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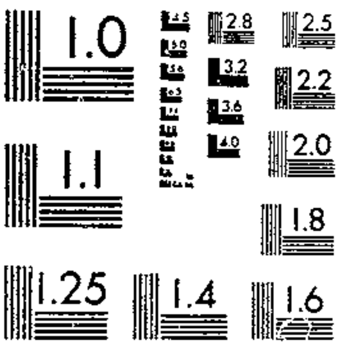

MICROCOPY RESOLUTION TEST CHART
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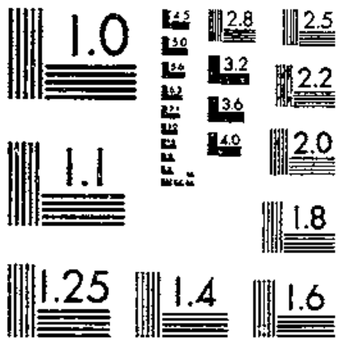

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TECHNICAL BULLETIN No. 111 — MAY, 1929

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

FISH OIL AS AN ADHESIVE IN LEAD-ARSENATE SPRAYS[1]

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INTRODUCTION

In recent years many experiments and tests have been made with various substances added to lead arsenate and other spray mixtures to increase their adhesive and spreading qualities. Some of these substances are soap, glue, casein, molasses, gelatine, glucose, and flour.

Washburn (*12*)[3] in 1891 recommended whale-oil soap as an adhesive for sprays of Paris green, and stated that it had given perfect satisfaction. Fernald (*2*) in 1894 recommended the addition of 2 quarts of glucose or molasses to each 150 gallons of lead-arsenate mixture, to cause the insecticide to adhere to the leaves. Sirrine (*8*) in 1895 and later used a resin-lime mixture as an adhesive for Paris green and Bordeaux mixture when applied to cabbage and cauliflower. Lowe (*6*) in 1896 stated that glue, used at the rate of 2

[1] This bulletin is a revision of and supersedes Department Bulletin 1439, Fish Oil, an Efficient Adhesive in Arsenate-of-Lead Sprays, published in 1926.

[2] The writer is indebted to A. F. Burgess, formerly in charge of gipsy-moth and brown-tail moth research investigations, Bureau of Entomology, under whose direction the work was conducted; to H. L. Blaisdell for cooperation in furnishing equipment and necessary help; and to coworkers in the gipsy-moth laboratory. The photographs reproduced in this bulletin were prepared by the author.

[3] Italic numbers in parentheses refer to Literature Cited, p. 27.

quarts to 45 gallons of green-arsenite mixture, proved more satisfactory than glucose, used in the same proportion. Parker (*7*) in 1912 suggested the possibility of using flour paste as an adhesive for arsenicals. Lees (*5*) in 1913 and 1914 tried a number of substances as adhesives for preparations of lime used as cover washes for trees in late winter and early spring. Some of the substances used were glue and flour, also a mixture of whiting, starch, glue, and potassium dichromate. Berger (*1*) in 1917 reported good results with linseed oil as an adhesive for Bordeaux mixture. Stearns (*10*) in 1920 stated that he had found that either calcium caseinate or sea-moss stock, prepared by boiling the moss in water, increased the adhesiveness of certain insecticides. Smith (*9*) in 1922 stated that the use of caseinate as a spreader in the codling-moth spray and the dormant lime-sulphur spray, recommended by him for the control of orchard insects in Idaho, added materially to their effectiveness. Headlee (*3*) found in 1923 that casein, and also flour, retain more than twice as much of the lead arsenate on the foliage as is retained when no adhesive is used.

In 1921 the writer began a series of experiments along this line, his purpose being to find, if possible, some substance which, when added to spray mixtures, would cause them to spread freely and adhere more strongly to foliage sprayed with them, especially glossy foliage.

WHY AN ADHESIVE IS NEEDED

Spraying operations against the gipsy moth begin about May 1 in New Jersey and much later in New England, and continue for from four to six weeks. All of the material is applied with high-power sprayers, and many tons of lead arsenate are used annually in the infested area. The areas to be sprayed are carefully planned, the crews for each sprayer selected, the necessary materials obtained, and the time required to cover these areas carefully determined in order that the spraying may be done promptly enough to be effective. There are many drawbacks, however, which more or less upset these plans, among them being bad weather, when no spraying can be done; at other times, when large areas are sprayed, frequent rains wash practically all of the poison from the foliage, and a second and sometimes a third spraying is necessary. In such cases the cost of spraying the area is doubled or tripled, and where large areas are concerned the expense is much greater. Further, to be effective, the spray mixture used in gipsy-moth work must be stronger than is ordinarily used against most leaf-feeding insects and when applied to the foliage should, for maximum efficiency, remain there during the entire larval season of the gipsy moth. From these facts it can be seen that a really good adhesive would economize materials and labor and save much valuable time.

PRELIMINARY EXPERIMENTS

IN 1921

In 1921, 1922, and 1923 the writer's experiments were conducted in a small way, with small hand sprayers, compressed-air sprayers, or an ordinary barrel pump equipped with two paddles at the bottom of the barrel for agitation. In 1921 a number of combinations were tried. The mixtures were sprayed upon glass plates and allowed to dry thoroughly, after which they were tested by rubbing them lightly with the fingers and by placing them beneath a stream of lightly running water, striking with about the same force as would be encountered in a moderately heavy rainstorm. In one case linseed oil was the adhesive tested; in seven cases two ingredients and in one case three ingredients were combined to make the adhesive. The following are the results recorded, the specified quantities of the ingredients in each case having been mixed with 100 gallons of water and 6¼ pounds of lead arsenate:

Ingredients and quantities		Results
Flour	6 pounds	Spread well; easily dislodged.
Plaster of Paris	3 pounds	
Flour	3 pounds	Do.
Glue	3 pounds	
Flour	3 pounds	Do.
Gelatine	3 pounds	
Casein	3 pounds	Spread well; adhere better than those mentioned above.
Hydrated lime	3 pounds	
Molasses	3 pounds	Spread fairly well; easily dislodged.
Hydrated lime	3 pounds	
Molasses	1½ quarts	Spread fairly well; rather easily dislodged.
Hydrated lime	3 pounds	
Soap powder	3 pounds	Do.
Casein	3 pounds	
Plaster of Paris	6 pounds	Do.
Casein	6 pounds	
Hydrated lime	6 pounds	
Linseed oil	3 gallons.	Spread well; not easily dislodged.

In these tests it was found that the most promising materials for adhesives were casein (lime being added to bring it into solution) and linseed oil.

IN 1922

In 1922 the casein and linseed oil were given further tests, together with another adhesive which was considered of possible value. Woodland trees, such as birch, cherry, maple, and oak, were sprayed with these materials and examined frequently during the summer, the quantity of spray washed off, if any, being noted. The rainfall during the summer of 1922 was excessive in the section where these experiments were conducted. From June 7 to September 20, when the last examination of the foliage was made. a total of 18.71 inches of rain had fallen. As in 1921, the specified quantity of the adhesive in each case was mixed with 100 gallons of water and 6¼ pounds of lead arsenate. The ingredients and quantities taken for these tests were as follows:

Linseed oil	1 gallon.
Linseed oil	2 quarts.
Linseed oil	1 quart.
Casein (proprietary)	Three-fourths pound.
Gum arabic	Each three-fourths pound.
Potassium dichromate	

The examination of the foliage on September 20 showed that in the plot treated with the largest proportion of linseed oil the greater part of the spray still remained on the foliage, but slightly less of the spray remained on the foliage in the other two plots on which linseed oil was used. In the plot on which casein was used only traces of the spray could be found on the foliage on September 20, whereas in that treated with gum arabic more spray could be seen than in the plot last mentioned but much less than in those treated with linseed oil.

IN 1923

As linseed oil proved the best adhesive of any tried in 1921 and 1922, it was decided in 1923 to try other vegetable oils and an animal oil, to find, if possible, one that would prove to be a good adhesive but much less expensive than linseed oil.

