Evaluation of Population Estimates and the Rate of Loss of Forage for the Meadow Spittlebug, *Philaenus leucophthalmus* (L.)[1]

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In the past 14 years the meadow spittlebug has become the major insect pest of forage legumes in Indiana. Records of requests for information on insects and related forms in the files of the Department of Entomology for the years 1924 through 1956 show an interesting pattern of the progress of interest in this insect and its increasing importance as a forage pest. Table 1 gives the percentage of requests received by the department on this insect and the areas from which these requests originated. It should be pointed out that grower interest in an insect problem does not develop until the insect is doing obvious damage or becomes numerous enough to attract attention. Therefore the spittlebug probably began to develop in numbers several years before any inquiries for information were received. Also these requests would tend to subside once the insect was recognized by growers in the infested area. Further reduction in the numbers of requests were the result of the issuing of a mimeograph publication, E-28, in 1951 on this insect, which was made available through county agricultural agents and other extension agencies. Variations in the numbers of inquiries would also be dependent on the severity of the infestation.

TABLE 1. Mail requests for information on spittlebugs received by Purdue University Department of Entomology, 1924-1956.

Year	Percent of requests	Location
1924	0.7	Covington, Indiana.—on pecan and English walnuts and other deciduous trees[1]
1925 to 1942	0.	no requests received for a period of 18 years
1943	0.7	northern half of Indiana
1944	0.7	northern half of Indiana
1945	0.7	northern Indiana
1946	9.5	northern third of Indiana from LaPorte to Fort Wayne
1947	9.5	46% from northern and 54% from central thirds of Indiana
1948	14.7	45% from northern, 40% from central and 16% from southern thirds of Indiana. 1 request Chicago, Ill.
1949	9.5	31% from northern, 54% from central and 15% from southern third of Indiana
1950	7.3	50% from northern, 20% from central and 20% from localities in Indiana not specified. 1 request from Ashland, Ohio

[1] Purdue University, Agricultural Experiment Station Journal Paper No. 1360.

[1] Probably not the meadow spittlebug.

Year	Percent of requests	Location
1951	19.7	64% from northern, 8% from central and 16% from southern Indiana. Also requests from White Pigeon, Mich., Harrison and Cincinnati, Ohio, and Bloomington, Ill.
1952[2]	5.1	72% from northern and 14% from southern Indiana. Requests also from Ashland, Ohio
1953	14.7	40% from northern, 40% from central and 15% from southern Indiana. Requests from Portsmouth, Ohio.
1954	2.2[3]	67% from northern and 33% from southern Indiana
1955	2.8[3]	100% from southern Indiana. Requests also from Erie, Michigan and Urbana, Illinois
1956	2.2[3]	all from northern Indiana. A request from Winnetka, Ill.

Indications are that the spittlebug probably became of importance as a pest of legumes in Indiana about 1940 (table 1). Until 1948, all requests for information originated from the northern half of Indiana. Following 1948, requests from the southern third of Indiana began to come in. However the spittlebug never developed into a serious pest in this part of the state until after the mimeo on its control was published. At the present time it is not a serious threat to forage legumes in the "pocket" counties of Posey, Vanderburg and Gibson, in southwestern Indiana.

Estimates of Population Densities

One of the problems associated with evaluating losses and damaging populations of an insect species is a good method of estimating the numbers of the insect present. Weaver and King (9) review several methods used by investigators to measure spittlebug populations and critically review their relative merits. Table 2 lists 6 methods used to evaluate spittlebug populations.

As pointed out in the table, populations evaluated by methods 3 and 4 may be greatly affected by the stand. Observations and data presented by Weaver and King (9) showed that new stands of legumes exhibited greater infestations of spittlebugs than old stands. This would infer that oviposition sites as presented by the straw stubble present, or possibly greater attractiveness of new stands of legumes to the ovipositing adults, might be factors in determining populations of spittlebugs that develop in the spring. If the presence of the straw stubble is the primary stimulus that determines abundance of ovipositing females, then the intensity of infestation as expressed in nymphs per stem, per cent of stems infested or masses per stem would be greater in fields where the stand of legumes was sparse and subsequent losses should be higher. Consequently we can infer that in two fields with equally good stands of wheat or straw stubble as

[2] Mimeograph E-28 on identification and control of the meadow spittlebug issued and made available to county agents and other extension groups. This undoubtedly reduced the number of mail requests as the publication became known.

[3] During these years, despite severe infestations, the identification and control had become so well established that very few requests were made directly to the Department of Entomology.

