Table 5. Influence of several aerial miticides on injury threshold level of citrus rust mite and citrus fruit quality.

	Amount product per acre	% Fruit above injury threshold[z] 1978	1980	1981	% Russetted Fruit 1978	1981	Fruit Diameter (inches) 1978
Difolatan 4F	3.0 qts			0.8		43.8	
Difolatan 4F	5.0 qts	3 a[y]	0.04		2.3 a		2.58
Difolatan 4F	10.0 qts	3 a			2.0 a		2.53
Difolatan 4F	12.0 qts		0.00				
Acaraben 4E	2.0 qts	5 a			6.8 a		2.58
Vendex 50W	1.5 lbs		0.04				
Vendex 4L	0.75 qt			1.6		36.7	
Vendex 4L	1.0 qt			1.3		33.8	
Untreated	—	20 b	1.70	1.4	26.4 b	37.9	

[z]Threshold is 75 or more mites per lensfield.
[y]Mean separation within columns by Duncan's multiple range test, 5% level.

formance of Difolatan in the May spray of 1978 complements its early season effectiveness and suggests that, when used at rates recommended in pre-bloom aerial application for disease control, rust miticide may be omitted from postbloom sprays.

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EVOLUTION OF CURRENT METHODS FOR CITRUS SCAB CONTROL[1]

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Abstract. **When copper fungicides and ferbam were the only materials used in Florida to control citrus scab, caused by** *Elsinoe fawcetti*, **at least 2 spray treatments were generally applied; yet the control was often poor. Better control has been provided by Benlate or Difolatan, even when applied only once, but problems with fungal tolerance recently have caused abandonment of Benlate in some groves. Difolatan was originally recommended only late dormant to avoid potential injury to new growth, but such early treatment required high rates of application to protect the fruit. It is now known that on Temples and Murcotts Difolatan can be safely and profitably delayed until bloom, when 1 to 2 pints of Difolatan 4F per 100 gal (dilute) can suffice. Recent inoculation and spray timing tests revealed that fruit rind remains susceptible to scab until 12 weeks after petal fall and that postbloom copper fungicide treatments as timed for melanose control, can supplement scab control.**

For many years in Florida, citrus scab, caused by *Elsinoe fawcetti* Bitanc. and Jenkins, was difficult to control because of a lack of highly effective fungicides. Copper fungicides (4, 13) or ferbam (1) were the only materials used to control the disease and even when they were applied routinely at the recommended times, just prior to spring shoot growth (late dormant) and again at 2/3 petal fall, the results were often poor. The late dormant treatment was intended to prevent a buildup of inoculum through infection of the spring growth flush, thus avoiding increased disease pressure on the fruit. No additional spraying after 2/3 petal fall was generally recommended specifically for scab control on fruit because the rind was thought to become resistant to attack in less than 4 weeks after petal fall (4, 13).

The superiority of captafol (Difolatan), over copper fungicide or ferbam, for scab control was first reported in Florida by Moherek (3), who began field trials with this material in 1965. Although now widely used for scab control, Difolatan does have certain limitations. To avoid excessive residue on fruit it can be applied only if the previous crop has been harvested. Furthermore, because injury to young shoots was sometimes observed (5), it was originally thought unsafe to apply it to any citrus cultivar after the spring growth flush started to emerge. High rates of Difolatan have to be applied late dormant to provide long enough protection of the fruit (3, 5). Nevertheless, the high cost of this dormant treatment was considered justified in that it provided a greater assurance of control than 2 copper or ferbam treatments, and it eliminated one spray operation (3).

In another breakthrough in scab control, Hearn and

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Childs in 1969 (2) found that benomyl (Benlate) was much more effective than copper fungicides. Benomyl, in contrast to Difolatan, could be applied safely after spring growth commenced and with the mature crop still unpicked. Single treatments of Benlate have performed better when applied at bloom than late dormant (5), but treatment at both times is necessary if disease pressure is heavy (8). Among the many other fungicides tested in Florida against citrus scab, only dithianon showed promise (5, 12), but it has not been registered for use in the U.S.A. Fungicides that have shown little or no potential for scab control include chlorothalonil, triforine, mancozeb, captan, folpet, fenarimol, dodine, thiram, prochloraz, fenapronil and CGA-64251 (5, 9, 11) and iprodione (Whiteside, unpublished data).