Vegetable oils are placed in three classes—drying, semidrying, and nondrying. Of these only the drying and semidrying oils were used, the drying oils being linseed oil, soy-bean oil, and Chinese wood oil, and the semidrying oils corn oil and cottonseed oil. Fish oil was the only animal oil used. Some of the properties of these oils and their drying qualities when applied as a thin film on any surface are here set forth.

Linseed oil is obtained from the seeds of the flax plant, *Linum usitatissimum*, a native of central Asia but cultivated in many parts of the world for the fiber, which forms linen, or the seed, from which the oil is obtained. The seeds contain from 36 to 42 per cent of oil, which is obtained from them by expression or extraction. It is of a golden-yellow color, dries rapidly on exposure to the air, and adheres closely to the surface beneath.

Fish oil, sometimes known as mossbunker oil, pogy oil, or whitefish oil, is obtained principally from menhaden, a shadlike clupeoid fish of the genus Brevoortia, very abundant on the North Atlantic coast of the United States. Light-pressed fish oil is obtained by steaming the fish and subjecting it to gentle pressure; the cheaper grades are extracted from the residues. The oil is yellow to brown and dries readily on exposure to the air, but adheres somewhat less strongly than linseed oil to the surface beneath. The current (1928) price is about 75 cents per gallon in barrel lots.

Corn oil, known also as maize oil, is obtained from the germ of corn, after it has been separated in the manufacture of starch, or from the residues of corn obtained in the fermentation of alcohol. The oil from the former source is pale to golden yellow; that from the latter, reddish brown. Corn oil dries readily on exposure to the air, but does not adhere so closely to the surface beneath as does linseed oil or fish oil. Its price is about $1 per gallon in barrel lots.

Soy-bean oil, sometimes known as soja oil or Chinese bean oil, is extracted from soy beans. It is pale yellow to brown and dries slowly on exposure to the air, forming a soft film. Its price is about $1.10 per gallon in barrel lots.

Chinese wood oil, known also as tung oil, is imported from the Orient, is pale yellow to dark brown, and on exposure to the air dries more rapidly than linseed oil, but does not adhere strongly to the surface beneath. Its price is about $2.60 per gallon in barrel lots.

Cottonseed oil is obtained from the seeds of the cotton plant, is pale yellow, and dries slowly on exposure to the air, but does not adhere to the surface beneath quite so well as does corn oil. Its price is about $1.05 per gallon in barrel lots.

As a preliminary test of the adhesiveness of sprays of lead arsenate, each containing one of the six oils which have just been described, it seemed best to spray them on glass plates and observe their behavior after drying. Standard lead-arsenate mixture was used, separate portions of which contained one-half of 1 per cent and one-fourth of 1 per cent of each of the oils, making 12 different mixtures, all successively sprayed on glass plates. A cylindrical sprayer of the compressed-air type was used, the material being agitated by an occasional shaking of the sprayer. All of the oils mix mechanically with the water and are distributed through it in very fine globules. It was found better to add the lead arsenate before adding the oil; by doing so the latter remained for a longer time distributed through the mixture, and undoubtedly the oil attached itself more or less to the particles of lead arsenate.

It was observed that linseed oil mixes well with the spray, spreads very well over the plate, and when dry adheres strongly to the glass. Fish oil mixes practically as well as the linseed oil and is nearly as adhesive. Corn oil mixes readily and spreads fairly well over the plate, but does not adhere so strongly as does linseed oil or fish oil. Soy-bean oil does not mix well with the spray mixture; even after violent agitation of the mixture the oil rises quickly to the surface. It does not adhere strongly to the glass plate. Chinese wood oil mixes readily and spreads fairly well over the plate, but does not adhere to the surface nearly so well as linseed oil or fish oil. It dries more rapidly than any of the other oils used. Cottonseed oil mixes fairly well with the mixture and is next to corn oil in its adhesiveness.

In this experiment linseed, fish, and corn oils gave the most satisfactory results. The mixtures containing one-fourth of 1 per cent of oil proved practically as efficient as those containing twice that proportion.

In the summer of 1923 standard lead-arsenate mixtures, each containing one-fourth of 1 per cent of one of the oils previously mentioned, were sprayed upon foliage, and observations were made frequently during the season. On June 15 of that year a few woodland trees—oak, birch, maple, and hickory—were sprayed with the lead-arsenate mixture containing linseed oil, and some oak, birch, hickory, beech, and maple trees with the mixture containing fish oil. On July 12 a few birch, oak, cherry, hazel, and ash trees were sprayed with the lead-arsenate mixture containing corn oil. Each of these three sprays, when applied to the foliage, has about the same spreading qualities.

On September 30 the last examination of the sprayed foliage was made. From the time of the application of the linseed-oil and fish-oil sprays to this date 5.74 inches of rain had fallen, and 4.95 inches from the time of application of the corn-oil spray. It was found that very little of the linseed-oil and fish-oil mixtures had been washed off. More of the corn-oil mixture had left the foliage, in spite of the fact that the linseed-oil and fish-oil sprays were subjected to a greater amount of rainfall. It was evident that corn oil is not quite so efficient an adhesive as is linseed oil or fish oil.

In the course of this season a few experiments were conducted with other materials as spreaders and stickers; some of the substances used were a semisolid sodium auto soap, powdered glue, and a proprietary casein product. Soap was used at the rate of 2 pounds to 100 gallons of water, and the lead-arsenate mixture containing soap was sprayed June 11, 1923, on the foliage of oak, cherry, birch, hazel, and maple trees. This material caused the spray to spread entirely over the surface of the leaf, and in all the experiments made no other substance used could quite compare with soap as a spreader. After a total of 4.15 inches of rain had fallen since the application of the spray on June 11, the foliage was examined on July 31, 1923, and practically all of the material was found to have been washed from it; only a very small quantity of the poison could be seen. On September 30 hardly a trace of the spray could be found.

As the results of the experiments with powdered glue and the proprietary casein product did not show much promise, no details relating to them are given. This season's result showed that linseed oil and fish oil were the most satisfactory adhesives, with linseed oil perhaps slightly the better of the two, but the difference was very slight. The price of linseed oil in barrel lots in April, 1923, was $1.17 per gallon; that of fish oil, 79 cents per gallon. As the difference in effectiveness between linseed oil and fish oil was so slight, and the difference in price was so great, it can be seen that fish oil was the best all-around adhesive used in the season of 1923.

EXPERIMENTS CONDUCTED ON A LARGE SCALE IN 1924

From 1921 to 1923, inclusive, all of the experiments with adhesives were conducted in a small way, small sprayers and very limited areas being used. In 1924 these experiments were conducted on a larger scale, with high-powered sprayers. (Fig. 1.) The adhesives tested were linseed oil, fish oil, corn oil, flour, a proprietary casein product, soap, and a proprietary miscible oil. Two large areas in Somerville, N. J., were used; one on Watchung Ridge, containing about 34 acres of deciduous growth, including more than 25 different species, and the other in Dukes Park, containing 9 acres of solid blue spruce.

EXPERIMENTS WITH DECIDUOUS TREES IN NEW JERSEY

On Watchung Ridge nine plots, containing from 2 to 4 acres each, were under observation. On these plots tests were made of lead arsenate with the following adhesives: Soap, corn oil, fish oil, linseed oil, proprietary casein product, flour, and proprietary miscible oil; and lead arsenate without an adhesive was also tested.

In the Dukes Park area seven plots were selected, each containing 1⅜ acres. The same adhesives were used here as in the Watchung Ridge plots, with the exception of the proprietary miscible oil. Another area of seven 1-acre plots, containing a mixed growth, was selected in Saugus, Mass., and in these plots the same adhesives were used as in the Watchung Ridge area, except the proprietary miscible oil and the soap. A small area was selected in Melrose Highlands, Mass., for experiments with the proprietary miscible oil.