TABLE 2. Methods of Evaluating Spittlebug Infestations

Method	Comments
1. Nymphs per square foot	Time consuming and laborious in heavy populations. Influenced by the presence of weeds more attractive than crop plants. Is most accurate method for small areas, uniform in stand and host plants.
2. Masses per square foot	Slightly less laborious than 1 above. Has same restrictions. Is less accurate as more than one nymph may occupy a mass particularly in heavy infestations Often on crops with a small crown-type of growth, masses will coalesce near the base of the stem and it is difficult to determine how many masses are present.
3. Nymphs per stem	Possible to sample wide areas and may be restricted to one or several crop plants. Does not give an estimate of numbers of insects present per unit area unless stand counts are made and percent of stems infested recorded. Influenced by stand, permits sampling of wide areas rapidly.
4. Percent of stems infested	May be restricted to single host plant. Does not give accurate estimate of insects present. Influenced by stand of crop. When combined with 3 above gives good estimate of population present.
5. Adults per net-sweep	Must be made within short period of time following maturing of adults. Effected by person making sweeps, crop density, weather conditions, etc. Gives good relative populations for insecticides and other types of treatments.
6. Visual ratings	Rapid, but does not give accurate estimate of high populations. Permits rapid evaluation of many plots or fields. Influenced by observers' estimate of population densities. Good for screening insecticides.

attractive ovipositing sites, the one with the better stand of legumes would suffer less loss than the one with the poorer stand, since there would be fewer nymphs per stem and probably fewer infested stems in the better field. Modifying factors in the field with the poorer stand might be increased egg mortality and an increase in the number of extraneous plants that might be more attractive to the spittlebug nymphs, thus reducing the numbers per forage stem. It has been observed that such plant species as plantain, white-top *(Erigeron)* and bull thistles support very high populations of spittlebug nymphs.

In 1950, four of the methods listed in table 2 were used to evaluate populations of spittlebugs in plots treated with various insecticides. The methods used consisted of nymphs per square foot, as the basic estimate of the populations, and visual ratings, masses per square foot and adults per net-sweep. Table 3 gives the data from this experiment.

The different insecticides and dosages of active ingredients per acre are listed not as a recommendation for their use, but to point out certain possible errors in the methods used. The visual estimates gave a close evaluation of the materials tested but the lapse of only one week between time of application and the making of the visual estimate resulted in a poor evaluation of such materials as DDT, methoxychlor and Rhothane which acted more slowly on the nymphs than did such materials as BHC, lindane and chlordane and its close relatives. The

TABLE 3. Measurements of populations of spittlebugs on plots treated with various insecticides. Lafayette, Indiana, 1950.

Insecticides (applied May 13)	Dosage[1]	Visual estimates[2] (May 21)	Square foot counts June 6 masses	Square foot counts June 6 nymphs	Adults per sweep[3] (June 14)
	Lbs.		No.	No.	No.
Dieldrin	1.0	2.67	.8	1.2	18.2
Methoxychlor	5.3	4.00	2.2	2.2	17.0
BHC	.5G	3.50	2.3	5.0	18.2
Lindane	.5G	3.83	2.5	6.7	21.1
DDT	4.0	7.50	5.7	11.7	23.8
Toxaphene	2.0	5.67	5.7	14.2	24.7
Rhothane	2.0	7.33	6.8	22.8	23.2
Chlordane	2.0	8.33	10.2	24.2	25.5
Aldrin	.5	8.17	9.7	30.7	29.4
Rotenone	.5	8.67	12.7	35.2	36.4
DDT (Fluorine analog)	1.0	8.50	11.2	39.5	35.9
Dilan	1.0	7.33	13.3	40.7	29.9
DDT (Colloidal)	2.0	8.33	13.0	44.3	31.0
Untreated	...	9.33	14.3	45.7	36.6
L.S.D. 19:1		2.06	4.0	18.0	8.5
99:1		2.74	5.4	23.9	11.3

heavy dosage of dieldrin and methoxychlor also may have had some residual effect on the adults after they matured.

In studying the relationship of the four methods of estimating the spittlebug populations in these plots, it will be observed that all evaluations exhibit a definite trend similar to that for the square foot sample estimates of the actual numbers of nymphs present. Correlation analyses were made and the constants derived from the analyses are given in Table 4.

TABLE 4. Correlation constants for various methods of estimating spittlebug populations in relation to actual counts of nymphs per square foot. Lafayette, Indiana, 1950.

y-variable	x-variable (Nymphs per square foot) A-value	b-value	r	r^2	sd_y
Masses per square foot	1.265	.286**	.978**	.9572	2.312
Adults per net-sweep	16.324	.392**	.931**	.8665	6.872
Visual estimates	3.765	.129**	.906**	.8205	4.747

The A-value is usually an extrapolated estimate of quantity of the dependent variable when the independent variable is zero. An absence of nymphs in plots predicates that masses, visual evaluation and adults

[1] Pounds of active ingredient per acre.

[2] Discrepancies may be the result of differential action time of the insecticides. 1-no spittlebug present, 10-spittlebug very abundant (maximum).

[3] 12-inch net used. Some discrepancies may be caused by effect of high dosages on adults.

