illinois, Maine, Manitoba, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, New Jersey, New Hampshire, New Mexico, New York, North Carolina, North Dakota, Nova Scotia, Ontario, Quebec, Vermont, Utah, Washington and Wisconsin."

It should be kept in mind that the several species of Philaenus are referred to here, not E. leucophthalmus alone. Brimley (12) lists only E. leucophthalmus for North Carolina.

From the literature reviewed relating directly to the distribution of the meadow spittlebug, it became evident that some sort of distribution map would be necessary to properly correlate the various recorded data. In order to determine the present area of distribution of this insect in North America, the writer visited the Department of Agriculture in Washington, D. C., and was allowed access to the records of the Division of Insect Identification and of the Insect Pest Survey. From these 2 sources the composite distribution shown in Figure 1 was developed. It should be noted that the distribution of E. leucophthalmus does not tell the whole story because the seriousness of the spittlebug as a pest is greater in some areas than in others. The abundance of this insect is apparently unknown in many of the states from which it has been recorded. There are understandable discrepancies as to the earliest date of recognition in the various states, for undoubtedly entomologists identified occasional specimens in many states during the period from 1935 to

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
 GENUS PHILAEMUS (DOERING)  
 P. LEUCOPHTHALMUS -  
 RECORDS SINCE 1930

Fig. 1. Present distribution of *P. leucophthalmus*

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1945, not knowing they were new distribution records. Since 1945, however, the meadow spittlebug has become a pest of major importance in several areas, a subject that will be discussed in the section devoted to "Economic Importance."

Life History. Osborn (54) made a rather thorough study of the habits of the spittlebugs of Maine. He believed that there was a single generation per year, and that the spittlebugs overwintered in the egg stage. Ball (4 and 6), an authority on Cercopidae and other Homoptera, divided his discussion of life cycles according to families. Concerning the Cercopidae he states, "All of our local species have a single annual generation, and all but one pass the winter in the egg stage." He did not mention this exception by name, but Dearing (21) and Garman (30) stated that *Leptocorixa quadrimaculata* passes the winter as an adult. Garman also noted that the alder spittlebug, *Clastoptera obtusa*, had 2 generations per year.

Several interesting greenhouse observations were made by Smith (63). As had been mentioned by others previously, he noted that the color varieties mated indiscriminately, "sometimes remaining in cality for 5 days." He was able to keep the adults alive for a maximum of 70 days, which was much longer than Ahmed and Davidson (1) were able to keep their specimens.

Brief life cycles were described by Schub and Zeller (61) and by Neiswander (52). Neiswanger (51) described in rather complete detail the life cycle as he observed it in New York. He noted that oviposition began in July but is most intensive in September and October. Females captured in September laid eggs in masses of 1 to 30 (average 6 per mass), and the number of eggs per female varied from 18 to 51. Neiswanger found 5 instars, as have most other authors. However, Ahmed and

Davidson (1) found only 4 instars in Ohio. From their data it would appear that they failed to distinguish between the first and second instars, an oversight that could easily happen. They recorded the time that various individuals remained in each instar. Thus, the longest average time in one stadium (12.7 days) appears to have been actually the combined total of the first and second stadiums. Their data were recorded for 18 individuals "which succeeded in reaching the adult stage."

Eggs. Osborn (54) described the size of the eggs of Philaenus, obtaining the data by teasing the eggs from fertilized females and photographing them. Barber and Ellis (9) measured eggs from 3 species of spittlebug, giving the following egg lengths: Philaenus lineatus, .98 mm.; P. leucophthalmus, 1.03 mm.; Philaronia bilineata, 1.22 mm. They concluded,

"Oviposition of these three species is very similar indeed. Individual eggs nearly agree both in shape and color and are deposited in the same manner...the female does not thrust her ovipositor through any portion of the plant tissue, but merely inserts the eggs between the stalk and leaf sheath."

This paper is often referred to in discussions of spittlebug eggs. Doering (23) compiled descriptions of egg deposition of various species of Cercepidae. Apparently some species (Aphrophora and Clastoptera) insert their eggs into plant tissue. Photographs of egg masses of Philaenus appear in papers by Schuh and Zeller (61). Mandinger (51) and Ahmed and Davidson (1).

Froth. The froth produced by spittlebug nymphs has attracted much attention among laymen, particularly those who are inclined to be superstitious. Naturally scientific investigators have not overlooked this spit-like mass. Doering (21) states that Morse (49) is usually credited with the discovery of the fluid nature of the spittle. He first published his results as early as 1875, but they evidently attracted little

attention until written in a popular style and published in a popular magazine 25 years later. Gruner (33) found the spittle to consist of 94.505 per cent water, 3.827 per cent organic substances, and 1.607 per cent inorganic salts. Kershaw (38) also investigated the spittle and stated, "It...appears to be a mucin or mucinoid...The fluid appears to have every substance excreted from the anus."

While a student at Ohio State University, Cecil (13) verified Kershaw's conclusions.

"The fact that no special glands with anal openings were found... indicates that the clear fluid from which the spittle is formed is the normal excretion from the alimentary canal...It is evident that the quantity of excretion is determined by the rate of feeding or that the spittlebug nymph is able to control the rate of flow of sap through the alimentary canal."

He also describes how the nymph is able to breathe while submerged in the spittle. The foregoing review of papers related to the froth was necessarily limited to the papers available to the writer, although other papers by European writers are known to exist.

Abundance. Only a few entomologists have hazarded guesses as to reasons for outbreaks of the meadow spittlebug. Davis (19) noted that "this insect is present every year...apparently the general outbreak this year was the result of cool, wet, and cloudy weather." Chamberlin and Medler (15) stated,

"The spring of 1949, until mid-June, was characterized by alternating periods of unusually high and low temperatures, especially during May...the alternating cool and warm periods retarded the appearance and development of spittlebugs early in the season without retarding the growth of legumes correspondingly."

Economic importance. The term "economic importance" infers an effect on man's economy in some manner. At times it is difficult for entomologists to determine whether certain insects, numerous though they may be, are causing plant damage or monetary loss to man. Pierce (57) wrote

editorially on this subject and stated, "The real damage comes when the insects reduce the yield below the normal productive capacity of the plant." We know now that spittlebugs can and do cause measureable damage to crops, and the following review of papers on this phase of Cercopidae will substantiate this statement.

As early as 1887 Lintner, the New York State Entomologist, received reports of large concentrations of spittlebugs from alarmed farmers (41). One farmer reported the county (St. Lawrence) was "full of them." Lintner at that time stated that spittlebugs had never been known to cause serious damage to grasses. However, the following year he mentioned that,

"Report has been made in Vermont of one or more of the grass infesting species causing considerable damage to the hay crop. It was estimated that in consequence of the depredations, the quantity of hay grown on some fields was one-third less than the natural yield, not including the depreciation in the quality of the crop." (42)

That seemingly incredible estimate of damage by spittlebugs was probably too much to accept at that time, for apparently no author except Osborn (54) has mentioned it since. However, it may have been an accurate estimate, for Weaver (73) in a recent experiment concluded that complete control of spittlebugs could increase hay yields by 55%. Fernald in 1891 mentions several spittlebug synonyms and described the two common species of Philaenus, i.e., spumarius (leucophthalmus) and lineatus.

The first ecological study of spittlebugs appears to have been Osborn's bulletin on "the Froghoppers of Maine" (54). He described life cycles of 6 species, presented instar measurements, brief host lists, drawings and descriptions of nymphs, and photographs of adults. The damage to plants by spittlebugs apparently led Osborn to a more thorough study of their habits, for he said, "The economic importance of these

species has been variously estimated though I think too generally overlooked." He had found in the Maine Farmer for July 26, 1866, a note by G. E. Brackett which described the general life cycle of spittlebugs and concluded that they were not particularly destructive to the plants upon which they fed. Following that reference, Osborn quoted from Lintner's 5th Report (42). Osborn continued with the observation,

"If old fields showed uniformly small plants there would be some reason to attribute the reduction in growth to the soil, or to running out, but when scattered stems stand at good height and produce excellent heads it seems that this explanation is insufficient. It is a peculiar sight in some fields to note a considerable number of tall well developed stalks with large heads in full bloom and along with them in exactly the same soil and exposure to sun, rain, and other conditions, numerous dwarfed plants with short blasted heads or no heads at all."

He attributes this type of injury to the feeding of Philaenus leucophthalmus and observed it most often on buttercup and clover. Osborn gathered the data during summer studies in 1914 to 1916. His keen observations are recorded in a rather easy writing style which has made this bulletin one of the outstanding papers on North American spittlebugs.

Garman (29) in his paper on P. lineatus concludes that that species "may cause considerable damage to grasses in meadows." During the years 1921 to 1923 Miss Deering made a very thorough study of the biology and morphology of Lepyronia quadrangularis in Kansas (21). In spite of the fact that this species was rather common in the region, relatively little had been recorded about its habits. Among other interesting and original observations were some she made on the damage by this insect to wheat heads.

"A good many [wheat] stalks were found bearing spittle masses [of L. quadrangularis]. These occurred chiefly at one side of the field next to the weeds, bordering a woods, and evidently they had migrated from the weeds to the wheat. In all cases where the nymphs were feeding on the wheat the heads were half



the size of the good heads. Nine good heads were averaged, and the number of kernels was 34 to a head. Eleven poor heads were averaged and the number was only 10, which makes an approximate loss of 33 percent."

From these observations she concludes that this species can become a pest of economic importance if they are left undisturbed to multiply in numbers.

By 1935 spittlebugs were numerous in New Jersey, particularly on clover and alfalfa. Specimens collected were identified by L. A. Stearns as Philaeus leucophthalmus. Driggers and Pepper (34) described the life history and recommended derris as a control measure. This bulletin indicates an increase in the population of this insect to the point where it could be called a pest.

