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TIMING OF SPRAY TREATMENTS FOR CITRUS GREASY SPOT CONTROL[1]

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Abstract. **Spray-timing experiments on grapefruit trees for the control of greasy spot, caused by** Mycosphaerella citri **Whiteside, showed that a single copper fungicide treatment was more effective when applied in the summer than in April or May. Only in some years did a copper spray in June or August control the disease as well as one applied in July. Even in 1982, when the greatest monthly release of ascospores was in April, 2 months ahead of normal, a single spray treatment in July of 0.5% oil plus 0.4 lb. copper/100 gal, controlled greasy spot as well as a 2-spray program consisting of 0.8 lb. copper/100 gal postbloom followed by a 1% oil in July. With oil, time of spraying from April to August had little or no effect on levels of greasy spot control obtained on leaves of the spring growth flush. Oil, unlike copper, often gave no control of greasy spot rind blotch and in some years it was much less effective than copper for greasy spot control on leaves. The results are discussed in relation to the behavior of the greasy spot pathogen and the action of the spray materials.**

In Florida, the number of spray treatments used to control greasy spot, caused by *Mycosphaerella citri,* is economically limited. Many citrus growers apply only an oil spray in the summer to control this disease. Copper fungicides are more reliable than oil for greasy spot control (7), but are normally used only if heavy disease pressure is expected.

Some citrus groves receive a copper fungicide spray postbloom (April or May) for the control of melanose, caused by *Diaporthe citri* Wolf, if the crop is intended for the fresh market. In the past, when most of citrus in Florida was marketed fresh, nearly all groves received a copper spray postbloom. This practice continues in many groves grown solely for processing in the belief that copper sprays so-timed help to control greasy spot. Thompson et al. (4) reported that a postbloom copper treatment sometimes protected the leaves from greasy spot. Griffiths (2), Cohen (1) and Whiteside (5) obtained better control of greasy spot with copper sprays applied in June or July than with those applied in May or August. Clearly, more study was required to determine to what extent greasy spot control might be sacrificed by eliminating a postbloom copper spray.

This paper summarizes data from spray-timing experiments on 'Marsh' grapefruit (*Citrus paradisi* Macf.) trees with copper fungicide and spray oil. Also, these studies were designed to develop a more reliable recommendation for the control of greasy spot rind blotch (GSRB), which is a major problem on grapefruit for the fresh market. More comprehensive reports of some of the experiments described here have been published (9, 10).

Materials and Methods

Experimental designs. Experiments 1, 2, 3, 5, and 6 were conducted in a 'Marsh' grapefruit grove at the Citrus Research and Education Center, Lake Alfred. The trees were 10 to 12 ft high and spaced 25 x 15 ft. The spray treatments were applied by handgun, using 8 gal/tree, to single-tree plots replicated 6 or 8 times in a randomized complete block design. Experiment 4 was conducted in an older 'Marsh' grapefruit grove about 2 miles from the other location. In this grove, the trees were 20 ft high and spaced 30 x 25 ft, and the spray treatments were applied by handgun at 15 gal/tree to 4- tree plots replicated 6 times in a randomized complete block design.

The spray materials used were basic copper sulfate, 53% Cu (Tribasic copper sulfate, Cities Service Co., Atlanta, GA 30302) and spray oil (Sunspray 7E, Sun Oil Co., Philadelphia, PA 19103), containing 99% refined petroleum distillate and meeting FC435-66 specifications (3). The only other material sprayed on the trees during the tests was ethion, which was applied separately from other treatments and up to 3 times a year to control rust mites.

Disease assessments. The severity of greasy spot on leaves was based on the amount of defoliation caused by the disease or, when the defoliation on untreated trees was less than 5%, on the number of leaves with disease symptoms. In the latter instance, any missing leaves were assumed to have abscised because of greasy spot and were added to the count of diseased leaves.

Assessments of disease severity were confined to the current year's spring growth flush. Shortly after this growth flush had expanded, the shoots to be sampled were labeled with white plastic tags, in groups of 10, at 4 locations arranged equidistantly around the canopy, at the same compass points on each tree. The total number of leaves on each shoot was then recorded.

