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TIMING OF FUNGICIDE SPRAY TREATMENTS FOR CITRUS MELANOSE CONTROL

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Abstract. **Days on which climatic conditions were favorable at Lake Alfred, Florida for infection of the spring growth flush and fruit by the melanose fungus,** Diaporthe citri, **were calculated for each year from 1966 to 1980. Melanose severity on fruit was related to the number of infection days that occurred between petal fall (normally early-April) and the time of rind resistance (normally late-June). The number of probable major infection days in April was zero in 11 years, 1 in each of 3 years and 2 in the remaining year, whereas the number of such days averaged 3.7 for May and 6.0 for June. These records, combined with the results of spray timing experiments on grapefruit trees, supported the contention that an optimum response to a single copper fungicide spray is usually obtained when application is delayed until late-April or early-May. A pre-shoot-growth treatment with a copper fungicide, unlike one with Difolatan, failed to aid melanose control and these results are discussed in relation to the known sites of action of fungicides against** D. citri.

Citrus leaves are susceptible to attack by the melanose fungus, *Diaporthe citri* Wolf, until they have fully expanded (12). Fruit rind remains susceptible to infection for about 12 weeks after petal fall, but the later the infection occurs, the smaller the resulting pustules (5). Thus, melanose infection periods that occur after late-June generally do not affect the fruit except in years when the bloom is late.

Disease severity is influenced by the amount of recently killed wood in the tree canopy, the number of fruiting bodies (pycnidia) of *D. citri* produced thereon, and the amount, frequency and duration of rainfall to liberate and splash the spores (pycnidiospores) from the pycnidia onto susceptible shoot growth and fruit rind.

A key feature in the epidemiology of melanose is the long period of continuous wetting needed to assure pycnidiospore germination and host penetration. The required period increases greatly as temperature decreases. For example, the minimum period of wetting for infection is 10 to 12 hr at 25°C (77°F), but it increases to 18 to 24 hr at 15°C (59°F) (8, 12). Thus, rainfall associated with the passage of fast-moving cold fronts, which are responsible for most precipitation before May, seldom promote melanose attack. In contrast, summer-type afternoon or evening thunderstorms that are followed, characteristically, by warm, humid and calm conditions overnight are much more conducive to infection.

Fruiting structures of *D. citri* are produced only on dead wood, not on the melanose pustules themselves. Consequently, there is no compounding increase in inoculum pressure (as can occur with the citrus scab fungus *Elsinoe fawcetti* Bitanc. and Jenk.), if spraying should be delayed until after some melanose pustules have already formed.

In Florida, melanose control is still based mostly on the use of copper fungicides. Although most researchers (2, 5, 6, 8, 12) have agreed that little or no benefit is derived from copper treatments applied before petal fall, opinions have varied as to the best time to apply a single copper spray after bloom. In 1927, Winston et al. (12) stated that "ordinarily the most opportune time for this application is just in advance of the May rains, which seldom set in before the 5th of the month." Ruehle and Kuntz (5), while recognizing that April is usually too dry for infection, advised that spraying should be delayed no longer than 3 weeks after petal fall, regardless of the time of bloom. Thompson (7) recommended spraying as soon as possible after fruit set, starting even before bloom if it takes more than 3 weeks to spray the entire acreage. Yet, Childs (1) reported better control when treatments were delayed until 4 to 6 weeks after petal fall and Cohen (2) obtained better control with a spray applied at 3 weeks after fruit set than with one applied only a few days after petal fall.

The "spray early" philosophy prevailed for many years and, even as recently as 1974, the Florida Citrus Spray and Dust Schedule (3) recommended that a single postbloom copper spray be applied 1 to 3 weeks after petal fall. This publication also advised applying the copper spray as early as 2/3 petal fall, if both melanose and scab were to be controlled. A second application of copper, 4 weeks later, was recommended only if melanose had been troublesome in past years, during very wet springs or in the event of a late or scattered bloom.

A reassessment of the probabilities of melanose attack in April vs. May was made in the early 70's and these data (8) strongly supported Winston's contention (12) that when only one copper fungicide application is made, it is best delayed until late-April or early-May. A revision to this effect first appeared in the Florida Citrus Spray and Dust Schedule in 1976 (4).

Another fungicide used to control melanose in Florida citrus groves is captafol (Difolatan). However, possible injury to fruit rind precludes its use postbloom. Furthermore, on some citrus cultivars, including grapefruit, Difolatan may injure young foliage, thus permitting its use only as a late-dormant pre-shoot-growth spray. Such early applications of Difolatan assure good control of melanose on fruit only if high dosages are applied (8). The high cost of treatment has rendered this method of melanose control mostly impractical.