This paper reports on (i) some fruit inoculation tests to determine how long the rind remains susceptible to scab attack and (ii) the effectiveness of some different spray programs for scab control tested from 1975 to 1980.

Age of Fruit and Susceptibility to Scab Attack

During 1975 and 1976, fruit inoculation tests were conducted outdoors on Temple and grapefruit trees that previously had little or no scab. Procedures used to produce the inoculum of *E. fawcetti* for these tests have been described previously (7). To inoculate fruit, a strip of absorbent cotton was wrapped around the fruit stalk and then around the whole fruit except for a small area at its stylar end which was left exposed. Leaves on the fruit stem that were close enough to the fruit were enclosed within the wrap, with their leaf blades flat against the fruit surface. The wrapped fruit were immersed in water to saturate the cotton. After dripping ceased, each fruit was held with its stylar end uppermost and 10 ml of inoculum suspension were poured onto the exposed rind.

The highest incidence of infection usually occurred where the leaf blade was in contact with the rind. This was probably due to longer retention of water at this location than elsewhere because liquid water is essential for infection. Inoculation was delayed until near sundown to reduce the chances of too rapid drying. The cotton wraps were removed the following day. Different groups of 20 to 40 fruit were inoculated at weekly intervals from 4 to 15 weeks after petal fall.

Inoculation tests showed that fruit rind does not become fully resistant to infection until about 12 weeks after petal fall, by which time the Temple fruit were 30 to 40 mm in diameter and the grapefruit were 50 to 60 mm in diameter. Winston (13) concluded that grapefruit rind became immune to attack before the fruit reached 20 mm in diameter, equivalent to about 4 weeks after petal fall. Discrepancies between Winston's results and mine were probably due to differences in the infection capacity of the inoculum used. I found that inoculum prepared according to procedures used by Winston contained few conidia and produced scab symptoms only on very young fruit. The inoculum I prepared for studies on the changing susceptibility of citrus rind with age always contained abundant conidia, which are the only known infection propagules produced by *E. fawcetti* in Florida citrus groves.

Spraying Experiments for Scab Control, 1975 to 1980

All experiments (Table 1) were conducted on Temple trees planted in 1961 at the AREC-Lake Alfred grove at Barnum City, Florida. The trees were irrigated during prolonged dry weather by a mobile overhead volume gun, but because this caused only brief wetting of the canopy it promoted little scab attack. Therefore, annual differences in scab severity depended mostly on the amount and frequency of rainfall while the spring growth flush and fruit rind were still susceptible.

Spray treatments were applied dilute (high volume) at 10 gal/tree (about 800 gal/acre) to 2-tree plots replicated 7 or 8 times in a randomized block design. A sample of 100 to 120 fruit was picked randomly from each tree and the numbers of diseased and healthy fruit were counted. Diseased fruit were classified as those carrying one or more conspicuous blister-type scab eruptions or more than 1 cm^2 of flat scurfy-type scab. Summaries of results of some of these tests have been reported previously (6, 8, 9, 11, 12).

Table 1. Control of citrus scab disease with different fungicide spray programs.