In all experiments except Experiment 5, the greasy spot severity assessments were made in late February or March, just as the new spring growth flush was beginning to emerge. In Experiment 5, the assessment was made immediately after the freeze of January 12-14, 1981, before freeze-induced leaf drop began.

To determine greasy spot severity on fruit, about 150 fruit were picked randomly from each tree. After washing, the rind on each fruit was examined for the presence or absence of GSRB.

Spore trapping. A Kramer-Collins 7-Day Drum Spore Sampler was operated continuously from April 1 to September 30 each year in the grove where all experiments except

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Experiment 4 were conducted. The trap orifice was 3 ft above the ground and the suction force was maintained at 2.6 gal/min. Daily segments of the tape were mounted on microscope slides, stained with lactophenol-cotton blue and examined at X1000 magnification. The number of ascospores present over a 180 μm-width pass of the deposit was recorded as the daily count.

Rainfall data were obtained from the National Weather Service Lake Alfred Recording Station located 500 yd from the spore trap.

Results

Experiment 1 (1977-1978). Monthly rainfall (Table 1) was below normal in March and April, but near normal for the other months the spore trap was operated. The numbers of trapped ascospores were very low in April, still relatively low in May, but high in June (Table 1).

Surprisingly, trees sprayed with basic copper sulfate on April 28 had more defoliation than untreated trees (Fig. 1). Best control on leaves resulted from the copper spray treatment on July 21. GSRB was controlled much better by the copper treatments applied on July 21 or August 31 than by the one applied on June 7. The copper treatment on April 28 did not reduce GSRB.

Time of application had no significant effect on the level of control on foliage obtained with oil. Oil reduced GSRB only with the June 7 time of application but, even then, it was much less effective than the copper treatments of July 21 or August 31.

Experiment 2 (1978-1979). Rainfall was below normal in March and April, and above normal in May, June and July (Table 1). Little leaf litter remained on the grove floor after June. Ascospore numbers were very low in April, relatively high in May, and exceptionally high in June, but low thereafter.

No control of greasy spot on leaves or fruit was provided by the May 5 copper treatment (Fig. 2). The June 15 application of copper controlled greasy spot better on fruit and leaves than the application made on August 21, but not significantly better than the one applied on July 14. Greasy spot control on leaves was better with the oil treatment applied on May 5 or June 15 than with the one applied on August 21.

Oil reduced GSRB only where applied on May 5, but even then it was much less effective than the June or July copper treatments. The August 21 application of oil significantly increased GSRB above that on the untreated control trees.