This paper reviews the results of some epidemiological studies and spraying experiments (8, 10, 11) that have led to a better understanding of the spray timing requirements for melanose control. In addition, a review is given of present knowledge on the sites of action of copper fungicides and Difolatan against *D. citri* to explain why prebloom sprays of copper, unlike those of Difolatan, fail to control melanose on fruit.

Compilation of Melanose Infection Days

A record was made of all known and probable melanose infection days at the Agricultural Research and Education Center, Lake Alfred for the period March 1 to June 30 for each year from 1966 to 1980. Criteria for infection were based on laboratory studies to determine the minimum wetting period required for infection at different temperatures (8, 12). Weather records used to determine probable infection periods included the type of rainfall (whether cold-front induced or due to summer-type afternoon and evening thundershowers), the time of precipitation and the

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minimum temperature overnight. Further corroboration of the requirements for major infection was provided by observing leaves or fruit for first appearance of symptoms, then studying the climatic conditions that prevailed on those days when the infection must have occurred.

Rainfall amounts of <0.1 inch were considered too low to cause much spore release or infection and were excluded from the compilation. Days on which rainfall ranged from 0.1 to 0.25 inches were recorded as minor infection days, but only if rain continued until 1500 hr and temperatures remained above 60°F (16°C) overnight. Major infection days were defined as those with >0.25 inches rain if this continued until at least 1700 hr and if temperatures remained above 60°F overnight. Days on which climatic conditions were deemed marginal for infection were also included, but only as minor infection days.

During March, the number of major infection days ranged from 0 in 9 of the years, to 1 in each of 4 years, and to 2 and 3 days, respectively for the other 2 years (Fig. 1). From 1966 to 1980, there was a total of only 5 major infection days in April, 2 of which occurred in April 1980. In contrast, there were 1 to 8 (average 3.7) major infection days per month in May and 0 to 11 (average 6.0) such days in June.

Results of Spraying Experiments for Melanose Control

All tests were conducted at Lake Alfred in a block of 20-foot-high 'Marsh' grapefruit trees planted about 1920. Sprays were applied dilute by handgun at rates of 15 to 20 gal per tree. Each treatment was applied to 2- or 4-tree plots replicated at least 6 times in a randomized block design. When naturally colored, 200 to 600 fruit per plot were picked, washed and graded into 2 categories consisting of fruit with conspicuous melanose pustules and those essentially melanose-free. The latter category included fruit with up to 100 pustules per fruit, provided they were <1 mm diameter.

In 1972, 1973, 1976 and 1979, the spring growth emerged in early March and bloom peaked in late-March. In 1974, shoot emergence was delayed until mid-March and bloom extended from mid-April to early-May. In 1975, shoot growth began in mid-February and the bloom extended from early-March to mid-April.

No melanose appeared on the spring growth flush in 1972, 1974, 1975 or 1976; light infection occurred in 1973 and a trace was observed in 1979.

A dormant application of Difolatan 4F at 1.0 gal per 100 gal gave good control of melanose on fruit in all the tests where it was included (Table 1), but it was never significantly better than a well-timed postbloom application of basic copper sulfate (53% metallic copper) at 1.5 lb. per 100 gal. Melanose control decreased when the rate of Difolatan 4F, applied dormant, was reduced to 0.5 gal per 100 gal.

The dormant treatment of basic copper sulfate applied in the 1972 test did not reduce melanose severity on the fruit. In most years, the postbloom copper treatment provided good control of melanose on fruit when delayed until late-April or early-May. Sometimes the half-rate of basic

