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CONTROL OF LYCHEE ANTHRACNOSE BY FOLIAR APPLICATIONS OF TEBUCONAZOLE, MANCOZEB, AND COPPER HYDROXIDE ON 'MAURITIUS' LYCHEE FRUIT UNDER SOUTH FLORIDA CONDITIONS

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Abstract. **Anthracnose is the major fungal disease of 'Mauritius' lychee (*Litchi chinensis* Sonn) in Florida and may reduce crop yields up to 100% in some years. Foliar applications of tebuconazole, mancozeb, and copper hydroxide were made to 'Mauritius' lychee trees from flowering (Feb.) to harvest (late May) in two commercial orchards. Tebuconazole was applied eight times at two rates in Orchard 1 and at one rate in Orchard 2. Ten mancozeb and copper hydroxide applications were made in both Orchard 1 and 2. Temperatures ranged from 52°F to 94°F and 13.0 inches of rainfall occurred during the test period Feb. to late May. The percentage of anthracnose infected fruit was determined on three dates in May, phytotoxicity ratings and yields were estimated once during May. Crop yields were estimated by counting total number of fruit per tree. Postharvest anthracnose infection was determined from a sample of fruit from each treatment in Orchard 2. Fruit was stored at a mean of 40 ± 2°F and 89 ± 5% RH and rated 4, 6, and 10 days after harvest. In general, tebuconazole and mancozeb treatments had a lower percentage of diseased fruit than copper hydroxide and non-treated control fruit. Phytotoxicity ratings on the fruit were low for all treatments. Mean fruit number per tree was significantly greater for trees treated with tebuconazole (1.56 oz ai acre^{-1}) compared to mancozeb, copper hydroxide, and non-treated control trees in Orchard 1. There was no significant difference in fruit number per tree among treatments in Orchard 2. There was no significant difference among the percentage of diseased fruit for any treatment after 4, 6 and 10 days of cold storage.**

Lychee was introduced to Florida around 1880 (Westgate and Ledin, 1953) and, during the 1940s and 1950s, went from a landscape fruit tree to a commercial crop encompassing about 350 acres (Knight, 1994; Young, 1966). During this period, 'Brewster' made up at least 95% of the commercial acreage. 'Brewster' produces a bright red-colored, good-flavored fruit that is resistant to anthracnose; however, the tree has an unreliable bearing habit. A number of freezing events from the winter of 1957 through 1989 and Hurricane Andrew (1992) reduced the lychee acreage in Florida to about 100 acres by 1993 (Knight, 1994; J. H. Crane, personal communication).

Today, Florida has about 611 acres of lychee with Dade County accounting for about 84% of the total State acreage (J. H. Crane, personal communication). The remaining acreage is distributed among Palm Beach, Broward, Lee, Martin, Sarasota, and Indian River Counties. 'Mauritius' is the predominant cultivar, comprising about 90% of the current acreage. About 6% of the acreage is planted to 'Brewster' and the remaining 4% is planted to various minor cultivars (e.g., 'Hak Ip', 'Bosworth 3').

'Mauritius' lychee was introduced into Florida from South Africa in 1951 (Ledin, 1957). It first fruited in 1957 and the fruit was noted to be affected by anthracnose, caused by *Colletotrichum gloeosporioides* (Penz.) Sacc.

Anthracnose is the major disease problem for lychee production in Florida at the present time (McMillan, 1994a) and in some years, crop losses from this disease may reach 100% if left uncontrolled. This is due to the predominance of 'Mau-

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Table 1. Fungicide application materials, rates, dates, and intervals for lychee Orchard 1 and Orchard 2.