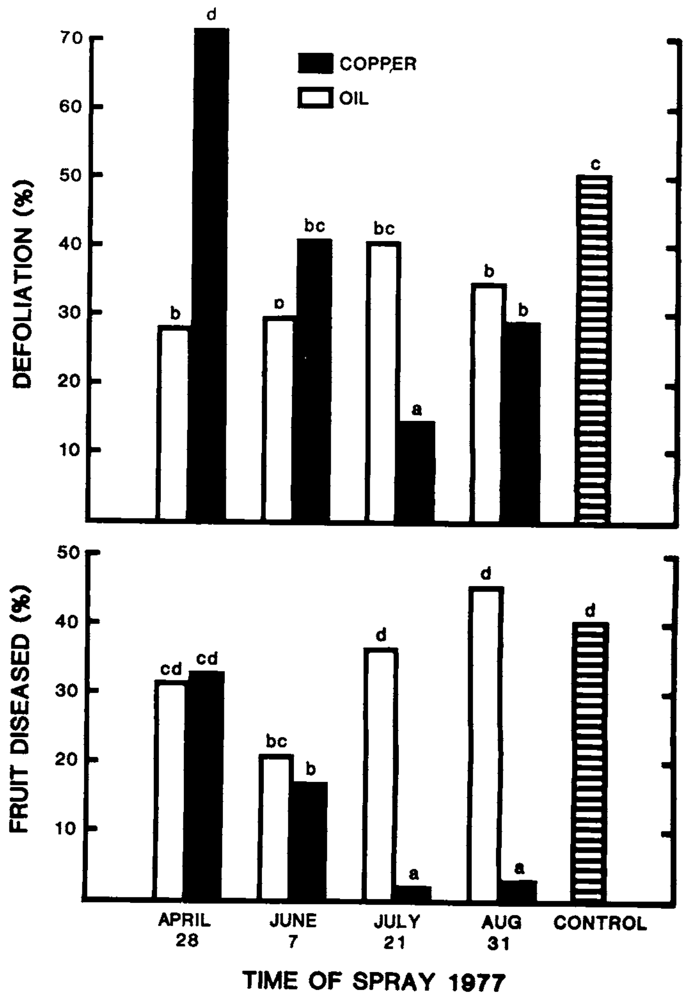

Fig. 1. Effect of time of spraying on greasy spot-induced defoliation and greasy spot rind blotch on 'Marsh' grapefruit trees, 1977-1978. Oil was applied at 1 gal/100 gal and basic copper sulfate (53% Cu) at 0.75 lb./100 gal. Mean separation by Duncan's multiple range test, 5% level.

Experiment 3 (1979-1980). Rainfall was near normal in March, below normal in April, but unusually high in May, when 13.9 inches fell compared with an average monthly total of 3.9 inches (Table 1). The leaf litter decomposed

Table 1. Relative numbers of ascospores of *Mycosphaerella citri* trapped each month and monthly rainfall totals at Lake Alfred, Florida.

Year		Mar	April	May	June	July	Aug	Sept
		Numbers of ascospores trapped and rainfall (inches) per month						
1977	Ascospores	—	8	269	4890	848	79	36
	Rainfall	1.3	0.3	4.2	5.6	6.7	8.1	8.9
1978	Ascospores	—	16	1462	14566	202	58	85
	Rainfall	2.3	0.5	5.7	10.6	9.8	3.9	2.0
1979	Ascospores	—	67	1286	463	639	557	73
	Rainfall	3.5	1.4	13.9	1.8	6.3	11.0	13.6
1980	Ascospores	—	40	726	1358	309	210	55
	Rainfall	2.3	2.6	7.3	8.0	5.6	2.8	2.8
1982	Ascospores	—	1642	1177	569	48	177	11
	Rainfall	4.8	3.2	6.9	10.1	8.5	5.8	6.0
Rainfall average[z]		4.0	2.7	3.9	8.2	7.9	7.2	6.9

[z]30-yr average 1941-1970.