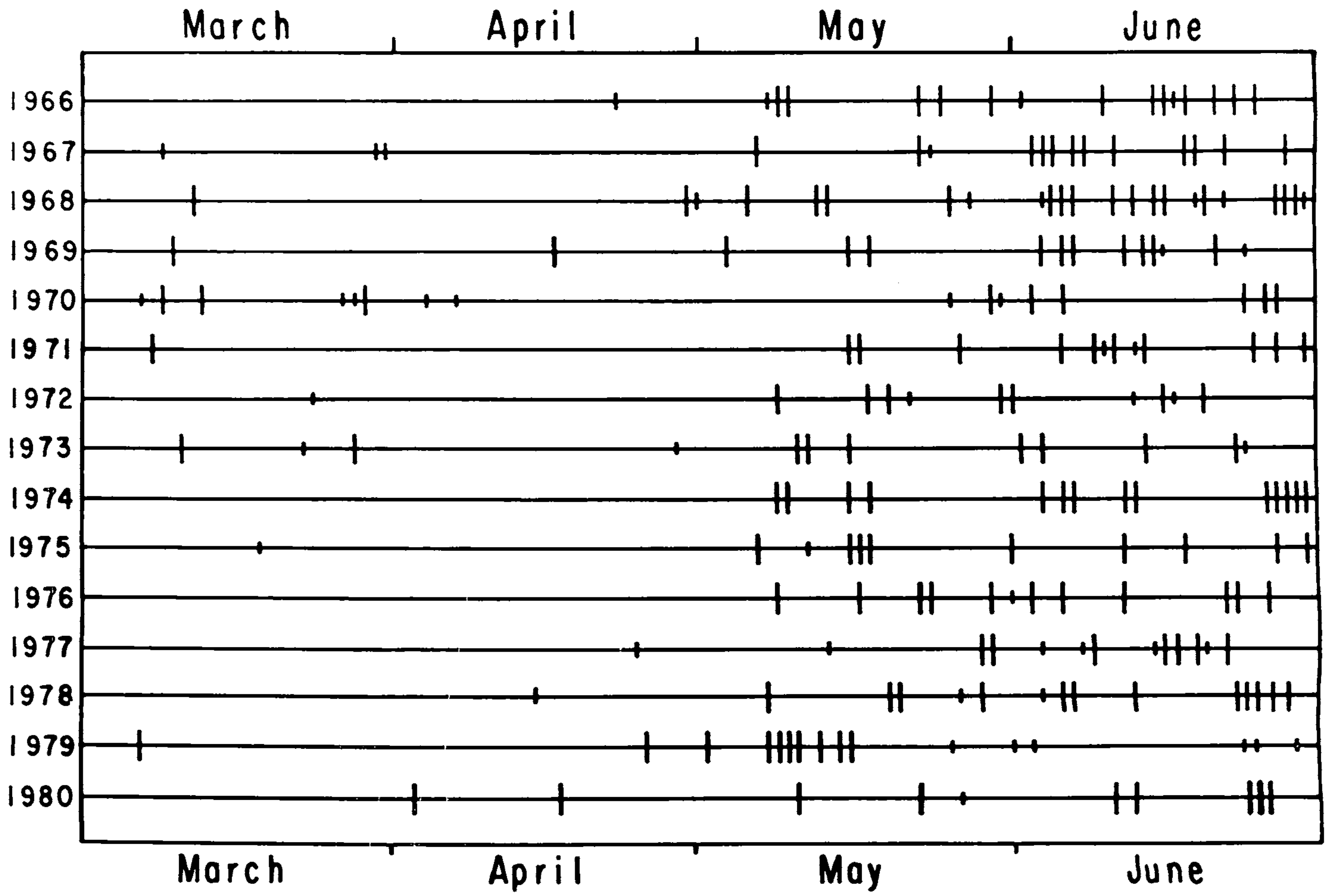

Fig. 1. Compilation of known or estimated melanose infection daysfrom March 1 to June 30 for each year at Lake Alfred, Florida from 1966 to 1980. Longer vertical lines denote climatic conditions favor-able for major infection. Short lines signify minor or doubtful infection days.

Table 1. Evaluation of fungicide treatments for melanose control on 'Marsh' grapefruit.

Year	Treatment and rate per 100 gallons	Dates of spraying	% fruit with conspicuous melanose
1972	Difolatan 4F 1.0 gal	February 28	14 b[z]
	Basic copper sulfate 1.5 lb.[y]	February 28	36 c
	Basic copper sulfate 1.5 lb.	May 1	5 a
	Basic copper sulfate 0.75 lb.	May 1	16 b
	Check	—	40 c
1973	Difolatan 4F 1.0 gal	February 27	5 a
	Basic copper sulfate 1.5 lb.	April 24	9 ab
	Basic copper sulfate 0.75 lb.	April 24	11 b
	Check	—	23 c
1974	Difolatan 4F 0.5 gal	March 1	69 b
	Basic copper sulfate 1.5 lb.	May 15	42 a
	Basic copper sulfate 0.75 lb.	May 15	57 b
	Check	—	83 c
1975	Difolatan 4F 1.0 gal	February 21	16 a
	Difolatan 4F 0.5 gal	February 21	29 b
	Basic copper sulfate 1.5 lb.	April 8	41 c
	Basic copper sulfate 1.5 lb.	April 24	31 bc
	Basic copper sulfate 1.5 lb.	May 9	11 a
	Basic copper sulfate 0.75 lb.	April 8 and May 9	11 a
	Check	—	65 d
1976	Difolatan 4F 1.0 gal	February 24	6 a
	Difolatan 4F 0.5 gal	February 24	16 b
	Basic copper sulfate 1.5 lb.	April 14	24 c
	Basic copper sulfate 1.5 lb.	April 28	10 a
	Basic copper sulfate 0.75 lb.	May 13	11 ab
	Basic copper sulfate 0.75 lb.	April 14 and May 13	7 a
	Check	—	73 d
1979	Basic copper sulfate 1.5 lb.	May 3	6 a
	Check	—	79 b