The season of 1924 was an excellent one for testing the adhesive qualities of different substances, the rainfall on the plots in both New Jersey and Massachusetts being above normal. After the spraying was finished and the materials were thoroughly dried, representative collections of the foliage were made from each of the plots. After each moderate or heavy rain another collection of foliage from each of the plots was made, care being taken to select samples which were not blotchy or oversprayed and which were located in the open where they would be subjected to the full force of the rain during the season. The quantity of spray material washed off was estimated by comparing it with the foliage taken from the plot shortly after the poison was applied. The same method was continued throughout the season. Careful examinations of the foliage were also made to note if any injury had taken place. The following year plots were sprayed with lead-arsenate mixtures both with and without an adhesive, collections of the foliage were made at different periods during the season, and chemical examinations of the spray remaining on the foliage were made. The results of these tests showed, by comparison, that they did not differ very materially from those made during the season of 1924.

FIGURE 1.—High-power spraying in operation at Watchung Ridge, Somerville, N. J., 1924

The auto soap previously mentioned was mixed with a small quantity of water and added to the contents of the spray tank. Lead-arsenate mixtures containing this material spread well, entirely covering the surface of all kinds of foliage. The spraying for testing this adhesive was done on a partly cloudy day. (Fig. 2.)

The corn oil, owing to excellent agitation, mixed immediately with the lead-arsenate mixture. The spraying was done on a partly cloudy day with a light wind. The spray spread fairly well over all kinds of foliage, but not so well as did the soap mixture. (Fig. 3.)

The fish oil, when added to the lead-arsenate mixture, mixed almost instantly. It was sprayed on a partly cloudy day with light

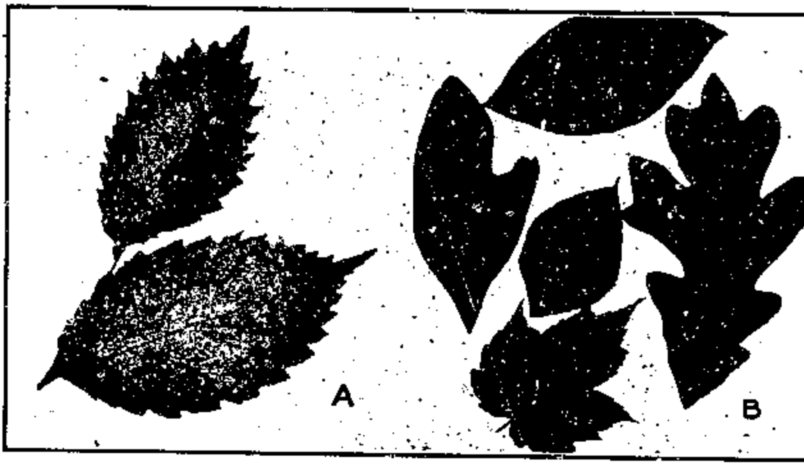

FIGURE 2.—Appearance of foliage in plot at Watchung Ridge, sprayed with mixture containing soap as adhesive. A, Foliage shortly after application of spray, June 4, 1924; B, foliage on September 17, 1924

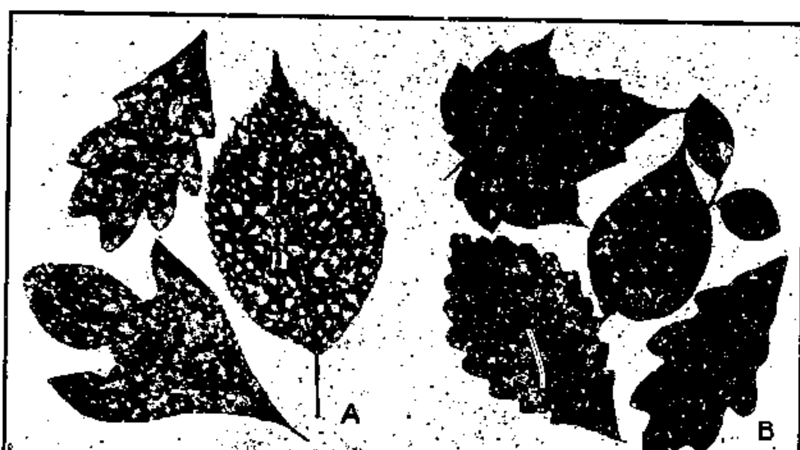

FIGURE 3.—Appearance of foliage in plot at Watchung Ridge, sprayed with mixture containing corn oil as adhesive. A, Foliage shortly after application of spray, June 4, 1924; B, foliage on September 17, 1924

to moderate wind. This material spread over the foliage slightly better than the corn oil, but not so well as the soap. (Fig. 4.)

The linseed oil mixed with the spray mixture as readily as did fish oil. The spraying was done on a partly cloudy day. The spray spread fairly well, but did not cover the entire leaf, as did the soap mixture. (Fig. 5.)

The proprietary casein product, a well-known article on the market, was mixed with a small quantity of water before being added to the lead-arsenate mixture in the spray tank. The weather at the time of spraying was partly cloudy to cloudy. This material spread well

FIGURE 4.—Appearance of foliage in plot at Watchung Ridge, sprayed with mixture containing fish oil as adhesive. A, Foliage shortly after application of spray, June 5, 1924; B, foliage on September 17, 1924

FIGURE 5.—Appearance of foliage in plot at Watchung Ridge sprayed with mixture containing linseed oil as adhesive. A, Foliage shortly after application of spray, June 5, 1924; B, foliage on September 17, 1924

over the surface of the foliage sprayed except the new growth on white oak; as a spreader it was not so good as soap, but somewhat better than any of the other materials used. (Fig. 6.)

The flour used as one of the adhesives contained 16 per cent of gluten and was thoroughly mixed with the lead arsenate before being brought into mixture in the spray tank. The day of the spraying was partly cloudy. The mixture spread fairly well over some of the foliage, but not well over that of white oak. It was only slightly better, if any, than the lead arsenate used alone. (Fig. 7.)

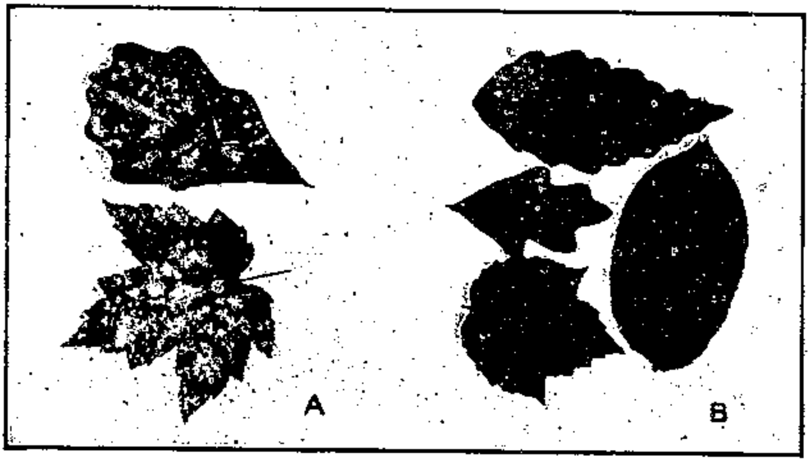

FIGURE 6.—Appearance of foliage in plot at Watchung Ridge sprayed with mixture containing casein as adhesive. A, Foliage shortly after application of spray, June 6, 1924; B, foliage on September 17, 1924

FIGURE 7.—Appearance of foliage in plot at Watchung Ridge sprayed with mixture containing flour as adhesive. A, Foliage shortly after application of spray, June 7, 1924; B, foliage on September 17, 1924

The proprietary miscible oil mixed readily with the lead-arsenate mixture. The day of spraying was partly cloudy. Mixtures containing this material did not spread well over the foliage, especially that of the oaks. (Fig. 8.)

Lead-arsenate mixture, without the addition of special adhesive, did not spread well over the foliage, especially the oaks, and very little, if any, would adhere to the new growth on white oaks. The spraying of this mixture was done on a partly cloudy day. (Fig. 9.)

