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Insecticidal Efficiency of Some Oils of Plant Origin [1]

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INTRODUCTION

Oils may be classified in three groups according to origin—plant, animal, and mineral. Oils of the last type, especially petroleum oils, have found wide utility in insect control, and most of the American investigational work has been done with this class. Although the petroleum oils have been used successfully against a variety of insects on a large number of host plants, the dosages necessary to obtain commercial control have sometimes produced injurious effects on the plants. Attempts to widen the range of usefulness of oil sprays by adding toxicants to the oil have encountered difficulties due to the low solubility of many organic compounds in refined petroleum oils. This experience has emphasized the need as a toxicant carrier of an oil that will be a better solvent than the refined petroleum oils commonly used for foliage sprays. Such a requirement is met by many vegetable oils, some of which are known to possess insecticidal properties, and which might be of value when used alone or in combination with added toxicants.

Snapp and Thomson (*12*)[3] showed that crude cottonseed oil was an effective carrier for paradichlorobenzene in the control of borers (*Conopia pictipes* (G. and R.)) in peach trees. Staniland (*13*) reported that rapeseed oil was a satisfactory insecticide and caused less damage to plants than mineral oil, whereas linseed oil was less efficient. Austin, Jary, and Martin (*1*) found that crude cottonseed oil and crude mustard oil were only slightly inferior to petroleum

[1] These experiments were conducted at Wooster, Ohio, where laboratory and greenhouse facilities were furnished by the Ohio Agricultural Experiment Station.
[2] Resigned October 31, 1939.
[3] Italic numbers in parentheses refer to Literature Cited, p. 15.

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oil in killing eggs of the common green capsid bug *Lygus pabulinus* (L.), but were ineffective against eggs of the apple grain aphid (*Rhopalosiphum prunifoliae* (Fitch)). Balachowsky (*2*) found that peanut oil and rapeseed oil, used as 2-percent emulsions, were equal or superior to lubricating oil against the scale insects *Aspidiotus ostreaeformis* Curt. and *Diaspis leperii* Sign. In tests on the hop powdery mildew (*Sphaerotheca humuli* (DC.) Burr.), Martin and Salmon (*11*) found that various vegetable and animal oils were capable of fungicidal action and that this property was associated with the glyceride structure of the oil.

In all the work mentioned the materials were evaluated on the basis of oil concentration in the applied spray rather than of the amount of oil deposited. Oil deposits, however, are not always completely controlled by the concentration of the diluted spray. The development by Dawsey and Hiley (*8*) of methods for measuring deposits of vegetables oils has made it possible to compare the efficiency of various nonvolatile fatty oils with that of a refined petroleum oil by determining the deposits on the plants. In some of the experiments reported herein equivalent deposits were not obtained, but knowledge of the oil deposits on the plants permitted an estimate of the relative efficiency of the oils being examined.

MATERIALS

Eight oils of plant origin and one petroleum oil, as a standard of comparison, were used in the sprays described in this report. The names and characteristics of all but one of these oils are shown in table 1. For coconut oil, a nondrying oil, constants were not determined, but according to Holde (*10, p. 424*) this oil has an iodine number in the range 8.6 to 9.4.

TABLE 1.—*Constants of oils used in tests for insecticidal efficiency*

Kind of oil	Saybolt viscosity at 100° F.	Index of refraction at 20° C.	Solidification point [1]	Loss due to volatility, 24 hours, 100° F.[2]	Acid value	Saponification number	Iodine value (Hanus)	Specific gravity at 20°/15° C.
Nondrying:	*Seconds*		*° C.*	*Percent*				
Peanut	206	1.4688	0	0.7	2.2	190	83	0.9143
Petroleum [3]	105	1.4669	−2	1.5	0	0	2	.8507
Semidrying:								
Refined corn	261	1.4756	−12	.3	1.1	194	108	.9308
Crude corn	177	1.4735	−11	.9	4.5	192	122	.9285
Refined cottonseed	178	1.4713	0	.9	0	193	110	.9195
Crude cottonseed	170	1.4702	−2	.8	4.0	195	107	.9207
Volatile:								
Pine	55	1.4801	<−50	100.0	.1	6	88	.9397
Orange	29	1.4708	<−50	97.3	.5	5	183	.8462

[1] Determined according to Holde (*10, pp. 36–37*).
[2] Determined according to Dawsey (*6*).
[3] Unsulfonatable residue 94 percent.

Emulsions were prepared with ground bone glue by means of a high-speed drink mixer as described in a previous publication (7). The earlier laboratory applications were made with the sprayer described in the same paper, but applications in December 1936 and in 1937 were made with a larger, though similar, apparatus operated at a pressure of 30 instead of 40 pounds per square inch.

