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MISCIBLE OIL VERSUS FISH OIL SOAP SPRAYS FOR THE CONTROL OF FLORIDA ALEYRODIDS¹

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Since the Division of Tropical and Subtropical Insect Investigations began its study of the Aleyrodid pests of *Citrus* in Florida in 1906, spraying experiments have been carried on more or less continuously, although for the first three years they were made secondary to problems associated with the biology of the pests (1) and their control by natural agencies (2) and fumigation (3, 4). Yet, in spite of the disconnected character of the work, a relatively large amount of data were secured either by, or under the direction of, Dr. A. W. Morrill, who was, until August, 1909, in field charge at Orlando. The work during this period definitely determined the relative value of the various home-made and the proprietary spray materials then on the market and gave data which proved beyond question the superiority of certain miscible oil sprays and standard brands of fish oil soap (5). The miscible oils tested, however, were rather expensive and, being of a proprietary nature, could not be recommended unreservedly. The development, therefore, during the past few years, by Mr. W. W. Yothers of the Bureau, of home-made miscible oil sprays, that are cheap, dependable and easily made, has been of great practical value to the citrus industry, and the enthusiasm with which his various formulæ and his spraying schedule for the control of Aleyrodid, rust mite and scale insect pests have been accepted by the leading citrus growers of Florida is evidenced by the rising vote of thanks given Mr. Yothers by the members of the Florida Horticultural Society at their 1915 meeting held at Tampa.

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Data proving the effectiveness of these home-made miscible oils have already been published by Messrs. Yothers and Crossman (6 to 9) and have been corroborated, if corroboration were necessary, by the senior writer during February and March, 1912, when he had temporarily resumed field charge of the investigations, and was assisted by Messrs. Wooldridge, Strickland and Rutherford. The data secured at this time merely emphasized the dependableness of Mr. Yother's formulæ, and various modifications of them. Sprays containing from $\frac{1}{4}$ per cent to 3 per cent oil were used without injury to foliage. It was rather surprising to find that sprays containing $\frac{1}{4}$ per cent and $\frac{1}{2}$ per cent of oil, made according to Formula IV of Mr. Yothers (7) were very effective, and it seemed probable that strengths less than the 1 per cent of oil recommended might be used profitably, particularly during the summer. Thus on 55 leaves picked from trees sprayed on February 27 with $\frac{1}{4}$ per cent oil and known to have been hit by the spray, 98.4 per cent of 5,040 pupæ were killed; while from two collections of leaves picked promiscuously from the trees which were sprayed at the same time and with the same strength of oil, 98.1 per cent of 1,972 pupæ found on 41 leaves and 98.7 per cent of 6,897 pupæ on 100 leaves were killed.

The purpose of this article is not so much to call attention to the effectiveness of home-made miscible oil sprays recommended by the Bureau, as it is to present certain data secured by the writers during the summer of 1910 which form a basis for comparison between these sprays and those made of fish oil soap. The results are based upon work with a proprietary miscible oil then on the market and a good fish oil soap. An analysis of the miscible oil made by the federal Bureau of Chemistry at the request of Mr. C. L. Marlatt, in charge of the Florida investigations, proved it to be practically the same as the home-made emulsions recommended later by Mr. Yothers. The analysis is as follows: specific gravity at 20° C., 0.9123; unsaponifiable oils (mineral oils), 63.24 per cent; fatty acids (from soap), 5.61 per cent; sodium oxid (Na_2O), 0.63 per cent; water and undetermined, 30.52 per cent; rosin oil not present.

So far as the writers are aware, no data have been published on the effect of summer showers upon the efficiency of insecticides in Florida. During the summer of 1910 a large amount of such data were secured which, in a greatly abridged form, is presented in Table I.

The complete data are on file. Each percentage recorded in Table I is an average of from three to seventeen similar averages, each in turn based upon an examination of over a thousand larvæ and pupæ. At least 210,000 larvæ and pupæ were examined.

