budwood sources commercially propagated on sour orange rootstocks in Florida. Proc. Fla. State Hort. Soc. 93:7-9.
13. Morris, T. J. and E. M. Smith. 1977. Potato spindle tuber disease: procedures for the detection of viroid RNA and certification of disease-free potato tubers. Phytopathology 67:145-150.
14. Ralph, R. K. 1969. Double-stranded viral RNA. Adv. Virus Res. 15:58-61.

Proc. Fla. State Hort. Soc. 97: 56-59. 1984.

RELIABILITY OF SPRAY TREATMENTS FOR REDUCING GREASY SPOT-INDUCED DEFOLIATION ON GRAPEFRUIT TREES[1]

J. O. WHITESIDE
University of Florida, IFAS,
Citrus Research and Education Center,
700 Experiment Station Road,
Lake Alfred, FL 33850

Abstract. **The reliability of different spray materials for controlling citrus greasy spot, caused by** Mycosphaerella citri **Whiteside, under heavy disease pressure was appraised. Results were compiled of 10 spraying experiments conducted from 1976 to 1983, in which the treatments were applied only once and in which heavy greasy spot-induced defoliation occurred by late winter. Basic copper sulfate, applied at 0.75 lb. product/100 gal (dilute), was the most reliable treatment for greasy spot control. Spray treatments with 1% (dilute) 435 oil or captafol at 0.5 lb. a.i./100 gal (dilute) sometimes equalled the copper treatment in effectiveness, but in some tests they failed to reduce disease severity significantly. Spray oil with 412 specifications was less effective than the standard 435 oil. Chlorothalonil reduced disease severity in some tests, but was never as effective as a copper treatment. Zineb, captan and folpet provided no control. Mancozeb significantly increased greasy spot in the one year in which it was tested.**

Greasy spot, caused by *Mycosphaerella citri*, is important mainly because it induces premature leaf drop. If excessive defoliation of citrus trees occurs before the end of the winter, the development of the spring growth flush is impaired and fruit yields can be reduced (10).

Despite the fact that greasy spot-induced defoliation has a greater potential impact on tree performance than the mere loss of photosynthetic area caused by the spots themselves, defoliation data have been used to quantify greasy spot severity only during the past 10 yr. Previously, disease severity was expressed only as the percentage of diseased leaves or leaf area with symptoms (9). This meant that disease assessments had to be made before substantial leaf drop began on nontreated check trees, often long before the end of the winter. When evaluated in that manner, some candidate materials showed more promise than was justified by later experience.

Earlier, defoliation data were not used to appraise greasy spot severity (9) because of considerations that other factors might cause premature defoliation. For example, citrus rust mite [*Phyllocoptruta oleivora* (Ashmead)] and citrus purple mite [*Panonychus citri* (McGregor)] were reported to cause leaf drop (4). After several years of monitoring of leaf drop from labelled grapefruit shoots, including some that were injured by these mites, I observed that greasy spot was the only biotic factor that could cause substantial abscission of leaves before they were 1 yr old. However, during the time of heavy seasonal leaf drop that occurs during March through May, many leaves, including healthy ones that were little more than 12 months old, did drop.

Greasy spot severity varies greatly from year to year, even in those groves that have a history of severe greasy spot. Disease severity depends on prevailing temperatures in the fall and winter (15) as well as on the amount of infection that occurs the previous summer.

Therefore, to appraise the reliability of different materials for controlling greasy spot more thoroughly, I have in this paper summarized the results of only those fungicide evaluation experiments conducted at the Citrus Research and Education Center, Lake Alfred from 1976 to 1983 in which substantial greasy spot-induced defoliation occurred by late winter. More comprehensive reports of some of these experiments have been published elsewhere (11, 13, 14, 16, 17).

Materials and Methods

The spray materials reported on in this summary of results were basic copper sulfate (53% copper), spray oils Sunspray 6E and 7E with FC412 and FC435 specifications (8), respectively; captafol (Difolatan) 4F and 80W Sprills; benomyl (Benlate) 50W; chlorothalonil (Bravo) 6F and 500; zineb (Dithane Z-78) 75W; mancozeb (Dithane M-45) 80W; captan (Orthocide) 50 W and folpet (Phaltan) 50W. No adjuvants were applied to any spray mixes. The rates of material applied are shown in Table 1.