Spittlebugs have been suspected of transmitting plant virus diseases, chiefly because they are closely related to the major virus vectors, the leafhoppers (Cicadellidae) and the aphids (Aphididae). Manns (43) reported the only case of apparent virus transmission by spittlebugs.

"In the spring of 1936 we fed this brown hopper, Philaeus leucophthalmus, on virulent Yellows and transferred them to large peach trees in a hopper-proof cage. Four trees came down with Yellows, 100 percent infection; the check trees remained healthy... Further work with this hopper on both Yellows and Little Peach should be continued."

The specimens suspected of virus transmission were submitted to P. W. Oman for identification. He replied they were 4 color varieties of Philaeus leucophthalmus. A check of literature and books that have been published in the years since 1940 has indicated no positive transmission of plant virus diseases by spittlebugs.

A phase of research on spittlebugs that has received relatively little attention is the listing of host plants for the various species.

Information of this type would seem of definite economic importance, yet only Doering (23) seems to have summarized and cross indexed the known hosts of the species of Cercopidae found in North America. In addition to host plants there are discussions of feeding habits and egg depositions. Miss Doering has been an authority on Cercopidae for many years and has been in a position to gather and evaluate host plant information. It is apparent from her host list for P. leucophthalmus that the species is able to maintain itself on many host plants, thus making control difficult and eradication practically impossible.

Among insect pests of strawberries in Ohio Weiswander (52) mentioned that nymphs of P. leucophthalmus were observed on more than half the plants during the 1940 season. This seems to be in agreement with other observations of the period for an increase in its importance as a pest.

Smith, et al. (64) reported P. leucophthalmus as a pest of peas and obtained some population data while making tests with DDT aerosols. These tests were conducted at Grantsville, Maryland, a town in the extreme western part of the state. A study of the literature indicates that this is the first record of this species in Maryland.

The meadow spittlebug has already been cited as a pest of strawberries in Ohio. In addition, Houser (38) mentioned that the same species occurred in

"enormous numbers in many parts of Ohio on clover and alfalfa... Because in some instances there were as many as 15 to 30 of these insects...on individual wheat heads, there was some alarm among the farmers that the crop would be damaged seriously... Examinations indicated that the damage, at most, was very slight."

P. leucophthalmus has the distinction of being the first Cercopid to be recorded from the Hawaiian Islands (25). Nymphs were found "in a market garden area where they infested celery, parsley, strawberry and many

other plants." Subsequently, a complete host list for Hawaii was compiled by Davis and Mitchell (17 and 18).

The meadow spittlebug was also numerous in Ontario, Canada, "apparently having migrated from newly sown meadows. Nursery stock [fruit trees]... was badly damaged." (53)

Detailed descriptions of spittlebug damage to alfalfa and red clover were made by Fisher and Allen (27). Their tests with caged insects proved that adults, as well as nymphs, can produce the outward symptoms of spittlebug damage (i.e., dwarfed, rosetted, blossom-blasted and necrotic conditions). Following approximately one month of feeding by the adults they noticed the damage was not so great as that by nymphs.

The meadow spittlebug as a pest of strawberry was discussed in detail by Kuntlinger (51). His observations of the life history in New York are comparable to those in other states. His photographs of egg masses are good. Ross (52) mentioned P. leucophthalma as abundant on strawberry "upwards of 40 nymphs per plant."

In addition to the increased attention paid to spittlebugs, Davis (19) stated that in 1946 the spittlebug was more common and destructive [in Indiana] than in any of the past 25 years for which we have records.

Wisconsin experiments conducted by Scholl and Medler (50) verified Osborn's earlier observation that spittlebug feeding does affect seed yield. If they knew of his work they did not refer to it.

Stirrett (69) mentions injury to several crops by heavy infestations of P. leucophthalma. Plantain and Canada thistle were among the severely affected weed hosts.

Parks (56) stated that spittlebug nymphs cause serious injury to strawberries and celery. Referring to the adults he said, "They collect on green heads of wheat, are found feeding at the tips of potato plants,

and have been known to seriously injure very young corn plants."

Weaver (73) reporting on some experiments in Ohio confirmed Osborn's beliefs on the effect of spittlebugs on crop yields. By the elimination of spittlebugs they were able to increase yields of red clover and alfalfa by 55 per cent. Large scale tests increased yields by 44 per cent.

Estimation of populations. One of the first steps in an insect problem is to determine what species are involved and their relative abundance. Estimates of insect populations are usually made with special attention to the habits of the insects being sampled. Entomologists often attempt to estimate the insect population for a certain area by sweeping with an insect net. The writer found 2 papers on this subject (10 and 20), and both were in general agreement that sweeping is an inaccurate method of estimating the population of active insects. DeLong had had considerable experience with leafhoppers (Homoptera, Cicadellidae) whose adult behavior pattern is quite similar to that of spittlebugs. He admitted that "it is impossible to capture all, or a definite proportion, of the insects which occur in a given area." Among the physical factors involved he listed: temperature, humidity, wind velocity, position of the sun, size and condition of the vegetation, rapidity and length of stroke, height of sweep, and farm practices and operations. Beall, an English statistician working in Canada, made a study of sampling with a sweep net. However, in addition to sweeping, he lowered a cylinder over a given area, killed all insects inside, and examined the collected material to a depth of several inches. Then he concluded that "the estimates of insect populations from cylinder collections and from sweeping are essentially based on different populations...A square mouth sweep net, rather than the usual round mouth, was employed without any substantial advantage."

Quantitative data on spittlebugs are relatively scarce, probably because no method has been devised for accurate estimation of field populations. However, Wolcott (75) made observations from May to October and found 61 spittlebugs in 100 square feet. Of the total 35 were E. leucophthalmus (26 nymphs and 9 adults).

Spittlebug nymphs are naturally less active than the adults and are, therefore, easier to count. Chamberlin and Medler (14) compared various methods for estimating spittlebug nymphs in alfalfa. They concluded,

"...Counting nymphs is too time-consuming to permit examination of adequate samples in ordinary field work. Counting infested stems [per 100 stems collected] has proved to be a rapid and, in general, a satisfactory method. According to the data presented, the efficiency of the insecticides would actually be higher than that indicated by the stem-count method. Estimates of efficiency based on such counts should, therefore, be conservative."

In a later article by Chamberlin and Medler (15)

"the efficiency of insecticides was determined largely from the proportions of stems bearing spittle masses in treated and untreated plots. The following materials were applied as emulsion sprays...: toxaphene, chlordane, DDT, lindane, aldrin and dieldrin...At the dosages used, toxaphene gave excellent control and was distinctly superior to chlordane. Of materials tested less thoroughly, lindane, DDT, and dieldrin were very good and appeared to be just as effective as toxaphene. Aldrin and methoxychlor gave very poor control. Parathion as a wettable powder at 0.5 pounds per acre gave only fair control."

Parasites and predators. Reports of either parasites or predators of Cercopidae are few and scattered. Baerg (3) described an unusual case of "parasitism." During the period of July 1-15, 1915, nymphs of Elastoptera obtusa were collected on alder. Attached to many of the nymphs were small maggots. By rearing the maggots to the adult stage, they were identified as Brosophila inversa, a species which feeds on plant sap (here in the form of spittle) and it also utilizes the spittle insect as a means of transportation.

Another case was described by R. Bohart (11) "Three stylopid specimens of the genus Philaronia were recently called to my attention by Dr. P. W. Oman. A mature male and two female specimens were dissected from the cercopids and proved to be Halictobes of a new species similar to the relatively common H. americana which parasitizes several genera of leafhoppers." Bohart went on to speculate on the manner in which the Strepsiptera enter the host, concluding that, "In the cercopids this would involve penetration of the spittle mass."

Stirrett (68) commented that, "A large number of Strepsipterous larvae were found in nymphal cercopids in collections of pasture insects, Ontario, July 26" (1946).

Cercopidae, by their mode of life, are almost immune from discovery and subsequent attack. This would probably account for the few recorded cases of parasitism in this family, and as a result their apparent increase in abundance in the last 7 to 10 years.

## BIOLOGY

Eggs. Survival of the overwintering eggs of Philaenus is dependent on (1) insulation against low temperature and (2) concealment from predators. Proximity of the eggs to tender plant growth is also a condition which often determines survival of the young nymphs. All of these conditions are usually satisfied as the females deposit their egg masses in the fall. Each mass of eggs is embedded in and covered by a white, frothy substance which acts as an insulator. The location of an egg mass naturally varies with the type of cover and concealment offered by the host plant. The dried petioles of both strawberry leaves and of red clover have a well defined longitudinal groove, and egg masses are deposited in these grooves more frequently than any other location. There may be several masses in the groove of a single stem. The stipules of strawberry plants are often utilized for egg deposition. The stipule location is ideal because the young nymphs are almost in the crown of the plant when they hatch. Commercial growers often use wheat straw as a winter cover for strawberry plants. The straw seems to rot or decay in layers. As a result, the female spittlebug often inserts her eggs between these layers and cements them together with the frothy insulation. Old garlic bulbs decay in much the same manner as wheat straw for eggs were discovered beneath loose scales of garlic in April, 1950. These were brought into the laboratory but failed to hatch. Egg masses found on alfalfa were relatively exposed, having the usual cover of old plant material over the froth, but the masses were easily located on the sides of stems. Crab grass was found to be an occasional host for the eggs. They had been inserted beneath the sheath while the tissues were green and pliable.

The appearance of the eggs themselves has been described by Barber and Ellis (8). They are pale yellow, elongate, more pointed on one end and are laid side by side in groups of 2 to 20. At times the end eggs were skewed at an angle to the others, rounding off the mass. This condition was observed more often when the eggs were laid on smooth stems where the only concealment was the vegetative material placed over the mass by the female.