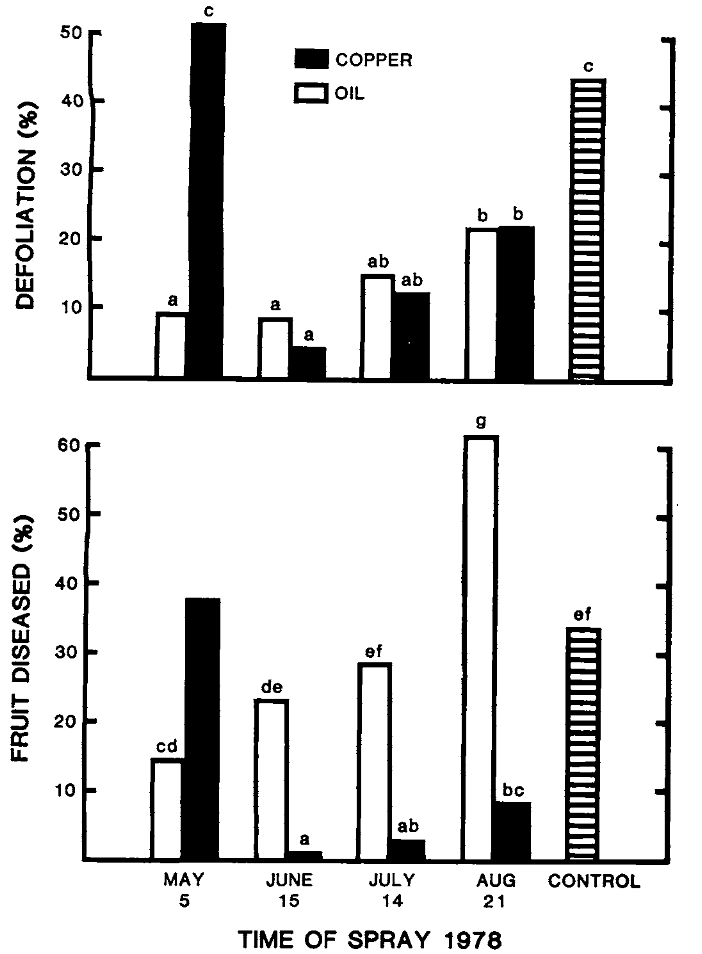

Fig. 2. Effect of time of spraying on greasy spot-induced defoliation and greasy spot rind blotch on 'Marsh' grapefruit trees, 1978-1979. Oil was applied at 1 gal/100 gal and basic copper sulfate (53% Cu) at 0.75 lb./100 gal. Mean separation by Duncan's multiple range test, 5% level.

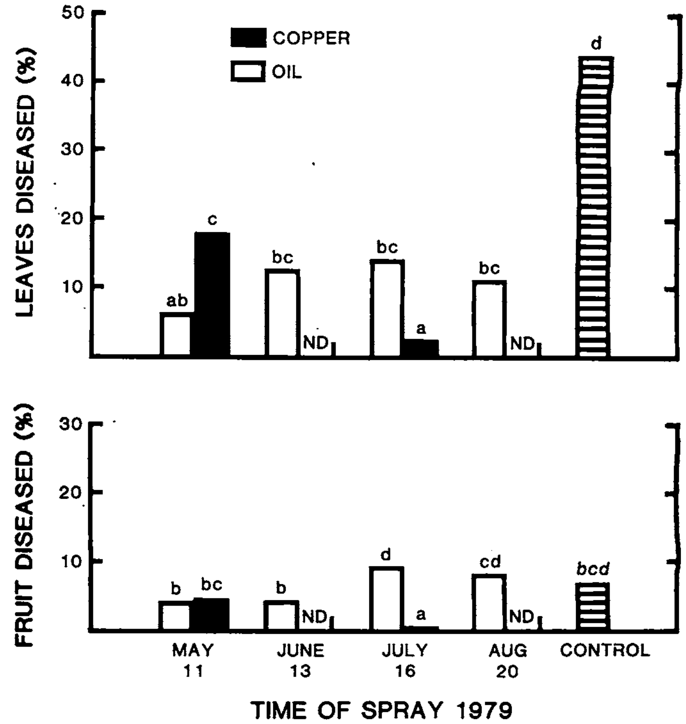

Fig. 3. Effect of time of spraying on the percentage of leaves with greasy spot symptoms and fruit with greasy spot rind blotch on 'Marsh' grapefruit trees, 1979-1980. Oil was applied at 1 gal/100 gal at all times of spraying. Basic copper sulfate (53% Cu) was applied at 1.5 lb./100 gal on May 5 and at 0.75 lb./100 gal on July 16. ND = No data, indicating that no copper treatment was applied on June 13 or August 20. Mean separation by Duncan's multiple range test, 5% level.

rapidly during May before many perithecia had developed, which reduced the overall inoculum potential from the fallen leaves for the rest of the season. However, dry conditions in June delayed the final exhaustion of the inoculum supply and the August ascospore count was higher than in the other years. The highest monthly count of ascospores was in May.

Greasy spot was much less severe than in the preceding 2 years. Defoliation on untreated trees was still only 4.3% at the end of February 1980. As in the previous experiments, oil was applied on 4 different dates, but the copper fungicide was applied only on May 11 or July 16 (Fig. 3). Even though the amount of basic copper sulfate applied on May 11 was twice that applied on July 16, greasy spot control was much better with the July treatment. The only treatment that significantly reduced GSRB was the copper treatment applied on July 16. Time of spraying with oil had no significant effect on the levels of greasy spot control on leaves.

Experiment 4 (1979-1980). No spore trapping data were obtained from the site of this experiment. Observations on leaf litter decomposition, however, indicated that the pattern of ascospore release was similar to that at the spore-trap site.

The single treatment of basic copper sulfate plus oil on July 2 gave better control of greasy spot-induced defoliation than the 2-spray program consisting of twice as much copper applied on May 3 and twice as much oil applied on July 2 (Table 2). GSRB was controlled only where copper was applied in the summer.

Table 2. Effect of different spray programs on the control of greasy spot on grapefruit leaves and fruit in 1979.