The test insects were the Mexican mealybug (*Phenacoccus gossypii* Towns. and Ckll.), the oystershell scale (*Lepidosaphes ulmi* (L.)), the willow scurfy scale (*Chionaspis salicis-nigrae* (Walsh)), and the fruit tree leaf roller (*Cacoecia argyrospila* (Walk.)).

TESTS WITH MEXICAN MEALYBUGS

Dosage-Mortality Tests

The Mexican mealybugs, which were the principal test insects, were reared on potted chrysanthemum plants in the greenhouse. About 1 week before the spraying tests other chrysanthemum plants, selected for uniformity of age and condition, were cut back to a height of approximately 12 inches and then infested with mealybugs by placing on them leaves and portions of the stems of the infested stock plants. As the introduced leaves and stems dried, the mealybugs moved to the new plants, most of them going to the stem or under surface of the leaves. Bugs on the stem were removed before the spraying, and mortality counts were limited to mealybugs 1 to 2 mm. long on the under surface of the leaves. The insects counted appeared to be largely in the third and early fourth instars, with no first instars or reproducing females.

The methods of spraying were previously described (7). Dosage-mortality tests were made for petroleum oil, peanut oil, crude corn oil, and crude cottonseed oil, deposits on the leaves being taken as the measure of dosage. The original plan was to apply each oil at four concentrations, two to be included in each day's tests, and to apply each concentration twice during the course of the experiments. The two concentrations of each oil for the first applications, on December 22, were selected at random, and the remaining concentrations were applied on January 26. Two concentrations of the sprays were repeated on February 16, the concentrations being selected at random again. The tank of 1 percent petroleum oil applied on this date was not agitated and the results were not used, but results from a test with 2 percent of this oil applied March 10 have been included. In the applications of March 23 some changes were made in the selection of concentrations, as may be seen in table 2, in order to get a better distribution of deposits. Except on March 10, when six plants were sprayed, two infested and two uninfested plants were treated with each application, the uninfested plants being used for measurements of oil deposits. The treated plants were kept in the laboratory on 10-inch tin cake pans, which were banded with sticky tree-banding material to catch the insects that dropped or crawled from the plants. This material had considerable repellent action and few insects were found thereon, but those that did get on were scored as survivors of the spray treatment.

Mortality counts were begun on the fifth day and finished not later than the seventh day after spraying. In most cases 100 mealybugs were counted from leaves selected from different portions of the plant. When less than 100 insects in the desired stage were present, all the insects were counted. Since mortality on unsprayed plants was always less than 2 percent, natural mortality was disregarded in estimating the percentage killed by the sprays.

TABLE 2.—*Dosage-mortality data following applications of oil emulsions to Mexican mealybugs*

Date sprayed	Oil concentration	Oil deposit per square centimeter	Insects counted	Mortality
PETROLEUM OIL				
	Percent	*Micromilliliters*	*Number*	*Percent*
1936				
Dec. 22	1	114	192	40.6
	5	383	196	90.3
1937				
Jan. 26	3	300	200	95.5
	7	587	200	95.5
Feb. 16	7	601	200	93.5
Mar. 10	2	128	300	42.3
Mar. 23	2	184	200	48.5
	3	254	200	56.5
	7	481	200	89.0
PEANUT OIL				
1936				
Dec. 22	1	81	200	12.5
	5	343	200	88.0
1937				
Jan. 26	3	213	200	90.5
	7	468	200	95.5
Feb. 16	3	237	182	91.8
	5	356	156	99.4
Mar. 23	2	269	200	82.0
	7	720	[1] 100	100.0
CRUDE CORN OIL				
1936				
Dec. 22	1	168	200	36.5
	3	346	200	93.0
1937				
Jan. 26	2	270	200	90.5
	5	591	200	100.0
Feb. 16	1	170	200	84.5
	5	617	200	100.0
Mar. 23	.75	137	192	39.6
	3	393	188	95.7
CRUDE COTTONSEED OIL				
1936				
Dec. 22	2	156	185	37.8
	3	200	177	74.0
1937				
Jan. 26	5	270	200	95.5
	7	483	173	97.7
Feb. 16	5	411	200	98.5
	7	573	200	99.5
Mar. 23	2	114	196	52.6
	3	309	200	81.5

[1] 1 plant lost.

Oil deposits were determined according to the method described by Dawsey and Hiley (*8*). Subsequent work has shown that part of the petroleum oil was volatilized during the drying process used in this method. Accordingly, the loss from volatilization of known quantities of oil was determined and the proper correction applied to the residues originally recovered. The size of the correction ranged from 23 percent when the deposit was 78 μml. per square centimeter to 4 percent when the deposit was 601 μml. per square centimeter.