The tests were conducted in groves of 'Marsh' and 'Ruby Red' grapefruit (*Citrus paradisi* Macf.) and sprays were applied with single-nozzled handguns. Some of the tests were made on 10- to 12-ft-high trees, with the whole canopy being sprayed. Other tests were made on 18- to 22-ft-high trees with only the southern half of each canopy treated, the other half being left as a buffer against spray drift. The volume of spray applied was equivalent to 8 to 10 gal for a 10-ft-high tree and 15 to 20 gal for a 20-ft-high tree. The only additional spray treatments that the trees received during the year of a test were with ethion, which has no effect on greasy spot and which was applied separately from the test treatments, up to 3 times per year, to control rust mites. The test treatments were applied to 6 to 9 (mostly 8) single-tree or half-canopy-tree plots arranged in a randomized block design.

In May or June, prior to spraying, shoots of the current year's spring growth flush were tagged. When the whole canopy was sprayed, 10 randomly selected shoots were labelled on the same four equidistantly spaced compass points on each tree. When only the southern half of each tree canopy was sprayed, 2 groups of 20 shoots each were labelled on the treated side of the tree. The total number of leaves on each shoot was counted before greasy spot-induced defoliation began and again in the winter, usually just as the spring growth flush began to emerge.

[1]Florida Agricultural Experiment Stations Journal Series No. 5822.

Table 1. Evaluation of spray treatments for controlling citrus greasy spot on the spring growth flush of grapefruit trees.

Material formulation and amount per 100 gal	Defoliation (%) 1976 Test 1	1976 Test 2	1977	1979	1980 Test 1	1980 Test 2	1981	1982	1983 Test 1	1983 Test 2
Check (no treatment)	30	53	17	28	38	49	40	13	92	95
Basic copper sulfate (53% Cu) 0.75 lb.	—	—	—	5***z	5***	4***	11***	3**	52***	28***
Basic copper sulfate (53% Cu) 0.75 lb. + oil (435) 0.5 gal	—	—	—	—	—	—	—	—	39***	—
Oil (435) 0.5 gal	—	—	—	—	13**	—	25*	—	93	—
Oil (435) 1 gal	8***	9***	11	5***	5***	13***	12***	12	85	82
Oil (412) 0.5 gal	—	—	—	—	28	—	20*	—	—	—
Oil (412) 1 gal	—	—	—	—	15**	26*	23*	13	—	—
Captafol 4F 1 pt	—	—	—	4***	8***	—	—	9	—	—
Captafol 4F 1 qt	—	6***	—	—	—	—	—	—	—	—
Captafol 80 Sprills 0.62 lb	—	—	—	—	—	—	—	5	79	76
Benomyl 50W 3 oz	—	—	4***	2***	—	—	—	—	—	—
Benomyl 50W 4 oz	7***	12***	—	—	—	—	—	—	—	—
Chlorothalonil 6F 0.8 pt	23	37	—	—	—	—	—	—	—	—
Chlorothalonil 500 1 pt	—	—	—	—	21*	—	—	15	81	57**
Chlorothalonil 500 1.5 pt	—	—	—	11**	—	—	—	—	—	—
Chlorothalonil 500 1 pt + oil (435) 0.5 gal	—	—	—	—	—	—	—	8	74	—
Zineb 75W 1 lb.	—	—	—	—	42	41	—	—	—	—
Mancozeb 80W 1 lb.	—	—	—	—	—	—	—	37†††y	—	—
Mancozeb 80W 1 lb. + oil (435) 0.5 gal	—	—	—	—	—	—	—	31†††	—	—
Captan 80W 1.25 lb.	37	37	—	—	—	—	—	—	—	—
Folpet 50W 0.4 lb.	28	36	—	—	—	—	—	—	—	—

z***, ** and * = significantly less defoliation than on the nontreated check at P = 0.001, 0.01 and 0.05 respectively by the LSD-test.
y††† = significantly more defoliation than on the nontreated check at P = 0.001 by the LSD-test.