The relative number of egg masses observed on the preferred hosts (red clover, strawberry and alfalfa) is shown in Table 1. These differences are magnified proportionately for larger areas. The present figures deal in samples of only one square foot. All samples of a certain host were repeated in the same field. However, the strawberry samples were taken from various experimental crosses as shown in Table 2. The alfalfa field was adjacent to the strawberry plot, providing a good comparison of host preference, as far as egg deposition is concerned. The alfalfa was not treated during 1949 or 1950. The strawberry crosses were transplanted in the summer of 1950 to the area adjoining the alfalfa field. These details are furnished to show that there is no apparent reason for the statistically significant difference in the number of egg masses deposited in this area of approximately 2 acres. The differences between the number of egg masses deposited in red clover and strawberry were significant at the 5 per cent level, but not at the one per cent level, as indicated in the table. These percentages were obtained by using procedures described by Wilcoxon (74) and Snedecor (65). The reasons for the differences are not known, nor would it be proper here to speculate on them.



Table 1. The number of egg masses of *P. leucophthalmus* observed on various preferred hosts. University of Maryland Farm, 1950.

Date	Hosts					
	Red clover		Strawberry		Alfalfa	
	Masses/sq.ft.	Rank	Masses/sq.ft.	Rank	Masses/sq.ft.	
Oct. 25	25	5	18	2		
26			49	9	2	
27	53	12				
30			31	6		
Nov. 1	72	14				
1	60	13				
2	43	7	19	3	1	
6	50	10	22	4		
7	44	8	6	1		
28			52	11		
Average	49.5		26.1		1.5	
Rank Total		62		36*		
AVG. eggs/mass	7.1**		5.0**			
Eggs/sq.ft.	351		140			

\* Probability = 5% (significant)

\*\* Figures obtained by counting eggs in 50 masses from each host

Table 2 is an expansion of the data on strawberries which appear in Table 1. Each sample was made at random without knowledge of the varietal cross to be examined. By chance two observations were made on different replicates of the same cross (Klondike x Wayzata). These data are rather consistent (19 and 22 egg masses per square foot). The names of the crosses are included to provide more detailed information, so that some explanation can be made for the variations observed among the other samples. It will be noted that the number of egg masses per square foot varied from 6 to 52, a wide range for natural variation. It would appear that the female spittlebugs prefer certain crosses for egg deposition. The nymphs also seemed to prefer to feed on certain crosses. The writer believes that the reason might be the variation in sugar content. However, the Head of the Horticulture Department did not share in this opinion.

More square-foot samples would have been desirable, but weather and time permitted only those listed in Table 1. The time required for a thorough search of one square foot of red clover or strawberry was at least 40 minutes, and often longer. Each piece of leaf, stem, or other plant material was scrutinized carefully to insure accurate data.

Time of hatching. The factors affecting hatching of spittlebug eggs have been carefully studied in central New York by Donald S. Marshall (45). In a January 1951 letter to the writer, he stated,

"From four years of observations in red clover and alfalfa, the meadow spittlebug eggs hatched on an average of about seven days after the first record of 70°F. had been obtained. Coincidental with this temperature a rain usually fell a day or two previous to the actual emergence. This combination of moisture and temperature appeared to stimulate egg hatching. Since the nymph must feed before it can produce its spittle secretion, it may be as long as two weeks before spittle masses appear in the field after the optimum temperature has been reached."

Table 2. Egg masses observed per square foot on various strawberry crosses. University of Maryland Farm, 1950.

Date	Varietal cross	Egg masses/sq. ft.
Oct. 25	Mastodon x Midland	18
26	Elonmore x Midland	49
30	Midland x Tennessee shipper	31
Nov. 2	Klondike x Wayzata	19
6	Klondike x Wayzata	22
7	Tenn. shipper x N.C. 1053	6
28	Temple x 3551	52

In the vicinity of Washington, D. C., the first eggs begin to hatch during the first two weeks of April, depending upon the temperature and rainfall. In 1950 the first nymphs were observed April 13, while in 1951 nymphs were first observed April 1. Table 3 shows the recorded temperature and rainfall for the months of March and April 1950 at College Park, Maryland. By applying the temperature and rainfall combination criterion mentioned by Marshall, it will be noted that this condition did not occur in 1950 until April 13. Although the first 70° recorded temperature was on March 27 and was followed by 2 days of rain with 70° temperatures, the temperatures fell below freezing at night and no more rainfall occurred until April 11. It was 2 days after this date that the first nymphs were observed, and these were difficult to find.

These observations are in general agreement with those of Osborn, if one extends his data to the Maryland area through the use of Hopkins Bioclimatic Law (36).

Life history. From the literature it has been shown that most spittlebug species have but a single generation per year. The eggs of the meadow spittlebug are laid in the late summer and fall, overwinter as eggs and hatch the following spring. Ahmed and Davidson (1) found the time from egg to adult averaged 34 days for 18 individuals in a greenhouse. In nature the length of the developmental period is affected by temperature more than any one factor. Generally speaking, nymphal development takes 4 to 6 weeks. The length of adult life is also dependent on temperature, ending with the date of first frost in the fall. In most of Maryland, therefore, the adult period would be from late May to late October. Weather Bureau records show the average date of the first frost to be October 27 for Washington, D. C. The first killing frost in the fall of 1950 occurred November 5.

Table 3. Climatological data for March and April, 1950, College Park, Md.

Day	March			April		
	Temperature		Rainfall	Temperature		Rainfall
	Max. °F	Min. °F	in.	Max. °F	Min. °F	in.
1	52	36	.01	54	25	-
2	44	22	-	62	39	-
3	36	13	-	60	62	-
4	41	14	-	79	43	-
5	61	18	-	78	45	-
6	56	31	-	51	35	-
7	49	24	-	52	25	-
8	53	34	.22	60	25	-
9	51	24	-	53	29	-
10	44	15	-	48	31	-
11	46	21	.59	71	35	.02
12	62	35	.29	68	40	-
13	61	39	.27	55	33	.10
14	45	30	.09	46	22	-
15	59	22	-	47	29	-
16	56	20	.12	61	25	-
17	46	21	-	74	28	-
18	47	33	-	76	48	-
19	46	22	-	81	47	-
20	49	21	-	78	45	.10
21	51	39	.72	56	43	.03
22	51	39	.11	64	30	-
23	46	30	.17	66	38	.40
24	63	39	.05	66	49	.01
25	60	33	.02	53	42	.01
26	60	31	.02	73	42	.04
27	75	42	-	75	38	-
28	76	60	.23	76	53	.35
29	73	42	.31	75	52	-
30	49	29	-	57	47	.19
31	51	24	-			

In the following tabulations the dates of various observed first occurrences are given.

Dates of observation of:

First nymphs	April 13, 1950
First adults	April 1, 1951
First mating of adults	May
First eggs	June 17
First killing frost	October 17
	November 5

The nymphs collected in 1950 and 1951 were all killed in a mixture of kerosene, ethyl alcohol, acetic acid and dioxan (16, p. 26). The specimens were transferred to and stored in 95% alcohol. There was slight shrinkage (0.25 mm.) of body length, but no distortion of the appendages. The green coloring of the later instars was naturally dissolved out in the alcohol so that the preserved specimens were as yellow as the first instar nymphs.

The average measurements of the various instars shown in Table 4 were made on preserved specimens with an ocular micrometer. The width of the head capsule across the eyes was rather constant, but some specimens had head widths whose measurements seemed to fall between instar averages. This happened more often with first and second instar nymphs whose differences are slight. It was believed that by measuring at least 20 specimens of each instar and averaging the values, sufficiently accurate data would be obtained. When this was completed the counting and measuring of collected specimens was begun.

Table 5 shows the collections of nymphs on certain dates, and it will be noted that nymphs were collected from several host plants on the same date. This was done in an effort to determine which hosts, if any,

Table 4. Summary of measurements of nymphs of *P. leucorhinalis*.

Instar	Nymphs averaged	Body length		Head width	
		Average mm.	Range mm.	Average mm.	Range mm.
1	20	1.32	.92 - 1.54	.42	.37 - .46
2	20	2.40	2.09 - 2.62	.64	.56 - .68
3	20	3.17	2.64 - 3.99	.91	.80 - .99
4	20	4.84	4.39 - 5.38	1.34	1.27 - 1.43
5	25	6.38	5.00 - 8.40	1.97	1.66 - 2.20

Table 5. Nymphs of *P. leucorhthalmus* in each instar collected on various hosts near College Park, Md., 1950.

