2. Stewart, I. and T. A. Wheaton. 1971. Effects of ethylene and temperature on carotenoid pigmentation of citrus peel. Proc. Fla. State Hort. Soc. 84:264-266.
3. Simanton, W. A. and K. Trammel. 1966. Recommended specifications for citrus spray oils in Florida. Proc. Fla. State Hort. Soc. 79:26-30.
4. Trammel, K. and W. A. Simanton. 1966. Properties of spray oils in relation to citrus pest control in Florida. Proc. Fla. State Hort. Soc. 79:12-18.
5. Trammel, K. and W. A. Simanton. 1966. Properties of spray oils in relation to effect on citrus trees in Florida. Proc. Fla. State Hort. Soc. 79:19-26.
6. Wardowski, W., J. Soule, W. Grierson, and G. Westbrook. 1979. Florida Citrus Quality Tests. Univ. of Fla., IFAS, Bul. 188.
7. Whiteside, J. O. 1989. Comparison of various spray oils for controlling greasy spot on grapefruit leaves and fruit. Proc. Fla. State Hort. Soc. 102:13-16.

Proc. Fla. State Hort. Soc. 103:4-7. 1990.

PROSPECTS FOR IMPROVED CONTROL OF CITRUS SCAB WITH FUNGICIDE SPRAY TREATMENTS

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

Abstract. **The introduction of benomyl and captafol to the Florida citrus industry in the early 1970's greatly facilitated the control of citrus scab caused by *Elsinoe fawcettii* Bitanc. & Jenk. Now, because of fungal tolerance problems with benomyl and the unavailability of captafol, Florida citrus growers have no consistently effective, registered material for scab control. Among materials previously tested in Florida for scab control, only dithianon showed promise, but it was not registered for use in the United States. In recent tests, dithianon again performed better than currently recommended copper fungicide treatments. However, the sterol-inhibiting fungicide, difenoconazole (CGA 169374), usually gave better control of scab than dithianon. Where spray treatments were delayed until after some fruit had already become infected, difenoconazole reduced scab severity even more than captafol, because of its unique ability to inhibit the further development of existing pustules.**

Citrus scab, caused by *Elsinoe fawcettii* Bitanc. and Jenkins is a major problem in Florida on the more susceptible citrus cultivars, notably on 'Temples' and 'Murcotts.' This disease occurs less commonly on grapefruit and it rarely appears on sweet orange.

Relatively few fungicides have proven useful against citrus scab. Before benomyl and captafol became available in the early 1970's, only copper fungicides and ferbam were used in Florida to control scab, but the results were often disappointing, particularly when disease pressure was heavy. For several years after its introduction, benomyl provided good control, but after repeated use it began to fail in some groves because of a major shift in pathogen population from benomyl-sensitive to benomyl-tolerant (2). Captafol performed even better than benomyl and no tolerance problems were ever recorded with it. Production of captafol ceased in 1987 and Florida citrus growers were then left with no consistently reliable registered products for scab control.

Over the years, many fungicides had been tested for scab control (3), but only one of them, dithianon, showed promise. Although this fungicide was approved in many other countries for use on several vegetable and fruit crops, including citrus, application for its registration in the United States was never actively pursued. More recently, some chemical companies have expressed an interest in the potential market for this product in the United States, which has prompted further experimentation with this material in Florida for citrus scab control.

This paper reports the results of some experiments conducted over the past 3 yr with dithianon and with 2 experimental sterol-inhibiting fungicides, diniconazole and difenoconazole. Some of the data presented here has been previously published (5, 6).

Materials and Methods

The fungicides tested and their sources of supply were: dithianon (Delan 75W and Delan 6.25 SC) EM Industries, Inc., Hawthorne, NY; diniconazole (Spotless 25W) Valent U.S.A. Corp., Tallahassee, FL; difenoconazole (CGA 169374 3.5 EC) Ciba-Geigy Corp., Greensborough, NC; captafol (Difolatan 80 Sprills) Chevron Chemical Co., Ortho Div., San Francisco, CA; and basic copper sulfate (Tribasic copper sulfate WP 53% Cu) Tennessee Chemical Co., Atlanta, GA.

Field experiments were conducted in 1987, 1988, and 1989 on 10-ft-high 'Temple' orange trees spaced 25 x 20 ft in the Citrus Research and Education Center's grove at Davenport, Florida. In 1989, one experiment was also conducted at Alcoma, Florida on 15-ft-high 'Temple' trees spaced 25 x 18 ft.