** Statistically highly significant.

would also be absent. In Table 4 visual estimates indicate that there were a "few plus" insects present, masses per square foot were 1.265, and adults per net-sweep averaged 16.324 when no nymphs were present. Since this is obviously an impossibility, two factors may be responsible. Since the A-value is usually an extrapolated value, the true relationship of a complete range of the independent variable might be curvilinear and pass through the origin for both variables, or the A-value in these cases may represent the amount error in estimating the relationship. Since few, if any, biological relationships are truly linear, the first explanation may account for most of the discrepancy from zero for the above variables.

The correlation coefficients (r) are highly significant for all three methods, and the numbers of nymphs per square foot accounted for 95.7, 88.6 and 82.0 per cents of the variations in masses per square foot, adults per sweep and visual estimates respectively. Thus masses per square foot gives the best estimate of the true population and visual estimates the poorest. This is probably accounted for by the fact that the variability is smallest in masses per square foot and while not the largest in visual estimates, this method of evaluating populations has a restricted range and depends on judgment of the observer, while adults per sweep are counts of a correlated population.

To visualize the relationships of the three methods the data from Table 3 is plotted in figures 1 and 2. A study of these graphs indicates that within the limits of the data the relationships of masses per square foot and adults per net-sweep with nymphs per square foot is

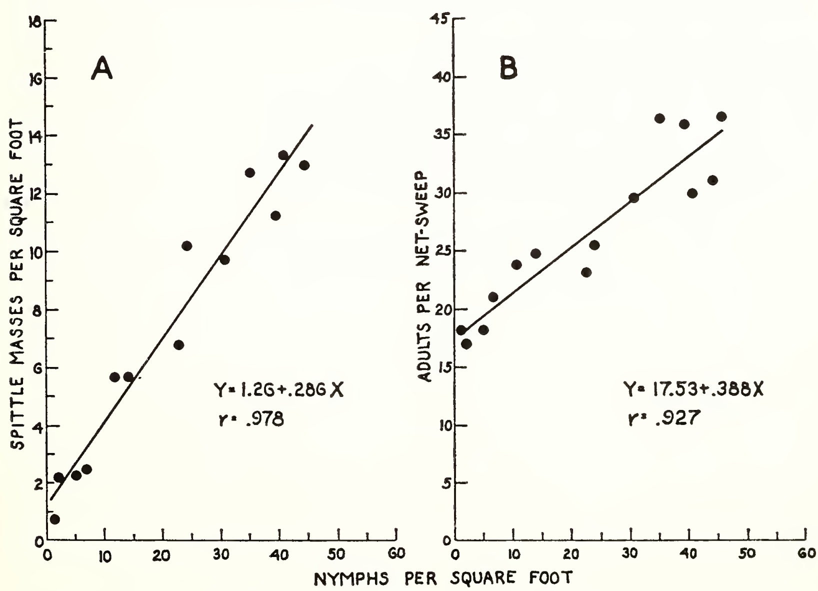

Figure 1. Relationship of two methods of estimating populations of the meadow spittlebug and the actual numbers of nymphs per square foot.
A—Masses per square foot.
B—Adults per net-sweep.

