$9,576,000 or about 14% of the total industry energy bill. The largest benefits would occur due to changes in irrigation with savings of 175,393 barrels of oil and in freeze protection with savings of 65,937 barrels of oil.

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# AERIAL DIFOLATAN FOR CITRUS RUST MITE CONTROL IN FLORIDA[1]

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*Additional index words.* Acaraben, captafol, Vendex, *Phyllocoptruta oleivora* (Ashmead), fenbutatin oxide, chlorobenzilate.

*Abstract.* **Difolatan (captafol) has been recommended for disease control in Florida citrus since 1972 and is effective when applied by aircraft as well as ground equipment. When applied by aircraft as a pre-bloom spray, Difolatan suppressed populations of the citrus rust mite,** Phyllocoptruta oleivora **(Ashmead), until July. Its use for disease control in the pre-bloom spray could eliminate the need for a miticide in dormant and post-bloom sprays.**

Difolatan (captafol) is effective in control of citrus scab, *Elsinoe fawcetti* Bitanc. & Jenkins, and melanose, *Diaporthe citri* (Fawc.) Wolf (3, 8). Since 1972, this fungicide has been recommended for control of those 2 diseases on Florida citrus (1).

Additional research indicated that the fungicide did not incite spider mite build-ups (3) but was lethal to the fungus *Hirsutella thompsonii* Fisher which is parasitic on the citrus rust mite *Phyllocoptruta oleivora* (Ashmead) (4). Its effectiveness vs. the citrus rust mite has also been demonstrated in evaluations of dilute sprays (2, 6).

Aerial application of Difolatan has provided successful disease control (3). The purpose of this investigation is to evaluate aerial application of Difolatan for control of the citrus rust mite.

## Materials and Methods

Experiments were conducted from 1978 through 1981 in a 12-acre (4.9 ha) block of 'Hamlin' orange trees planted 20 x 25 ft (6.1 x 7.6 m) on single beds during 1956 in Swain Grove 7E in St. Lucie county. The block was partitioned into sixteen 0.6-acre (0.242 ha) plots to create 4 replicates for each treatment in a randomized block design.

Treatments were applied with a Rockwell Aereo Commander 'Thrush'[2] fitted with 6 Micronair® AU3000 rotary atomizers and flown at 100 mph (161 kph) at tree-top height between tree rows.

All treatments in 1978 and 1979 were applied in 10 gallons per acre (93.5 liter/ha) of finished spray with spray volume per acre calculated on a 30-foot swath width (9.14 m). Treatments in 1980 and 1981 were applied in 15 gallons per acre (140.8 liter/ha) of spray.

Evaluation of chemical treatments was judged by reduction in mite population and % infestation after treatment. Twenty leaves and/or fruit were examined on each of 5 trees located in the center row of each plot. Trees were at least 75 ft (23 m) from adjacent treatments. One 10X lensfield on the upper and lower leaf surface and 2 sites on the peel surface of fruit, selected while the examiner circled target trees, were viewed to determine % infestation as well as population density. The presence of 1 live mite in a lensfield classified the leaf or fruit as 'infested.' Population density was determined by tallying all motile mites seen within each of two 1.2 $cm^2$ lensfields per leaf or fruit. Population density was measured on 400 fruit per treatment.

Fruit russetting was determined in October with the aid of a 2 $ft^2$ frame positioned at a height of 6 ft (1.8 m) on the perimeter of the tree canopy (7). Each fruit within an imaginary square extending from the frame toward the tree trunk was examined for mite injury. For each treatment, a frame count was made in each quadrant of 20 trees.

During 1978, 5 and 10 qt (4.70 and 9.46 liters) of Difolatan 4F were compared with 4 pt (1.89 liter) Acaraben 4E (chlorobenzilate) for control of rust mite. Treatments were applied on May 25 between 1000 and 1045 hr. The experiment was terminated after 11 weeks and the complete area treated with an ethion spray applied by airblast sprayer.