The experimental plots were arranged in a randomized complete block design and replicated 6 to 8 times. Each plot consisted of 2 or 3 trees at Davenport and single trees at Alcoma. The spray mixes were applied dilute by handgun to runoff using an equivalent of 600 to 800 gal/acre, the actual volume depending on tree height.

The Davenport grove was not irrigated. Therefore, infection at this site was associated only with rainfall, which was recorded from bloom until late June, when the fruit became essentially resistant to further infection (3). The Alcoma grove received overhead sprinkler irrigation when rainfall was lacking. Rainfall was not recorded at Alcoma. At this site, scab was promoted by irrigation as well as by rainfall and consequently the infection pressure there was much heavier than at the Davenport grove.

The incidence of scab was determined on a 100-fruit sample of fruit, which was picked randomly around each

Florida Agricultural Experiment Station Journal Series No. N-00257.

tree canopy at 4 to 7 ft above the ground. A fruit was regarded as diseased even if it carried only one scab pustule.

In 1989, after a field test indicated that difenoconazole possessed curative properties, a greenhouse test was conducted on artificially infected leaves to investigate this phenomenon. Container-grown rough lemon seedlings were pruned to induce new shoot growth. After new leaves appeared, but before all of them had emerged from the apical meristem, the shoots were sprayed with a suspension of conidia using a pressurized handsprayer. The inoculum was produced as previously described (1). After inoculation, the plants were kept in a moist chamber for 2 days and then kept dry in the greenhouse to prevent further infection. The fungicide treatments were applied with a pressurized handsprayer at specified times after inoculation to determine how long treatments could be delayed before losing their postinfection activity.

Results

1987 Experiment No. 1. Open bloom began in late March and the bloom duration was relatively short, with two-thirds petal fall being reached by about 10 April. During April, the only rainfall was on 15 April and this was apparently too light to promote infection. Rain was recorded on 5, 9, 11, 12, 14, and 18 May and on 6 and 7 June. There was no further rain until 20 June which was probably too late to have induced much further infection because of increasing resistance of the rind to attack by this time.

Because the single applications of basic copper sulfate on 22 May did not reduce disease severity (Table 1), this indicated that the rainfall of 6 and 7 June probably promoted little, if any, infection. Essentially, the results (Table 1) reflected the efficacy of the spray treatments applied on 21 April in reducing infection during May. Under these circumstances, the program consisting of 2 applications of diniconazole performed as well as the one with captafol followed by basic copper sulfate. The 2-treatment program with basic copper sulfate gave inferior results.

1988 Experiment No. 1. The bloom period was short, with two-thirds petal fall being reached by 5 April. Rain fell on 12 and 20 April, 1, 14, 22, 23, and 26 May, and on 6, 22, 24, 27, and 28 June, but the rain in late June probably had little impact on infection because of increasing rind resistance.

In this experiment (Table 1), difenoconazole and captafol were more effective than diniconazole in controlling scab, and dithianon appeared to be intermediate in effectiveness. There was no significant reduction in the incidence of scab with 2 applications of basic copper sulfate or with the program consisting of diniconazole (lower rate) + oil followed by basic copper sulfate.

1988 Experiment No. 2. This experiment (Table 1) was conducted at a site adjacent to 1988 Experiment No. 1. By the time the first treatments were applied on 13 April, practically all the petals had fallen.

Difenoconazole provided better scab control than diniconazole and dithianon again seemed intermediate in effectiveness between the 2 sterol-inhibiting fungicides. The efficacy of diniconazole was not improved by adding oil to the spray mix.

1989 Experiment No. 1. Open bloom commenced in late-February and continued into early April. However, most

Table 1. Effect of different fungicides and spray programs on the control of citrus scab on 'Temple' orange fruit.