EXPERIMENTS WITH CONIFEROUS TREES IN NEW JERSEY

As already stated, a 9-acre tract of blue spruce was chosen for testing the various adhesives when sprayed on the foliage of coniferous trees. The foliage of the blue spruce trees was very thick, and it

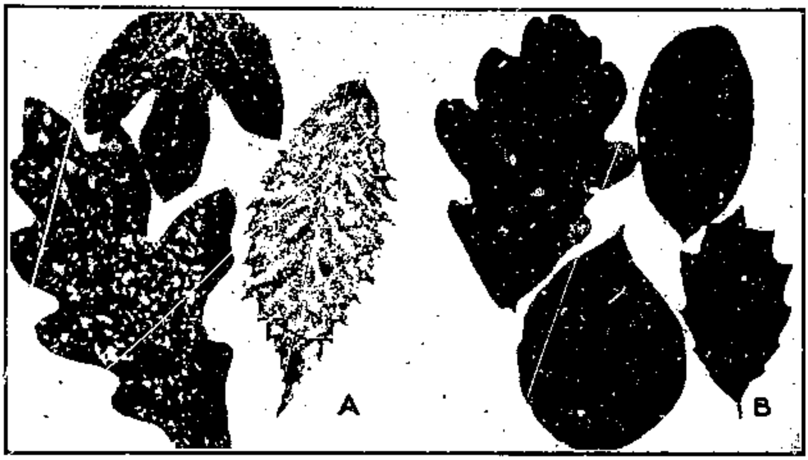

FIGURE 8.—Appearance of foliage in plot at Watchung Ridge sprayed with mixture containing proprietary miscible oil as adhesive. A, Foliage shortly after application of spray, June 9, 1924; B, foliage on September 17, 1924

FIGURE 9.—Appearance of foliage in plot at Watchung Ridge sprayed with lead-arsenate mixture without the addition of special adhesive. A, Foliage shortly after application of spray, June 9, 1924; B, foliage on September 17, 1924

was found necessary to use a spreader on the spraying nozzle, and to force the spray in between each tier of branches. Both the new foliage of the season and the older foliage were observed. The various adhesives were mixed with the lead-arsenate mixtures in the same manner as in the experiments with deciduous trees. The proprietary miscible oil, which had been tried in the experiments with deciduous trees, was not used with coniferous trees.

No special plot was laid out for experimenting with soap, as large areas of spruce throughout the park were being sprayed with lead-arsenate mixture containing it. In all cases the spray spread well over the old foliage but not so well over the new growth.

The fish oil spread well over the old foliage but not quite so well over the new growth. On the latter, however, it was just as good as soap, if not a trifle better. The mixture containing it was sprayed on a partly cloudy day with a light wind.

The linseed oil spread well, about as well as the fish oil, over the old growth. The day of spraying was partly cloudy with a light wind.

The corn oil did not spread so well over the foliage as did fish oil and linseed oil. When the spraying was done the weather was cloudy.

The spray mixture containing flour spread fairly well on the old growth when sprayed on spruce, but not so well on the new growth, being only slightly better than lead arsenate alone. The spraying was done on a partly cloudy day.

The proprietary casein product was found to spread very well over the old growth, but over the new growth not any better than the fish oil, if as well. It was sprayed on a clear day.

The lead-arsenate mixture without special adhesive spreads fairly well over the old foliage, but will not spread over the new growth, and only a very little of the spray will remain on it.

For all the plots, 25 pounds of powdered lead arsenate was used to 400 gallons of water, and to this mixture was added the quantity of adhesive recorded in Table 1.

The spraying of the deciduous and coniferous foliage used for these experiments was begun June 4 and completed June 9, as far as the trees at Watchung Ridge and Dukes Park were concerned. On June 14 an examination was made of the foliage which had been sprayed with the different mixtures, except the coniferous foliage sprayed with the mixture containing soap as the adhesive, and in the case of each one an estimate was made of the percentage remaining of the spray which had originally adhered. Between this date and that of the latest spraying all of the foliage had been subjected to rainfall of from 1¼ to 1½ inches. On June 26 a similar examination was made of foliage of several kinds, including that previously omitted; up to this time the rainfall since the last date of spraying had amounted to 3 inches. Similar examinations were made on July 9, August 11, September 17, and October 1, the total rainfall on the sprayed foliage at those dates being 5½ to 6, 9, 15½, and 19 inches, respectively. At least three, and in nearly all cases four, examinations were made for each spraying with a given adhesive. Table 1 gives various data relating to the adhesives used, their application, and the results of the several examinations of the foliage sprayed.

TABLE 1.—*Data relating to tests of adhesives in lead-arsenate sprays at Somerville, N. J., in 1924*

Adhesive	Quantity of adhesive used with 25 pounds of lead arsenate and 400 gallons of water	Growth sprayed	Date of spraying	First examination				Second examination				Third examination				Fourth examination			
				Date	Days after spraying	Rainfall after spraying (inches)	Percentage of spray remaining on foliage	Date	Days after spraying	Rainfall after spraying (inches)	Percentage of spray remaining on foliage	Date	Days after spraying	Rainfall after spraying (inches)	Percentage of spray remaining on foliage	Date	Days after spraying	Rainfall after spraying (inches)	Percentage of spray remaining on foliage
Soap	8 pounds	Deciduous	June 4	June 14	10	1.1	20	July 9	35	6.07	15	Sept. 17	105	15.53	10				
		Coniferous	do	June 26	22	1.84	20	do	35	6.07	15	Oct. 1	119	18.85	10				
Corn oil	1 gallon	Deciduous	do	June 14	10	1.1	95	do	35	6.07	85	Aug. 11	68	9.66	80	Sept. 17	105	15.53	75
		Coniferous	June 6	do	8	1.02	90	June 26	20	2.76	85	July 9	33	5.99	75	Oct. 1	117	18.77	50
Fish oil	do	Deciduous	June 5	do	9	1.1	95	July 9	34	6.07	90	Aug. 11	67	9.66	85	Sept. 17	104	15.53	80
		Coniferous	do	do	9	1.1	95	June 26	21	2.84	90	July 9	34	6.07	85	Oct. 1	118	18.85	60
Linseed oil	do	Deciduous	do	do	9	1.1	95	July 9	34	6.07	90	Aug. 11	67	9.66	85	Sept. 17	104	15.53	80
		Coniferous	do	do	9	1.1	95	June 26	21	2.84	60	July 9	34	6.07	85	Oct. 1	118	18.85	70
Casein [1]	4 pounds	Deciduous	June 6	do	8	1.02	75	July 9	33	5.99	45	Aug. 11	66	9.58	35	Sept. 17	103	15.45	20
		Coniferous	June 9	do	5	.43	90	June 26	17	2.17	55	July 9	30	5.40	40	Oct. 1	114	18.18	15
Flour	6 pounds	Deciduous	June 7	do	7	.59	50	July 9	32	5.56	25	Aug. 11	65	9.15	20	Sept. 17	102	15.02	15
		Coniferous	do	do	7	.59	55	June 26	19	2.33	45	July 9	32	5.56	30	Oct. 1	116	18.34	15
Miscible oil [1]	4 gallons	Deciduous	June 9	do	5	.43	60	July 9	30	5.40	50	Aug. 11	63	8.99	45	Sept. 17	100	14.86	40
None [2]		Deciduous	do	do	5	.43	60	do	30	5.40	35	do	63	8.99	25	do	100	14.86	15
		Coniferous	do	do	5	.43	55	June 26	17	2.17	45	July 9	30	5.40	25	Oct. 1	114	18.18	15

[1] Proprietary.

[2] Lead-arsenate mixture without special adhesive.

EXPERIMENTS WITH DECIDUOUS TREES IN MASSACHUSETTS

In order to compare the results of the tests made on the Somerville, N. J., plots, especially those of the Watchung Ridge area, with results of similar tests on plots located in New England, a mixed woodland was selected at Saugus, Mass. Seven plots, each containing about an acre, were sprayed, and the same adhesives were used with the lead arsenate as were used in the Watchung Ridge area, with the exception of the proprietary miscible oil, which was tested in a small plot at Melrose Highlands, Mass. Deciduous growth only was used in Saugus and Melrose Highlands. The adhesives were added to the spray mixtures in the same proportions as were used in the experiments in Somerville. The spraying was done on June 12 and 13, except that for the miscible oil which was done on June 24. The sprayed foliage was examined on June 26, July 22, August 5, and September 23, except that at Melrose Highlands, which was examined on the last two dates only. On these four dates the total rainfall after the dates of spraying was about 1, 2½, 3, and 15½ inches, respectively. In Table 2 are presented various data relating to these tests, more particularly the estimated percentages which remained of the adhering spray. Here, as in the preceding tests, the drying oils are shown to be superior to the other adhesives used.