Treatment, rate/100 gal and application date		Defoliation (%)	Fruit with greasy spot rind blotch (%)
May 3	July 2		
Basic copper sulfate 1.5 lb.	Oil 1 gal	11.5 b	17.4 b
Basic copper sulfate 1.5 lb.	Basic copper sulfate 0.75 lb. + oil 0.5 gal	2.7a	2.3a
—	Basic copper sulfate 0.75 lb. + oil 0.5 gal	1.5a	4.5a
Untreated	—	58.6 c	17.4 b

Mean separation within columns by Duncan's multiple range test, 5% level.

Experiment 5 (1980-1981). Above-normal rainfall in May hastened maturation and release of the ascospores, giving May the second highest ascospore count for the season after June (Table 1).

The basic copper sulfate treatment at 1.5 lb/100 gal on May 7 gave no control of GSRB and was much less effective in controlling greasy spot on leaves than were any of the later applications of copper at half this rate (Fig. 4). Oil controlled greasy spot on leaves to a similar extent at all application dates. Oil reduced GSRB as well as copper where applied on June 16 and July 8, but on August 8 it was inferior to the copper treatment applied on that date.

Experiment 6 (1982-1983). Climatically, the winter and spring of 1982 were extremely abnormal. First, there was a severe freeze in mid-January which caused heavy premature leaf drop. Second, the unusually high and frequent rainfall

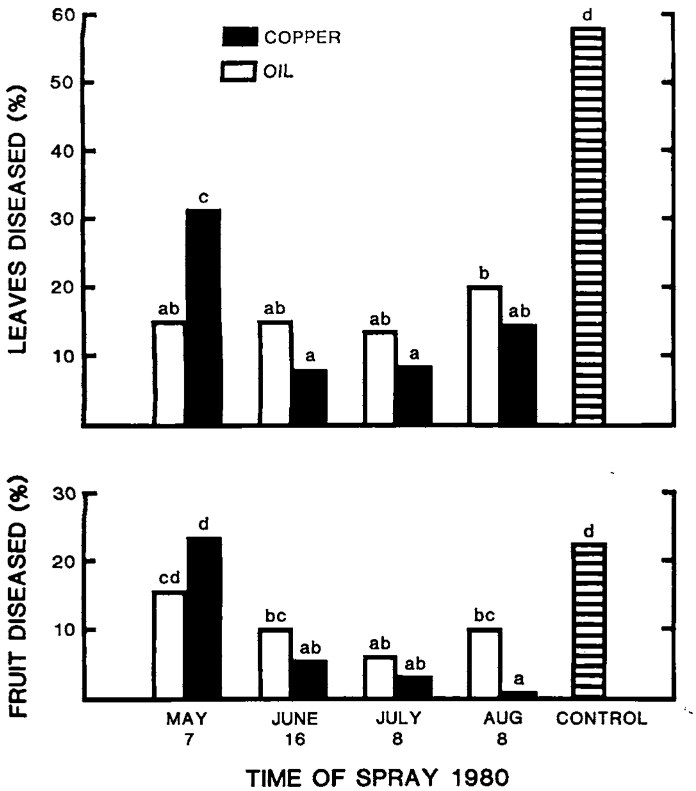

Fig. 4. Effect of time of spraying on the percentage of leaves with greasy spot symptoms and fruit with greasy spot rind blotch on 'Marsh' grapefruit trees, 1980-1981. Oil was applied at 1 gal/100 gal at all times of spraying. Basic copper sulfate (53% Cu) was applied at 1.5 lb./100 gal on May 7 and at 0.75 lb./100 gal on the other 3 spraying dates. Mean separation by Duncan's multiple range test, 5% level.

during succeeding weeks and months caused early breakdown and development of perithecia on the fallen leaves. In fact, the ascospore count for April was the highest of the season, with May having the second highest total (Table 1).

Because of the freeze, too few fruit were produced in this experiment to provide data on the control of GSRB. A treatment of 1% oil alone on July 1 gave poor control of greasy spot on leaves (Table 3). In contrast, good greasy spot control was obtained with those programs that included copper, regardless of whether it was applied postbloom or in the summer. Nevertheless, the control was just as good with a single treatment of 0.75 lb. basic copper sulfate (0.4 lb. Cu)/100 gal + 0.5% oil on July 1 as it was with a 2-spray program, consisting of 1.5 lb. basic copper sulfate (0.8 lb. Cu/100 gal on April 28 followed by a 1% oil spray on July 1.