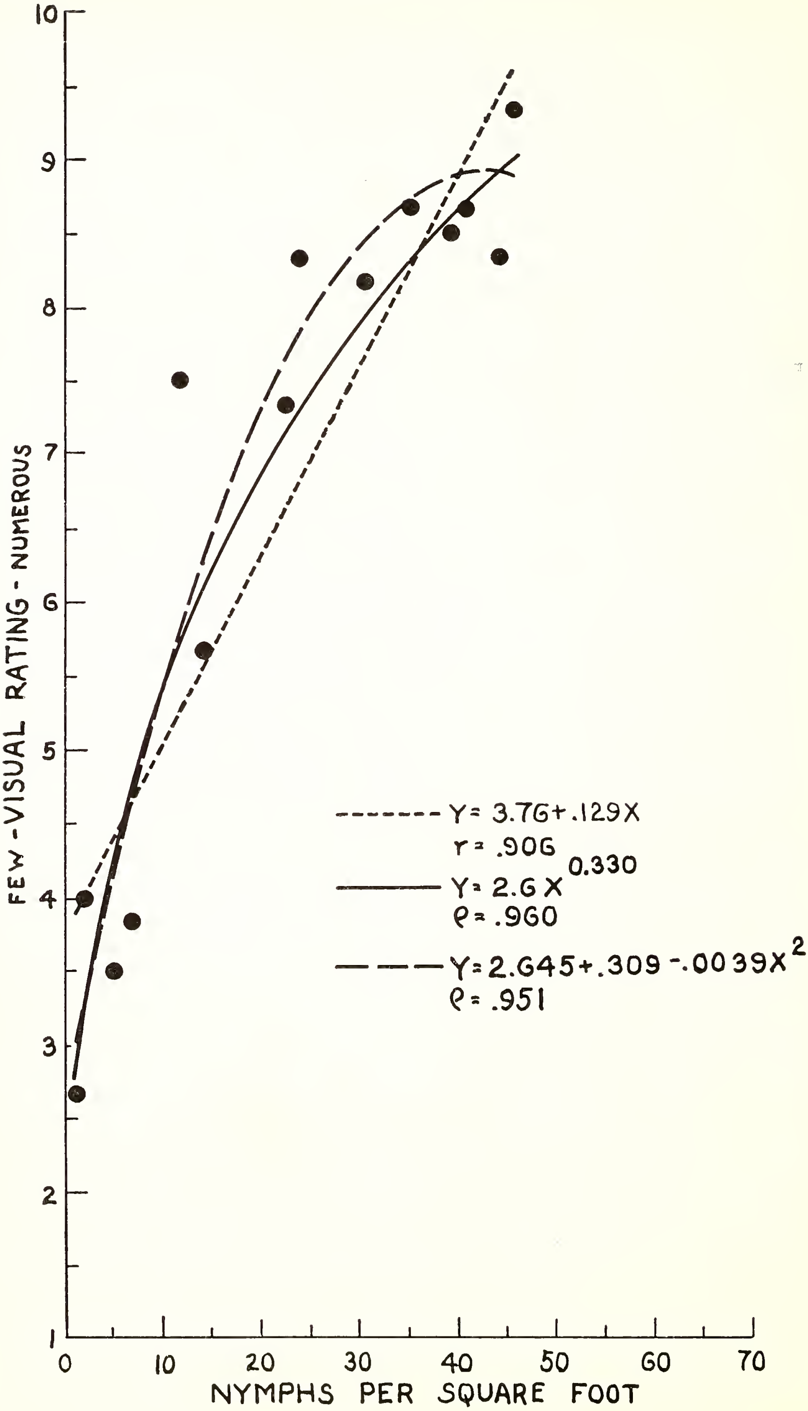

Figure 2. A comparison of the types of curves fitted to data on visual estimates of infestation of the meadow spittlebug and actual counts of nymphs per square foot.

linear. However that of visual ratings and nymphs per square foot is definitely curvilinear even though the linear regression was highly significant. To determine the type of curve that best expressed this relationship the power-log and second degree parabola were fitted to the data, in addition to the linear function. Calculating the index of correlation, P-value, it was determined that the second degree parabola gave the best fit to the data with a P-value of .960 compared with .951 for the power-log. The errors of estimate were reduced from 2.312, for the visual estimates without the correlation, to .645 for the parabolic function, .714 for the power-log and .946 for the linear.

Thus for these three methods, the masses per square foot gave the best estimate of the true population as expressed in nymphs per square foot and visual estimates gave the poorest. However, any of the three could be used as a method of evaluating losses caused by the meadow spittlebug. Visual estimates, although showing the lowest correlation with the actual population would be valuable in speeding up the process of screening insecticides, since at lower population levels it is quite accurate.

From a study of large plots Weaver and King (9) found the relationship of adults per net-sweep and nymphs per square foot to be approximately 9 to 1. In the data presented from the Lafayette plots this ratio was 114 to 100. This indicates a wide range of variation in the relationship of these two measurements. Such factors as stand uniformity, similar environmental conditions and time of sweeping, net size and the sweeping peculiarities of the collector contribute to this variability.

Weaver and Whitney (10) studied the relationship of per cent of stems infested and nymphs per stem and evolved formulae to express the true population from a known proportion of stems infested. They showed that this relationship is parabolic function and differed for red clover and alfalfa. At the higher levels of infestation, the nymphs per stem and population densities were much greater for red clover.

Evaluation of Forage Losses

Reports of losses from the meadow spittlebug date back to 1864 when Sibbald (6) in England made the statement that unless the foam was wiped off it burned up the plants. Hardy (5) reported that the Swedes believed the spittle caused madness in cattle. Baxter (1) reported losses for the first time in the United States and stated that the spittlebug reduced hay yields one third. Many others reported various kinds and degrees of loss. An excellent resume of the history of reports of damage and loss to various crops by this insect is given by Weaver and King (9). However, a careful perusal of these reports indicate that seldom or never were actual losses associated with definite numbers of the insect so that a survey of the spittlebug population in a field or area could be used to estimate the loss incurred.

Since hay yields are measured in pounds per acre and since density of stand affects both the yield and measurements such as per cent of stems infested and nymphs per stem, the insects responsible for losses should be measured by some unit area. Since hay fields are generally composed of mixed stands of legumes, grasses and weeds, a true evaluation of loss of forage will depend upon the effect of a known population of these insects on the individual components present in each field.

Another factor which may influence the loss in yield is the amount of soil water available during the growing period when the infestation by nymphs occurs. Weaver and King (9) give data where red clover was grown under different levels of available water and conclude that although differences in yield attributable to control of the nymphs was significant at the 1% level, the interaction was non-significant, indicating that plant injury caused by feeding was similar under different levels of water. They record green weights of forage from treated and untreated areas and showed that the losses in forage were similar, with less reduction under drought conditions and high moisture conditions (Table 5). Since these data are based on green weights, the

TABLE 5. Losses in forage from feeding by nymphs of the meadow spittlebug under different levels of moisture. (From Weaver and King (1954).)