TABLE 2.—*Data relative to tests of adhesives in lead-arsenate sprays at Saugus and Melrose Highlands, Mass., in 1924, on deciduous growth*

Adhesive	Date of spraying	June 26			July 22			Aug. 5			Sept. 23		
		Days after spraying	Rainfall after spraying (inches)	Percentage of spray remaining on foliage	Days after spraying	Rainfall after spraying (inches)	Percentage of spray remaining on foliage	Days after spraying	Rainfall after spraying (inches)	Percentage of spray remaining on foliage	Days after spraying	Rainfall after spraying (inches)	Percentage of spray remaining on foliage
Casein [1]	June 12	14	0.88	75	40	2.2	40	54	2.92	30	103	15.63	20
Corn oil	do	14	.88	95	40	2.2	90	54	2.92	85	103	15.63	70
Flour	June 13	13	.88	50	39	2.2	30	53	2.92	25	102	15.63	15
Fish oil	do	13	.88	95	39	2.2	90	53	2.92	85	102	15.63	75
Linseed oil	do	13	.88	95	39	2.2	90	53	2.92	90	102	15.63	80
None	do	13	.88	45	39	2.2	30	53	2.92	25	102	15.63	15
Miscible oil [1]	June 24 [2]							43	2.40	65	91	15.11	40

[1] Proprietary. [2] Between June 12 and June 24, 0.52 inch of rain fell.

SUPERIOR ADHESIVENESS OF DRYING OILS

The value of any adhesive material is determined by the length of time that it will bind the spray to the foliage. Heavy rainfall or an excessive amount of fog or dew causes the poison gradually to disappear. Lead-arseniate sprays to which any of the three drying oils tested—i. e., fish oil, linseed oil, or corn oil—were added resisted throughout the season the washing action of the rain. The other materials tested were less satisfactory, as they failed to bind the poison firmly to the foliage. There was a tendency for the small particles of poison to become loosened and detached after having been exposed to considerable moisture, whereas the only observed effect of rainfall on the drying oils was a slight weathering of the poison on the sprayed surface. When growing foliage is treated a considerable loss of poison per unit area results, owing to the rapid increase in the leaf area, with no increase in the quantity of poison on the leaf. This is true, regardless of the adhesive used, but more spray remains if one of the drying oils named is added to the lead arsenate.

FIGURE 10.—Appearance of foliage in plot at Saugus, Mass., 47 days after application of spray mixture containing fish oil as adhesive; the foliage had meanwhile been exposed to 10 inches of rainfall

TESTS WITH A BARREL PUMP

On August 15, 1924, two small plots in a mixed woodland at Saugus, Mass., were sprayed with the standard lead-arsenate mixture to which was added one-fourth of 1 per cent of linseed oil for one plot and one-fourth of 1 per cent of fish oil for the other plot. The pump used was of the ordinary barrel type, having two paddles at the bottom as an agitator. After the water and the lead arsenate had been mixed in the barrel the oil was added and the whole agitated for five minutes. The mixture was allowed to stand for one hour. Most of the oil was taken up by the lead arsenate, but a small quantity of free oil arose to the surface. The pump was then started and the spray applied. The material spread well over the foliage. The plots were examined on October 1, 47 days after the spraying, more than 10 inches of rain having fallen in the meantime. It was estimated that not over 15 per cent of the originally adhering material in the linseed-oil plot and 20 per cent of that in the fish-oil plot had been washed off, and no injury was noted on any of the foliage. (Fig. 10.)

ADHESIVES INJURIOUS TO FOLIAGE

MISCIBLE OIL

For testing its possible injuriousness to foliage, the proprietary miscible oil was used in two dilutions; one, the stronger, in the proportion of 1 gallon of the oil to 100 gallons of water, and the other in the proportion of 1 to 150. Two plots of foliage in the Watchung

Ridge area were sprayed on June 9, 1924, each with one of these dilutions.

On July 9 the sprayed foliage on both plots was carefully examined, and on both some of it had suffered injury, the more extensive damage being found on the plot sprayed with the weaker mixture. Here the foliage on the maple, oak, ash, elm, and dogwood trees showed burning, some of it severe. In the other plot slight burning was noticed on some of the maple, oak, and dogwood foliage. The adhering spray seemed to have been washed away from the leaves here much more than from the foliage on the plot sprayed with the weaker mixture, which may account for the more severe injury to the latter. Slightly more burning in both of these plots was observed later in the season.

The proprietary miscible oil, diluted in the same two proportions as for the plots at Watchung Ridge, was similarly tested on two plots at Melrose Highlands, both of which were sprayed on June 24. On June 26, two days later, in the plot sprayed with the stronger mixture, young, tender growth on red oak was found to be badly burned, and wild cherry foliage somewhat less so. On June 28 these injuries were more severe, especially in the case of the wild cherry, a number of leaves having suffered so badly that they had fallen off, and fruit which had been touched by the spray had become discolored and injured. On July 2 many wild cherry leaves had fallen off and some of them had turned entirely black. Slightly more burning was noted from time to time for the rest of the season.

The foliage sprayed with the weaker mixture suffered less injury. On June 26 and 28 the wild cherry leaves were slightly burned, and much more severely on July 2. As in the case of the other plot, the injury progressed slightly during the season.

CORN OIL

In the Watchung Ridge area at Somerville, N. J., slight burning was observed on dogwood foliage sprayed with the mixture containing corn oil, but no injury was noted on any of the other trees. Slight burning was noted on some of the foliage in the plot in the same area sprayed with the mixture containing no adhesive, so that the injury in this area may not have been due to the corn oil. No other injury was found in any of the other plots, either at Somerville or Saugus.

TESTS WITH RAW OILS

On August 7, 1924, to determine the effect of the direct application of raw oils to foliage, linseed oil, fish oil, and corn oil were sprayed separately in a raw state upon cherry, oak, and gray birch foliage on selected trees at Melrose Highlands. The trees were located at the edge of a woodland and in the direct sunlight. The spraying was done between 2.30 and 3 p. m., the temperature in the shade being 96° F. All of the oils spread over the entire surface of the foliage to which they were applied. When the foliage was examined August 9 at 10 a. m., all was found in good condition. It appeared waxy, and the oils were almost entirely dry. (Fig. 11.) It was again examined August 13, but no burning by any of the oils was noted; on September 2 the foliage still appeared waxy, with no burning apparent. As a further test, on September 6 a few cherry, hazel, and gray birch trees were sprayed with crude (raw) fish oil, the cheapest grade obtainable. The foliage was examined September 11, no signs of burning being found; still later examinations showed no injury. It may be inferred from these experiments that foliage would not be injured if the oil added to the spray mixture should be applied unevenly to the trees.

EXPERIMENTS WITH COATED LEAD ARSENATE

In 1924 woodland plots located in Somerville, N. J., and Saugus, Mass., were sprayed with lead arsenate coated with lead oleate, and the results obtained were given in Department Bulletin 1439 (*4*). The formula used was unsatisfactory, as indicated by the results.