Discussion

In years when ascospore counts peaked unusually early, a copper fungicide treatment applied in April or May might have been expected to control greasy spot better than one applied in the summer, but it did not. In one of the experiments of 1979 (Fig. 3), basic copper sulfate at 0.75 lb./100 gal on July 16 controlled greasy spot better than basic copper sulfate at 1.5 lb./100 gal applied on May 11, during the month of heaviest ascospore discharge. In the other experiment of that year (Table 2), one application of 0.75 lb. basic copper sulfate/100 gal plus 1% oil on July 2 was more effective than the 2-spray program of 1.5 lb. basic copper sulfate/100 gal on May 3 plus a 1% oil on July 2. In 1982, however, the postbloom copper treatment played a greater role in greasy spot control than in the previous year; yet the single copper-oil treatment applied on July 1 still provided as much greasy spot control as the 2-spray postbloom copper plus oil in the summer program, in which twice as much spray material was consumed.

Table 3. Effect of different spray programs on the control of greasy spot on grapefruit leaves in 1982.

Treatment, rate/100 gal and application date: April 28	July 1	Diseased leaves (%)
Basic copper sulfate 1.5 lb.	Oil 1 gal	1.2a
—	Oil 1 gal	20.1 b
—	Basic copper sulfate 0.75 lb. + oil 0.5 gal	1.7a
Untreated	—	32.8 c

Mean separation by Duncan's multiple range test, 5% level.

The results seemed to contradict the principle that for a protectant fungicide such as copper to control a fungus disease it has to be deposited at the infection site ahead of major spore release. To explain why this principle does not fully apply to greasy spot control, it is necessary to consider the unique behavior of the greasy spot pathogen.

A key feature in greasy spot epidemiology is the epiphytic branching mycelium that *M. citri* produces on the leaf or fruit surface following germination of ascospores. The hyphal tips on this mycelium are able to penetrate the stomata as easily as freshly emerged germ tubes and thus, they greatly increase the infection potential. Furthermore, they increase the possibilities for large numbers of stomata per unit area to be penetrated, which is essential for disease development (8). The amount of epiphytic growth can, therefore, be much more important in determining disease severity than the numbers of ascospores that reach the host. The environmental requirements for epiphytic growth, high humidity and high temperature, occur commonly in Florida in the summer, but seldom before June (8).

A copper fungicide kills existing epiphytic growth on contact. Furthermore, any hyphae that have not yet proceeded beyond the stomata can also be killed by the copper. Because deep penetration of infection hyphae is usually delayed for several weeks after the epiphytic growth begins, a copper treatment can be safely delayed until several weeks after the epiphytic growth starts.

A copper fungicide, as applied in July, is also needed to protect the host surfaces against those ascospores that are still to be released from the leaf litter. Thus, it is important not to apply the fungicide too early. The results from Experiment 1 (Fig. 1) indicated that a very early application of copper without a follow up treatment can even increase greasy spot severity. Copper may have acted by preventing early colonization of the leaf surface by competing organisms, thus reducing competition for space when *M. citri* reached the leaf surface. By the time the ascospores reached the leaf in large numbers and conditions became favorable for epiphytic development of *M. citri*, the copper deposit had presumably dissipated.

In 1978 and 1980 (Fig. 2, 4), June and July applications of copper were about equally effective in controlling greasy spot. In 1977 (Fig. 1), the July 21 treatment gave better control than one on June 7. An August treatment was never better than a July treatment and in 1977 it was inferior (Fig. 1). Therefore, overall, July seems the most appropriate month to apply a copper fungicide for greasy spot control. Another reason for delaying a copper treatment until July is that by this time at least some of the summer growth flush should have emerged, so that the leaves on this flush as well as those on the spring growth flush can benefit from the treatment.

