prevent hitch-hiking fruit flies. Careful inspection and treatment of products moving to the Mainland are required. California has been carrying on a trapping program in order that if the fly should find its way there the infestation would be discovered while still in the incipient stage. The results of this trapping program have thus far been negative in California.

Plant quarantine policies and procedures have been undergoing rather frequent and rapid changes. Progress in the development of insecticides, additional information as to the distribution and abundance of plant pests, and the possibility of long-distance dissemination all have contributed to this situation. In this country the State plant quarantine officials, by working together, have made notable progress in simplifying, coordinating, and streamlining the State quarantines and procedures which affect interstate shipments of plants and plant products. Their organizations—the regional and the National Plant Boards — have afforded a medium for free friendly discussion of their mutual problems. It is believed that progress in dealing with other countries is possible through similar means. Long strides in this direction have been made in our dealings with our neighbors, Canada and Mexico. Working at greater distance there has been excellent ground work laid for further cooperative relationships with Argentina, Australia, and Holland. Better understandings lead to better cooperation. From our point of view better cooperation means fewer plant pests accompanying agricultural imports and that is the aim which must be kept ever before us.

POSSIBILITIES FOR THE USE OF CONCENTRATED SPRAYS ON CITRUS IN FLORIDA

JAMES T. GRIFFITHS, C. R. STEARNS, AND W. L. THOMPSON

Florida Citrus Experiment Station

Lake Alfred

During the past few years, spray machines have been developed for applying concentrated sprays to deciduous fruit trees. The purpose of such sprays was to apply the required amount of the active ingredient to the tree with a minimum amount of water. By reducing the actual gallons of spray per tree the cost of application may be decreased both by eliminating the hauling of water and by reducing the time required to refill the spray tank. If the spray mixture is concentrated four times the ordinary strength, then there is a saving of 75% in the amount of water hauled, and a similar amount of time saved in filling the tanks. With concentrated sprays such a low volume of fluid is delivered per tree that no run-off or dripping occurs. The purpose of this paper is to present results on the use of concentrated sprays on citrus in Florida.*

The first concentrate type sprayers to be used on citrus in Florida were tested by King and Griffiths (2) in 1947. Two machines (Buffalo Turbine and Hessian Microsol Generator) were tested in the control of the American grasshopper in citrus groves. These machines gave very poor insecticide distribution on the tree. In spite of this, relatively satisfactory grasshopper control was obtained. However, it was concluded that

*For those readers who desire information concerning the history and theory of concentrated sprays reference is suggested to a thesis by R. M. Pratt (6).

this type of machine would not be practical for the control of sedentary citrus pests.

At the start of the 1949 spray season, a Hardie mist sprayer** was loaned to the Citrus Experiment Station. This machine is powered by a 45 h.p. gasoline engine. Air is delivered to only one side at the rate of approximately 20,000 cubic feet of air per minute and at a velocity of 110 miles per hour. The pump capacity is 18 gallons per minute, and the pressure is maintained at approximately 400 pounds. The principles involved in the design of this machine were developed at Cornell University (4,5,6). The basic design is such that the air is driven up into the tree, and the desired spray particle size is produced by the use of high pressures.

Also in 1949, the Speed Sprayer Company began developmental work on modified nozzles to be used in a Speed Sprayer (Model 36) for the delivery of concentrated sprays. In contrast with the Hardie sprayer, a Speed Sprayer delivers approximately 44,000 cubic feet of air to two sides or 36,000 to one side, and the velocity varies between 90 and 105 miles per hour. It is powered by a 110 h.p. gasoline engine. A centrifugal pump is employed to deliver spray solution at a pump capacity of 150 gallons per minute at 65 pounds pressure.

A number of other concentrate sprayers are being offered for sale in other parts of the United States. One of these, the Lawrence Mist-o-Matic Sprayer, was tried in the summer of 1950. The distribution of spray materials appeared to be satisfactory in the tops and on the off-sides of the trees, but the lower 6 feet of the tree adjacent to the sprayer were not covered. This machine will require considerable modification in order to make this a practical sprayer for use in citrus groves.

During 1950, some caretakers have successfully applied double concentrations of toxicants at half gallonage with the conventional nozzles in a Speed Sprayer. Such semi-concentrates represent a compromise between dilute and concentrated sprays, but they represent a trend in the direction of concentrated mixtures.

The work reported here deals with experiments conducted during the 1949 and 1950 seasons using the Hardie sprayer and the Speed Sprayer. In most cases, the spray was applied at one-eighth the gallonage and at six times the concentration normally used. This meant that three-fourths as much material was being applied per tree as with a dilute spray. Previous work on apples had indicated that less material was necessary when no drip occurred (1,3).