The data indicate that the miscible oil sprays are scarcely affected

TABLE I.—EFFECT OF SUMMER SHOWERS UPON THE EFFECTIVENESS OF MISCIBLE OIL AND SOAP SPRAYS

Miscible Oil, Strength	Period of Time between Application of Spray and First Showers	Percentage of Larvæ and Pupæ Killed	Fish Oil Soap Strength	Period of Time between Application of Spray and First Showers	Percentage of Larvæ and Pupæ Killed
1½%	35 min. to 30 hours	98.2	16 lbs. to 50 gals. water	35 min. to 5 hours	90.2
	5 to 30 hours	98.6		5 to 10 hours	92.6
	30 to 34 hours	98.8		24 to 30 hours	96.2
	99 hours	99.3		99 hours	97.4
1¼%	1 min. to 5 hours	95.3	14 lbs. to 50 gals. water	1 min. to 5 hours	81.7
	5 to 34 hours	96.9		5 to 10 hours	82.5
	99 hours	99.5		27 to 32 hours	85.2
				99 hours	97.0
1%	35 min. to 5 hours	92.0	12 lbs. to 50 gals. water	35 min. to 5 hours	72.8
	5 to 10 hours	92.5		5 to 10 hours	73.7
	24 to 34 hours	93.2		27 to 32 hours	74.4
				99 hours	97.6
			8 lbs. to 50 gals. water	1 min. to 2 hours	68.6
				99 hours	96.2
			5 lbs. to 50 gals. water	2 hours	71.8
				99 hours	79.8 ¹
				No rain (spring)	96.3 ²

¹ Larvæ in third and pupal stages, and therefore more resistant to this strength.² Larvæ in first and second stages.

by showers, except when these fall almost immediately after application. Detailed data show that summer showers falling after the oil spray has once had an opportunity to dry on the foliage, have very little effect upon the efficiency of the spray. Since the leaves gathered for the examination of the Aleyrodids were picked promiscuously, one must be prepared for slight unexpected variations in the percentages of forms killed. The main point to be emphasized is the greater weakening effect showers have upon the different strengths of soap spray than upon those of the oil spray. Thus showers, falling about 30 minutes after the oil spray had been applied, had little effect upon the percentage of forms killed, while they had a very evident effect upon that killed by the soap spray. The weaker strengths of fish oil soap were much more influenced by showers than the weaker strengths of the oil spray.

Miscible oil sprays appear to have a second advantage over soap sprays in that aside from being more resistant to showers, they are operative over a longer period of time after application, even when

no showers fall. Foliage sprayed with miscible oils remained slightly oily both in appearance and to the touch for several weeks after the sprays had been applied. Fish oil soap leaves no such evidence that the trees had been sprayed. In experimental work on a large scale, it became quite evident that the miscible oil sprays used were giving better results than the soap sprays. An examination into the subject proved that the greater efficiency of the oil spray seemed not to be due to a higher percentage killed of the larvæ and pupæ on the leaves when the spray was applied at the proper strength, but to the effect these insecticides had upon unhatched eggs or the young larvæ hatching therefrom within ten days to two weeks after application. The data in Table II represent the condition of the white flies in adjoining rows of the same badly infested grove during the summer of 1910.

TABLE II.—REINFESTATION OF FOLIAGE FOLLOWING USE OF MISCIBLE OIL AND SOAP SPRAYS

Insecticide	Percentage of Larvæ and Pupæ Killed	Total Number of Larvæ and Pupæ Counted	Total number of Leaves Examined	Total Number of Leaves Counted to Determine Reinfestation	Average Number per Leaf of 1st and 2nd Instar Larvæ Hatching after Spraying
Miscible oil 1½%	98.3	20389	170	170	0.9
Miscible oil 1½%	98.0	72270	995	995	1.4
Miscible oil 1%	95.7	28077	500	165	2.0
Miscible oil ½%	92.5	21344	170	170	2.1
Fish oil soap:					
16 lbs. to 50 gals. water	92.8	27712	225	225	8.2
14 lbs. to 50 gals. water	84.5	74642	705	398	12.7
12 lbs. to 50 gals. water	74.5	36103	350	211	10.9
8 lbs. to 50 gals. water	71.7	8247	400	125	24.2