Orchard	Fungicide (ai acre⁻¹)	Dates of application (all during 1997)	Spray interval (days)[z]
1	Tebuconazole (1.56 oz)	2-22, 3-4, 3-14, 3-28, 4-8, 4-22, 4-28, 5-6	start, 10, 10, 14, 11, 14, 6, 8
	Tebuconazole (2.34 oz)	2-22, 3-4, 3-14, 3-28, 4-8, 4-22, 4-28, 5-6	start, 10, 10, 14, 11, 14, 6, 8
	Mancozeb (1.95 lb)	2-22, 3-4, 3-14, 3-24, 3-21, 4-8, 4-16, 4-22, 5-3, 5-14	start, 10, 10, 10, 7, 8, 8, 6, 11, 11
	Copper hydroxide (1.10 lb)	2-22, 3-4, 3-14, 3-24, 3-21, 4-8, 4-16, 4-22, 5-3, 5-14	start, 10, 10, 10, 7, 8, 8, 6, 11, 11
	Non-treated control	—	not sprayed
2	Tebuconazole (1.56 oz)	2-22, 3-4, 3-13, 3-27, 4-9, 4-23, 4-28, 5-13	start, 10, 9, 14, 13, 14, 5, 15
	Mancozeb (1.95 lb)	2-22, 3-4, 3-13, 3-25, 4-1, 4-15, 4-23, 4-28, 5,5, 5-13	start, 10, 9, 12, 7, 14, 8, 5, 7, 8
	Copper hydroxide (1.10 lb)	2-22, 3-4, 3-13, 3-25, 4-1, 4-15, 4-23, 4-28, 5-5, 5-13	start, 10, 9, 12, 7, 14, 8, 5, 7, 8
	Non-treated control	—	not sprayed

[z]Start refers to the date on which fungicide treatments were started.

ritius' acreage and the hot, humid, rainy weather which occurs in Florida during the lychee fruit development period (March through June/July). Previous fungicide trials on anthracnose control on lychee fruit reported benomyl, mancozeb, and benomyl plus mancozeb applied at frequent intervals to be effective (McMillan, 1994b). However, disease resistance to benomyl and the possibility of alternative fungicidal materials with good disease control necessitates further field testing. The purpose of this investigation was to compare the efficacy of tebuconazole, mancozeb, and copper hydroxide fungicides for control of anthracnose on lychee fruit under field conditions.

Materials and Methods

The efficacy and phytotoxicity of three fungicides and a non-treated control were compared at two commercial plantings (Orchard 1 and Orchard 2) of "Mauritius' lychee in Homestead, Florida during 1997. Foliar applications of tebuconazole (Folicur 3.6F), mancozeb (Dithane DF), and copper hydroxide (Kocide 2000) were made from flowering in February to mid-May during fruit maturation. In Orchard 1, air-layered trees were 4 years old and spaced 20 ft × 25 ft (6.1 m × 7.6 m). Treatments were arranged in a Completely Randomized design with three replications per treatment and one to three trees per replication. In Orchard 2, air-layered trees were 3 to 7 years old and spaced 12 ft × 25 ft (3.7 m × 7.6 m). Treatments were arranged in a Randomized Complete Block design with four blocks, four replications per treatment, and three trees per replication.

Tebuconazole was applied eight times at 6 to 15 day intervals at 4 and 6 fluid oz of product acre⁻¹, respectively; (1.56 and 2.34 fluid oz ai acre⁻¹) in Orchard 1 and at only the 4 fluid oz rate in Orchard 2 (Table 1). Mancozeb and copper hydroxide were applied 10 times at 6- to 12- and 5- to 14-day intervals in Orchard 1 and Orchard 2, respectively. Mancozeb was applied at 2.5 lb acre⁻¹ (1.95 lb ai acre⁻¹) and copper hydroxide at 2.4 lb acre⁻¹ (1.10 lb metallic Cu acre⁻¹).

Ambient temperatures in the Homestead area ranged from 52°F to 94°F with 13.0 inches of rainfall occurring during the test period Feb. to mid-May (Anonymous, 1997).