Moisture level[1]	Reductions in yield per square yard	
Inches	Pounds	Percent
Trace	0.029	73
2	0.99	48
4	1.00	36
6	0.72	20

losses at the lower levels of moisture might possibly represent a greater proportion of dry matter. The proportional loss was greater at low levels of moisture indicating that controlling the spittlebug would be of greater benefit in seasons of low rainfall.

The same authors in tests on the drying time of hay infested with spittlebug nymphs, found that treated hay required longer time to dry than that containing spittle and concluded control of the insect actually increased drying time due to the increase in yield and moisture content of the hay from treated areas, although the differences in drying time were of no importance from the standpoint of normal farm operations. Under severe infestations on red clover the high humidity resulting from the spittle masses may result in a sooty mold developing on the stem and killing the leaves.

Other effects of spittlebug infestations were reported by Weaver and Hibbs (8). They observed differences in protein and caretenoid content in hay infested with spittlebugs, but indicated the differences were not important enough to indicate that spittlebugs reduced the nutritive value an appreciable amount.

Reductions in yields of forage have been reported by recent investigators. Blackburn and Stivers (2) reported at infestations of 90 per cent, yields of red clover were increased from 4018 to 5230 pounds

[1] per month.

per acre when control measures were applied. Gyrisco, Muka and Hopkins (11) reported that control of spittlebug infestations of 2 to 26 per square foot resulted in increased forage yields of 0 to 59 per cent in green weight. However, Weaver, App and King (7) stated that infestations of less than 0.6 nymphs per stem (approximately 24 per square foot), had little effect on yields of alfalfa or red clover. Weaver and King (9) present data showing ranges in loss of forage in alfalfa fields from 918 to 1575 pounds of hay per acre for populations of 3.32 to 8.65 nymphs per stem and 64.5 per cent infestation. Red clover losses ranged from 1297 to 2339 pounds of hay per acre with infestations from 69 to 75 per cent and one stem populations of 5.6 nymphs.

Examination of the data presented and field observations indicate that feeding by spittlebug nymphs reduce plant growth, either through the introduction of a toxic substance or by the reduction of the moisture content of the plant below that level for optimum growth. Fisher and Allen (4) reported alfalfa and red clover revealed necrosis, dwarfing, rosetting, and blossom blasting in fields heavily infested with spittlebug nymphs in Wisconsin. Caging nymphs on red clover and alfalfa for 1 month showed similar symptoms as in the field. Whitetop and bull thistles also show a similar reduction in the length of the internodes during the period of feeding by the nymphs. Plantain exhibits a distortion of the leaf areas similar to that caused by 2,4,D.

To obtain a better estimate of the magnitude of forage losses in relation to specific populations of nymphs, an experiment was set up in 1952 near Lafayette, Indiana. The field where the test was conducted had a uniform stand of medium red clover free of weeds and apparently uniformly infested with spittlebugs. Five levels of infestation were obtained by adding additional infested stems from other parts of the field and by the use of three dosages of lindane. Since the application of the insecticide might result in the control of insects other than the meadow spittlebug, examinations were made to determine what other insects were present and their general distribution. The clover leaf weevil was negligible, averaging less than one larvae per square foot, and randomly distributed throughout the test area. Leafhoppers were few in number and even though the insecticide might kill some of these insects, they would re-establish uniform populations in a short time. Also the clover leafhopper, which predominated, is not greatly affected by lindane at the dosages used. The lesser clover leaf weevil was not present at the time examinations were made, although it is possible some oviposition might have occurred. Since other injurious insects were at such low levels of infestation, it is believed that the differences in yields between the treatments are almost entirely associated with the number of nymphs present.

The plots were 20 x 20 feet and the treatments were arranged in 8 completely randomized blocks. The insecticide treatments were applied May 3 with a small plot bicycle-type sprayer, equipped with a pressure regulator and speedometer to assure accurate and uniform dosages. Populations of spittlebug nymphs were determined from counts made in 3 samples, 6 inches by 18 inches, in each plot. Forage yields were obtained by harvesting and weighing a swath 36 inches wide across the entire plot. Moisture samples were then taken and dried to obtain the percentage of moisture at harvest. Seed yields from the second crop were obtained from 3 samples 12 inches by 36 inches in each plot. These were dried and harvested with a small sample huller. The data from this experiment are given in Table 6.

TABLE 6. Spittlebug populations, yields and moisture content of hay and seed yields from plots of red clover. Lafayette, Indiana, 1952.