Results

Mite Control.—During the 1949 and 1950 seasons the two concentrate spray machines were compared with a dilute Speed Sprayer in an orange grove near Auburndale. The dormant spray (zinc, DN, sulfur), the post-bloom spray (copper and sulfur), and summer and fall sulfur sprays were applied with this machinery. The summer spray for scale control was an oil emulsion applied by a hand machine. Careful checks were made of purple mites and rust mites throughout the two years. There was no significant difference in the control of these pests that could be attributed to the use of concentrate sprays. In similar small scale tests, rust mite and purple mite control was as satisfactory with concentrated as with dilute sprays.

Scale Control.—Three rather extensive scale control experiments have been performed. In 1949, a parathion experiment was carried out in a grove near

**Mist sprayer as defined by Pratt (6) is a sprayer to be used for the application of concentrated sprays.

Auburndale. Parathion was used as a concentrated material and compared with both a 1.3 percent oil spray and a dilute parathion spray, both of which were applied by hand as well as by Speed Sprayer. Duplicate plots were used in all experiments.

The concentrated material was applied with the same nozzle settings in all plots, but the machines were driven at three speeds, which resulted in more gallons being applied per tree at the slower speeds. The concentration of insecticide was so regulated that the comparable amounts of parathion were applied per tree. Half of the plots sprayed with concentrate had the parathion concentration arranged so that only three-fourths of the standard quantity was used per tree. The results of this experiment are shown in Table 1. In one of the Hardie plots, purple scale control was unsatisfactory, apparently due to nozzle stoppage and to the fact that distribution of the insecticide was poor. It was concluded from this experiment that there was no significant difference in control caused by the use of dilute as compared to concentrate sprays, by the use of the Hardie Mist Sprayer versus Speed Sprayer, or by the use of 25 percent less parathion as compared to the usual amount of parathion.

Another scale control experiment was performed at Lake Placid in 1949. This compared dilute sprays in a Speed Sprayer with concentrated sprays in both the Hardie Mist Sprayer and the Speed Sprayer. The standard application was supposed to consist of 28 gallons per tree of a 1.3 percent oil spray. All sprays were applied at the rate of 1 mile per hour. Three nozzle sizes were used in both the Speed Sprayer and the Hardie Sprayer. This was done in order to vary the amount of water applied per tree. The concentration of oil used in the Speed Sprayer was arranged so as to deliver the same amount of oil per tree as would be applied if a 1 percent oil were used at 28 gallons per tree. For the Hardie Sprayer, three oil concentrations were used which were equivalent to the oil

TABLE 1.
SUMMARY OF PURPLE SCALE CONTROL IN GROVE AT AUBURNDALE ON JUNE 30, 1949.

	Speed Mi./Hr.	Gal./ Tree	Lbs. Parathion/Tree	% Mortality Avg. of Two Plots
Speed Sprayer Concentrate	1.0	5.0	.032	98
	1.0	5.2	.073	99
	1.5	3.5	.049	99
	1.5	3.3	.071	100
	2.0	2.3	.042	99
	2.0	2.3	.064	97
Hardie Sprayer	1.0	3.0	.031	93
	1.0	3.6	.054	80
	1.5	2.7	.042	98
	1.5	2.9	.068	97
	2.0	2.5	.052	100
	2.0	2.5	.078	97
Speed Sprayer Dilute	1.0	25.0	.062	99
	1.0	25.0	1.3% oil	100
Pressure Sprayer Dilute	......	18.0	.041	99
	......	17.0	1.3% oil	99

that would have been applied in the 1.3, 1.0 and a 0.8 percent oil emulsion, all used at 28 gallons per tree. The results are shown in Table 2. The gallons of spray per tree, the actual pints of oil per tree, and the oil deposit on the foliage is shown. There were significant correlations between the amount of oil sprayed per tree and the amount deposited per unit leaf area. Both of these factors were, in turn, significantly correlated with purple scale control. Red scale control was generally more satisfactory than purple scale control, and as a result, the former did not show correlation between the rates of application and the percent control It was concluded that the amount of oil deposited evenly over a tree was the important factor, and it appeared that it did not make any difference what strength or gallonage was applied so long as sufficient oil was spread uniformly over the leaf and twig surfaces.

Leaf drop was not severe following this spray. However, where the concentrate sprayer turned around the tree at the end of a row, the terminal tree had severe leaf drop. This suggested the fact that with oil sprays at least, the sprayer should come out of the grove, drive past the end tree, and then cut off the spray before turning around. This

TABLE 2.
A COMPARISON OF CONCENTRATE AND DILUTE SPRAYS WHEN OIL WAS USED TO CONTROL SCALE AT LAKE PLACID IN 1949.