Date	Host	Nymphal instar					Total
		1	2	3	4	5	
Apr. 13	strawberry	10	0	0	0	0	10
16	strawberry	4	0	0	0	0	4
18	clover	3	0	0	0	0	3
24	strawberry	0	0	2	0	0	2
28	plantain	0	0	3	0	0	3
May 1	plantain	0	0	2	0	0	2
4	bouncing bet	1	3	41	6	0	53
6	plantain	0	17	58	47	1	123
8	dandelion	0	2	11	14	6	33
9	yellow clover	0	0	7	20	0	27
9	plantain	0	1	3	28	0	32
9	grass	0	0	0	4	0	4
9	rose	0	0	1	4	0	5
10	wild strawberry	0	0	3	2	0	5
10	hollyhock	0	0	0	1	0	1
10	blackberry	0	1	5	5	1	12
11	*alfalfa	13	23	0	0	0	36
13	strawberry	0	1	14	28	5	48
13	plantain	0	1	23	24	3	51
13	grass in alfalfa	0	0	2	10	0	12
13	alfalfa	0	1	3	4	1	9
13	wheat	0	0	0	6	1	7
15	plantain	0	0	0	7	10	17
16	assorted weeds	0	1	1	32	25	59
17	spinach	0	0	0	6	0	6
17	wheat	0	0	0	8	4	12
18	plantain	0	0	0	0	32	32
19	white clover	0	0	0	8	54	62
21	red top	0	0	0	0	1	1
21	alfalfa	0	3	6	12	44	65
22	many shrubs	0	0	1	7	15	23
22	strawberry	1	0	0	13	27	41
23	plantain	0	0	0	0	9	9
24	plantain	0	1	1	8	51	61
25	plantain	0	0	0	0	17	17
26	clover	0	0	0	3	24	27
27	alfalfa	0	1	1	2	33	37
28	lt. rye grass	0	0	0	1	30	31
28	alfalfa	0	0	0	10	118	128
June 2	alfalfa	0	0	0	0	47	47
<b>Total</b>						<b>1161</b>	

\* Alfalfa field in Harford County



supplied more nutriment than others. The result would be a greater number of later instar nymphs on one host than on the others. However, the data indicate there was little difference among hosts as to their food value. In all, 1161 nymphs of *E. laevis* were collected and sorted according to instars, as shown in Tables 5 and 6.

Osborn and Ahmed and Davidson gave some measurements on the various instars. Unfortunately, the relatively small differences between the first and second instars were not noticed by the authors of either of these 2 papers. The writer also was unable, at first, to separate the first and second instar nymphs. It was not until a series of specimens had been ranked according to size that a definite break or gap in the measurements was noted. In addition to the measurements recorded, the length of the antenna of a first instar nymph is about half that of a second instar nymph. In the third instar the wing pads begin to make their appearance so that the stage of the wing pad development makes differentiation relatively easy in the later instars, even with the unaided eye.

The nymphs that emerge from the eggs are quite small, sometimes less than a millimeter in length. These first instar nymphs often escape detection in spite of their lemon-yellow color. Their small size allows them to crawl between appressed young leaves of clover and strawberry or between the stipule and stalk on strawberry and alfalfa. In such locations their spittle mass does not need to be copious for there is little danger from evaporation and predators. Later instars are more active and are able to surround themselves with froth more quickly. Evaporation and predators are stressed because they are the usual cause of natural death of these insects as observed by the writer. If kept from sucking plant sap for more than an hour without their protective froth they soon become dehydrated and die. In all the hours spent observing these insects only

Table 6. Per cent of nymphs of F. leucophthalmus in each instar recorded for certain dates. College Park, Md. 1950.

Date	Total nymphs examined	Nymphal instar				
		1	2	3	4	5
April 13	10	100				
16	4	100				
18	3	100				
24	2			100		
28	3			100		
May 1	2			100		
4	53	1.9	9.4	77.4	11.3	
6	123		13.8	47.2	38.2	0.8
8	33		6.1	33.3	42.4	18.2
9	68		1.5	16.2	82.3	
10	18		5.6	44.4	44.4	5.6
11	36	36.1	63.9			
12	127		2.4	33.1	56.6	7.9
15	17				41.1	58.9
16	59		1.7	1.7	64.3	42.3
17	18				77.8	22.2
18	32					100
19	62				12.8	87.2
21	70		4.3	8.6	20.0	67.1
22	64	1.2		1.2	32.0	65.6
23	9					100
24	61		1.6	1.6	13.1	83.7
25	17					100
26	27				11.1	88.9
27	37		2.7	2.7	5.4	89.2
28	159				6.9	93.1
June 2	47					100
	<u>1161</u>					

on one occasion was a nymph observed that was being attacked by a predator, in this case a spider.

Habits of Nymphs. The habits of the nymphs as described by Osborn and later authors were also observed on the various Maryland hosts. The nymphs are able to crawl about rapidly when disturbed and, in later instars, seem to migrate of their own volition. Before the first adults appeared many plants showed areas where spittle masses had dried, and the absence of nymphs in the areas indicated their migration. When disturbed many nymphs would crawl about seeking shelter until a spittle mass was located - though it may or may not have been the one from which they emerged.

At the completion of their nymphal life they seem to stop sucking plant sap but remain within the spittle mass. The adult emerges from the fifth instar exuvium and waits for its wings to expand and harden. Then, with a sudden leap, it breaks out and flies a short distance away.

When preparing to suck plant sap the spittlebug (nymph or adult) inserts its proboscis into the material several times as if testing or probing to find a favorable feeding site.

Seasonal History. Among other considerations of the spittlebug problem is the question of whether or not nymphs of a certain generation utilize the same host or hosts as the previous generation. If the same hosts are available year after year the insects do feed on the same hosts. Strawberries are often in the same location each year and are one of the preferred hosts. Alfalfa is sometimes planted in one field year after year without rotation. Without crop rotation the population of spittlebugs is thus encouraged to increase. In rotated crops it is sometimes difficult to ascertain the host successions. From the observations made in 1950 it would appear that nymphs of a particular generation are

influenced very little by the choice of hosts made by their parent generation. A striking example of this was found in a flower garden in Wheaton, Montgomery County, Maryland. Prior to 1950 there had been only a few shrubs and evergreens in this particular yard. In the spring of 1950, however, seeds were planted and a number of young plants were purchased to enlarge existing plantings and to create new ones. Observations made May 22, 1950, indicated nymphs of P. leucocephala on 14 different hosts among the plants in this yard. Most of the host plants were new to that location, and thus could not have been available as hosts for the preceding generation. The nymphs observed at Wheaton in 1950 seemed to have no preferred hosts, since the numbers feeding were about equally distributed on the various host plants. Apparently the nymphs will try to feed on the nearest succulent growth which may or may not be that on which they passed the egg stage.

## QUANTITATIVE STUDIES

Obviously the economic importance of E. leucocephalus as a pest depends on the density of population that exists on cultivated host plants. Data obtained in observations in typical areas give some idea of the degree of infestation that may occur in Maryland and, in consequence, of the meadow spittlebug as a pest. Quantitative data of this kind have been almost completely lacking in the past.

Host List for Maryland. The hosts of the meadow spittlebug have been listed for some of the midwestern states and for Hawaii, but host records for the eastern-seaboard region do not seem to have been catalogued. The host records presented in Table 7 are limited to those actually noted by the writer during the 1950-1951 observations reported here and should not be considered complete. It is hoped that this list will stimulate interest in the local hosts of this pest and that new entries will be added. The table is divided into cultivated and weed hosts listed alphabetically according to the common name. Whether nymphs or adults or both were found on the individual hosts is also indicated.

Of the 64 hosts listed, 22 are new host records for this species. The most interesting of the new hosts are poison ivy and wild garlic, 2 species of plants that are considered relatively immune from insect attack. It is doubtful if either is more than an occasional host, for the only record for poison ivy was May 9, 1950. In this connection, 3 nymphs of Lepyronia quadrangularis were also observed feeding on poison ivy (July 14, 1950; Arlington, Virginia). These observations were of interest to the writer, even though it is recognized that they are of no economic importance.

Table 7. Host records for P. leucophthalmus in Maryland, 1960.

Cultivated plants			
Common name	Scientific name	Nymphs	Adults
Alfalfa	<u>Medicago sativa</u>	x	x
*Apple	<u>Malus domestica</u>		x
Barley	<u>Hordeum sativum</u>	x	x
Broccoli	<u>Brassica oleracea botrytis</u>	x	x
*China rose	<u>Rosa chinensis</u>	x	
Chrysanthemum	<u>Chrysanthemum</u> sp.	x	
Clover, red	<u>Trifolium pratense</u>	x	x
Clover, white	<u>Trifolium alba</u>	x	x
Clover, white sweet	<u>Melilotus alba</u>	x	
Clover, yellow	<u>Melilotus officinalis</u>	x	
Corn	<u>Zea mays</u>		x
*Hollyhock	<u>Althea rosea</u>	x	
Honeysuckle	<u>Lonicera</u> sp.	x	
*Hydrangea	<u>Hydrangea</u> sp.	x	
*Iris	<u>Iridia</u> sp.	x	
*Lilac	<u>Syringa vulgaris</u>	x	
Mint	<u>Monarda</u> sp.	x	x
Morning glory	<u>Ipomoea</u> sp.	x	
*Oats	<u>Avena sativa</u>		x
Pec	<u>Pisum sativum</u>	x	x
*Phlox	<u>Phlox</u> sp.	x	
*Poppy	<u>Papaver</u> sp.	x	
Potato	<u>Solanum tuberosum</u>		x
Privet	<u>Ligustrum</u> sp.	x	
Raspberry	<u>Rubus occidentalis</u>	x	x
Red top	<u>Acrastis palustris</u>	x	x
Rhubarb	<u>Rheum rhabarbarum</u>	x	
Rose	<u>Rosa</u> sp.	x	
*Spinach	<u>Spinacia oleracea</u>	x	
*Spirea	<u>Spirea</u> sp.	x	
Strawberry	<u>Fragaria virginiana</u>	x	x
Vetch	<u>Vicia sativa</u>	x	x
*Vesicaria, red	<u>Vesicaria</u> sp.	x	
Wheat	<u>Triticum sativum</u>	x	x

(continued on next page)

Table 7. Host records for P. leucophthalmus in Maryland, 1950.