Difolatan was phytotoxic to fruit and its influence on fruit size was measured on hanging fruit in December when injured fruit was deliberately selected and the equatorial region 'calipered.' Unblemished fruit from Acaraben plots served as controls.

The second experiment, conducted during 1979, compared 3.0 and 9.2 qt (2.8 and 8.7 liter) of Difolatan 4F with 4 pints of Acaraben 4E for control of citrus rust mite. Treatments were applied to dry trees on March 9 under windless conditions, 50% relative humidity, and 69°F (20.5°C) temperature between 1050 and 1125 hr. The experiment was terminated after 17 weeks and the area received a summer spray including a miticide applied by airblast sprayer.

The third experiment, conducted in 1980, compared 5 and 12 quarts (4.7 and 11.4 liters) Difolatan 4F with 1.5 lb Vendex 50W (0.68 kg) (fenbutatin oxide). Treatments were applied March 19 in still air, 68.5°F (20.5°C), 99% relative humidity, and dew on the foliage. Rohm & Haas Triton CS-7 was mixed in the Vendex spray batch at the rate of 1 pint/100 gallons of spray (0.47 liter/378 liter). The experiment was terminated after 16 weeks and, within 7 days, the area received a 2X concentrate oil emulsion spray containing ethion and copper.

The fourth experiment, conducted in 1981, compared 0.75 and 1.0 quart (0.70 and 0.95 liter) of Vendex 4L with 3 quarts of Difolatan 4F. Treatments were applied June 22 between 0725 and 0855 hr with intermittent crosswinds of 1 mph (1.6 kph) while relative humidity fell from 100% to 88% and temperature rose 4 degrees to 82°F (27.7°C).

[1]Florida Agricultural Experiment Station Journal Series No. 3368.
[2]Aircraft and pilot were provided by Southeastern Aerial Crop Service of Ft. Pierce, FL 33454.

There was dew on the shaded fruit and foliage.

The experiment was terminated after 4 weeks and the area treated 3 weeks later with a 2x concentrate oil emulsion spray containing ethion and copper.

## Results and Discussion

During 1978, Difolatan and Acaraben provided lower % infestation and population density levels in all surveys than occurred in natural populations (Table 1). McCoy et al. (5) reported that the damage threshold for summer mite populations is reached when 1% of the surveyed fruit harbors 75 or more mites per 1 cm² lensfield. This was exceeded in all chemical treatments and contributed to the significantly greater amount of russetted fruit encountered in the absence of treatment (Table 5). Fruit size was not affected by peel injury resulting from Difolatan phytotoxicity (Table 5). Rind blemish was also reported by Moherek (3) on 'Hamlin' oranges receiving post-bloom spray applied by helicopter. The blemish had no adverse effect on fruit development, juice quality, or yield.

During 1979, mite populations receiving chemical treatments, as well as unsprayed mite populations, never reached lensfield densities considered to be of economic importance (Table 2). No mite injury occurred in this trial. While there was no significant difference in performance of chemical treatments, data suggest that Acaraben and the high rate of Difolatan were superior to the low rate of Difolatan.

In 1980, mite populations in all chemical treatments were significantly lower than unsprayed populations after 12 weeks (Table 3) and the miticide prevented lensfield densities from developing beyond the damage threshold (Table 5).

Treatments applied in 1981 (Table 4) failed to suppress mite populations or prevent the injury threshold from being exceeded or russetting to occur. The Difolatan treatment produced a rind blemish.