Year of test and experiment no.	Fungicide, rate of formulated product/100 gal and date of application	% fruit with scab
1987 No. 1	Captafol 80 Sprills 0.62 lb 21 April + basic copper sulfate[z] 1.5 lb 22 May	7.2 a[y]
	Basic copper sulfate 1.5 lb 21 April + basic copper sulfate 1.5 lb 22 May	30.7 b
	Basic copper sulfate 1.5 lb 22 May	50.0 c
	Diniconazole 25W 0.8 lb 21 April + diniconazole 25W 0.8 lb 22 May	10.3 a
	Check (untreated)	51.1 c
1988 No. 1	Captafol 80 Sprills 0.62 lb 5 April	6.4 ab
	Captafol 80 Sprills 0.62 lb 5 April + basic copper sulfate 1.5 lb 16 May	4.2 ab
	Basic copper sulfate 1.5 lb 5 April + basic copper sulfate 1.5 lb 16 May	29.1 ef
	Diniconazole 25W 0.88 lb and Sunspray 7E oil 2 pt 5 April	19.5 cde
	Diniconazole 25W 0.44 lb and Sunspray 7E oil 2 pt 5 April + basic copper sulfate 1.5 lb 16 May	22.3 def
	Dithianon 75W 0.8 lb 5 April	11.9 abcd
	Dithianon 75W 0.4 lb 5 April + basic copper sulfate 1.5 lb 16 May	14.2 bcd
	Difenoconazole 3.5 EC 0.5 pt 5 April	3.9 a
	Difenoconazole 3.5 EC 0.25 pt 5 April + basic copper sulfate 1.5 lb 16 May	7.9 abc
	Check (untreated)	35.1 f
1988 No. 2	Diniconazole 25W 0.44 lb 13 April	9.1 d
	Diniconazole 25W 0.44 lb and Sunspray 7E oil 2 pt 13 April	13.6 d
	Diniconazole 25W 0.44 lb 13 April + diniconazole 25W 0.44 lb 16 May	8.7 d
	Diniconazole 25W 0.44 lb 13 April + basic copper sulfate 1.5 lb 16 May	8.4 cd
	Dithianon 75W 0.8 lb 13 April	4.1 bc
	Dithianon 75W 0.4 lb 13 April + dithianon 75W 0.4 lb 16 May	3.4 bc
	Dithianon 75W 0.4 lb 13 April + basic copper sulfate 1.5 lb 16 May	4.3 bc
	Difenoconazole 3.5 EC 0.5 pt 13 April	1.1 ab
	Difenoconazole 3.5 EC 0.25 pt 13 April + difenoconazole 3.5 EC 0.25 pt 16 May	0.6 a
	Difenoconazole 3.5 EC 0.25 pt 13 April + basic copper sulfate 3.5 EC 0.25 pt 16 May	1.9 ab
	Check (untreated)	20.3 e
1989 No. 1	Basic copper sulfate 1.5 lb 13 April + basic copper sulfate 1.5 lb 19 May	6.9 bc
	Diniconazole 25W 0.35 lb 13 April	7.7 c
	Diniconazole 25W 0.35 lb 13 April + diniconazole 25W 0.35 lb 19 May	3.5 abc
	Dithianon 6.25 SC 0.5 pt 13 April	2.5 abc
	Dithianon 6.25 SC 0.25 pt 13 April + dithianon 6.25 SC 0.25 pt 19 May	2.1 ab
	Difenoconazole 3.5 EC 0.2 pt 13 April	1.5 ab
	Difenoconazole 3.5 EC 0.1 pt 13 April + difenoconazole 3.5 EC 0.1 pt: 19 May	0.2 a
	Check (untreated)	21.9 d

Table 1. (Continued).

Year of test and experiment no.	Fungicide, rate of formulated product/100 gal and date of application	% fruit with scab
1989 No. 2	Captafol 80 Sprills 0.5 lb 28 March	59.0 b
	Basic copper sulfate 1.5 lb 28 March + basic copper sulfate 1.5 lb 4 May	91.2 d
	Diniconazole 25W 0.35 lb 28 March + diniconazole 25W 0.35 lb 4 May	81.9 c
	Dithianon 6.25 SC 0.5 pt 28 March	75.0 c
	Dithianon 6.25 SC 0.25 pt 28 March + dithianon 6.25 SC 0.25 pt 4 May	68.3 bc
	Difenoconazole 3.5 EC 0.2 pt 28 March + difenoconazole 3.5 EC 0.2 pt 4 May	13.6 a
	Check (untreated)	99.3 e

[z]Basic copper sulfate was a wettable powder containing 53% copper.
[y]Mean separations within each experiment by Duncan's multiple range test, 5% level.

of the early bloom was destroyed by an unusually late frost. Much of the fruit that eventually set was derived from bloom buds which survived and opened in late-March and early-April. Scab pressure was relatively light. Although some infection occurred with rainfall on 13 April and 1 May, most of the infection was apparently associated with rain that fell on 29 May and on 5, 8, and 12 June.