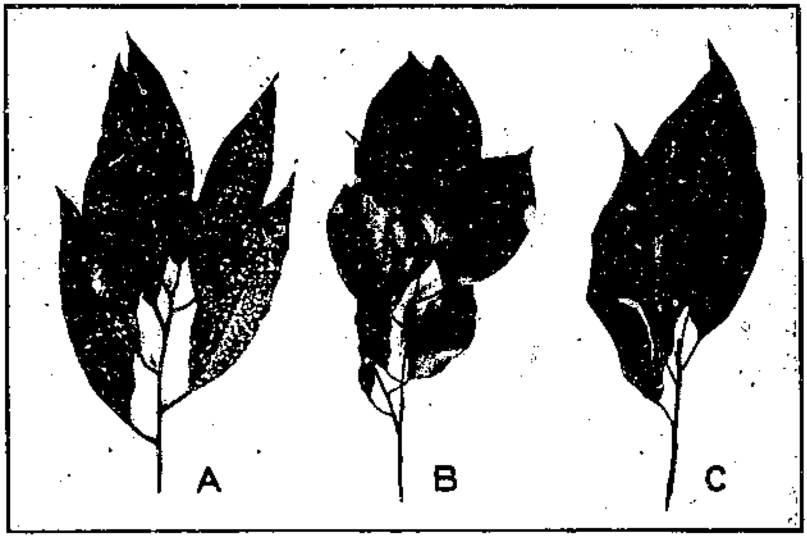

FIGURE 11.—Appearance of leaves as affected by spraying: A, Foliage sprayed with lead-arsenate mixture containing fish oil; B, foliage sprayed with raw fish oil; C, foliage not sprayed

In 1927 further experiments were conducted with coated lead-arsenate paste, prepared by a concern which manufactures this material according to the latest specifications recommended for the control of the Japanese beetle. This coated lead-arsenate paste (*11*) contained 2 per cent of lead oleate.

In using this coated lead-arsenate paste it is necessary to apply two and one-half times the required quantity (by weight) of powdered lead arsenate in order to have an equivalent quantity of arsenic pentoxide (As_2O_5).

Accordingly two large woodland plots heavily infested with the gipsy moth were selected in Freetown, Mass., and were sprayed the same day. One was treated with coated lead arsenate in the proportion of 10 pounds to 100 gallons of water and the other with 4 pounds of powdered lead arsenate and 1 pint of fish oil in the same quantity of water. Duplicate tests were also made at Saugus, Mass.

Equal poisoning of the caterpillars resulted in all of the plots and no foliage injury was noted.

The spray was applied in the Freetown plots on June 3, 1927, and collections of foliage were made on that date and on August 10 after a total rainfall of 10 inches. Analyses[4] of the collected samples showed that 51.6 per cent of the spray, expressed in terms of As_2O_5, remained on the foliage in the lead arsenate and fish oil plot and 18.4 per cent in the coated lead-arsenate plot.

The Saugus plots were sprayed June 24 and foliage collections were made on that date and on August 1. During this period 6 inches of rain fell. The analyses of collected samples showed that 66.3 per cent of the spray remained on the foliage in the lead arsenate and fish oil plot and 17.5 per cent in the coated lead-arsenate plot.

EXPERIMENTS WITH DIFFERENT QUANTITIES OF POISON IN 1926 AND 1927

The experiments conducted with adhesives from 1921 to 1924 resulted in the adoption in 1925 of fish oil as an adhesive in all of the spraying operations conducted by the Bureau of Entomology in the barrier zone and in the New Jersey extermination work against the gipsy moth, except in areas where livestock was pastured. The results were very satisfactory and indicated a possibility that equal results might be secured with a smaller quantity of poison, hence further experiments were conducted.

In 1926, 11 woodland areas, ranging in size from nine-tenths of an acre to 3⅛ acres, were selected in the towns of Sandwich and Barnstable, Mass., in a region heavily infested by the gipsy moth. The quantity of lead-arsenate powder used ranged from 3⅛ pounds to 6¼ pounds per 100 gallons of water. These plots were sprayed when the gipsy-moth larvae averaged less than half grown. Cloth mats were placed on the ground in some of the plots to obtain a record of the number of dead larvae from day to day. Fish oil was used with lead arsenate in all of the plots with the exception of one, where lead arsenate with no adhesive was applied.

The number of dead larvae collected on the different mats ranged from 12 to 126 per square foot of mat surface. This great difference was due to a number of factors, such as the date of spraying, the intensity of the infestation, and the distance of the mats from the outside heavily infested areas. The infestation was very heavy in all of the plots, with one exception, and was sufficient to have caused complete defoliation if it had been left untreated. Early spraying when the caterpillars were small gave excellent results when fish oil was used with different strengths of lead arsenate.

The mat containing 99 square feet, upon which an average of 126 dead gipsy-moth larvae were collected during the season on each square foot of surface, or at the rate of 5,488,560 larvae per acre, was placed about 25 to 30 feet in from the edge of the sprayed plot and near a side adjacent to a heavily infested unsprayed area. This plot was sprayed on June 11, 1926, with a mixture containing 3⅛

[4] Arsenic determinations made by S. F. Potts, Bureau of Entomology.

pounds of lead-arsenate powder to 100 gallons of water. The mat was placed beneath one of the trees on June 12, and was first examined on the 14th. Figure 12 shows the rapid rise in the mortality for the first five days after spraying. On the sixth day the mortality took a sudden drop to less than 500, remaining at that point for five days and then dropping to about 100 on the 23d. From this date the number of dead larvae removed from the mat would have continued to drop until the end of the season but for the fact that on June 23 the unsprayed area adjacent to this plot was practically 100 per cent defoliated. (Fig. 13.) The caterpillars in this area, because of lack of food, immediately began to migrate and entered the sprayed areas in large numbers. As a result the number of dead

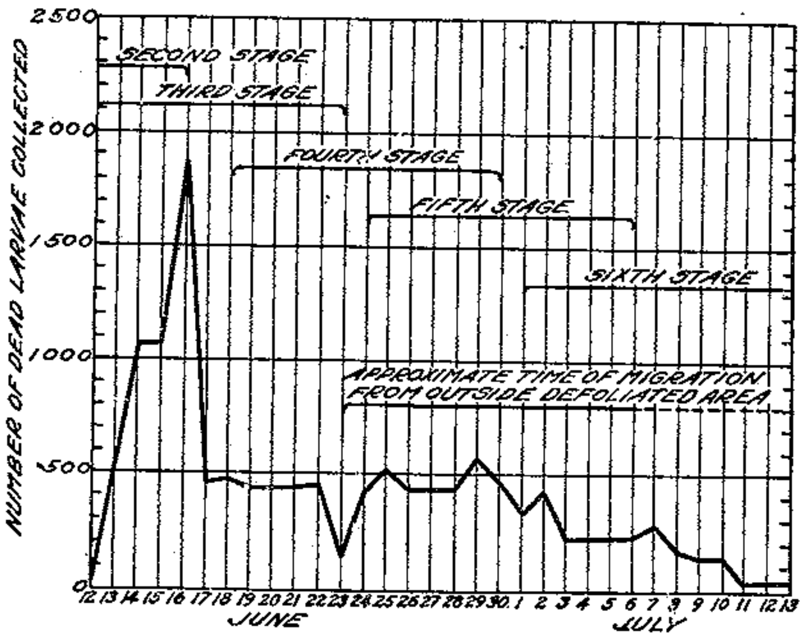

FIGURE 12.—Diagram showing the rise and fall of the number of dead gipsy-moth larvae removed from the mat during June and July, 1926. The rise after June 23 was due to the migration of larvae from the outside unsprayed area

larvae on the mat rose to 416 on the 24th and averaged 441 per day for nine days, when the number dropped gradually until the end of the season.

The average number of dead gipsy-moth larvae removed per square foot during the season from the other seven mats was 33, and the number of dead larvae removed daily after the first 10 days decreased rapidly until the end of the season.

It is rather remarkable that a total of 126 dead gipsy-moth larvae were removed from each square foot of mat placed beneath a small oak which at the end of the season was only 45 to 50 per cent defoliated, and that the quantity of lead arsenate used was only 3⅛ pounds to 100 gallons of water.

FIGURE 13.—Appearance of sprayed and unsprayed areas of woodland, 1926. At the left is shown a corner of a plot which was sprayed on June 11 with a mixture containing 3½ pounds of lead-arsenate powder to 100 gallons of water, with fish oil as adhesive. From a mat containing 99 square feet, placed beneath a tree in the sprayed area, 12,552 dead gipsy-moth larvae were removed during the season. Beyond and to the right of the sprayed plot is shown part of a tract of about 200 acres of woodland entirely defoliated

Good control was noted in practically all of the areas, whereas the outside unsprayed areas were 100 per cent defoliated.