With oil, time of spraying generally had no significant effect on the levels of greasy spot control obtained on leaves of the spring growth flush. These results supported the contention (6) that the main action of oil in reducing greasy spot severity is by preventing or delaying the development of symptoms, even when the pathogen is already established deeply in the host. An oil spray, like one of copper, is best delayed until July and for 2 important reasons: first, to provide greasy spot control on any summer growth flush present by this time as well as on the spring growth flush and second, to provide more timely control of sooty mold.

While oil sprays sometimes controlled greasy spot on leaves as well as a summer application of copper fungicide, oil alone often gave no control of GSRB. Thus, it is particularly important to apply copper in the summer to groves intended to produce blemish-free grapefruit for the fresh market. If a copper fungicide is not added to a summer oil spray, there can even be an increase in GSRB (Fig. 2). The reason for this is unknown. A similar response to oil has occurred in other experiments not reported here (Whiteside, unpublished).

In summary, the results showed there is little or no value in applying a copper fungicide postbloom if only greasy spot is to be controlled, not even in atypical years when the period of major ascospore discharge begins early. When heavy disease pressure is likely, a summer treatment of copper is needed in any case to assure greasy spot control, particularly GSRB. Thus, a copper treatment postbloom should not be regarded as a substitute for a summer copper treatment as far as greasy spot control is concerned.

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OIL SPRAYS CONTROL CITRUS RUST MITE[1]

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Additional index words. Phyllocoptruta oleivora (Ashmead); *Citrus sinensis* (L.) Osb.

Abstract. **Oil sprays were included in tests evaluating acaricides against citrus rust mite** Phyllocoptruta oleivora **(Ashmead) from 1971-80. Oil sprays at 1% gave control of rust mite on foliage equal to or longer than that obtained with chlorobenzilate (ethyl 4,4'-dichlorobenzilate) in 7 tests. Oil gave control equal to that obtained with Vendex® (fenbutatin oxide) (hexakis (2-methyl-2-phenylpropyl)-distannoxane)) in 1 test but control did not last as long as Vendex in 4 tests. Control with oil was equal to that obtained with dicofol (Kelthane®), [4,4'-dichloro-a-(trichloromethyl)benzhydrol] in 1 test.**

Oil emulsion sprays have been used for many years to control various pests on citrus but have not been considered adequate for the control of citrus rust mite. Yothers and Mason (6) reported on tests with oil to control citrus rust mite from 1912-1922. They reported that oil concentrations of 0.5% and higher killed nearly all the mites treated. In several trials applications of 1% oil gave control of citrus rust mite, with fruit reasonably free of russet at harvest. Other tests with oil gave less satisfactory results. They concluded that oil sprays were only partially effective, owing to imperfect spraying. Thompson (5) reported that summer oil sprays following dormant and postbloom sulfur sprays checked low populations of citrus rust mite to such an extent that further control measures were unnecessary until late summer or, in some sections, until the winter months.

Johnson (2) reported results of brushing-type spray applications of oil emulsion with and without other acaricides. No attempt was made to obtain complete coverage. The goal was to obtain an outside coverage, and although Johnson reported poor control of citrus rust mite with 1.3% oil in these tests, other materials were no better. He speculated that control with some or all of the treatments would have been more effective if they had been applied as full-coverage sprays.

Simanton and Trammel (4) compared oils of various specifications and developed recommendations for oils to be used on citrus in Florida. One set of specifications, identified as FC 435-66, was designed for normal summer use with maximum pesticidal activity and minimum physiological effects on tree and fruit. Oils meeting these specifications have been used extensively in Florida since 1966.

Garrett (1) reported on grove management practices he had used over several years on ca. 7,000 acres of citrus. His program consisted of a postbloom concentrate spray of oil (FC 435-66), 5 gal in 100 gal of water/acre followed by a 1% oil emulsion dilute application in June-July. Wettable sulfur at 35-40 lb./acre concentrate applied in August-September was followed in October-November with a final concentrate oil spray. According to Garrett, the use of oil had several advantages, one of which was that it controlled citrus rust mite. McCoy and Couch (3) evaluated the mycoacaricide Mycar® (*Hirsutella thompsonii* Fisher) for citrus rust mite control and included one treatment involving an application of FC 435-66 oil in July. They reported that the performance of oil alone equalled other summer treatments. They also found no russet on fruit in the oil treatment.

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