Pre-bloom applications of Difolatan provided reliable suppression of citrus rust mite until summer spray. Acaraben and Vendex were also effective. Attempts to control developing populations in June failed with the rates of Difolatan and Vendex used in the experiment. The per-

Table 4. Efficacy of several aerial miticides on citrus rust mite during 1981.

| | Amount Product in 15 GPA | Fruit population density[z] Weeks pre- and post-treatment | | | |
|---|---|---|---|---|---|
| | | −1 | +1 | +2 | +4 |
| Difolatan 4F | 3.00 qts | 8.7 | 8.8 | 12.7 | 21.7 |
| Vendex 4L | 0.75 qt | 9.7 | 7.1 | 8.8 | 18.6 |
| Vendex 4L | 1.00 qt | 9.6 | 7.4 | 13.3 | 12.5 |
| Untreated | — | 5.9 | 7.1 | 11.3 | 16.7 |

[z]Mean mite population density in 1.2 cm² lensfield on fruit.

Table 1. Efficacy of several aerial miticides on citrus rust mites during 1978.

| | Amount Product in 10 GPA | % Fruit infested Weeks pre- and post-treatment | | | | | | Population density[z] Weeks post-treatment | |
|---|---|---|---|---|---|---|---|---|---|
| | | −1 | +1 | +3 | +6 | +9 | +12 | +9 | +12 |
| Difolatan 4F | 5 qts | 14 | 25 | 14 | 32 | 40 | 32 | 6.9 a[y] | 3.4 a |
| Difolatan 4F | 10 qts | 13 | 24 | 10 | 34 | 33 | 22 | 6.4 a | 2.7 a |
| Acaraben 4E | 2 qts | 15 | 14 | 7 | 25 | 41 | 44 | 11.0 a | 9.4 ab |
| Untreated | — | 19 | 42 | 33 | 51 | 60 | 58 | 34.3 b | 13.3 b |

[z]Mean mite population density in 1.2 cm² lensfield on fruit.
[y]Mean separation within columns by Duncan's multiple range test, 5% level.

Table 2. Efficacy of several aerial miticides on citrus rust mite during 1979.

| | Amount Product in 10 GPA | Leaf population density[z] Weeks pre- and post-treatment | | | | Fruit population density[z] Weeks post-treatment | |
|---|---|---|---|---|---|---|---|
| | | −1 | +1 | +3 | +7 | +15 | +17 |
| Difolatan 4F | 3.0 qts | 0.01 | 0.58 | 0.80 | 1.27 | 1.90 | 4.4 |
| Difolatan 4F | 9.2 qts | 0.00 | 0.04 | 0.11 | 0.28 | 1.40 | 2.9 |
| Acaraben 4E | 2.0 qts | 0.01 | 0.00 | 0.04 | 0.04 | 2.00 | 3.4 |
| Untreated | — | 0.01 | 0.19 | 0.20 | 1.12 | 2.30 | 5.0 |

[z]Mean mite population density in 1.2 cm² lensfield on leaves and fruit.

Table 3. Efficacy of several aerial miticides on citrus rust mites during 1980.

| | Amount Product in 15 GPA | Leaf population density[z] Weeks pre- and post-treatment | | | | | Fruit population density[z] Weeks post-treatment | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | −1 | +1 | +2 | +4 | +6 | +8 | +10 | +12 | +14 | +16 |
| Difolatan 4F | 5 qts | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.6 a[y] | 6.5 a | 1.6 a |
| Difolatan 4F | 12 qts | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.3 a | 2.8 a | 0.8 a |
| Vendex 50W + CS-7 | 1.5 lbs | 0.4 | 0.1 | 0.1 | 0.1 | 0.1 | 0.3 | 0.4 | 0.7 a | 6.1 a | 1.9 a |
| Untreated | — | 0.1 | 0.3 | 0.1 | 0.1 | 0.1 | 0.3 | 0.6 | 2.2 b | 17.1 b | 4.8 b |

[y]Mean separation within columns by Duncan's multiple range test, 5% level.
[z]Mean mite population density in 1.2 cm² lensfield on leaves and fruit.

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] | | | % Russetted Fruit | | Fruit Diameter (inches) |
|---|---|---|---|---|---|---|---|
| | | 1978 | 1980 | 1981 | 1978 | 1981 | 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 post-bloom 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

[1]Florida Agricultural Experiment Stations Journal Series No. 3275.