Year	Treatment, rate of product[z] per 100 gallons and dates of application	% fruit with scab
1975	Difolatan 2 qt, Feb 17	2.4 a[y]
	Benlate 8 oz, Feb 17	11.5 bc
	Benlate 4 oz, Feb 17 + Benlate 4 oz, March 21	5.9 ab
	Benlate 4 oz, March 21	14.7 c
	BCS 1.5 lb, Feb 17 + BCS 1.5 lb, March 21	43.6 d
	Check	53.2 d
1976	Difolatan 2 qt, Feb 25	19.3 b
	Difolatan 1 qt, Feb 25	40.2 c
	Difolatan 1 qt, Feb. 25 + Benlate 4 oz, April 5	9.7 a
	Benlate 4 oz, Feb 25	37.3 c
	Benlate 4 oz, April 5	33.9 c
	Benlate 4 oz, Feb 25 + Benlate 4 oz, April 5	11.0 a
	Check	78.7 d
1977	Difolatan 1 qt, March 31	0.4 a
	Difolatan 1 qt, June 8	8.5 b
	Benlate 4 oz, March 31	2.4 a
	Benlate 4 oz, June 8	7.1 b
	BCS 1.5 lb, March 31	10.7 bc
	BCS 1.5 lb, June 8	11.2 bc
	Check	15.4 c
1978	Difolatan 2 qt, March 3	4.9 bc
	Difolatan 1 qt, March 3	11.5 d
	Difolatan 1 qt, April 4	1.3 a
	Difolatan 1 qt, March 3 + Difolatan 1 qt, May 5	1.6 a
	Difolatan 1 qt, March 3 + Benlate 4 oz, April 4	2.4 ab
	Difolatan 1 qt, March 3 + Benlate 4 oz, May 5	3.7 ab
	Benlate 4 oz, April 4	12.3 d
	Benlate 4 oz, March 3 + Benlate 4 oz, April 4	8.1 cd
	Benlate 4 oz, March 3 + Benlate 4 oz, May 5	11.4 d
	Check	48.8 e
1979	Difolatan 1 qt, April 6	0.5 a
	Benlate 4 oz, April 6	4.4 bc
	BCS 1.5 lb, April 6 + BCS 1.5 lb, May 9	7.7 cd
	Benlate 4 oz, April 6 + Benlate 4 oz, May 9	1.6 ab
	Benlate 4 oz, April 6 + BCS 1.5 lb, May 9	2.0 ab
	Benlate 4 oz, May 9	11.4 d
	BCS 1.5 lb, May 9	12.4 d
	Check	35.2 e
1980	Difolatan 1 qt, April 8	2.3 a
	Difolatan 1 pt, April 8	6.9 bc
	Difolatan 1 pt, April 8 + BCS 1.5 lb, May 7	3.9 ab
	BCS 1.5 lb, April 8	19.9 de
	BCS 1.5 lb, April 8 + BCS 1.5 lb, May 7	12.7 cd
	Check	28.3 e

[z]Formulation of products = Difolatan 4F; Benlate 50W; BCS (Basic copper sulfate) a wettable powder containing 53% copper.
[y]Numbers for each experiment followed with a letter in common are not significantly different (DMRT P = 0.05).

1975 Experiment. Treatments were intended for application just prior to shoot emergence and at bloom. However, because of unseasonably mild weather, shoot growth began unexpectedly early and the intended "late dormant" spray was not applied until some shoots were already 3 inches long. The second treatment date was about 2 weeks after peak bloom.

Because of low and infrequent rainfall during February and March there was little infection of the spring growth flush. Consequently, primary infection of fruit arose mostly from overwintering scab lesions on leaves and unpicked late-bloom fruit. The high-rate Benlate treatment of February 17 was less effective than the high-rate Difolatan treatment, and no better than the single lower-rate treatment of Benlate applied on March 21. Disease severity was not reduced significantly by the 2 Basic copper sulfate treatments. Difolatan caused no injury to the spring growth flush, despite the fact it had started to emerge before treatment.

1976 Experiment. Above-normal rainfall in March during shoot emergence promoted relatively heavy infection of the spring growth flush, which increased disease pressure on the fruit. Petal fall began in early April. Fruit infection was heavy and even the 2-qt rate of Difolatan applied late dormant provided inadequate control. The best results were obtained with 2 spray treatments: either Difolatan late dormant followed by Benlate at bloom or 2 Benlate treatments.

1977 Experiment. A major objective of this year's experiment was to determine the practical importance of the results from the recently conducted fruit inoculation tests.

The spring growth flush emerged in March and escaped attack because of dry weather. The bloom peaked in late March. Rainfall through April and May was very low and, consequently, fruit infection was relatively light.