The data are give in table 2.

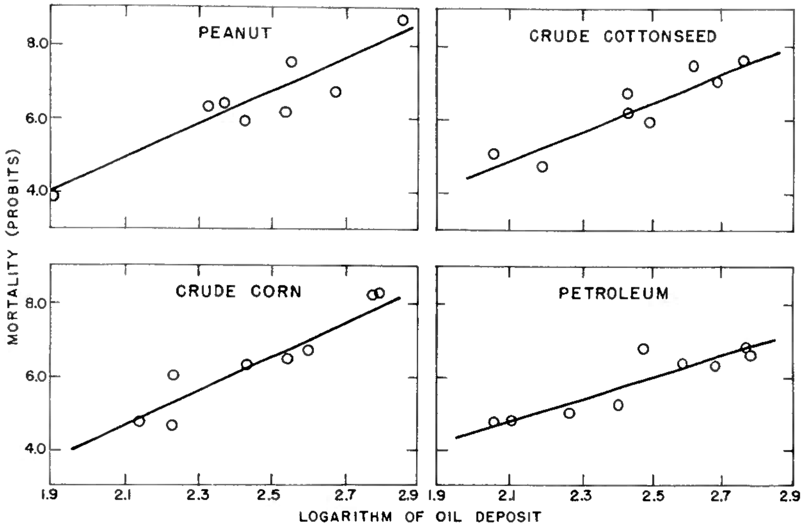

FIGURE 1.—Dosage-mortality curves for peanut, crude cottonseed, crude corn, and petroleum oils in tests with Mexican mealybugs.

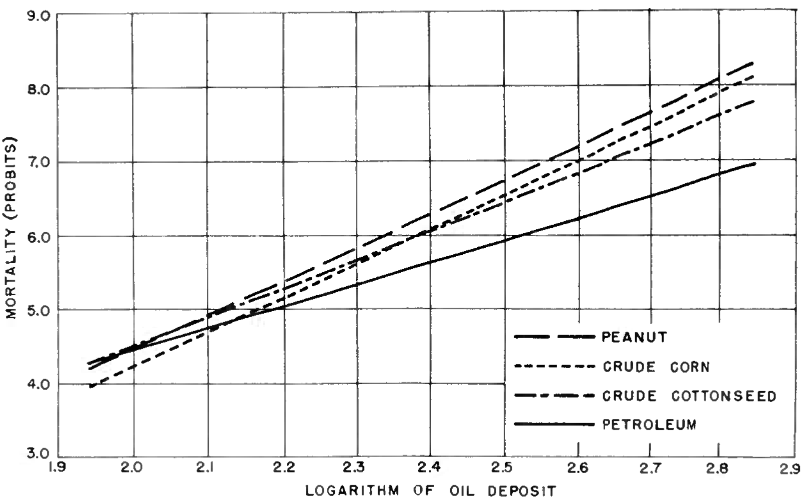

FIGURE 2.—Curves of figure 1 shown in one graph to illustrate relative positions.

The analysis of these results follows the methods developed by Bliss (*3*, *4*). The percentages of insects killed were converted to probits, which were plotted against the logarithms of the oil deposits. The curves are shown in figures 1 and 2, and their important constants in table 3.

TABLE 3.—*Constants describing dosage-mortality curves shown in figure 1*

Oil	Mean mortality	Mean logarithm of oil deposit	Regression coefficient	V_a	V_b	χ^2	n
	Probits						
Petroleum	5.48	2.35	2.87	0.0185	0.3154	110	7
Peanut	5.82	2.31	4.49	.0336	.6885	64	5
Crude corn	5.56	2.29	4.62	.0463	1.8864	122	5
Crude cottonseed	5.64	2.30	3.82	.0347	.9872	90	5
All 3 vegetable oils	5.66	2.30	4.29	.0107	.3067	290	19

In every case the value of χ^2 was greater than would be expected for homogeneous data. Bliss (*4*) has pointed out, however, that in experiments extending over a period of time in an uncontrolled environment agreement with χ^2 cannot be expected. Such a condition does not vitiate the results but reduces their precision. There was no significant difference in the position of the lines, nor was the difference in slope significant when any two oils were compared. The curves for the vegetable oils all had steeper slopes than the curve for petroleum oil, intersecting the latter below the 50-percent mortality point (5 probits). If a composite curve for all the vegetable oils, the constants of which are shown in the last line of table 3, is compared with that for the petroleum oil, it is found that the difference is significant. The data show that the vegetable oils were at least as effective as the petroleum oil in the regions of higher kill, and possibly more so.