In 1927 nine woodland plots, each containing an acre, were selected in the towns of Freetown and Lakeville, Mass., and sprayed with different strengths of lead arsenate. Fish oil was added at the rate of 4 ounces to each pound of lead arsenate used in the mixture. Table 3 gives details concerning these experiments.

TABLE 3.—*Data relating to experiments with lead-arsenate sprays in Freetown and Lakeville Towns, 1927*

Plot No.	Date of spraying	Lead arsenate used		Dead larvae	
		Per 100 gallons of water	Per acre	Removed during season per square foot of mat	Rate per acre
		Pounds	*Pounds*		
1	June 1	4 1/6	25	22	958,320
2	do	2 1/12	12½	18	784,080
3	do	2½	15	12	522,720
4	do	3⅓	20	21	914,760
5	June 6	2½	15	34	1,481,040
6	do	3⅓	20	38	1,655,280
7	June 7	3¾	30	34	1,481,040
8	June 2	3⅛	25	30	1,306,800
9	June 3	2½	20	26	1,132,560

Each mat contained 144 square feet and was located at or near the center of the area, so the number of dead larvae collected on it was not affected to any extent by the migration into the plot from the outside unsprayed area. In each plot five points were selected for observation and for collection of foliage; one was at the center of the plot and four were 75 feet in from each corner toward the center. The trees in plots 1 to 6 averaged 25 to 35 feet in height; in plots 7, 8, and 9 the trees averaged 45 to 55 feet in height. The percentage of defoliation was taken at each of the five points and was also estimated from the entire plot in general at the time of spraying and when the gipsy moth was pupating. Definite check areas were selected for comparison with the sprayed areas. The plots were sprayed from June 1 to 7 and the percentage of defoliation ranged from 8 to 20. The larvae at this time were less than half grown. On July 21 the defoliation in these areas ranged from 18 to 25 per cent, while the check areas were practically 100 per cent defoliated. The average number of dead gipsy-moth larvae removed from the mats in the nine plots was 26 per square foot, or 1,132,560 per acre.

Table 4 gives the percentage of defoliation at time of spraying and at time of pupation in the treated and in the check plots.

TABLE 4.—*Percentage of defoliation in plots at time of spraying and at time of pupation of the gipsy moth, in Freetown and Lakeville Towns, Mass., 1927*

Plot No.	Defoliation at time of spraying		Defoliation at time of pupation	
	Treated area	Check area	Treated area	Check area
	Per cent	*Per cent*	*Per cent*	*Per cent*
1	8	8	20	97
2	8	8	20	97
3	8	8	21	97
4	8	8	18	97
5	20	22	25	100
6	20	22	24	100
7	12	8	22	100
8	8	8	19	100
9	8	8	21	100
Average	11.1	11.1	21.1	98.6

The average percentage of defoliation in the treated plots increased from 11 to 21 while that in the check plots increased from 11 to 98. The area surrounding the plots was very heavily infested, consequently some of the trees near the margins in the treated plots were more seriously defoliated and thus increased the average percentage of defoliation of the treated plots. An increase of 10 or 15 in the percentage of defoliation in any sprayed plot is the maximum to be expected in a definite area, when the spray is applied early in the season, provided the spray is of sufficient strength, includes an adhesive, and is thoroughly applied. If isolated areas are well sprayed early in the season, the increase in percentage of defoliation should not be over 5 or 10, provided of course the fish oil is added as an adhesive. If, however, a lead-arsenate mixture is applied without fish oil as an adhesive, a fairly heavy rainfall shortly after application will wash a large part of the poison from the foliage, resulting in a much greater percentage of defoliation.

It will be noted from Table 3 that the quantity of lead arsenate used in the nine plots ranged from $2\frac{1}{12}$ pounds to $4\frac{1}{6}$ pounds per 100 gallons. Very good control was noted in all of the plots, whereas most of the outside unsprayed areas, including the check plots, were entirely defoliated.

During 1927 a few roadside areas 209 feet long by 52 feet deep (in the town of Freetown) were sprayed with lead-arsenate mixture to which fish oil was added as an adhesive. The gipsy-moth caterpillars at this time were small, being mostly in the second and third stages. The proportion of lead arsenate used ranged from $3\frac{1}{8}$ to $3\frac{3}{4}$ pounds per 100 gallons of water. The infestation in the plots ranged from medium to heavy and the defoliation at time of spraying, on June 3 to 7, ranged from 15 to 25 per cent. The sprayer used in these experiments was of the high-power type, developing pump pressure up to 500 pounds and producing an open or solid-stream spray. In all of the plots, with the exception of one, a $\frac{3}{16}$-inch tip was used on the nozzle, while in the other plot a $\frac{1}{4}$-inch tip was employed.

In the plots where the $\frac{3}{16}$-inch tip was used a moderate quantity of spray was noted on the foliage 40 to 50 feet back from the road, whereas in the plot where the $\frac{1}{4}$-inch tip was used the spray was noticeable on the foliage 50 to 60 feet from the road. The distance back from the road that a spray may go depends on the pump pressure, size of tip, height of trees, and the direction and velocity of the wind.

Very good control was maintained in all of the sprayed areas, with an average increase of 10 in the percentage of defoliation. This average increase would have been less but for the fact that some of the trees at the back of the sprayed areas showed considerable defoliation, owing to migration from the outside unsprayed area. In the areas back of the sprayed plots the increase in the percentage of defoliation ranged from 35 to 80, the average increase being 59.

Although this season's work indicates that a rate as low as 3 pounds to 100 gallons gave effective results when the larvae were small, it seems necessary to obtain more data before recommending so great a decrease for general use throughout the spraying season.

In the extermination work carried on by the Bureau of Entomology against the gipsy moth in the barrier zone of western New England and eastern New York and in New Jersey, lead-arsenate powder has been used at the rate of 6¼ pounds to 100 gallons of water. In New England extensive spraying is done in many towns infested with the gipsy moth by State, city, or local organizations. Much of this work is conducted for the purpose of preserving the shade or roadside trees and for keeping down the infestation. The proportion of lead-arsenate powder which has ordinarily been used in roadside spraying and on private estates has been 6¼ pounds, and sometimes more, to 100 gallons of water.

The experiments which have been conducted over a period of years have clearly shown that a reduction in the quantity of lead arsenate used in all of the gipsy-moth spraying operations can be safely made. Uneven distribution of the spray and irregular covering of the foliage commonly occurs when spraying is conducted on a large scale. The poison dosage must be sufficient to overcome these defects as much as possible and also to kill the caterpillars when nearly full grown. The large-scale tests, however, have demonstrated that 5 pounds of lead-arsenate powder per 100 gallons is sufficient at all times to control the gipsy moth, if 1¼ pints of fish oil is added as an adhesive. If the spraying is done when the gipsy-moth larvae are small, the proportion of lead arsenate per 100 gallons of water can be materially reduced.

TESTS ON GROWING FOLIAGE

During the season of 1926 about 14 acres of mixed woodland heavily infested with the gipsy moth in Sandwich and Barnstable Towns, Mass., were sprayed with lead-arsenate mixture, to which fish oil was added as an adhesive. Some of the plots were sprayed during the early part of June, and as the season was a little backward, none of the foliage was out in full, the white-oak leaves being only one-third to one-half grown.

While making observations during the season in these early sprayed areas, it was noted that as the foliage expanded some of the spray had been carried along with the growth of the leaf.

In view of the fact that near the sprayed areas there were hundreds of acres of woodland entirely defoliated and that most of the trees would refoliate, it was decided to conduct some experiments on the new, rapidly growing foliage.