Spittlebug nymphs per square foot No.	Moisture content of hay at harvest Pct.	Hay yield per acre at 12% moisture[1] Lbs.	Yield of seed per acre[2] Lbs.
64.0	78.7	4739	48.2
39.1	77.8	5028	55.9
17.9	78.3	5352	51.8
10.2	78.0	5230	53.1
2.2	77.8	5496	44.4

The moisture content of the hay at harvest did not differ significantly with the different levels of infestation (Table 6). This is contrary to the findings of Weaver and King (9) and might be explained by the possibility that rainfall was sufficient to offset the moisture extracted from the plants by spittlebug feeding. Chamberlin and Medler (3) reported that spittlebug infestations reduced first crop seed yield of alfalfa in Wisconsin. In this experiment there was no consistent effect of the infestations on the seed yield from the second crop of red clover. The fact that Chamberlin and Medler were studying the first crop seed yields when the spittlebug nymphs were actively feeding and the data from Lafayette was taken from the second cutting of red clover when only a relatively few adult spittlebugs were present, probably accounts for the different results.

As the population of spittlebug nymphs decreased the yield of hay increased (Table 6). A highly significant correlation coefficient of .958 was obtained between the two variables indicating that the variation in the numbers of nymphs per square foot accounted for 91.8 percent of the variation in the yield of cured hay per acre. The rate of loss was determined as 11.235 pounds of cured hay per acre for each additional spittlebug nymph per square foot. Since it is generally accepted that an average of one nymph per stem constitutes a minimum economic population and that generally 40 stems per square foot represents a normal stand of forage, 40 spittlebugs per square foot would reduce the yield of red clover approximately 450 pounds per acre. When the data is expressed graphically as shown in figure 3, there is no indication of curvilinearity.

In 1953, through the cooperation of Mr. Irvin Mount, an aerial applicator in Marion, Indiana, and Mr. M. E. Cromer, County Agricultural Agent in Muncie, Indiana, several farmers agreed to put on field tests

[1] Harvested June 15.
[2] Harvested October 5.