Weeds			
Common name	Scientific name	Nymphs	Adults
*Bouncing bet	<u>Saponaria officinalis</u>	x	
*Chickweed, mouse-ear	<u>Cerastium vulgatum</u>	x	
*Chicory	<u>Cichorium intybus</u>	x	
	<u>Chrysanthemum leucanthemum</u>	x	
Cockle, purple	<u>Acrostemma aithaeae</u>		x
*Cress, winter	<u>Barbarea verna</u>	x	
*Cress, winter	<u>Barbarea vulgaris</u>	x	
Daisy fleabane	<u>Erigeron ramosus</u>	x	x
Dandelion	<u>Taraxicum sp.</u>	x	x
Sewberry	<u>Rubus canadensis</u>	x	x
Dock	<u>Rumex sp.</u>	x	x
Evening primrose	<u>Oenothera biennis</u>	x	
French sorrel	<u>Rumex acetosella</u>	x	x
*Garlic, wild	<u>Allium sp.</u>	x	x
Goldenrod	<u>Solidago sp.</u>	x	x
Italian rye grass	<u>Lolium multiflorum</u>	x	x
Lambs quarters	<u>Chaenopodium album</u>	x	x
*Milkweed	<u>Asclepias sp.</u>		x
*Night flowering catchfly	<u>Silene noctiflora</u>	x	
Orchard grass	<u>Dactylis glomerata</u>	x	x
*Oxalis	<u>Xanthoxalis sp.</u>	x	
Plantain, broad leaf	<u>Plantago major</u>		x
Plantain, English	<u>Plantago lanceolata</u>	x	x
*Poison ivy	<u>Rhus toxicodendron</u>	x	
Ragweed, fine cut	<u>Ambrosia elatior</u>	x	x
Rose, wild	<u>Rosa sp.</u>	x	
Strawberry, wild	<u>Fragaria sp.</u>	x	
Sumac	<u>Rhus glabra</u>	x	x
Sunflower, wild	<u>Helianthus sp.</u>	x	x
Ragweed	<u>Ambrosia trifida</u>	x	

\* Indicates new host record

Quantitative Studies. Quantitative data were obtained on all 3 stages of the meadow spittlebug in order to fill in some of the gaps in our knowledge concerning the abundance of this pest.

The method employed when estimating an insect population will naturally vary according to the species being surveyed. However, there seem to have been no easy, rapid and accurate methods devised for spittlebugs. Wolcott counted the entire population in a certain area. Chamberlin and Medler collected lots of 10 alfalfa stems at random and counted the infested stems. The latter method has the advantage of being more rapid, but the data can be used only as a relative index of infestation in alfalfa. The percent infestation, as measured by the stem-count method, is intended more as an index of effectiveness in the application of insecticides than as a measure of insect population. That such a count is not a reliable means for estimating population is clearly indicated by some data obtained in this study and shown in Table 9. It will be noted that the number of nymphs per infested stem ranges from 1.8 to 6.6 in these data. Such a variation would preclude the use of a count of infested stems for population-estimating purposes. Neither of the procedures mentioned in the literature seemed applicable to the present study, so a different method was devised. An open frame of light wood having an inside area of one square foot was constructed. This frame was tossed at random on the vegetation being investigated, and the nymphs within the area bounded by the frame were counted. Though the procedure was time-consuming and tedious, the data were then applicable to any area of land and were not limited by the nature of the vegetation. Counts could be made on dense, low-growing plants, such as clover or on tall grasses, such as wheat.



Table 8. Spittlebug nymphs found on alfalfa stems in certain square foot sample areas. University of Maryland Farm, 1950.

Date	Stems No.	Infested stems		Nymphs No.	Average nymphs /inf. stem
		No.	%		
May 27	42	22	52	91	4.1
	35	15	60	46	3.1
	44	14	32	48	3.4
	27	5	19	17	3.4
May 28	38	27	71	168	6.6*
	42	27	69	109	4.0*
	35	19	54	73	3.8*
June 2	23	4	17	11	2.6
	26	4	15	7	1.5
	38	14	37	29	2.1
	35	17	49	32	1.9
	28	12	43	35	2.9

\* Figures obtained from individual counts of 20 infested stems

The preferred hosts of economic importance to the people of Maryland were found to be the same as those recorded in other states, viz., alfalfa, strawberry, white and red clover, and wheat. Therefore, they were the host plants observed most intensively, as will be noted in Tables 9 and 13.

One of the first field surveys was made May 11, 1950, on some alfalfa located in Harford County. This particular field was infested with spittlebug nymphs sufficient in numbers as to seriously reduce the yield and very probably the quality of the crop. Part of the field had been treated with 46 per cent chlordane emulsion at the rate of 1 quart per acre at the time of examination. Some quantitative data were obtained for both the treated and untreated portions. The count was 237 nymphs per square foot in the untreated part of the field, and 153 nymphs per square foot in the treated portion. These data are included in Table 9. Time was not available to make a survey sufficiently comprehensive to establish definitely that the difference was due entirely to the treatment. Certainly some effect of natural variation may have been present in the data. Measurements made in an old stand of alfalfa, less than  $\frac{1}{2}$  mile from the sprayed field, indicated that there were 96 nymphs per square foot. The general condition of this latter field was rather poor and probably not vigorous enough to support a greater spittlebug population. However, even this count indicates a heavy infestation.

In order to obtain data on the general level of infestation in hayfields, since hay is an important economic crop in Maryland, a detailed study was made of a somewhat weedy hayfield in the vicinity of Olney, Montgomery County, Maryland. A preliminary inspection indicated that the field could be considered typical of the area and that, while some nymphs

Table 9. Spittlebug nymphs counted on various hosts. Maryland, 1950.

Date	Host	Sq. ft. examined	Nymphs/sq. ft.	Average/sq. ft.
Apr 13	strawberry	5	1,0,1,0,0	.8
Apr 14	red clover	1	0	0
Apr 14	alfalfa	4	7,43,0,9	14
Apr 16	alfalfa	4	1,8,16,17	10.5
Apr 16	grain (rye)	3	0,0,0	0
Apr 16	red clover	1	0	0
Apr 16	strawberry	5	1,0,3,1,1	3
Apr 18	rye	3	0,0,0	0
Apr 18	chickweed	1	0	0
Apr 18	white clover	5	2,6,1,3,0	2.4
Apr 18	strawberry	5	17,0,3,3,3	5
Apr 18	alfalfa	1	4	4
Apr 23	alfalfa	1	13	12
Apr 23	strawberry	2	0,0	0
Apr 24	strawberry	10	0,2,1,0,0,0,0,1,0,1	.5
Apr 24	alfalfa	1	6	6
Apr 26	alfalfa	2	8,16	12
Apr 28	dandelion	1	12	12
Apr 28	English plantain	1 plant	58	
Apr 28	English plantain	1 plant	58	
May 1	strawberry	10	0,0,19,0,2,0,4,19,23,4	7.1
May 1	white clover	1	33	33
May 6	white clover	1	10	10
May 6	alfalfa	1	41	41
May 6	plantain	1 plant	130	130
May 11	alfalfa (treated)	1	153	153
May 11	alfalfa (untreated)	1	237	237
May 11	nonrotated alfalfa (untreated)	1	96	96
May 11	weedy alfalfa	2	71,74	72.5
May 11	white clover (treated)	1	32	32
May 13	strawberry	9	1,14,27,5,11,13,12,2,9	10.4
May 13	alfalfa	5	11,41,17,21,16	23
May 13	wheat and barley		none observed	0
May 13	plantain	1 plant	53	
May 17	spinach	50 plants	5	
May 17	wheat	10	2,2,0,0,0,0,1,3,5,1	1.4
May 21	alfalfa	5	23,55,36,65,55	46.8
May 22	strawberry	6	0,14,2,15,7,24	10.3
May 27	alfalfa	3	46,48,17	37
May 27	wheat	10	0,0,1,4,1,1,0,0,1,1	.9
May 28	alfalfa	3	168,73,109	116.7
June 2	alfalfa	5	11,7,29,32,35	23

were present, most of the nymphs had emerged as adults. The adult population seemed to be quite large. The area appeared to be a favorable one in which to make a quantitative study, and permission was obtained from the owner to carry on such a survey.

The procedure followed in making the survey was, in general, that of sweeping with a standard lightweight insect net 12 inches in diameter at a sufficient number of systematically located stations to produce adequate, representative data.

The insects collected were killed in cyanide jars and transferred to collecting bottles for later counting. The material in the collecting bottles naturally was a mixture of spittlebugs, other insects, spiders and plant parts. The separation of the extraneous material from the adult spittlebugs required much time and patience. It is of interest, however, that about 95 per cent of the insects collected were adults of the meadow spittlebug.

The insects were counted by volumetric measurement, because of the large number collected at each sampling point. Spittlebugs were placed in a small graduated cylinder in sufficient quantity to fill it to the 5 cc. mark after shaking. These were then poured out on a sheet of paper and counted individually. The process was repeated 10 times, and the average figure, expressed as number of spittlebugs per 5 cc. of volume, was used as a basis for converting volume to numbers in reporting the results of the survey. In this particular case the value ranged from 151 to 180 insects, the average being 168. These values were the result of nearly one week's counting following the actual collection of the insects.

The field in which the survey was made was roughly rectangular in shape. In a survey made on June 9, prior to mowing, the collection points were spaced along the 2 diagonals of the field at approximately

equal intervals and also transversely across the field at midlength. The pattern was selected in order to give good general coverage to a rather large area (nearly 25 acres). The locations of the various stations,

drawn to scale, together with the number of insects collected at each are shown in Figure 2. Careful estimates of the area covered by 10 sweeps indicated that, in general, this was about 50 square feet (or 5 square feet per sweep).

Subsequently the field was mowed and partially raked, and on the day following the raking, June 12, a second survey was started. After collections had been made at the 5 points shown in Figure 3 rain prevented further field work on that day. Although this second survey was much less comprehensive than the first, the data are significant and are believed to be generally representative.

The population in the field was again sampled 16 weeks after the initial survey. Dairy cattle were grazing on it, and the height of the vegetation was no more than 4 inches. On this occasion samples were taken at 20 points, the locations of which are shown in Figure 4.