Results

1976 test 1. The treatments were applied on July 20, 1976. A severe freeze occurred on January 18 and 19, 1977 and the final leaf counts were made on January 20, before freeze-induced defoliation began. The only treatments that significantly reduced defoliation were benomyl and spray oil (Table 1).

1976 test 2. The spray treatments were applied on June 23, 1976. Because there was little damage from the freeze in this test, the recording of greasy spot-induced defoliation was delayed until March 4, 1977. Defoliation was significantly reduced only by spray oil, captafol and benomyl.

1977 test. Spray treatments were applied on July 13, 1977 and defoliation was recorded on February 20, 1978. Only benomyl reduced defoliation significantly.

1979 test. Treatments were applied on July 13, 1979 and defoliation was recorded on February 13, 1980. At P = 0.001, only basic copper sulfate, spray oil, captafol and benomyl reduced greasy spot significantly.

1980 test 1. Treatments were applied on July 13, 1980. Leaves remaining on the tagged shoots were counted on January 20, 1981, which was before a severe freeze of January 12 and 13 began to induce additional leaf drop. Only basic copper sulfate, captafol and the 1% rate of 435 spray oil reduced defoliation significantly at P = 0.001. The 0.5% 435 oil and 1% 412 oil reduced defoliation at P = 0.01. Chlorothalonil reduced defoliation only at P = 0.05, and zineb and 0.5% 412 oil were ineffective.

1980 test 2. Spray materials were applied on July 9, 1980 and defoliation was recorded on January 15, 1981, before freeze-induced leaf drop began. The 435 oil reduced defoliation at P = 0.001, whereas 412 oil reduced it only at P = 0.05.

1981 test. Treatments were applied on July 16, 1981 and defoliation was recorded on February 16, 1982. A significant reduction in defoliation at P = 0.001 occurred only with basic copper sulfate and the 1% 435 oil.

1982 test. Treatments were applied on July 16, 1982 and defoliation was recorded on March 11, 1983. Basic copper sulfate was the only material that reduced greasy spot significantly. Mancozeb significantly increased defoliation even when oil was included in the spray mix.

1983 test 1. The treatments were applied on July 6, 1983. Greasy spot had already caused much defoliation before a severe freeze occurred on December 25 and 26, 1983. Data were obtained on January 18, 1984 only after considerable freeze-induced defoliation had occurred. They thus reflect freeze-induced and greasy spot-induced abscission plus the compounding effects of a freeze on leaves that were already damaged by greasy spot. Basic copper sulfate was the only material that significantly reduced overall defoliation in this test.

1983 test 2. Treatments were applied on July 18, 1983. This test was also affected by the freeze. Defoliation due to the combined effects of greasy spot and freezing temperature was recorded on January 20, 1984. Both basic copper sulfate and chlorothalonil reduced defoliation, but only basic copper sulfate reduced it at P = 0.001.

Summary of results. Basic copper sulfate reduced defoliation at P = 0.001 in 6 tests and at P = 0.01 in the remaining test in which it was included. A 1% oil with 435 specifications gave significant control in 6 of 10 tests. Oil with 412 specifications was less effective than 435 oil. Chlorothalonil reduced defoliation in only 3 of the 7 tests where it was included, and never at a higher level of significance than P = 0.01. Benomyl was highly effective in controlling greasy spot. Captafol performed well in the tests of 1976 and 1979, but not in those of 1982 and 1983. Zineb, mancozeb, captan and folpet provided no significant control of greasy spot.

Discussion

In a previous summation of the relative effectiveness of different materials for greasy spot control, published in

1973 (9), copper fungicides were the most effective materials for greasy spot control among those materials then registered for use on citrus trees in Florida. Although their effectiveness and low cost could have made them a logical choice for use against greasy spot, they were not widely used. Many growers were reluctant to use copper fungicides because 1) they might increase populations of citrus rust mite by killing *Hirsutella thompsonii* Fisher which parasitizes these mites and because 2) repeated application might eventually lead to the accumulation of toxic concentrations of copper in the soil.