The degree of anthracnose control was determined on three dates (2, 8, and 16 May in Orchard 1 and 2, 16, and 23 May in Orchard 2) prior to harvest by counting the number of diseased and total number of fruit on three randomly selected panicles per tree. Phytotoxicity was evaluated on 8 May in Orchard 1 and 2 May in Orchard 2 on two to three panicles per tree on the following scale: 0, no phytotoxicity; 1, a brownish burn-like texture to the fruit surfaces and; 2, necrosis of the peel. Fruit yields were estimated on 8 May in Orchard 1 and 16 May in Orchard 2. Crop yields were determined by counting total number of fruit per tree. A postharvest anthracnose rating was determined from one panicle of fruit with no visible anthracnose lesions taken from three trees per treatment harvested from Orchard 2 on 23 May 1997. Fruit was stored in closed paper bags at a mean of 40 ± 2°F and 89 ± 5% RH and rated 4, 6, and 10 days after harvest. The same rating scale and data analysis was used as for disease ratings in the field. All data were tested for whether it met the assumptions for analysis of variance. If the data were found not to conform, then they were transformed appropriately (e.g., arcsin or square root transformed) and analyzed (J. Harrison, University of Florida, personal communication).

Results and Discussion

Fungicide efficacy. In Orchard 1, the percentage of diseased fruit was not significantly different among treatments on 2 and 8 May (Table 2). However, the percentage of diseased fruit was significantly less for tebuconazole-treated fruit (7.8% and 6.4%) compared to copper hydroxide treated fruit (16.1%) on 16 May. The percentage of diseased fruit in the control and mancozeb treatments was not significantly different to that for the tebuconazole treatment.

In Orchard 2, the percentage of diseased fruit was not significantly different among treatments on 2 May (Table 2).

Table 2. Effect of tebuconazole, mancozeb, and copper hydroxide applications on the percentage of anthracnose infected 'Mauritius' lychee fruit on three dates in Orchard 1 and 2.

Orchard	Treatment (ai acre⁻¹)	Date of disease rating		
		Mean percentage of diseased fruit[z]		
		2 May	8 May	16 May
1	Tebuconazole (1.56 oz)	10.7 a	12.0 a	7.8 a
	Tebuconazole (2.34 oz)	9.2 a	12.4 a	6.4 a
	Mancozeb (1.95 lb)	2.5 a	24.9 a	13.6 ab
	Copper hydroxide (1.10 lb)	10.6 a	24.2 a	16.1 b
	Non-treated control	7.6 a	22.4 a	18.2 ab
		2 May	16 May	23 May
2	Tebuconazole (1.56 oz)	5.0 a	16.0 a	14.6 a
	Mancozeb (1.95 lb)	8.0 a	23.6 ab	15.5 a
	Copper hydroxide (1.10 lb)	5.6 a	36.3 bc	39.2 b
	Non-treated control	8.9 a	42.5 c	37.2 b

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

Table 3. Effect of tebuconazole, mancozeb, and copper hydroxide applications on fruit phytotoxicity ratings and estimated fruit yields of 'Mauritius' lychee from Orchard 1 and 2.[z]

			Estimated mean yield	
Orchard	Treatment (ai acre^{-1})	Mean phytotoxicity rating	Fruit no tree^{-1}	Fruit wt tree^{-1} (lb)[x]
1	Tebuconazole (1.56 oz)	0.58 ab	290 a	14.1
	Tebuconazole (2.34 oz)	0.15 a	133 ab	6.5
	Mancozeb (1.95 lb)	0.44 ab	59 b	2.9
	Copper hydroxide (1.10 lb)	0.75 b	44 b	2.2
	Non-treated control	0.33 ab	70 b	3.4
2	Tebuconazole (1.56 oz)	0.67 a	327 a	15.9
	Mancozeb (1.95 lb)	0.75 a	321 a	15.7
	Copper hydroxide (1.10 lb)	0.83 a	408 a	19.9
	Non-treated control	0.42 a	276 a	13.5

[z]Phytotoxicity ratings and fruit no. tree^{-1} mean separation in columns by Duncan's multiple range test, 5% level.
[y]Phytotoxicity ratings are 0, no damage; 1, a brownish burn-like texture to the fruit surfaces and; 2, necrosis of the peel.
[x]Fruit no. per tree was multiplied by 0.78 oz per fruit and divided by 16 oz per lb to estimate fruit wt per tree.