There was considerable variation in the deposits obtained with the same concentration of the same oil, especially peanut and crude cottonseed oils (table 2). The deposits of crude corn oil were uniformly higher than those from the same concentrations of the other oils, with the exception of the 2-percent application of peanut oil on March 23. Comparison of the deposit-concentration curves (omitting the last two peanut-oil applications) indicated that corn-oil deposits were about 80 percent higher than the others at 2-percent concentration, and over 60 percent higher at 5-percent. No large differences between peanut oil, crude cottonseed oil, and petroleum oil were found. If comparisons of control had been made on the basis of oil concentration applied, a marked superiority of the crude corn oil would have been indicated, which would be erroneous. In other experiments crude corn oil at 2.5 and 3 percent has given more than twice the deposit given by petroleum oil. Whether similar deposit-concentration relations will hold with other emulsifiers has not been determined.

OTHER TESTS

Less extensive tests on mealybugs were made with refined corn, refined cottonseed, orange, pine, and coconut oils. Because of the high melting point of coconut oil, it was combined in the proportion of 30 parts to 70 parts of petroleum oil. The mealybugs were reared and sprayed in the same manner as in the dosage-mortality tests, except that insects on the stems were not removed before treatment. Deposit-mortality curves for these oils were not determined, but deposits of each oil were measured, and with most applications a spray of the same concentration of petroleum oil was included for comparison.

The nonreproducing insects were divided into three classes according to length—less than 0.75, 0.75 to 1.50, and more than 1.50 mm. Reproducing females were disregarded because of their variable natural mortality. The materials were rated on the basis of their effect upon the two classes over 0.75 mm. long on stems and leaves. Movements of survivors following application invalidated any distinction as to mortality on different parts of the plants. Since there were large differences in the susceptibility of insects of different sizes, approximately equal numbers of each size were counted and the mortalities of both classes were then averaged. Inasmuch as insects on the stems were included in these counts and the age distribution differed from that of the previous tests, the results are not directly comparable. The same petroleum oil was used in both series, however, and all spray materials may be compared with this standard oil. Because of the effect of differences in environmental conditions and in the average density of infestation from time to time, comparisons were limited to sprays applied on the same day. The data are summarized in table 4.

TABLE 4.—*Mortality of Mexican mealybugs sprayed mith various vegetable-oil emulsions*[1] *as compared with mortality due to petroleum sprays*

Date sprayed	Oil concentration	Kind of oil	Oil deposit per square centimeter	Insects counted	Average mortality
1935	*Percent*		*Micromilliliters*	*Number*	*Percent*
Aug. 15	4	Orange		1,496	25
Oct. 3	1	Pine		[2] 521	1
17	3	Petroleum	264	2,054	63
		Refined corn	261	2,039	50
		Refined cottonseed	243	1,805	48
Nov. 5	2	Petroleum	230	1,272	48
		Peanut	154	1,994	47
		Refined cottonseed	153	1,877	39
30	3	Petroleum	264	1,970	54
		Peanut	238	1,708	63
1936					
Aug. 20	2.5	Petroleum	213	1,580	63
		Refined corn	198	1,810	41
Oct. 1	2	Petroleum	133	1,794	60
		Refined cottonseed + cottonseed fatty acid:			
		Acid value 2.2	141	1,934	50
		Acid value 4.5	155	1,996	50
1937					
Mar. 10	2	Petroleum	128	305	42
		Petroleum 70 percent + coconut 30 percent	114	255	28

[1] 5 plants were sprayed in each application except those of August 15, when 4 plants were sprayed, and March 10, when 3 plants were sprayed with each oil.
[2] Mealybugs on only 2 plants were counted. Inspection of others showed that no scales had been killed by this spray.

Refined corn oil at 2.5 and 3 percent was less effective than the petroleum oil at the same percentages. At a concentration of 2 percent the difference between refined cottonseed and the petroleum oil was not significant, but at 3 percent the difference in favor of the petroleum oil was significant. Peanut oil gave about the same kill as the petroleum at 2 percent, but was more effective at 3 percent. The addition of free cottonseed fatty acids to the refined cottonseed oil did not increase its effectiveness. The combination of coconut and petroleum oils gave significantly smaller oil deposits and killed fewer mealybugs than the same concentration of petroleum oil alone.