	Speed Mi./hr.	Oil Equivalent	Gal. of Spray/Tree	Pts. Oil/ Tree	Oil Deposit Mcg./Cm²	% Mortality Purple Scale	Red Scale
	1.5	1.3	7.4	2.2	57	60	80
		0.8	9.3	1.6	36	37	87
		1.3	6.7	2.7	36	70	97
		1.0	6.8	2.3	46	72	97
		0.8	8.6	2.0	43	73	100
		1.3	6.0	3.8	60	86	91
Hardie Mist		1.0	5.3	2.7	59	65	96
Sprayer		0.8	5.0	1.8	43	77	96
	1.5	1.3	5.3	2.3	33	57	90
		1.0	6.1	1.9	44	75	89
		0.8	5.0	1.3	25	24	97
		1.3	4.4	2.5	55	90	92
		1.0	4.4	1.9	44	82	98
		0.8	4.9	1.6	36	75	93
		1.3	3.9	3.8	59	85	97
		1.0	3.9	2.8	84	90	100
		0.8	3.2	1.8	49	84	100
	1.0	1.0	12.9	2.7	56	74	90
		1.0	9.5	2.8	56	85	98
Speed Sprayer		1.0	6.2	3.0	62	75	97
	1.5	1.0	10.3	3.1	38	79	90
		1.0	7.0	3.1	50	93	100
		1.0	4.5	3.3	88	90	100
	1.0	1.3	23.0	2.3	28	77	90

would avoid excessive oil deposits and subsequent leaf drop on the end tree.

In 1950, oil emulsion and parathion sprays were compared in a grove near Auburndale. These materials were applied by hand with pressure rigs, as dilute sprays in the Speed Sprayer, and as concentrated sprays in both the Hardie Mist Sprayer and the Speed Sprayer. The results of this experiment are shown in Table 3. The basic spray was considered to be 25 gallons per tree of a 1.3 percent oil or parathion at 2 pounds of 15 percent wettable material per 100 gallons of spray. The concentrated sprays were designed to apply equal amounts of insecticide in one set of plots and only three-fourths as much in another set. Because of irregular delivery by both machines, no conclusions could be made regarding the rate of dosage. Purple scale control was satisfactory in all applications regardless of the method of application. There was more leaf drop following oil than parathion and more with concentrated than dilute oil, but in no instance was the leaf drop severe.

Fruit Grade in Packinghouse.—In 1949, representative samples of fruit from the experimental plots at Auburndale were checked in the packinghouse in order to compare grade as well as insect and mite injury on fruit. In this comparison, there was no difference either in grade or external quality which could be attributed to a difference in the methods of application. In other words, concentrated sprays appeared to have produced as satisfactory or as good quality fruit as that produced by dilute spray machinery.

Discussion

During 1949 and 1950 sufficient work with concentrated sprays has been performed to demonstrate that they will probably be practical for use on citrus in Florida. Lime-sulfur, wettable sulfur, DN, zinc sulfate and lime, neutral copper, oil, and parathion have all been applied successfully. However, before concen-

TABLE 3.
PURPLE SCALE CONTROL AND LEAF DROP FOLLOWING THE USE OF DILUTE AND CONCENTRATED SPRAYS ON JULY 7, 1950.

Machine	Gal. Oil/Tree	% Reduction of Purple Scale	Leaf Drop*	Lbs. Parathion/ Tree	% Reduction of Purple Scale	Leaf Drop*
Hardie Sprayer	.20	80	64	.059	80	5
	.23	92	56	.052	100	32
	.29	75	78	.056	97	16
	.36	77	118	.080	100	32
Hand Sprayer	.29	91	52	.060	100	22
	.34	92	40	.081	99	59
Speed Sprayer Dilute	.33	96	39	.066	97	19
	.29	82	56	.066	93	43
Speed Sprayer Concentrate	.24	91	63	.067	96	29
	.31	84	33	.080	93	35
	.25	89	94	.060	95	39
	.33	82	33	.057	97	34
	.42	95	67	.072	95	22
	.31	90	93	.072	87	33

* Based on total newly dropped leaves on 1/5 of the area under the tree on July 31.

trate sprays can be generally used, a number of problems must be studied and solved. The grower will no longer be able to think in terms of how many pounds of material to use per 100 gallons of spray. Rather he will have to know how much copper is needed on a given size tree to control melanose, how much zinc sulfate is needed on a given size tree to maintain optimum zinc levels, and how much parathion per tree is needed for scale control. As an example, it may take two-thirds of a pound of 15 percent parathion on a large grapefruit tree to control scales, and it may take only one and one-half pounds of sulfur to control the rust mites. In this case, parathion and sulfur will be used in a ratio of 4 pounds of 15% parathion to 9 pounds of sulfur. If three gallons are to be applied per tree, then 33 trees will be sprayed with 99 gallons and each 100 gallons of spray will contain approximately 22 pounds of 15 percent parathion and 50 pounds of sulfur. This example shows that considerable calculation may be necessary in order to figure out the proper amounts of material to use per tank of spray.