However, on 16 and 23 May tebuconazole (16.0% and 14.6%) and mancozeb (23.6% and 15.5%) had a significantly lower percentage of diseased fruit than the non-treated control (42.5% and 37.2%). Mancozeb-treated and copper hydroxide-treated fruit were not significantly different. On 23 May, tebuconazole-treated (14.6%) and mancozeb-treated (15.5%) fruit had a significantly lower percentage of diseased fruit compared to copper hydroxide-treated (39.2%) and non-treated (37.2%) control fruit. Mancozeb was found to be effective in a previous trial (McMillan, 1994b).

By 16 May, the incidence of diseased fruit in Orchard 1 appeared to be less than in Orchard 2 by 23 May (Table 2). This may have been influenced by the rate of fruit maturity and the amount of rainy weather and high relative humidity experienced in each orchard as fruit matured. About 2.4 inches of rain fell in the Miami area between the last disease rating in Orchard 1 (16 May) and Orchard 2 (23 May). The stage of fruit maturity may have also influenced the ratings as we noted that immature fruit were frequently less affected by anthracnose than more mature fruit.

Fungicide phytotoxicity. Phytotoxicity ratings were low for all treatments in both orchards and suggest none of the materials tested are phytotoxic to lychee fruit (Table 3). However, there was a significant difference among phytotoxicity ratings for treatments in Orchard 1. Copper hydroxide-treated fruit had significantly more phytotoxicity compared to tebuconazole-treated fruit at the 6 oz rate. However, differences in phytotoxicity ratings among tebuconazole at the 4 oz rate, mancozeb, copper hydroxide, and non-treated control fruit were not significantly different. However, these statistical differences appeared not to have any practical significance since ratings were all less than one. Some fruit scarring may have been due to abrasion of the fruit caused by leaves moved by wind.

Estimated fruit yields. In Orchard 1, trees treated with tebuconazole at the 4 oz rate produced more fruit than copper hydroxide and non-treated control trees but was not significantly different that tebuconazole-treated trees at the 6 oz rate (Table 3). The amount of fruit produced by tebuconazole-treated trees at the 6 oz rate, mancozeb, copper hydroxide, and non-treated control trees was not significantly different.

In contrast, the number of fruit produced was similar among treatments in Orchard 2 (Table 3). Crop yields in Orchard 1 were substantially less than in Orchard 2. Year to year and orchard to orchard variability in lychee crop production is not unusual (Olszack, 1986) and may be due to microclimatic differences among orchards (Menzel and Simpson, 1994).

Postharvest disease rating. There was no significant difference in the percentage of diseased fruit among treatments at 4, 6 and 10 days after storage (Table 4). However, there was a trend for the percentage of diseased fruit to increase with time and for non-treated control fruit to have a higher percentage of diseased fruit compared to tebuconazole and mancozeb-treated fruit. Drying and browning of the stored fruit was noticed 5 days after storage, however, these symptoms were easily discernible from anthracnose lesions on the fruit.

Conclusion. In general, fruit from tebuconazole and mancozeb treated trees had a lower percentage of anthracnose diseased fruit compared to copper hydroxide and non-treated control fruit (Table 2). Although there was a significant difference among treatment phytotoxicity ratings in Orchard 1, ratings were low and probably not of practical importance (Table 3). Tebuconazole-treated trees in Orchard 1 had significantly more fruit per tree than trees from all other treatments; however, there was no significant difference among treatments in Orchard 2 (Table 3). There was no significant difference among the percentage of diseased fruit for any treatments after 4, 6 and 10 days of storage (Table 4). However, there was a trend for non-treated control fruit to have a higher percentage of diseased fruit compared to all other treatments.