Because of the low population levels found after mowing it was simpler to make counts of the individual insects as collected, rather than to use the procedure as described for obtaining the counts in the first survey.

The number of spittlebugs collected per 10 sweeps in the preliminary examination of June 8 and in the comprehensive survey of June 9 are given in Table 10 and, as stated previously, the location of the collection stations with the corresponding individual counts are shown in diagram form in Figure 2. The data from a preliminary count made on June 8 are included because they are in general accord with the data obtained on

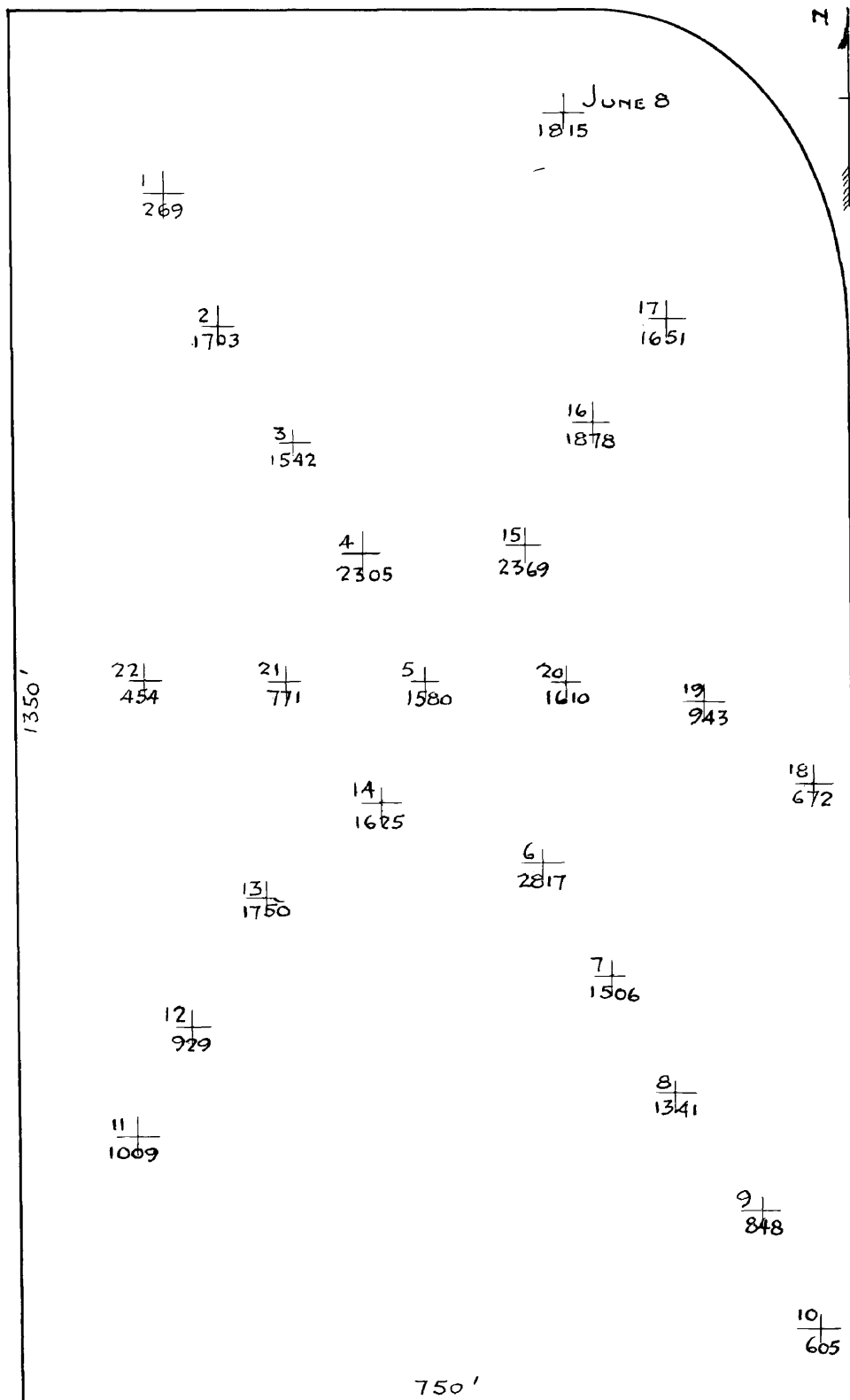


Fig. 2 Diagram of hayfield showing number of adult spittlebugs collected per 10 sweeps at certain points. Dowling Farm, Olney, Md. June 8-9, 1950.

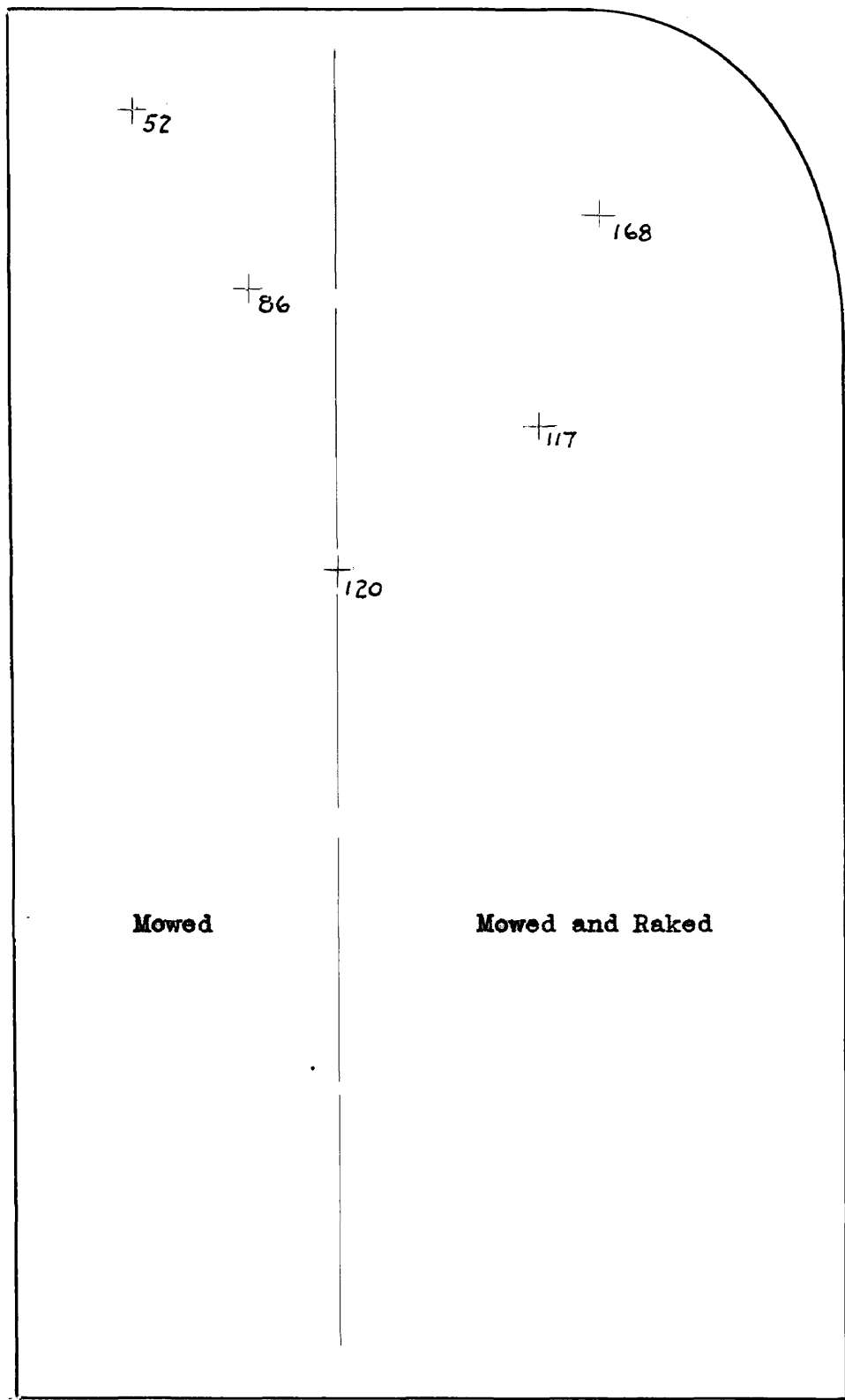


Fig. 3 Diagram of hayfield showing number of adult spittlebugs collected per 10 sweeps at certain points. Dowling Farm, Olney, Md. June 12, 1950.