The gallonage to apply per tree poses another difficulty. In experimental work, one-eighth the normal gallonage has been used in most cases. It may be determined subsequently that still greater concentrations will be satisfactory, but, in any case, the gallons to be applied per tree will determine the amount of material per 100 gallons of spray. If the grower plans to apply 3 gallons and actually applies 3½ gallons per tree, he will not only use an extra half gallon per tree, but also this will represent a 17 percent increase in material costs. With dilute sprays, a half gallon error resulted in less than a 5 percent increase in material costs. With concentrated sprays, small errors in gallons delivered per tree will result in big differences in the amount of material applied per tree.

In the case of the Hardie Sprayer, gallonage is regulated by the aperature size in the spray disc and not by the number of nozzles. Thus, the rate of delivery into the top or the bottom of a tree is also regulated by disc size. It will take considerable knowledge on the part of the operator to properly set the nozzle sizes and adjust the air flow baffles for proper distribution over the tree as well as for the proper gallonage per tree. Tall trees need larger nozzle sizes at the top and small trees need more spray concentration at the bottom.

In the case of the Speed Sprayer, gallonage can be regulated either by nozzle aperature size or by the number of nozzles. Since the number of nozzles will probably be less than one-fourth the number now used with dilute sprays, distribution will again be a problem, as it will be difficult to determine which pipe is to hold 1 and which 2 or 3 nozzles.

None of these problems are insurmountable. Most can be solved by time and thought, but before attempting to use concentrated sprays a grower should be acquainted with the difficulties involved, and he should have sufficient information to be able to adequately determine the amount of material to use and the gallons per tree to employ.

The use of concentrated sprays on citrus can result in savings to the grower. Probably less insecticide will be needed per tree. Table 4 presents sulfur deposits for one experiment where the Hardie Mist Sprayer was compared with a Speed Sprayer delivering dilute sprays. The deposits are calculated on the basis of micrograms of sulfur deposited on a square contimeter of leaf surface per pound of sulfur applied to the tree. Thus, they are a measure of the amount of sulfur which stuck to the

TABLE 4.
MICROGRAMS OF SULFUR DEPOSITED PER CM² PER LB. OF SULFUR FROM SAMPLES TAKEN FROM THREE LOCATIONS ON THE TREE.

	Hardie Mist Sprayer Concentrated Spray			Speed Sprayer Dilute Spray		
	On Side	Off Side	Top	On Side	Off Side	Top
Four Duplicate Plots	35	42	19	19	19	8
	33	49	25	19	21	14
	25	26	15	32	36	10
	34	46	25	32	44	9
Avg.	32	41	21	25	30	10

leaf surface. The figures are for the sides of the tree adjacent to the sprayer (on side), the side between the trees (off side), and the tops. The concentrated spray deposited 25 to 50 percent more sulfur than did the dilute spray. This is similar to information from other sources (1,3). In the case of oil emulsion sprays this may not be true, but in all other instances there are definite indications that the amount of material can be reduced over that which is normally sufficient to dilute sprays.

In addition to material savings, there should also be operational savings. It will no longer be necessary to use one or possibly two supply units for an individual sprayer. Whereas a 500 gallon tank of dilute spray will spray possibly only 25 trees, 200 trees can be sprayed with a tank of concentrate. Therefore, one supply unit should be able to supply 2 or even 3 sprayers in a single grove. This represents a saving in spray labor as well as in the use of the machinery.

Summary and Conclusions

Concentrated sprays have been used experimentally during the 1949 and 1950 spray season on citrus in Florida. Two machines, the Hardie Mist Sprayer and the Speed Sprayer, appear to offer good possibilities for use with this type of spray. In general, one-eighth the normal gallonage was used per tree. and indications were that with the possible exception of oil, less spray material could be used per tree than with dilute sprays. In comparative trials, the control of rust mites, purple mites, scale insects, and melanose have been as satisfactory with concentrated sprays as with dilute sprays. It was concluded that the use of this type of spray should be practical on citrus in Florida.

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