Benomyl was cleared for use in Florida citrus groves in 1974. It became popular with many growers, despite its relatively high cost, partly because it was a non-copper product and could not cause possible soil problems and partly because it was reported to have less impact than copper fungicides on *H. thompsonii* (5). By 1979, disease control failures occurred in many groves sprayed with benomyl because of fungal tolerance problems (12). Thereafter, the use of this fungicide to control greasy spot declined markedly.

Because of the tolerance problem with benomyl that emerged during the late 70's some growers relied on oil alone to control greasy spot. Consequently, there was increased disease severity in many groves, particularly on the more susceptible cultivars. Other growers added zineb to the oil spray to try to improve greasy spot control despite its known unreliability for this purpose (9). Relatively few additional growers used copper fungicide to provide more reliable greasy spot control.

Another problem that arose in the late 70's, and early 80's was a shortage of the standard 435 oil. Many growers had to substitute with 412 oil and this led to reduced greasy spot control.

During the winter of 1982-83, greasy spot caused exceptionally heavy defoliation in many commercial groves, particularly where no copper fungicide had been applied the previous summer. Many of these diseased groves had been sprayed the previous summer with a mixture of zineb and oil. Results of the 1982 test (Table 1) with mancozeb, which is a dithiocarbamate closely related to zineb, indicated that the zineb may have actually increased greasy spot severity. Possibly, both mancozeb and zineb may have reduced the activity of some antagonistic or competitive microorganisms on the leaf surface, thus permitting more development of the extramatrical hyphal growth of *M. citri* on the phylloplane and increasing the number of stomatal penetrations by this pathogen.

Since the last summary on the effectiveness of spray materials was published in 1973 (9) several newer experimental materials, including fenarimol, trimidal, ectacorazole, prochloraz, and iprodione have been tested (11, 13, 14, 16, 17). However, none of these material showed promise for greasy spot control under heavy disease pressure.

Despite earlier optimism about the possible value of chlorothalonil for greasy spot control (6, 9), this material has not performed as well as copper or even oil alone under heavy disease pressure. Some materials that possess marginal activity against *M. citri*, might provide better control if applied more than once during the summer, but the increased costs thus incurred would probably be prohibitive.

Among the noncopper fungicides currently registered for use on citrus trees, only captafol has shown sufficient promise to be considered as a possible substitute for copper for greasy spot control. However, captafol cannot be mixed with oil or be applied within 60 days of an oil spray, because of the risks of spray injury. This practically rules out any possibility of applying an oil spray the same summer, which means sacrificing sooty mold control. While captafol is more costly than copper fungicides, there could be some compensation for this if its reported action against rust mites (3) is sufficient to eliminate the need for an additional miticide in the summer spray mix.

Overall, the chances of finding a substitute for copper fungicides to control greasy spot seem poor in the near future. The potential risks of using copper fungicides would have to be insurmountable to justify the greatly increased costs that would be incurred if less effective materials had to be used and applied repeatedly to provide acceptable control.

The risks of a copper fungicide increasing the population of rust mites can be compensated for by applying more effective miticides in the summer spray mix. Thus, the possibility of repeated application of copper fungicide leading to irreversible accumulations of copper in the soil is the more serious cause for concern. While the adverse effects of high concentrations of copper in the soil where the pH is low is well documented (7), there is little information on the effects of a high soil copper content when the pH is relatively high.

Although liming the soil to pH 7 has been recommended as an effective means of dealing with a high copper content, it is uncertain whether this completely solves the problem of copper toxicity. While excessive amounts of soluble copper have an immediate effect on tree performance (7), it is doubtful whether an equivalent accumulation of total copper in the soil after repeated application of copper fungicide could also be hazardous to the tree roots. Copper added to the soil may in time become fixed in a more stable, less soluble and less toxic form, probably by forming insoluble complexes with organic matter in the soil (7). In a grapefruit grove maintained at pH 6.8, trees on soil containing 558 lb. Cu/acre were as productive as trees on soil containing 106 lb. Cu/acre (2). Therefore, there may be little risk in applying a small amount of copper fungicide annually to a citrus grove, even though most of it persists in the soil.