Orange oil, applied at a concentration of 4 percent, killed only 25 percent of the mealybugs sprayed and caused severe damage to the foliage. Its ineffectiveness may be due to rapid volatilization, as indicated in table 1. Further data on the rate of evaporation were obtained by tests in which paraffin-covered plates were sprayed with the pure oil. Applications were made with a hand atomizer, and the spraying was stopped before any drip occurred. The plates were kept at room temperature and weighings were made at intervals after spraying. More than 86 percent of the original deposit evaporated in the first half hour.

Pine oil also was rather volatile. Sprays containing 1 percent of oil caused no measurable mortality of mealybugs but severely burned chrysanthemum plants. However, other laboratory experiments confirmed the findings of Headlee (*9*) that pine oil is effective against hibernating codling moth larvae. Pine-oil and orange-oil deposits on foliage could not be measured, because the rapid rates of evaporation prevented application of the chemical methods.

TESTS WITH THE WILLOW SCURFY SCALE

Willow twigs bearing overwintered eggs of the willow scurfy scale were collected in the field in January and March 1936 and placed in cold storage. The following summer they were cut into sections about 20 inches long and rooted in pots of moist sand, five or six twigs to a pot. The twigs were given nutrient solutions at intervals until the nymphs hatching from the overwintered eggs reached maturity. On September 16 some of the twigs were placed on a turntable and sprayed for 1 minute with 3-percent emulsions of petroleum, refined corn oil, and crude corn oil, and then placed in a greenhouse until mortality counts were made 2 to 3 weeks later. Unsprayed twigs were used for estimation of natural mortality.

Since removal of leaves for oil-deposit analysis might have impaired the condition of the infested twigs, freshly cut twigs bearing enough foliage to furnish an adequate sample for oil analysis were put in pots of sand and sprayed in the same manner as the infested twigs. Average deposits of 78, 87, and 145 μml. of the respective oils were obtained.

Nearly all the living scales had begun to deposit eggs at the time of spraying, and mortality counts were limited to scales with eggs present, although all scales were considered in estimating population density. On the basis of such criteria as parasitization, dryness of the body, and presence of fungus or mites, it was judged that certain scales that had deposited eggs had died previous to the treatment, and these were also disregarded in mortality estimates. After all such scales had been separately classified, there remained a natural mortality of 2.8 percent in the scales on the unsprayed twigs. The data from the sprayed twigs were corrected accordingly to determine the percentage of scales killed by the spray.

Population density was measured in a manner similar to that described for the camphor scale (*5*). The number of scales on each centimeter length of twig was recorded, and dead and living scales for each population-density interval of 10 scales per square centimeter were then totaled. The average scale area was determined from camera-lucida drawings of samples of sprayed scales, and the number of scales per square centimeter was converted to proportion of twig area covered by scales. As in the camphor scale experiments, the proportion of living scales increased at the higher levels of infestation in spite of the fact that there was very little overlapping of scales until about 90 percent of the twig area was covered. The effect is probably general among the diaspine scales, and is probably due to oil from the surrounding surface being drawn beneath the scale covering by capillary action. Consequently scales begin to "compete" for the same oil long before there is any overlapping or even touching of covers.

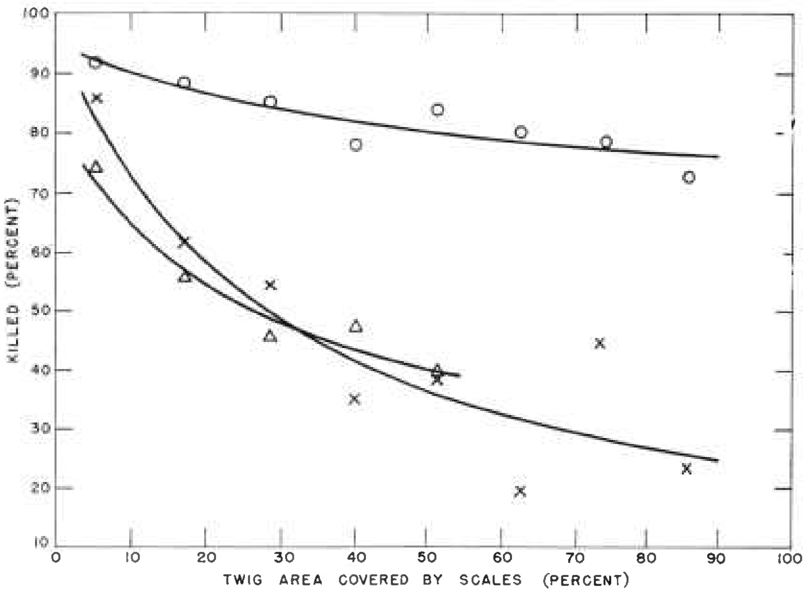

FIGURE 3.—Mortality of the willow scurfy scale caused by applications of crude corn oil (circles), petroleum oil (crosses), and refined corn oil (triangles).