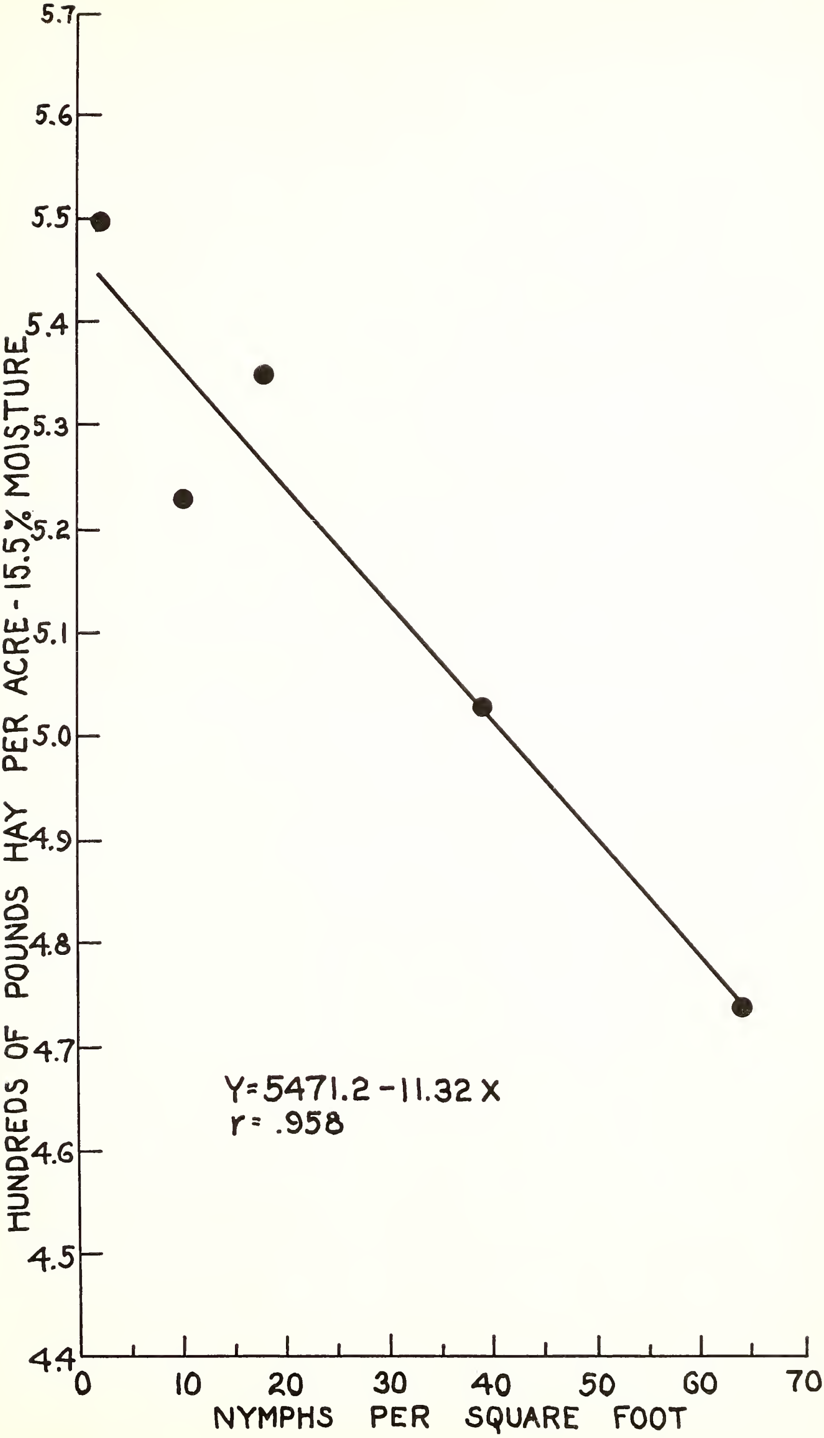

Figure 3. Reduction of yield of red clover forage and the numbers of nymphs of the meadow spittlebug per square foot.

to demonstrate the value of controlling the spittlebug. A field of mixed hay in Grant County was treated by airplane with BHC. One half the field was untreated. Counts of the nymphs in the treated portion of the field showed almost complete control as no nymphs were found in the sample areas. The untreated portion averaged 90 nymphs per square foot. Samples of forage were collected from both parts of the field, weighted and dried. From these samples the yield of hay at 12 percent moisture was determined as 3850 pounds in the untreated area and 4765 pounds per acre in the treated area. This difference of 915 pounds averaged approximately 10.2 pounds per acre per spittlebug nymph per square foot. This rate of loss is slightly less than that obtained in the experimental plots in 1952. This difference may be due to the presence of timothy and alfalfa in the field. These forage plants could have different rates of loss or the rate of loss at the higher level of infestation in 1953 could deviate from the straight line regression obtained the previous year.

In Delaware County, data obtained from forage fields of three cooperative growers where observations could be made, are given in Table 7. The estimates of the adult spittlebug population were obtained by taking four samples of 10 sweeps each in each part of the field. Yield estimates were obtained by harvesting 4 square yard samples in both the treated and untreated parts of the field. These were dried and converted to an acre basis at 12 percent moisture.

TABLE 7. Adult spittlebugs per net-sweep and yields of forage from fields partially treated with insecticides. Delaware County, Indiana, 1953.

Field	Treatment	Adult spittlebugs per net-sweep	Yield of hay per acre at 12% moisture
Owner		No.	Lbs.
	BHC	7.4	6202
Findley	Untreated	56.8	4666
	BHC	7.7	6164
Lizar	Untreated	109.0	4159
	BHC	11.8	5892
	Methoxychlor	13.7	5161
Jackson	Untreated	147.0	4159

Although these fields were widely separated, with different backgrounds of farm practices and rotation systems, and differed in the potential yield of hay, the data were combined and plotted in figure 4. It is apparent that the relationship between adults per net-sweep and yield of hay per acre under these conditions is curvilinear. Three types of curves in addition to the linear regression were fitted to the data. Table 8 gives the constants for these curves and the measures of goodness of fit. Using either the P-value (rho) or the errors of estimate, it is evident that the poorest fit is the linear regression. Although there was a highly significant correlation of .895, the straight line correlation reduced the errors of estimate only 55 percent. The best