The March 31 treatments of Difolatan and Benlate were equally effective in controlling scab on fruit. Scab was reduced even when application of these materials was delayed until June 8. This meant that the fruit were still susceptible during at least part of June, which corroborated the conclusions from the fruit inoculation tests. The March 31 Difolatan treatment caused no apparent injury to the young growth or bloom. The June 8 treatment with Difolatan caused severe fruit injury, but only after a 1% oil spray was applied on July 1.

1978 Experiment. The spring growth flush emerged in March and escaped attack because of dry weather. Bloom peaked in early April. Fruit infection occurred mostly during May and June. The single treatment of Difolatan 4F at 1 qt/100 gal was more effective when delayed until April 4 than when applied on March 3. Furthermore, the single Difolatan treatment of April 4 was more effective than the high-rate late-dormant Difolatan treatment or either of the 2-treatment Benlate programs. In this experiment, the Difolatan treatment applied on May 5 caused no injury to the rind, even though it was followed by an oil spray on June 30. However, in another test conducted on Temples in 1978, in which oil sprays were applied at various periods after Difolatan treatment, severe rind injury occurred even when there was an interval of 7 weeks between treatments.

1979 Experiment. The spring growth flush was attacked only lightly by scab. Bloom peaked in the first week of April. Most of the fruit infection occurred during an unusually wet period from late April to mid-May. The single Difolatan treatment controlled scab better than either of the single Benlate treatments. Once again, the bloom treatment of Difolatan was not phytotoxic. The postbloom copper fungicide and Benlate treatments both reduced the incidence of scab.

1980 Experiment. By this time, strains of *E. fawcetti* tolerant to Benlate had been detected in the Temple grove used for the previous spraying experiments (10). Therefore, Benlate was not included in the 1980 experiment.

Because of relatively few overwintering scab pustules and dry weather during the emergence of the spring growth flush in March, disease pressure on the fruit was relatively light this year. Scab control with *Difolatan 4F* was significantly less at 1 pt/100 gal than at 1 qt/100 gal, but not when the 1 pt/100 gal treatment was followed by Basic copper sulfate about 4 weeks after bloom. The copper fungicide reduced scab significantly only when it was applied postbloom as well as at bloom. None of the spray treatments was phytotoxic.

Practical Considerations in the Selection of Fungicide Spray Programs for Scab Control

After Difolatan and Benlate became available for use in citrus groves, it seemed that scab control would no longer present major problems. Both materials performed well, but where Difolatan could not be used because the mature crop was still unpicked or where there was a risk of injury to the new foliage, Benlate was the preferred material.

During the past 3 years, problems have arisen in some Benlate-sprayed groves because of a major shift in the pathogen populations from Benlate-sensitive to Benlate-tolerant. This has occurred in some cases after applying the material twice a year for as few as 5 consecutive years (10). While the usefulness of Benlate might be prolonged by alternating it with Difolatan, tolerance problems can be expected to become increasingly serious and widespread following its continued use, thus imposing a greater dependence on Difolatan for scab control.

While Difolatan is outstanding for scab control, greater economy of usage has been necessitated by its increasing costs and periodic shortages of supply. The use of a single late-dormant treatment has lost its appeal because of the high rates needed to assure protection of the fruit. Repeated observations on Temples and Murcotts that Difolatan can be applied safely anytime up to petal fall has led to a more realistic appraisal of the role that Difolatan can play in controlling scab on these 2 highly susceptible cultivars. The results reported in this paper indicate that Difolatan 4F at 1 qt/100 gal can suffice when the single application is delayed until bloom. Furthermore, the results of the 1980 test indicated that 1 pt Difolatan 4F/100 gal might suffice if disease pressure is not heavy, particularly if a postbloom copper fungicide treatment will be applied for melanose control.

The knowledge that application of Difolatan can be safely delayed until bloom (normally late March-early April) on Temples and Murcotts has helped to solve 2 problems. First, considerable economy can be achieved by reducing the amount of Difolatan required to provide acceptable control. Second, Difolatan can be used to control scab in groves that are not harvested until March which otherwise would not have received a late-dormant treatment, for fear of leaving excessive residues on the fruit.