[z]Letters indicate Duncan's multiple range grouping of treatments which do not differ significantly at the 5% level.
[y]Wettable powder containing 53% copper.

copper sulfate also provided acceptable control, particularly if there was little or no fruit infection before mid-May and the spray was applied late, as in 1976.

Poor results were obtained with copper fungicide in the 1974 test. Some infection had already occurred before the treatment was applied on May 15 and, at this time, the later-set fruit was still too small to retain much fungicide.

The results of the 1975 and 1976 spray timing tests strongly supported the contention that if only one postbloom copper is to be applied it is best delayed at least until the end of April.

In 1979, there were more infection days in the first half of May than in any other year reviewed (Fig. 1). The May 3 treatment proved to be timely, even though it was preceded by 2 infection days.

Sites of Action of Difolatan and Copper Fungicides in Controlling Melanose

The results of previous tests (9) showed that Difolatan and copper fungicides act as protectants when applied directly to the fruit. Other tests, also reported previously (9), were made to determine if these fungicides have any other site or mode of action by using the following procedure. Equal numbers and lengths of inoculum-bearing twigs were immersed in spray mixes of Difolatan or copper fungicide for 30 seconds. After air-drying, the treated twigs were suspended outdoors over potted greenhouse-grown trap plants with young susceptible shoots to await rainfall. The amount of melanose that developed on these shoots following a rain-induced infection period was rated and compared with that on plants exposed to the same quantity of water-treated, inoculum-bearing twigs.

Dipping the twigs in a copper fungicide did not reduce the amount of melanose that subsequently developed on the trap plant shoots (9). Evidently, the copper spray had not reduced the inoculum-producing potential of the twigs. Furthermore, insufficient copper was redistributed by rain from the twigs to protect the shoots on the trap plants from infection by *D. citri*.

Treatment of inoculum-bearing dead twigs with Difolatan greatly reduced the amount of melanose that subsequently developed on the trap plants. This effect was due partly to a reduction in the amount of viable inoculum that reached the test plants (9). Difolatan did not affect the pycnidia themselves, but acted against the pycnidiospores only after they were discharged from these structures. Even brief contact of the extruded pycnidiospores with Difolatan deposits on treated bark caused high spore mortality. No such action was observed following brief contact of the spores with bark carrying a copper fungicide deposit. A further action of Difolatan resulted from its redistribution by rainfall from the original site of deposition to shoots and fruit that developed after treatment. Meaningful redistribution of Difolatan occurred either simultaneously with spore dispersal or in advance of an infection period, thereby providing a protective deposit of fungicide on the fruit to guard against later attacks (9).

Practical Considerations in the Timing of Copper Fungicide Treatments for Melanose Control

The results of spraying experiments reported here and elsewhere (2, 5, 6, 8, 12) and of studies on the site of fungicide action indicate that copper fungicides are effective against melanose on fruit only if applied postbloom. In Florida, applications of copper before fruit-set cannot even be justified to combat shoot infection, because melanose is seldom economically important on the spring growth flush. Furthermore, treatments applied during shoot emergence would be of doubtful value because they would not prevent infection of leaves that had not emerged by the time of spraying.

Because of the high costs of spraying, citrus growers usually try to control melanose on fruit with only one postbloom treatment. Unfortunately, one treatment can only be expected to afford good protection for a part of the 12-week period of rind susceptibility. If the treatment is applied soon after petal fall, while the fruit is still very small, the period of protection is relatively short. A small fruit retains relatively little spray material and the resulting fungicide residue soon dissipates through fruit enlargement and erosion. If, on the other hand, the treatment is delayed too long, infection could occur before the fruit is protected. Therefore, a decision on how to obtain the greatest benefit from a single postbloom spray has to be based on the probable frequencies of melanose attack at different times during the period of rind susceptibility.