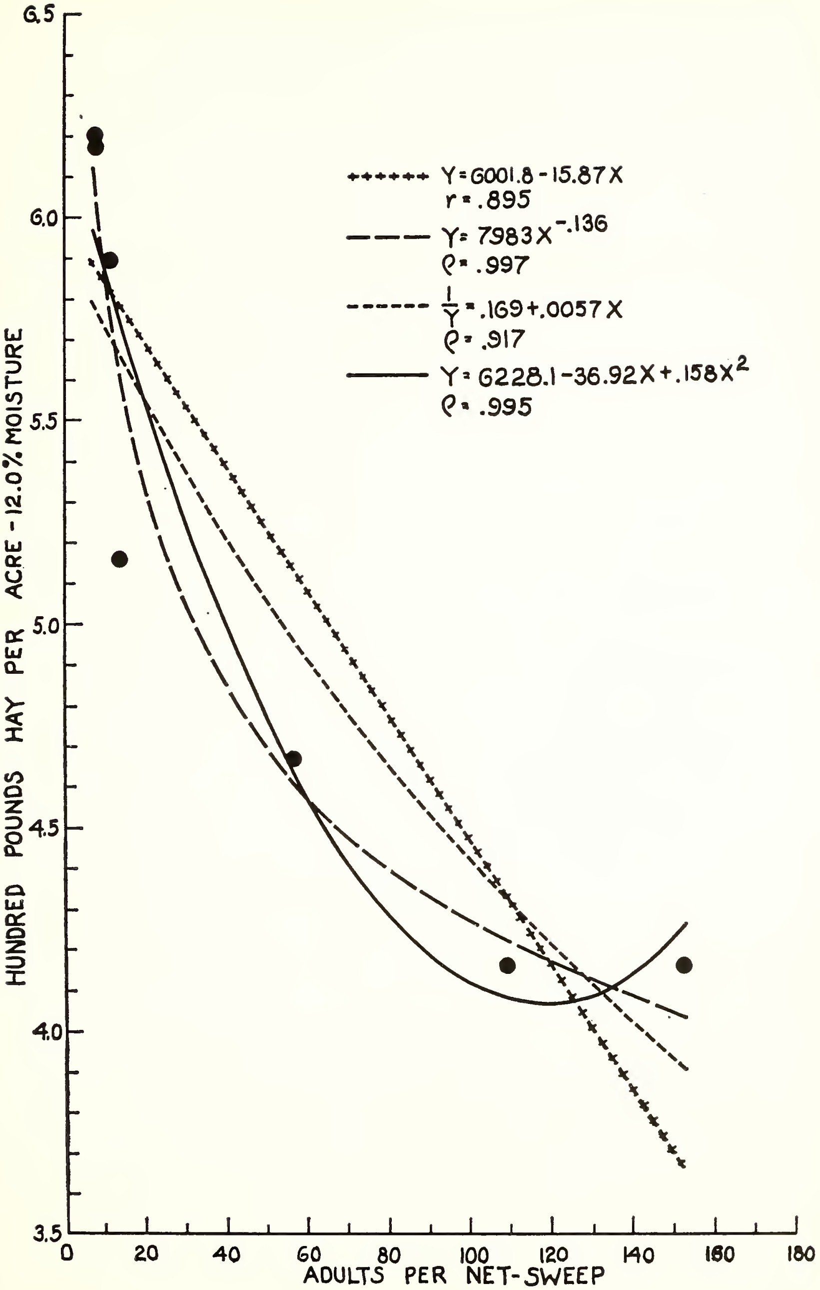

Figure 4. Reduction in yields of mixed hay and the numbers of adult meadow spittlebugs per net-sweep. An evaluation of the types of curves best fitted to the data.

fitting curve was the power log with a P-value of .997 and a reduction of the errors of estimate of 76 percent. The second degree parabola gives the second best fit and the reciprocal curve falls about midway between the linear regression and the parabola.

TABLE 8. Rho-values and errors of estimate for curves fitted to data on yield of forage and adult spittlebugs per net-sweep. (Table 7 and figure 4.)

Curve type	P-value	Errors of estimate	Reduction of errors of estimate
		Lbs.	Pct.
Straight line	.889	381.4	55
Second degree parabola	.995	264.0	68
Power log	.997	197.9	76
Reciprocal	.917	333.7	60

Although the relationship in reduction of yield per unit area of infestation can not be readily interpreted from the curvilinear regressions, the b-value from the highly significant linear regression is 15.78 pounds of curved hay per adult spittlebug per net-sweep. Using the ratio of adults to nymphs found when these two populations were compared, (114 to 100) the rate of loss of cured hay per acre per spittlebug nymph per square foot would be 13.8 for the field tests. This compares quite favorably with 11.3 pounds per acre loss for red clover in Lafayette plots in 1952, when we consider the number and divergencies of the other variables that enter into the relationship in data from diverse and widely separated areas. From the data obtained in these two years, the loss of forage from feeding by spittlebug nymphs averages about 12.5 pounds of cured hay per acre for each additional spittlebug nymph per square foot. Such a loss would give a gross loss of one fourth ton of cured hay per acre for a minimum economic population of one nymph per stem or 40 nymphs per square foot.

Summary

The development of the meadow spittlebug as a serious pest of forage legumes in Indiana began about 1940 in the northern part of the state and spread southward. Today it is present in economic numbers over the entire state except the extreme southwest area of Vanderburg, Posey, Gibson and adjoining counties. Of the six methods critically evaluated, four were compared statistically. Masses per square foot, adults per net-sweep and visual ratings of populations were highly significantly correlated with actual counts of nymphs per square foot. The relationships of masses and adults with nymphs was linear, while that of visual ratings and nymphs was curvilinear and best expressed by a second degree parabola ($Y = A + BX + CX^2$). Experiments to measure the yield of red clover forage when infested with different levels of infestation indicated that there was a reduction of 11.3 pounds of cured hay for each additional spittlebug nymph per square foot, over a population range of 2.2 to 64.0 spittlebug nymphs per square foot. Large

scale tests in fields of mixed hay using the numbers of adults per net-sweep gave a reduction of 15.8 pounds of cured hay per acre for each adult per net-sweep. In the experiment where adult populations were correlated with nymphal populations, a ratio of 114 adults to 100 nymphs was found. Using this ratio, the rate of loss in the field tests would average 13.8 pounds of hay per spittlebug nymph per square foot. The relationship of hay yields and spittlebug adults was curvilinear and best expressed by the power log curve ($Y = AX^B$).

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