Since the percentage of survival increased with the density of infestation, the dosage per scale was assumed to be inversely proportional to a function of the population density. Mortality in probits was therefore plotted against the logarithm of the reciprocal of the proportion of twig area covered by scales. The values for each oil could be fitted by a straight line up to the point where about 91 percent of the twig area was covered by scales. Beyond this point the results became erratic, probably because of the protective action of overlapping scales. The values of χ^2 for the two corn-oil sprays indicated homogeneous data ($P = 0.5$), but χ^2 for the petroleum oil was above expectation.

The regression lines as so calculated are not measures of toxicity in the same way as are the previous mortality curves, since the mortality has been plotted against the logarithm of a function of the dosage rather than the logarithm of the dosage itself, and the constants of this function may differ for the different oils. For example, if the dosage were equal to $1/KX^n$, where X is the population density and K and n are constants, a straight line would be obtained if the mortality were plotted against the logarithm of $1/X$, as was done here, and different values of K and n would lead to different positions and slopes of the curves. The probit transformation as here used, however, is a convenient way of transforming the data to permit fitting by straight lines. The values have been converted back to percentages killed, and a graphic comparison of the results is made in figure 3.

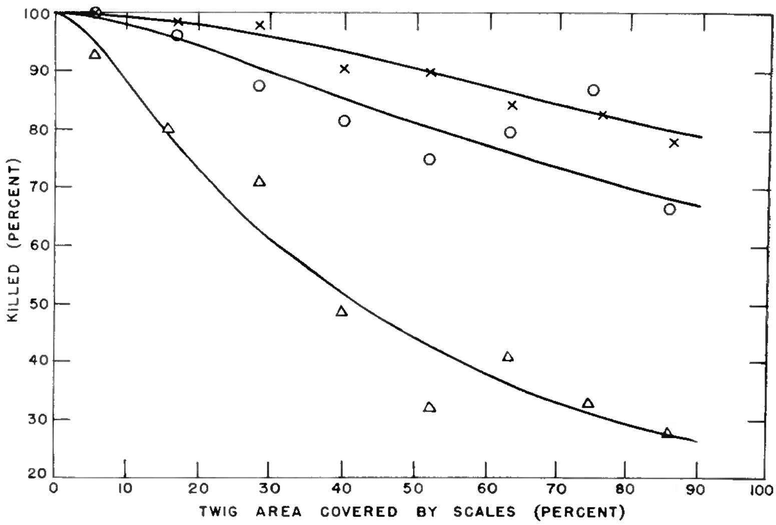

FIGURE 4.—Mortality of the oystershell scale caused by applications of crude corn oil (circles), petroleum oil (crosses), and refined corn oil (triangles).

In spite of a somewhat heavier deposit from the refined corn oil, there were no significant differences between the mortality from this oil and that from the petroleum oil. The deposit from crude corn oil was more than twice that from the petroleum oil, and this oil consistently gave a higher mortality than the other two oils. There were no significant differences in the slopes of the curves.

TESTS WITH THE OYSTERSHELL SCALE

Willow trees infested with the one-generation form of the oystershell scale were sprayed in the field on August 13, 1936, with 1.75 percent of petroleum, refined corn oil, and crude corn oil, applications being made with a small power sprayer operated at a pressure of 300 pounds per square inch. Most of these scales had begun to deposit their overwintering eggs, and mortality records were limited to such scales. An appreciable natural mortality occurred between the time of application and the completion of the counts. This mortality was marked by the presence of dead scales and eggs that had a brownish color but a drier appearance than those killed by oil, and was most noticeable on heavily infested succulent twigs. Such scales, as well as those attacked by parasites or fungus diseases and the spent scales of the older broods, were recorded separately to be used in calculation of the population density. A natural mortality of 5.3 percent in the remaining scales was indicated by examination of unsprayed twigs. Curves were fitted as in the scurfy scale experiments and are shown in figure 4.

Differences in the slopes of the curves were not significant, but crude corn oil gave a higher kill than the petroleum at equivalent population densities, and refined corn oil was the least effective. Oil deposits were not measured, but, judging from the results of other experiments reported herein, crude corn oil probably gave a heavier deposit than the other oils.