The single application of difenoconazole.(Table 1) was more effective than the single application of diniconazole, and 2 treatments of difenoconazole gave better scab control than 2 treatments of basic copper sulfate. In this experiment, there was no clear distinction between the effectiveness of dithianon and the other fungicides.

1989 Experiment No. 2. This was the experiment (Table 1) conducted in a commercial grove at Alcoma, Florida. The bloom was exceptionally long, beginning in mid-February and continuing into early April. By the time of the first spraying date of 28 March, early-set fruit were up to 0.5 inches in diameter and many of them already had scab pustules. Heavy inoculum pressure from pustules on the previous year's shoots and unpicked late-bloom fruit, plus overhead sprinkler irrigation, had promoted particularly heavy infection of the current year's spring growth flush and young fruit.

The spray program consisting of 2 applications of difenoconazole was much more effective than any of the other treatments. The incidence of scab on fruit on trees sprayed with captafol was higher than previously experienced. This was because in this experiment, much infection had already occurred before the captafol was applied. Although captafol reduced secondary spread of infection, the pustules formed before treatment continued to develop, thereby still putting the fruit into a scab-affected category at maturity. In contrast, difenoconazole inhibited the further development of many of the early-formed pustules as well as acting as a protectant against later attack. In fact, the *curative* action displayed by difenoconazole was so efficient that many of the infected fruit were classified as essentially scab-free at maturity.

Despite the high incidence of disease, some differences were also discernible between the other spray programs. Dithianon provided better control of scab than basic copper sulfate, even when applied only once, but it was not significantly different from diniconazole.

1989 Experiment No. 3. This experiment (Table 2) was conducted at the same location as 1989 Experiment No. 1. Hereagain, the bloom or bloom buds were affected by a late frost and relatively few of them survived to produce fruit. However, the trees later responded by setting a heavy crop of fruit from a bloom which emerged in July. Disease incidence was determined separately on the regular in-season and the late-season fruit.

The incidence of scab on the in-season fruit was reduced significantly by captafol, dithianon, and difenoconazole, but not by basic copper sulfate or diniconazole. The carryover effect of the 12 April application of fungicides in reducing the incidence of scab on the fruit derived from the July bloom was more evident with difenoconazole and captafol than with dithianon. This suggested that the rate of inoculum recovery was more rapid after spraying with dithianon than after spraying with captafol or difenoconazole.

Observations on the postinfection effects of difenoconazole on leaves inoculated with Elsinoe fawcettii in greenhouse tests. After inoculating the young shoots with *E. fawcettii*, the plants were kept wet in a damp chamber for 48 hr. Infection could have occurred anytime during this period, but not later, because following their removal from the damp chamber, the foliage of each plant was quickly dried to prevent further infection. The plants were sprayed with difenoconazole 3.5 EC at 0.25 pt/100 gal at specified times after inoculation.

The time of inoculation was defined as the time the plants were removed from the damp chamber. No scab pustules ever appeared on shoots treated as soon as 24 hr after inoculation. Early symptoms of scab began to appear at 3 to 4 days after inoculation, but no pustules developed on shoots sprayed 4 days after inoculation. Only about 10% of the original scab symptoms remained discernible 1 month later on leaves treated at 8 days after inoculation, whereas the pustules on leaves sprayed at 15 day intervals after inoculation continued to develop.

Discussion

Previously published results (3, 4, 5) and the data presented herein, showed that copper fungicides are often

Table 2. Incidence of scab on fruit derived from spring and summer blooms on 'Temple' trees sprayed with fungicides on 12 April 1989.

Fungicide and rate/100 gal	% fruit with scab — Fruit set from bloom in: late-Feb to early-April	July
Captafol 80 Sprills 0.5 lb	4.3 a[z]	31.4 ab
Basic copper sulfate (53% Cu) 1.5 lb	28.9 b	67.0 c
Diniconazole 25W 0.35 lb	14.2 ab	39.7 abc
Dithianon 6.25 SC 0.5 pt	10.5 a	52.6 bc
Dithianon 6.25 SC 0.25 pt	11.6 a	48.8 bc
Difenoconazole 3.5 EC 0.2 pt	3.6 a	14.4 a
Difenoconazole 3.5 EC 0.1 pt	5.6 a	21.8 a
Check (untreated)	28.7 b	60.4 c

[z]Mean separations within columns by Duncan's multiple range test, 5% level.

inadequate for scab control. Only in 1989 Experiment No. 1, where copper was applied postbloom as well as shortly after petal fall, was there a substantial reduction in the incidence of scab, but here the scab pressure was relatively light.