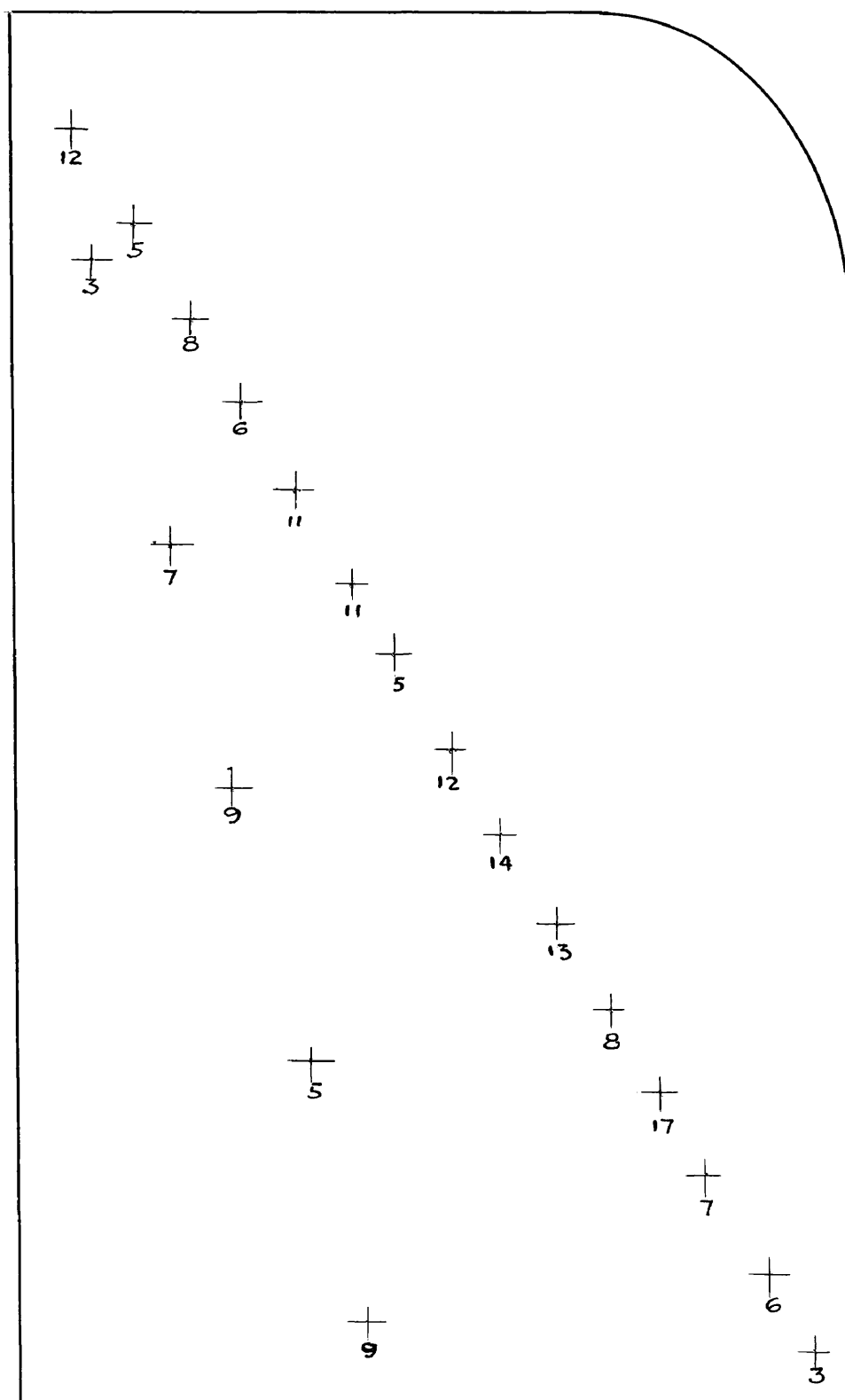


Fig. 4 Diagram of hayfield showing number of adult spittlebugs collected per 10 sweeps at certain points. Dowling Farm, Olney, Md. September 29, 1950.



June 9. In Table 10 the names of the predominating host plants at each collection station are also given.

The field had been planted in red clover and timothy originally. At the time of the survey rank weed growth had all but choked these plants out in certain areas. The weeds most often encountered were English plantain, Plantago lanceolata (L.) and Erigeron ramosus (Walt.). The latter, a composite with small daisy-like flowers, seems to be a favorite host of the meadow spittlebug in the Maryland area.

Special samples were also taken from purple cockle (Acrastemma althago (L.)) and from orchard grass (Dactylus glomerata (L.)). The data show that these plants are not preferred as hosts when red clover or Erigeron are nearby. For example, the count for orchard grass was 65 per 10 sweeps and for cockle 99 per 10 sweeps as contrasted with an overall average of 1391 per 10 sweeps for the field as a whole.

As will be noted from the data on Table 10 the number of adult spittlebugs collected in 10 sweeps at the several stations ranged from 269 to 2817. It was observed that in certain low, damp areas (stations 1, 10, and 23) the clover was sparse and stunted. In these areas low counts were obtained. In contrast the spittlebug population was observed to be particularly high in areas of densest vegetation. This is probably the result of the more succulent food and greater protective foliage available.

While the owner thought that the field was "about 17 acres" measurement with a steel tape showed it to be more nearly 23 acres. A determination of the area was necessary in order that the average counts could be related to area and a measure of overall population density for this field could be obtained.

As stated previously, the average number of spittlebugs per 10

Table 10. Collections of P. leucophthalmus adults in hayfield.

Dowling Farm, Olney, Md. June 8 and 9, 1950.

Collection station	Number adults/ 10 sweeps	Plant hosts in area sampled			
		Clover	<u>Erigeron</u>	Plantain	Others
June 8	1815	x			
June 8	488*		18 heads		
1	269	x			
1	66*				orchard grass
2	1703	x	x		
3	1542	x	x		
4	2305	x	x		
5	1580	x	x		daisy
6	2817	x	x	x	
7	1506	x	x	x	
8	1341	x			
9	848	x	x		
10	99*				cockle
10	605		x		
11	1009	x	sparse		timothy (sparse)
12	929	sparse	sparse		timothy
13	1750	x	x		
14	1625	x	x	x	
15	2369	x	x		
15	286*				orchard grass
16	1878	x	x		timothy and orchard grass
17	1651	x			
18	672	x	x	x	
19	943	x	x		timothy
20	1610	x	x		
21	771	x		sparse	
22	454	x			
Total	31,992				
Average	1,391				

\* Counts not included in the Total or Average

x Indicates predominant hosts

sweeps, or 50 square feet of area, was 1391. An extension of this value to larger and smaller areas leads to the following interesting result:

28 spittlebugs per square foot
2762 spittlebugs per 100 square feet
1,211,829 spittlebugs per acre
27,872,000 spittlebugs in the 23-acre field

This value (1391), while admittedly an estimate, was arrived at by a method that is believed to be sufficiently comprehensive to lead to fairly accurate average densities. The amazing number of insects found in this more or less typical field clearly shows why the spittlebug is now classed as an important agricultural pest. In fact, one county agent in Maryland ranked it as the foremost insect pest in his county.

In view of the large number of spittlebugs present in the vegetation of this field prior to mowing, it was considered desirable to make some follow-up studies to determine the population density after mowing and to learn, if possible, what became of the insects.

As has been stated, the field was mowed and partially raked on June 10 and 11. Some sampling was done on June 12 until rain made it necessary to stop. Collections had been made and counted at 5 locations. It was found difficult to make sweeps in the area that had been mowed but not raked since it appeared that the insects sought cover in the mowed hay and could not be brought into the net. There was no difficulty, however, in making collections in the mowed and raked area. The data obtained on this date are shown in Figure 3 and Table 11. It will be noted that the counts were much lower than before mowing and that the counts were only about half as great in the mowed area as in the mowed and raked area. It seems likely that this difference is due to the protection afforded the insects by the cut vegetation rather than to any real difference in population.

The sharp drop in the spittlebug population after moving, as shown by a comparison of the data in Table 11 with those in Table 10 is striking. It is probable that only a relatively small number were actually killed by the moving operation. The natural inference is that the drop was caused by migration of the spittlebugs to more favorable conditions of vegetation. However, a careful examination of 2 adjoining wheat fields and a pasture did not indicate the presence of more spittlebugs than existed at the same time in the moved field. Thus, in this study there is no evidence of mass migration to adjacent areas although it seems reasonable that, in general, the population did migrate to a more favorable environment.

As mentioned earlier, the population of the field under study was again estimated on September 29, some 16 weeks after the first survey, at a time when the field was being used by the owner as afternoon pasture for his dairy herd and plant height was being kept at about 3 or 4 inches by grazing.

On this occasion there was no difficulty in making sweeps. A somewhat different pattern of collecting stations was used for this survey. One series of 15 stations was along a diagonal of the field. Another series of 5 stations was made along another line running obliquely across the field in the manner shown in Figure 4. The counts were made at each station as they were collected in the net.

The number of spittlebugs per 10 sweeps is shown in Figure 4 and Table 12. It is at once apparent that by this date the drop in population had been very great with an average count of 9 per 10 sweeps as compared with 1391 on June 9. The counts on September 29 show rather conclusively that there had been no return of the spittlebugs after their original migration at the time of moving.

Table 11. Number of adult spittlebugs collected per 10 sweeps in newly mown hay. Dowling Farm, Olney, Md. June 12, 1950.

Number of spittlebugs per 10 sweeps	Average number	Condition of field
52	59	mowed only
86		" "
120	135	mowed and raked
117		" " "
<u>168</u>		" " "
Total 543	Average 109	

Table 12. Number of adult spittlebugs collected per 10 sweeps in same field as in Tables 10 and 11 but used as pasture. Dowling Farm, Olney, Md. September 29, 1950.

Number of adults collected per 10 sweeps			
13	11	8	9
5	5	17	5
8	12	7	9
6	14	6	7
11	13	3	3
Total 171		Average	9

Of particular interest are some data recorded from a field of red clover located on the University of Maryland Farm. The study began in 1950 as series of observations of egg masses, and when they seemed to be rather uniformly abundant, it was decided to attempt a correlation of the egg-mass data with the infestation that would result after hatching. As shown in Table 1 the average number of egg masses per square foot was found to be 49.5 with an average of 7 eggs per mass. Estimates based on these figures would be approximately 350 eggs laid per square foot. On April 28, 1951, sample counts were made on the nymphs present in this particular clover field in order to learn the present infestation and to compare that with the estimate of 350 per square foot. The counts recorded were 382, 204, 343, and 348 nymphs per square foot, an average of 317 per square foot. Therefore, on this basis, the overwinter mortality would be a little more than 9 per cent. Since some mortality is to be expected, these data seem reasonable. The counts are known to be quite accurate. The importance of this study lies in the fact that with such a correlation the infestation for the next growing season can be estimated rather accurately 5 or 6 months in advance. Then, if necessary, ovicidal treatments could be applied during the winter while the vegetation is dormant.