The data compiled in Fig. 1 strongly support previous contentions (1, 8, 12) that postbloom treatment can be safely delayed in most years until late-April or early-May. The fungicide will then be applied closer to the time of more frequent attack and at a time when the fruit will be larger and retain more fungicide than if sprayed shortly after petal fall.

Timing of a postbloom spray for melanose control can be expressed more appropriately on a calendar basis than in relation to the time of bloom. If the bloom is earlier than normal, the timing need not be amended because the chances of melanose infection in March, as in April are relatively low. However, in years of late or extended bloom one spray, timed for late-April or early-May, will not provide adequate protection. Late-bloom fruit remain susceptible into July and they will be more severely affected by June attacks than fruit set at the normal time. Therefore, when the bloom is late or unduly extended, 2 postbloom copper sprays are advisable, the first in late-April and the second 3 to 4 weeks later.

The principle of delaying a postbloom copper fungicide for melanose control until late-April or early-May also applies to groves that receive overhead sprinkler irrigation. Such irrigation, even when applied for 12 hr, promotes little or no melanose attack under Florida conditions (Whiteside, unpublished data). Therefore, any effects of overhead irrigation in promoting melanose attack are likely to be negligible compared with the risks of later rainfall-induced infection.

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CITRUS ROOTSTOCKS FOR TREE SIZE CONTROL AND HIGHER DENSITY PLANTINGS IN FLORIDA[1]

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Abstract. **A closely spaced planting of virus-free nucellar 'Marsh' grapefruit** (Citrus paradisi **Macf.) and 'Valencia' sweet orange** [C. sinensis **(L.) Osb.**], **respectively, on 18 rootstocks was established in 1968 in Candler fine sand, a soil typical of the well-drained citrus-growing sites of central Florida. Rootstock influenced tree growth, fruit quantity and quality and production efficiency calculated as yield/unit of canopy volume or ground area. Trees on all stocks were smaller than those on rough lemon and in some instances had a greater yield/tree. The smallest trees were not necessarily the most desirable nor was it apparent that vigorous stock-scion combinations should be discarded for use in higher density plantings. Rootstocks with promise for use in such plantings were Rubidoux trifoliate orange** (Poncirus trifoliata **Raf.), Rusk citrange** (P. trifoliata x C. sinensis), **Koethen sweet orange x Rubidoux and Rangpur lime** (C. limonia **Osb.) x Troyer citrange. Preliminary data were obtained from a nearby 5-year-old planting of 'Ruby' grapefruit and 'Pineapple' orange trees on 28 rootstocks spaced 15 x 20 ft. Trees on Flying Dragon trifoliate orange, Changsha mandarin** (C. reticulata **Blanco), Rangpur lime x Troyer citrange,** Citrus sunki **(Hort ex Tanaka) x Swingle trifoliate orange and Morton citrange exhibited favorable horticultural performance which in some instances was superior to that of trees on Carrizo citrange.**

A primary objective of the rootstock research program at the Lake Alfred Research Center is tree-size-control (4). Several approaches to this goal, for example, viral dwarfing, and the use of plant material from the genus *Citrus* and related genera as interstocks, are being examined. In addition, conventional field trials to evaluate new rootstocks are also a part of the research effort. The development of plant material and techniques which provide trees of predictable, favorable behavior is an essential element in our tree spacing and management investigations.

The performance of 44 rootstocks presently being evaluated for their effects on tree vigor, yield and fruit quality in 2 separate rootstock experiments is presented in this report.

Materials and Methods

The first experiment consists of adjacent plantings of virus-free, nucellar 'Valencia' sweet orange [*Citrus sinensis* (L.) Osb.] and 'Marsh' grapefruit (*C. paradisi* Macf.) (3). Each planting of the respective scion on 18 rootstocks was set in 1968 as a randomized complete-block design with 3 replications of 4-tree plots. The trees were spaced 10 x 15 ft or 290 trees/acre. The rootstocks (Table 1) were chosen for their previously exhibited dwarfing nature either as a rootstock or as an untested seedling.

Nearly all trees had formed into hedgerows by 1975. Thus, the trees were periodically hedged as needed with a hand-held pneumatic saw. Since 1978, the trees have been individually hedged each year and the fresh weight of the prunings recorded. The trees have also been topped at

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