Maximum yields of 'Valencia' orange on rough lemon rootstock were obtained by liming to pH 7 (1). These tests were conducted on soils that had low copper contents (Anderson, personal communication). Thus, the costs of maintaining the soil pH at this level cannot be considered as a penalty for applying copper fungicides. To answer the ongoing question about the risks of adding too much copper to the soil, it will be necessary to obtain more data on the impact, if any, of high copper accumulations when the pH is well maintained. An answer to this question has become even more urgent now that there seems to be no immediate chance of finding economically feasible alternatives to copper fungicides for controlling greasy spot under heavy disease pressure.

Literature Cited

1. Anderson, C. A. 1970. Effects of soil pH and calcium on yields and fruit quality of young Valencia oranges. Proc. Fla. State Hort. Soc. 84:4-10.
2. Anderson, C. A. 1982. Persistence of accumulated copper in soils of citrus groves. Proc. Florida Fertilizer and Lime Conf. 12:6-15.
3. Bullock, R. C. 1981. Aerial Difolatan for citrus rust mite control in Florida. Proc. Fla. State Hort. Soc. 94:3-5.
4. Griffiths, J. T. and W. L. Thompson. 1957. Insects and mites found on Florida citrus. Bul. 591. Univ. Fla. Agr. Expt. Sta., Gainesville.
5. McCoy, C. W., R. F. Brooks, J. C. Allen, A. G. Selhime and W. F. Wardowski. 1976. Effect of reduced pest control programs on yield and quality of Valencia orange. Proc. Fla. State Hort. Soc. 89:74-77.
6. Moherek, E. A. 1979. Bravo, a promising spray fungicide for Florida citrus. Proc. Fla. State Hort. Soc. 92:8-10.
7. Reuther, W. and P. F. Smith. 1954. Toxic effects of accumulated

copper in Florida soils. Proc. Soil & Crop Sci. Soc. Florida 14:17-23.
8. Trammel, K. and W. P. Simanton. 1966. Properties of spray oils in relation to citrus pest control in Florida. Proc. Fla. State Hort. Soc. 79:12-18.
9. Whiteside, J. O. 1973. Evaluation of spray materials for the control of greasy spot of citrus. Plant Dis. Rptr. 57:691-694.
10. Whiteside, J. O. 1977. Behavior and control of greasy spot in Florida citrus groves. Proc. Intern. Soc. Citriculture 3:981-986.
11. Whiteside, J. O. 1978. Evaluation of materials for greasy spot control, 1977. Report No. 277. *In* Fungicide and Nematicide Tests, Vol. 33. Amer. Phytopathol. Soc.
12. Whiteside, J. O. 1980. Tolerance of *Mycosphaerella citri* to benomyl in Florida citrus groves. Plant Dis. 64:300-302.
13. Whiteside, J. O. 1981. Screening of materials for greasy spot control, 1979-80. Report No. 98. *In* Fungicide and Nematicide Tests, Vol. 36, Amer. Phytopathol. Soc.
14. Whiteside, J. O. 1982. Screening of materials for greasy spot control, 1980. Report No. 104. *In* Fungicide and Nematicide Tests, Vol. 36, Amer. Phytopathol. Soc.
15. Whiteside, J. O. 1982. Effect of temperature on the development of citrus greasy spot. Proc. Fla. State Hort. Soc. 95:66-68.
16. Whiteside, J. O. 1983. Greasy spot control on leaves and fruit, 1981-82. Report No. 432. *In* Fungicide and Nematicide Tests, Vol. 38, Amer. Phytopathol. Soc.
17. Whiteside, J. O. 1984. Screening of materials for greasy spot control, 1982. Report No. 366. *In* Fungicide and Nematicide Tests, Vol. 39, Amer. Phytopathol. Soc.

Proc. Fla. State Hort. Soc. 97: 59-61. 1984.

INDUCTION OF CITRUS BLIGHTLIKE ZINC ACCUMULATION IN THE WOOD AND BARK OF 3-YEAR-OLD 'HAMLIN' ORANGE TREES IN SOLUTION CULTURE

H. K. Wutscher
U.S. Department of Agriculture,
Agricultural Research Service,
2120 Camden Road, Orlando, FL 32803

Additional index words. zinc, wood, bark, root growth.