OVICIDAL EFFECTS

Willow twigs infested with the willow scurfy scale were collected in the field March 28, 1936. They were cut into sections, inserted into pots of moist sand, and sprayed in the same manner as previously described for willow twigs. Sprays containing 4 percent of petroleum, refined corn, crude corn, refined cottonseed, and peanut oils were applied on March 30 and April 4, 15 twigs being treated with each material. At this time overwintering eggs were found between the dorsal and the lighter, but definite, ventral covering, the body of the dead female being pushed forward to one end of the scale. Fifty scales on each twig were examined 2 to 3 weeks later. Since it was impracticable to determine the number of eggs that hatched, scales were classified according to whether crawlers had been able to emerge from or settle beneath the scale coverings. Death might have occurred, therefore, either in the egg stage or immediately after hatching. There was usually no doubt as to the class in which the scales should be placed, but in cases of doubt the relative abundance of eggshells and dead crawlers and the presence or absence of newly settled nymphs just outside the scale were considered. Twigs of equal degree of infestation were selected to eliminate the need for consideration of the population-density effect.

The following percentages of scales with all eggs and crawlers dead resulted from treatment with the various oils: Petroleum 73.1, peanut 51.3, crude corn 19.7, refined cottonseed 9.6, and refined corn 3.7. From a total of 2,721 scales on unsprayed twigs only 2.6 percent had all eggs and crawlers dead.

Records made in this manner do not show the true mortality, since many scales were classified as showing successful emergence even though the treatment had killed an appreciable number of eggs and crawlers beneath such scales. Nevertheless, a relative ranking of the materials was made. None of the vegetable oils was as effective as the petroleum oil. Peanut oil was the most effective of the vegetable oils, but the difference between petroleum and peanut oil was clearly significant ($P<0.01$).

There was a high correlation between the effectiveness of the oils and their drying property as measured by the iodine number. Corn and cottonseed oils, which were semidrying, were least effective in preventing emergence, and hardened sufficiently to permit large numbers of crawlers to move over the twigs and settle. Peanut oil was more effective in preventing settling, but not quite so much so as the petroleum oil. Mortality of the crawlers that emerged on the twigs sprayed with petroleum oil was nearly 100 percent.

Oil deposits were not measured in these tests owing to the absence of foliage, but previous experiments with similar sprays indicated that comparable deposits were obtained for at least the emulsions of petroleum, peanut, cottonseed, and refined corn oils. If crude corn-oil spray gave a heavier deposit, it was not sufficient to cause any great increase in mortality over that from the two other semidrying vegetable oils.

The effects of petroleum and refined corn oil were also compared on overwintering eggs of the fruit tree leaf roller on apple twigs collected in the vicinity of Sturgeon Bay, Wis.[4] The eggs were handled in the same manner as those of the willow scurfy scale. Mortalities of 74.8 and 19.2 percent of the viable eggs treated with these two materials again indicated a marked superiority of the petroleum oil in ovicidal properties.

From the standpoint of ovicidal action in these tests, it appears that the best oils were those with the lowest iodine values as listed in table 1.

PHYTOCIDAL EFFECTS

Plant-susceptibility tests were carried on in which uninfested plants were sprayed and kept under observation in the greenhouse. Three chrysanthemum plants each were sprayed with petroleum, crude corn, crude cottonseed, and peanut oils on December 22, 1936. Three weeks later oil injury characterized by brown spots on the leaves had appeared on all the plants treated with 5 percent of peanut oil and on one plant sprayed with 3 percent of corn oil. Oil deposits were 343 and 346 μml. per square centimeter, respectively. The other plants were not injured. Additional plants for observation of spray injury were included in the January 26, 1937, sprays. These plants had been dusted with sulfur about 3 weeks previously. On February 9 all plants showed brown spots on the leaves, as well as marginal and tip burning. Leaves that had opened since treatment were distorted and crinkled. It was evident that severe injury had been caused by the combination of oil and sulfur residue. The effect seemed to be independent of the amount of oil deposit or of the kind of oil.

Since cabbage plants are generally susceptible to the unsaturated components of oils, four potted cabbage plants were treated with each material applied March 23, 1937 (table 2). Three weeks later these materials ranked in the following order of increasing injury, the sprays grouped together producing equal effects:

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[4] Collected by H. W. Bingham

Kind of oil:	Oil concentration (percent)
Crude corn	0.75
Petroleum	2
Petroleum	5
Peanut	2
Petroleum	7
Crude cottonseed	2
Do	3
Peanut	7
Crude corn	3

The greatest injury resulted from the 3-percent concentration of crude corn oil. All the leaves on the plants sprayed with this material either dropped or showed severe burning. Two and 3 percent of crude cottonseed oil caused about as much injury as 7 percent of petroleum and peanut oil.