Unfortunately, Difolatan cannot be applied without reservation at bloom on grapefruit or Minneola tangelo trees because Difolatan sometimes causes injury to the young foliage on these cultivars. Where *Benlate has failed* to control scab in grapefruit or Minneola groves, the only solution at present is to apply Difolatan dormant or to rely on postbloom copper treatment (preferably 2 applications) to protect the fruit.

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DETERMINING MOST PROFITABLE LEVEL OF NITROGEN FERTILIZATION FOR CITRUS[1]

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Additional index words. yield response, marginal analysis, economics, Hamlin, Valencia, irrigation.

Abstract. **Applying nitrogen fertilizer to citrus groves has long been recognized as a way to increase fruit yields. However, applied research shows that as increasing increments of nitrogen fertilizer are added to a grove, fruit yield response becomes less and less until additional increments of nitrogen result in declining fruit yields. Therefore, the efficiency of utilizing nitrogen to increase yield decreases as maximum production is approached. The most profitable rate of nitrogen application will depend on the relationship among the price of nitrogen and value of fruit and the response of the grove to nitrogen fertilization. Nitrogen yield response data from recent research are used to evaluate most profitable nitrogen fertilization rates using both current nitrogen-fruit price relationships and anticipated future price increases.**

In the 1940's and 1950's nitrogen prices were low and rates applied were usually high with extreme cases of 400-500 lb. of nitrogen applied per acre per year (4). Research in the late 1950's and early 1960's demonstrated that nitrogen rates in excess of 200 lb. of N per acre per year in non-irrigated groves and 250 lb. of N per acre per year in irrigated groves could seldom be justified (3). Nitrogen fertilizer prices have increased dramatically since the early 1970's. Further increases will likely occur in the immediate future as current contracts for natural gas, a major feedstock in nitrogen fertilizer production, expire. Natural gas prices are expected to be several times higher under new contracts.

In the event of increasing nitrogen prices, citrus grove managers must decide what nitrogen fertilization rates will produce maximum profits, not necessarily maximum yields. Therefore, in this study, data from nitrogen fertilization experiments with Hamlin and Valencia orange groves were evaluated to find the most profitable nitrogen fertilization rates under differing nitrogen prices and fruit values.

Materials and Methods

Yield response of Hamlin and Valencia oranges to increasing rates of nitrogen fertilization formed the basis for this paper (1, 2). In one study (2) both varieties received normal grove care management including irrigation. The study began with 12-year-old Hamlin and Valencia trees in 1972-73 and continued for five years. Nitrogen rates of 70, 130, 190 and 250 lb. per acre annually were applied. In addition, data from an irrigation-nitrogen study using only Valencia orange was analyzed (1). The irrigation-nitrogen study began with 12-year-old trees in 1973-74 and continued for four years. Nitrogen rates of 80, 160 and 240 lb. per acre per year were used in this study. Three irrigation levels were also included: no irrigation (I-1), soil water level maintained at 35% of field capacity 0-60" depth (I-2) and soil water level maintained at 65% of field capacity 0-60" depth (I-3). Only the I-3 treatment is considered in this paper.

Yields in lb. solids per acre for each nitrogen rate were averaged over the period for each variety. Average yields from each nitrogen treatment were plotted on graph paper (Figs. 1, 2) and a smooth curve was fitted to the data points by graphic technique. Nitrogen rates beginning at 70 lb. per acre and in 30 lb. increments were plotted and corresponding yields in lb. solids per acre were read from the graph.

A marginal analysis of the data was performed by determining the additional yield from each 30 lb. increment of nitrogen. The most profitable nitrogen rate was determined by equating the cost of a 30 lb. increment of nitrogen fertilizer with the value of the corresponding yield *increase*. Maximum profit is realized when the cost of an increment of nitrogen is just equal to the corresponding *increase* in yield.

Results and Discussion

The yield response of both the Hamlin and Valencia oranges (Figs. 1, 2) clearly exhibits the law of diminishing

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