In general, the quantitative data to be found in the literature are not in such form as to make possible a conversion to number of insects per unit of land area. For this reason it is difficult to make direct comparisons of the population densities found in Maryland with those reported elsewhere. It will be readily apparent that the degrees of infestation found during the course of this investigation are sufficient to constitute a real economic problem.

Observations on small grains. A number of accounts in the literature refer to the migration of adult spittlebugs into small grains after they have reached maturity on pasture plants. Fortunately, this phase of their ecology could be observed on the University of Maryland Farm. For the past few years, several experimental fields had been planted with the same grain crop without rotation; some were in barley, some in oats, and some in wheat. It was observed that these fields were not infested to any greater extent than were the rotated fields. While nymphs were able to develop into adults in wheat and other grains, Table 9 would indicate that those crops were certainly not preferred hosts. Adult concentrations on these hosts were also at a relatively low level. The highest count shown in Table 13 (16.8 adults per 10 sweeps) was recorded on June 7 which is but a fraction of the number recorded 2 days later in the hayfield survey. It would seem, therefore, that while occasional concentrations of adults may occur in small grains, they are not due to the absence of rotation of those grains.

Dispersal. As a part of the hayfield survey near Olney, Maryland, observations were made in 2 wheat fields near the hay. Prior to mowing the hayfield was much preferred to the headed wheat. The day after mowing, many of the spittlebugs had left the hay, and some probably migrated to the wheat. Sampling of the wheat was confined to marginal sweeps by a barbed wire fence. These samples averaged about 125 adults per 10 sweeps, slightly higher than the mowed hay, but not appreciably so.

Table 13. Adults of P. leucophthalmus collected per 10 sweeps from various hosts. Maryland, 1950.

Date	Host	Adults/10 sweeps	Average/ 10 sweeps
May 30	wheat	3,1,0,1,0,0,1,0,0,0	.6
May 30	barley	0,0,0,0,0,0	0
May 30	wheat near barley	0,0,0,0,0,0,1,0,0,0	.1
June 2	alfalfa	277	277
June 5	wheat	12,16,10,10,9,20,4,8,15,5	10.9
June 5	potato	0,3,6,5,6	5
June 5	wheat	16,7,4,8,12,2	8.1
June 5	barley	3,4,3,3,5,1,4,11,5	4.3
June 7	strawberry	9,12,13,25,9,7	12.5
June 7	ragweed	10,25,36,37,19,12,7,17,27,17	17.3
June 7	wheat	13,19,17,21,15,16,7,9,21,14	16.8
June 9	hayfield survey	see Table 10	
June 12	hayfield survey	see Table 11	
June 14	alfalfa	115,203,267,142,85	162.4
June 17	wheat	7,10,5,6,10,6,13,18,9	9.3
June 21	ragweed	26,21,40,31,37,67,32,43,20	35
June 28	goldenrod	3	3
Sept 18	alfalfa	6,9,4,4,5,9,6,8,11,7	7
Sept 18	strawberry	2,4,6,4,5	4
Sept 29	hayfield survey	see Table 12	
Oct 4	weedy red clover	5	5
Oct 4	red clover	10,11,23,15,25,21,28,20,27,28	21
Oct 17	strawberry	2,2,1,6,2,1,3,9,7,7	4



## DAMAGE AND CONTROL

Character of damage. The damage inflicted on plants by spittlebugs has been described by several authors (2, 21, 27, 51, 54 and 60). From their papers the inference seems to be that the drainage of plant sap reduces not only the turgor of the cells, but certain nutriments are taken up by the insect that are necessary for proper development of flowers, fruits, and seeds. Strawberry growers, for example, discover that their berries are withered and distorted, making them unsalable or much reduced in quality. In addition to their effects on the reproductive parts of plants the stems of hay plants are usually stunted. An important economic aspect of spittlebug damage is that commercial seedsmen suffer considerable financial losses when the plants fail to produce viable seeds. Figure 5 shows some of the effects on alfalfa stems produced by spittlebug feeding. Table 14 indicates the comparative effects of spittlebug injury in another way. Both the stem heights and the average internode lengths are affected to significant degrees. There also seemed to be an increase in the number of internodes, but this effect was not great enough to be statistically significant. Data in Table 14 were taken from alfalfa stems which had been carefully selected for the presence or absence of typical spittlebug injury symptoms. Plants were not selected for measurement if there was the slightest indication of injury by other insects. Stem height was not considered in the selection.

Many articles dealing with spittlebugs refer to one or two nymphs per spittle mass. On numerous occasions during the course of this study more than a dozen nymphs were observed in the same spittle mass. The common weed hosts, such as plantain and dandelion, are sometimes heavily attacked. Several English plantain plants were discovered that were supporting from 55 to 130 nymphs per plant. It is of interest, therefore,



Fig. 5. Comparative growth of normal alfalfa plant (a) and one stunted by spittlebug nymphs (b).

Table 14. Comparative data showing effects of injury by spittlebug nymphs on alfalfa. University of Maryland Farm, 1950.

Stem condition	Stem No.	Stem height		No. stem internodes		Average internode length	
		cm.	Rank	No.	Rank	cm.	Rank
Injured	1	57	4	28	10	1.94	1
	2	58	6	22	9	2.58	5
	3	53	3	21	7	2.46	3.5
	4	45	1	18	2.5	2.46	3.5
	5	50	2	20	4.5	2.39	2
Rank Total			16*		33		15**
Uninjured	1	58	6	15	1	3.82	10
	2	56	10	20	4.5	3.28	8
	3	65	9	21	7	2.95	7
	4	58	6	21	7	2.60	6
	5	64	8	18	2.5	3.36	9
Rank Total			39		23		40

\* Probability (P) of chance occurrence of a rank total equal to or less than 16 with 5 replicates is 1 in 50.

\*\*  $P \leq .01$  (1 in 100, highly significant)

to observe the effects of large numbers of spittlebugs on such a hardy plant species. For the two weeks, April 28 - May 15, 1950, observations were made on one plant, which finally withered and died from attacks by the nymphs. When such large numbers of nymphs are close together and sucking sap, their spittle masses coalesce to form one large mass, which may be as large as a preying mantis egg mass, and is naturally easy to see from a distance of several feet.

Ovicidal experiments. Nymphal control has been rather thoroughly discussed in the recent literature (1, 15, 45, 51 and 73), and was not made a part of this study; in fact, control measures of any sort were not a primary objective of this program of investigation. However, a limited study was made of the effects of certain treatments on the egg masses, and the results of this study will be discussed briefly.

In the early spring of 1951 typical egg masses were collected from a field of red clover and taken into the laboratory for treatment and observation. The basic purpose was to observe the effects on the egg masses of DM-111 and oil emulsions, with and without DDT.

The oil emulsions containing DDT were variations of the formula as recommended for corn ear worm control in Maryland. Three different viscosities of oil were used in making up the emulsions. The egg masses were divided into groups such that each treatment was replicated 5 times, together with untreated control groups.

It was found that hatching occurred in the untreated egg masses and in those treated with DM-111, while no hatching occurred in the egg masses that were treated with the oil emulsions, whether DDT was present or not.

While it is recognized that these observations were not sufficiently comprehensive to support any firm conclusion, it is believed that the results are sufficiently indicative to warrant further investigations of oil treatments of egg masses as a control measure.

## SUMMARY

In the course of this study of the meadow spittlebug in Maryland a thorough review of the literature disclosed a considerable amount of information regarding the biology of the insect, some listing of host plants in other areas, a number of observations as to the nature of the damage done by these insects, and a limited amount of data of a quantitative nature. Very little information and no quantitative data were found for the Maryland area, however. On the basis of data obtained from Department of Agriculture records a map was prepared showing the present distribution of the meadow spittlebug in the United States and southern edge of Canada.

A field study was made to develop information on the biology of the insect Maryland. It was found that there is a single generation per year and 5 nymphal instars. Eggs laid in the fall begin hatching in early April. This is followed by about 6 weeks of nymphal development, with adults appearing in late May. A rather close correlation was obtained between the number of eggs deposited in a certain area in the fall of 1950 and the number of nymphs found in that area the following spring. A mortality of less than 10 per cent was indicated.

On the basis of observations made during this study a host list of both cultivated plants and of weeds was prepared. This list contains the names of 64 plants of which 22 were not mentioned as hosts in the literature reviewed.

Quantitative studies were made of the spittlebug population in typical areas, particularly on host plants of economic importance, such as alfalfa, strawberry and clover. Some of the methods used in obtaining sample counts were especially devised for this study. Heavy infestations were found in some areas. One hayfield, for example, was found to contain

an estimated 27, 672, 000 spittlebugs in an area of 25 acres, an average of about 1, 312, 000 per acre. Several examples are given where the number of spittlebugs exceeded 100 per square foot, a figure considerably greater than that usually found in other published reports. Some data on the effect of mowing, spraying, and time of year on the spittlebug count are included.

In the literature are numerous descriptions of the character of damage resulting from the attack of this insect. Greatly decreased yield, stunted growth, decreased vitality, poor fruit and poor seeds are among the types of damage reported. In this study the effect of attack was observed and, in general, the observations of others were confirmed. The actual killing of such a hardy weed as plantain was found to take place as a result of a heavy spittlebug attack over a period of 2 weeks.

The damage that these insects can do to valuable cultivated plants, and the degree of infestation found in typical areas in Maryland indicate the seriousness of the meadow spittlebug as an agricultural pest.

Although control measures were not a primary object of this investigation some observations were made on the effect of the application of certain insecticidal materials on the hatching of the egg masses under laboratory conditions. The possible value of oil emulsions as ovicides is indicated.

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