Since coleus is also susceptible to the unsaturated compounds, young coleus plants were included in the tests of December 22, 1936, and January 26 and March 23, 1937 (table 2). Records on leaf abscission were kept in the hope of obtaining a quantitative expression of plant injury, but the results from one series to another were so inconsistent that no conclusions could be reached.

Following the field applications of petroleum, refined corn, and crude corn oils to willow, an appreciable number of leaves dropped from all the heavily infested twigs, but no abnormal leaf drop took place on vigorous branches.

The response of different plants to these materials, and even of the same plants from one time to another, was so variable that the question of their safety would have to be decided on the same plants and under the same conditions that would apply in the use of the sprays in commercial practice.

POSSIBLE INSECTICIDAL USES OF THE VEGETABLE OILS

In the foregoing experiments the crude vegetable oils were at least as effective as a refined petroleum oil when tested against the active stages of several insects. The refined vegetable oils, however, were not so effective as the petroleum oil. Vegetable oils are generally more expensive than petroleum oil and hence would have to be superior to petroleum oil in other respects to justify their use. One advantage lies in their greater solvent action on organic insecticides. Since the use of toxicants in oils is under investigation at the present time, this property might be of value. Emulsions of crude corn oil prepared with ground glue have consistently given heavier deposits than petroleum-oil emulsions of equivalent oil content. If this relation holds for emulsions prepared in other ways, the increased oil deposit may compensate for the greater cost of the eorn oil.

The vegetable oils were inferior to the petroleum oil in ovicidal action, and their tendency to dry in a hard film would shorten the period of effectiveness of the oil residue. This is a serious disadvantage in treatments for scale insects made during periods of reproduction and emergence of young, but it might be overcome by the addition of antioxidants.

The plant reactions should be thoroughly investigated before the vegetable oils are used on an extensive scale.

From these considerations the most promising use of the vegetable oils appears to be in combination with toxic materials that it is desired to dissolve in the oil phase. In this way advantage is taken of the insecticidal action of the toxicant and the oil, as well as of the wetting and penetrating properties of the oil which promote contact between the toxicant and the insect.

SUMMARY

The insecticidal efficiencies of a number of oils of plant origin have been compared with that of a refined petroleum oil. Emulsions were prepared by mixing these oils with ground bone glue in a high-speed drink mixer.

Mexican mealybugs reared on potted chrysanthemum plants in the greenhouse were sprayed in the laboratory. Mature females and eggs of the willow scurfy scale on willow twigs and fruit tree leaf roller eggs on apple twigs were collected in the field and brought to the laboratory for treatment. Adult females of the oystershell scale on willow were sprayed in the field with a power sprayer.

Crude corn oil was equal or superior to the petroleum oil in tests on Mexican mealybugs in which dosage-mortality curves were determined and comparisons made on the basis of equivalent oil deposits. In tests with adult females of the willow scurfy scale and the oystershell scale, crude corn oil gave a higher kill and heavier oil deposits than equivalent concentrations of the petroleum oil. Oil deposits of crude corn oil from sprays against the willow scurfy scale were more than twice those obtained from petroleum oil.

Crude cottonseed and peanut oils were equal or superior to a petroleum oil in tests on Mexican mealybugs.

Refined corn oil was less effective than the petroleum oil in sprays applied to the Mexican mealybug and the oystershell scale.

In the tests with the oystershell scale and willow scurfy scale the percentage of survival increased with the density of infestation.

Refined cottonseed oil was not so effective as the petroleum oil against mealybugs. The addition of cottonseed fatty acid did not increase the toxicity.

A mixture of coconut oil and petroleum oil gave smaller oil deposits and killed fewer mealybugs than an equivalent concentration of petroleum oil.

Orange oil and pine oil had little effect upon mealybugs and severely injured chrysanthemum plants. These oils were so volatile that the initial spray deposits were soon lost.

Tests on eggs of the willow scurfy scale and fruit tree leaf roller indicated that the ovicidal effects of the oils used were closely correlated with their drying properties. Peanut oil, a nondrying oil, was superior to the other vegetable oils but less effective than the petroleum oil. Crude corn, refined corn, and refined cottonseed, all semidrying oils, were relatively ineffective.

Deposits of crude corn oil ranged from 60 to more than 100 percent higher than those obtained from equivalent concentrations of the other oils. In most cases there was little difference in deposits of petroleum, peanut, refined corn, refined cottonseed, and crude cottonseed oils.

Results of plant-injury tests were so variable that it was concluded that plant tolerance to the different oils would have to be determined on the same plants and under the conditions prevailing when these materials are used in practice.

Although vegetable oils are generally higher priced than petroleum oil, they possess superior solvent action for certain organic insecticides, and may find new uses because of this property.

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