The examinations upon which the data of Table II are based, were made between two and three weeks after the application of the spray. At all times during the summer months adults of both *Dialeurodes citri* and *D. citrifolii* are more or less abundant and depositing eggs. At times of summer spraying there are comparatively few leaves on infested trees, especially those infested by *citri*, that do not bear unhatched eggs in varying numbers. Those in touch with the white fly problems appreciate the fact that no matter how effective an insecticide may be in killing larvæ and pupæ on the leaves at the time the spray is applied, if it does not either kill these unhatched eggs or is operative long enough to kill larvæ that subsequently hatch, much of the benefit of the spraying is counterbalanced by the reinfestation thus brought about. In one grove in which 95 per cent of the larvæ and pupæ were killed by fish oil soap, a sufficiently large number of larvæ hatched after the spray was applied to cause a blackening of the

foliage within a comparatively short time. In a second grove sprayed with the miscible oil mentioned above, an equally large number of insects were killed, but the grove remained clean, *i. e.*, free from sooty mold on the leaves and fruit, for a very much longer time. Two neighboring groves sprayed during late April when the Aleyrodids (*citri* and *citrifolii*) were mostly in the early larval stages, one with the miscible oil used at the strength of $1\frac{3}{4}$ per cent oil, and the other with fish oil soap, 5 and 8 pounds to 50 gallons of water, perhaps emphasizes the importance of the point in question more than any large scale work undertaken by the writers. Both groves were sprayed by the writers and Mr. W. W. Yothers with equal thoroughness and with the aid of a power outfit. Results secured about ten days after spraying showed that the fish oil soap at 5 pounds to 50 gallons had killed as many insects as the miscible oil, and it was regretted that fish oil soap had not been used on both groves on account of the saving in the cost of insecticide. However, the grove sprayed with fish oil soap began to blacken and by July required a second spraying and needed a third by October to keep the fruit free from sooty mould. On the other hand, the grove sprayed with the miscible oil remained clean throughout the summer and was blackening in October only in places.

It is unfortunate that the percentage of larvæ and pupæ killed by the oil and soap sprays, given in Table II, are not more alike as there may be those who will think the much larger average number per leaf of living first and second instar larvæ, found on the leaves two to three weeks after spraying, is the direct result of the comparatively small number of forms killed by the fish oil soap at the time of application. It is possible, and more than probable, that in any grove so heavily infested, even if practically all the forms had been killed by the sprays at time of application, a certain amount of reinfestation from without would occur as migrating adults are quite active and may begin ovipositing within a day after emergence. However, the rows of trees sprayed with both oil and soap sprays were equally subject to reinfestation. No examinations for the first and second instar living larvæ were made until two to three weeks after the spraying in order to give the insects in these instars when the spray was applied, and that escaped the action of the spray, an opportunity to develop into third instar larvæ. Studies of the biology of *citri* (1) have proved that during the summer months the egg stage averages 10–12 days; the first larval, 7.2 days; and the second larval, 5.4 days. The corresponding instars of *citrifolii* are a trifle longer. These facts make it certain that the first and second instar larvæ recorded as living are those which hatched from the eggs present on the foliage when it was sprayed, or from a relatively small number of eggs deposited after spraying.

It cannot be stated whether the oil spray killed a larger percentage of the eggs than the soap spray as the eggs themselves were not examined at the time of spraying, and the newly hatched larvæ which would naturally feel most the hold-over effect of the spray are quite apt to fall from the leaf if they succumb before they have settled to feed. As the spraying was done by the writers themselves with the aid of a power outfit, on the same days and after much experience in manipulating a spraying outfit, it is unlikely that the oil and soap sprays were applied with such differences of thoroughness as to account for the marked differences in effectiveness recorded in Table II. As each strength of insecticide used in the work of Table II is known to be effective from a killing standpoint if brought in contact with each insect and permitted to act unmolested by rains, with the exception of the weakest strength of fish oil soap when used against mature larvæ and pupæ, the writers are of the opinion that the differences in the general effectiveness of the oil and soap sprays used were due partly to the weakening effect of showers, and, in the case of the miscible oil, to the hold-over effect of the insecticide upon the eggs or the larvæ hatching from eggs during at least a ten-day period after spraying.

Incomplete as are the data presented in this paper, they indicate an advantage that miscible oil sprays have over fish oil soap sprays which is of a most practical, though subtle, nature. When growers of *Citrus* appreciate that it is much more profitable, and not more expensive, to spray their groves when the average number of Aleyrodids per leaf is small, rather than large, as is now the custom, this advantage will be even more valuable in postponing future blackening of the trees and fruit by the sooty mould.

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