On July 22, 1926, a small area was sprayed with the lead-arsenate and fish-oil mixture, the foliage at this time being one-fifth to one-half grown. On August 7 the foliage was practically full grown, and in many cases good spray distribution was noted over a greater part of the leaves. As examples, one leaf had expanded from an area of 4.2 square inches to 6.4 square inches, another from 2.4 to 16

FIGURE 14.—A, Appearance and comparative size of leaf when full grown, 16 days after it was sprayed (actual size, 16 square inches); B, comparative size of the same leaf when it was sprayed (actual size, 2.4 square inches). One-half natural size

square inches, and still another from 4.5 to 16.3. In spite of this great expansion in leaf area, the poison was fairly well distributed over a greater part of the leaf. (Fig. 14.)

During the season of 1927 it was decided to spray a heavily infested woodland (in Lakeville Town, Mass.) with a lead-arsenate and fish-oil mixture very early in the season to note the control which could be obtained by this procedure. The foliage at the time of spraying on May 27 was one-sixth to one-fourth grown, the gipsy-moth larvae were small and very abundant, and the defoliation at the time was about 5 per cent. After the area was sprayed, a number of the leaves were tagged, while a number were removed and the average area and quantity of poison on each determined.

Very good control was manifest in this area during the season, it being 20 per cent defoliated, whereas the check areas were 55 per cent defoliated, and a wooded area adjoining and to the west of the sprayed plot was 90 to 100 per cent defoliated.

On August 3, after a rainfall of over 9 inches since the spray had been applied, foliage samples were taken throughout the area and the quantity of poison on each was determined. Although the foliage had expanded on an average to over four times its area, 34.1 per cent of the original spray still remained on it. These experiments indicate that fish oil added to lead-arsenate mixture causes it to adhere strongly to growing foliage.

In the spraying operations against the gipsy moth it has been the common practice to wait until most of the trees were in full leaf before applying the poison. These experiments show conclusively that spray mixtures containing fish oil as an adhesive can be applied much earlier, even when the foliage is only half grown, and satisfactory results secured.

THE USE OF FISH OIL IN SPRAYS

QUANTITY OF FISH OIL NECESSARY

The quantity of fish oil necessary in lead-arsenate sprays is governed entirely by the weight of the poison used. For every pound of lead arsenate in the mixture, 4 ounces of fish oil should be added; that is, if 2 pounds of the poison is used to 50 gallons of water or to 100 gallons of water, it would require 8 ounces or approximately one-half pint of fish oil in either case. The quantity of water in the spray tank has no bearing on the quantity of fish oil to use. The lead arsenate takes up a definite quantity of fish oil and no more; therefore, if the proper quantity is added, practically no oil will rise to the surface of the mixture when agitation in the spray tank ceases. However, if more than the necessary quantity of fish oil is added, the free oil rises to the surface of the mixture when the agitation is halted. This surplus oil sticks to the tank, the strainer, and the pump, accumulating rapidly, especially on the strainer, which must consequently be cleaned often. It is therefore good policy to use just the right proportion of fish oil, as a surplus does not appreciably increase the adhesiveness of the mixture.

METHOD OF MIXING FISH OIL WITH SPRAY MATERIALS

In using fish oil as an adhesive, the best results are obtained by pouring the oil into the spray tank after the lead arsenate has been well mixed with the water and while the mixture is being agitated. The mixture should be agitated at all times while it is being applied, not only to obtain an even coating of poison but to get maximum adhesiveness. In large spraying outfits the agitator is usually very satisfactory, but in some of the smaller ones, such as the barrel pump, the agitator is less efficient, hence the results are not so satisfactory, either in even distribution of the poison or in the adhesive qualities of the mixture.

A new method of using fish oil as an adhesive has been tried by Porter and Sazama (*13*), which consists of mixing the lead arsenate and water into a thin paste, adding the fish oil, and pumping the whole two or three times, the lead arsenate emulsifying the fish oil.

SPECIFICATIONS FOR FISH OIL

Large quantities of fish oil are used in gipsy-moth spraying operations. The fish oil is sometimes adulterated with mineral oil, the presence of which would be shown by the lowering of all the characteristics given in the specifications.

The best grade of fish oil should always be used. This is known as light pressed fish oil and is yellow to brown in color. A cheaper grade known as crude fish oil can be obtained, but as this contains stearin it is likely to clot, and there would be no economy in using it. The specifications for light pressed fish oil are as follows:

Saponification value	190 to 193.
Iodine value	139 to 193.
Specific gravity at 15° C	0.927 to 0.933.
Free fatty acid	Less than 5 per cent.

COST OF FISH OIL

In view of the fact that fish oil is only slightly less efficient than linseed oil and is much less expensive, it is obvious that the former is the one to be recommended. The price of raw linseed oil and fish oil is variable from year to year. From 1925 to 1928 the wholesale price of fish oil ranged from $0.56 to $0.75 per gallon and the price of raw linseed oil ranged from $0.85 to $1.23 per gallon. It can be readily seen that a great saving in the cost of spraying can be effected by the use of fish oil, especially when used in large quantities.

Fish oil can usually be obtained in all the larger cities, and linseed oil can be obtained in all cities and in towns of any size. In small operations, where only a few barrels of the spray are to be applied, raw linseed oil can be substituted for an equal quantity of fish oil.

USE OF FISH OIL WITH BORDEAUX MIXTURE

In spraying to control the gipsy moth, it is sometimes necessary to treat apple orchards, and the question has been asked whether Bordeaux mixture could be added to the lead-arsenate mixture. In order to obtain definite information, a few experiments were conducted, and the results indicate that fish oil is a very efficient adhesive in a Bordeaux and lead-arsenate mixture. In using fish oil with this combination, assuming that the rule is used of adding 4 ounces of fish oil for every pound of lead arsenate or insoluble matter in the mixture, 4 pounds of lead arsenate and 64 ounces or 2 quarts of fish oil would be required in a 6–6–100 Bordeaux mixture. If the quantity of Bordeaux or lead arsenate in the mixture is increased or reduced, the fish oil should be increased or reduced accordingly, the quantity being based on the weight of the solid matter.

On bearing apple trees, if the spraying for the gipsy moth is done at the time of the calyx application or immediately after this period when the fruit is very small, no danger of any arsenical residue on the fruit when harvested would be encountered. It has not been sufficiently demonstrated, however, that it is safe to use fish-oil sprays after the periods mentioned above.

SPRAYING NEAR BUILDINGS

In the control of the gipsy moth or other insects it is sometimes necessary to spray shade or fruit trees in proximity to dwelling houses or other buildings. When this is done, even with the utmost care, some of the material may drift upon buildings, and if allowed to dry would render them unsightly. Spray mixtures containing fish oil as an adhesive can be readily washed from buildings if the latter are drenched with water before the spraying is begun and again sprayed with a garden hose after the spraying with the insecticide is finished. The final water treatment should be applied promptly, while the spray material is still moist, as the oil dries rapidly after the evaporation of the water in the spray material.

CONCLUSION

As a result of experiments conducted over a period of years, it has been decided that for gipsy-moth extermination and general control work the quantity of lead-arsenate powder can safely be reduced from 6¼ pounds to 5 pounds per 100 gallons of water, if fish oil is used as an adhesive. If the spraying is done when the larvae are less than half grown, the proportion of lead arsenate in the mixture can be further reduced, provided fish oil is added as an adhesive.

By the use of fish oil as an adhesive in lead-arsenate mixtures, the spraying season can be somewhat lengthened, as the spraying operations can be started when the foliage is small and good results obtained.

A few experiments have indicated that fish oil is likewise a good adhesive to use with Bordeaux mixture or a combined lead arsenate and Bordeaux mixture.

Fish oil should be added to the spray mixtures at the rate of 4 ounces by weight to each pound of lead-arsenate powder or insoluble matter used. One quart of fish oil weighs approximately 31 ounces.

Warning.—Mixtures containing fish oil not only adhere strongly to the foliage on the trees but also to the undergrowth and vegetation beneath. Under no circumstances should livestock be allowed to graze during the season beneath trees that have been sprayed with such mixtures, as poisoning may result. Even in late September the spray is so abundant on the vegetation beneath the trees that livestock may be poisoned by feeding upon it.

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