Table 4. Effect of tebuconazole, mancozeb, and copper hydroxide applications on the percentage of anthracnose infected 'Mauritius' lychee fruit from Orchard 2 after 4, 6, and 10 days of cold storage.[z,y]

		Mean percentage of diseased fruit		
		Days after storage		
Orchard	Treatment (ai acre^{-1})	4	6	10
2	Tebuconazole (1.56 oz)	8.3 a	19.4 a	21.8 a
	Mancozeb (1.95 lb)	5.9 a	16.3 a	15.1 a
	Copper hydroxide (1.10 lb)	19.3 a	40.8 a	23.9 a
	Non-treated control	6.6 a	32.3 a	32.6 a

[z]Mean separation in columns by Duncan's multiple range test, 5% level.
[y]Fruit were stored at 40 ± 2°F and 89 ± 5% RH.

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FLOOD DAMAGE ASSESSMENT OF AGRICULTURAL CROPS IN SOUTH DADE COUNTY AS A RESULT OF TROPICAL STORM GORDON

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Abstract. **Agriculture in Dade County has an annual economic impact of over $834 million. The agricultural area in Dade County is bounded by urban development in the north, Biscayne National Park to the east, Everglades National Park to the west, and Biscayne and Florida Bays to the south and southeast. The elevations range from sea level to about 25 ft above sea level. Flooding in the agricultural area during Tropical Storm Gordon (November 12-17, 1994) caused damage to agricultural crops. Crop damage data from the Farm Services Agency (FSA) were compiled by crop and acreage. The FSA reports after Tropical Storm Gordon suggest at least 1,300 acres, 8,612 acres, and 2,087 acres of fruit, vegetable, and ornamental plantings, respectively, were flooded as a result of Tropical Storm Gordon. This represented about 16.7% (11,999 acres) of the total agricultural acreage in the county during 1994 (71,955 acres). Twenty-one and 40 different fruit and vegetable crops were affected, respectively. Sixteen different categories of ornamental nursery crops were also damaged. Damage to plants included defoliation, stem and limb dieback, plant death, crop loss, and delay in harvest and cultural practices. Damage was estimated at $89.7 million. The general location of damage due to flooding during Tropical Storm Gordon is reported.**

The agricultural industry of south Dade County, Florida is situated in a unique geographic, climatic, ecological and sociological area. The agricultural area is located at the southern end of the Florida peninsula at 25°35' longitude north and 80°30' west latitude. The climate is marine subtropical with a yearly mean of 73°F, 65 inches of annual rainfall, mean annual RH of 62%, and average constant winds of 5-10 mph (Butson and Prine, 1968; Getz, 1979, Barrick and Black, 1980; Qualyle et al., 1995). The growing season is approximately 320 days, with the main vegetable season from August to May and fruits and ornamental crops (field and containerized) grown year-round.

The agricultural area is bounded by urban development to the north, Biscayne National Park to the east, Everglades National Park to the west, and Florida Bay to the south. The entire area is underlain by the Biscayne Aquifer. The indigenous fauna and flora, surficial aquifer, varied and extensive wetlands, marine coastal waters (bays and ocean), along with the marine climate, are highly sensitive to human activities. The warm climate, high humidity, and ample rainfall allow the production of tropical and subtropical crops year-round and traditional vegetable crops 8 out of 12 months of the year.

Agriculture in Dade County is worth over $521 million annually in gross sales and has an economic impact of over $834 million to Dade County (Degner et al., 1997). Most of the agricultural products produced in Dade County are exported out of the county throughout the U.S. and to foreign markets. Over 23,000 people in the county are employed in the agricultural and related industries (Moseley, 1990).

Tropical Storm Gordon occurred from 12 to 17 November 1994 in the south Dade County area. During the storm, the amount of rainfall reported in the area ranged from 6.89 to 9.48 inches (Anonymous, 1994; Krome, 1994). Flood damage varied by commodity and included crop loss and delay in planting and/or harvest of vegetable crops including potato, malanga, beans (bush green, bush wax, pole), squash, boniato (sweet potato), and tomato. Vegetatively propagated plant-

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