Abstract. **Three-yr-old 'Hamlin' orange,** Citrus sinensis **(L.) Osbeck, trees on rough lemon,** C. limon **Burm. f., and sour orange,** C. aurantium **L., rootstock were grown in 2 solutions for 8 months, one high in sulfate and low in silicon (solution 1), the other high in silicon and low in sulfate (solution 2). Trees on rough lemon accumulated higher Zn levels in the wood, especially the outer layers of the wood and the bark when grown in solution 1. Trees on sour orange accumulated Zn only in the outer wood. The affected trees had blotchy leaves, poor and abnormal root growth and a higher wood pH.**

The debate about the nature of citrus blight has been underway for at least 50 yr (9, 10). Contradictory evidence of its transmissibility has been published recently (11, 20). Work on explaining blight has been hampered by the lack of reliable visible symptoms, but water injection into the trunk (4, 6) and analysis of the outer wood for Zn (13) are accepted as diagnostic tests in areas where citrus blight occurs (2, 5, 15). The level of Zn in the trunk wood fluctuates seasonally (16) and Zn accumulation occurs simultaneously or precedes visual symptoms by no more than 1 yr in most cases (18). Lower sulfate and chloride levels in the soil under blight-affected than under healthy trees have been reported (17, 18), but the view that blight is a nutritional disorder is far from universally accepted in spite of evidence for this (3, 14, 17, 18, 19). Because anions seemed to be involved in blight, a solution culture experiment was set up to test the hypothesis that anion nutrition has an effect on blightlike symptoms.

Materials and Methods

Seedlings of rough lemon and sour orange were grown in flats in peat moss/perlite (50:50, v:v) in a greenhouse and transplanted into 23-cm-diameter pots containing sterile sand-peat moss-perlite mix (50:25:25) in 1980. When the seedlings were pencil size, they were budded with virus-free 'Hamlin' orange buds from a mother tree which had grown in the greenhouse for 4 yr. When the trees were 18 months old, they were transplanted into 27 cm-diameter pots containing a 2:1 sand-red subsoil clay mix limed to pH 6.8 with calcitic limestone. In September 1983, when the trees were 32 months old, 6 trees on rough lemon and 6 trees on sour orange rootstock were removed from the pots and their root systems washed clean. They were then grown in a greenhouse in aerated solution culture in 10-liter crocks for 8 months. In May 1984, the trees were harvested and divided into leaves, bark, wood and roots. After washing and drying at 65°C, the various tissues were analyzed by standard methods (14). Stem segments were checked for plugs in the xylem and for water uptake by the syringe test (6). The pH of fresh wood was measured as described recently (18). There were 2 solution treatments, each with 3 trees on rough lemon and 3 trees on sour orange. The composition of the solutions (actual analysis values) is shown in Table 1. Both solutions were made with ammonium nitrate and triple superphosphate as N and P sources, using tap water (37 ppm Ca, 8 ppm Mg, 14 ppm Cl, 5 ppm S, 6 ppm Si). Solution 1 (high SO_4, low Si) contained langbeinite (18% K, 11% Mg, 22% S), a natural mineral sold as a soluble K and Mg source. In solution 2 (low SO_4, high Si) potassium silicate was the K source, with Mg supplied as magnesium sulfate; 4.1 g of water-insoluble calcium silicate was also added to each 10-liter culture at each solution change. Equal amounts of minor elements in form of a stock solution devised by Smith (7) and 1 ml/culture of metalaxyl, a fungicide, were added to both solutions. The solutions were changed every 2 weeks. The solution pH was measured at the beginning of the experiment, 10 days before and at harvest time. In an effort to increase leaf symptoms, the concentrations of N, P, K, Mg and S were doubled in solution 1 for the last 38 days, with no change in minor element addition. Solution levels were maintained by daily additions of tap water and the trees were checked frequently for visual symptoms. The *F*-test was used to compare treatments and rootstocks; the t-test was used to analyze the wood pH data.

Results and Discussion

Equal amounts of N, P, and minor elements were added to both solutions, yet there were some differences in the levels found by analysis (Table 1). This could be due to ionic interferences or precipitation. The only large differences between the 2 solutions were in S and Si, however. The pH of both fresh solutions was 7.6; over 10 days the pH of double strength solution 1 fell to 4.1, the pH of