At present, only copper fungicides, ferbam, and benomyl are registered for use against citrus scab in Florida. Clearly, more effective materials than copper or ferbam are needed for this purpose, particularly on the more susceptible cultivars. While benomyl is still useful for the control of scab where it has not been used much in the past, alternatives to benomyl are urgently needed because of the unreliability of this fungicide after repeated use. In some groves, benomyl has failed to control scab after using it one time a year for 4 to 5 consecutive yr (2).

Dithianon is one of the older fungicides that could be used instead of benomyl to control scab provided it is registered for use in the United States. In the experiments reported here, dithianon generally performed better than copper, as it did in previous experiments (3). Applications of dithianon as timed for scab control would also be beneficial for the control of melanose caused by *Diaporthe citri* Wolf (7).

Based on the results reported here, difenoconazole shows more promise for scab control than diniconazole. Diniconazole was more effective than basic copper sulfate only in some experiments, whereas difenoconazole was consistently better in this respect. Difenoconazole performed better than dithianon in 1988 Experiment No. 2 and 1989 Experiment No. 2. Difenoconazole equaled captafol in effectiveness in 1988 Experiment No. 1 and 1989 Experiment No. 3, and exceeded it in 1989 Experiment No. 2. The lower incidence of fruit with conspicuous scab pustules in 1989 Experiment No. 2 on trees sprayed with difenoconazole, as compared with those sprayed with captafol, reflected the unique curative properties of difenoconazole and the beneficial effects derived therefrom where some infection had already occurred before spraying.

The observation that further development of existing scab pustules can be inhibited or terminated by applications of difenoconazole would have considerable practical value. It would mean that spraying before any infection occurs would be less essential than with materials that have only an antisporulant or protectant action. The greater flexibility in spray timing would be particularly useful on a susceptible cultivar such as the 'Temple' orange which frequently blooms over a long period. Whereas it is advisable to apply other materials no later than two-thirds petal fall, it should be possible to delay an application of difenoconazole for 1 to 2 wk after petal fall, or perhaps even longer, and still obtain acceptable control.

The greenhouse tests on inoculated leaves indicated that difenoconazole could exert a curative effect even if delayed until 8 days after infection. However, the low incidence of scab symptoms at the time of fruit maturity in 1989 Experiment No. 2 suggested that the postinfection action of difenoconazole on fruit infections may continue for longer than 8 days. In this experiment, many fruit had scab pustules that were much older than this by the time the difenoconazole was applied. Yet, relatively few fruit showed conspicuous scab pustules by the time the fruit had fully developed.

More research will be needed to determine how to obtain acceptable scab control with a minimum amount of difenoconazole. This fungicide could probably best be utilized by applying it at two-thirds petal fall or shortly thereafter and then following it with a copper fungicide postbloom. The postbloom copper treatment would be necessary anyway to control melanose, because difenoconazole itself has proven ineffective against this other rind-blemishing disease (7).

Literature Cited

1. Whiteside, J. O. 1978. Pathogenicity of two biotypes of *Elsinoe fawcettii* to sweet orange and some other citrus cultivars. Phytopathology 68:1128-1131.
2. Whiteside, J. O. 1980. Detection of benomyl-tolerant strains of *Elsinoe fawcettii* in Florida citrus groves and nurseries. Plant Dis. 64:871-872.
3. Whiteside, J. O. 1981. Evolution of current methods for citrus scab control. Proc. Fla. State Hort. Soc. 94:5-8.
4. Whiteside, J. O. 1988. Control of citrus scab with fungicide sprays, p. 306. *In*: Fungicide and Nematicide Tests 43. Amer. Phytopathol. Soc., St. Paul, MN.
5. Whiteside, J. O. 1989. Evaluation of fungicides for control of citrus scab, p. 278. *In*: Fungicide and Nematicide Tests 44. Amer. Phytopathol. Soc., St. Paul, MN.
6. Whiteside, J. O. 1990. Evaluation of fungicides for control of citrus scab, p. 308-309. *In*: Fungicide and Nematicide Tests 45. Amer. Phytopathol. Soc., St. Paul, MN.
7. Whiteside, J. O. 1990. Protectant activity of fungicides for control of melanose on fruit, p. 304. *In*: Fungicide and Nematicide Tests 45. Amer. Phytopathol. Soc., St. Paul, MN.