Timing of Fungicide Applications for Control of Postbloom Fruit Drop of Citrus in Florida

L. W. TIMMER, Professor, and S. E. ZITKO, Senior Biologist, Citrus Research and Education Center, University of Florida, Institute of Food and Agricultural Sciences, 700 Experiment Station Road, Lake Alfred 33850

ABSTRACT

Timmer, L. W., and Zitko, S. E. 1992. Timing of fungicide applications for control of postbloom fruit drop of citrus in Florida. Plant Dis. 76:820-823.

Fungicide application schedules of benomyl or captafol for control of citrus postbloom fruit drop caused by *Colletotrichum gloeosporioides* were evaluated in three orchards during the 1989–1991 bloom periods. In seasons and locations where disease incidence was low, a single application of either fungicide at midbloom or two applications, one at early bloom and one at midbloom, reduced blossom blight incidence and the formation of persistent buttons (floral disk and calyx). Where disease incidence was great, only weekly or 10-day schedules provided a high degree of control of blossom blight and button formation. The number, rather than timing, of applications during the bloom period appeared to be the primary determinant of the degree of disease control. Blossom blight incidence and button formation decreased exponentially as the number of applications increased in many cases. When disease incidence was low or moderate, fruit counts or total yields were not increased by any application schedule. In one case, when disease incidence was high, fruit counts were increased about sevenfold and total yield was increased threefold when applications were made every 10 days, but other application schedules in the same experiment did not increase fruit counts or yield.

Postbloom fruit drop (PFD) of citrus is caused by a strain of *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc. in Penz. (3). The fungus infects petals, producing peach- to orange-colored necrotic spots, and under favorable conditions can affect entire flowers and clusters, producing blossom blight. Abundant acervuli and conidia are produced on the surface of blighted flowers. After flower infection, fruitlets drop, but "buttons" composed of the peduncle, floral disk, calyx, and nectaries remain. These persistent buttons are diagnostic for the disease.

PFD was first described in Belize in 1979 (3) and now has been reported from most humid citrus areas in South and Central America and the Caribbean (1). The disease first appeared in 1983 in southern Florida on Persian limes (6). Subsequently, it has caused sporadic, locally severe problems on most citrus varieties in various areas in the state (9).

Benomyl and captafol, alone or in various combinations, have proven the most effective fungicides for control of PFD in Belize (4). One to four applications during the bloom period were needed to control the disease (4). In vitro studies indicated that benomyl also was effective against the pathogen in Florida (8). Applications of several fungicides alone or in combination reduced button formation on Persian lime in trials in southern Florida (5).

No information is available in Florida on the timing or number of sprays required to control PFD or on the effect of the disease on yields. This article presents the results of fungicide timing trials with benomyl or captafol for 3 yr in three orchards.

Florida Agricultural Experiment Station Journal Series R-02132.

Accepted for publication 24 March 1992.

MATERIALS AND METHODS

Study sites. Three orchards in southwestern Florida with severe postbloom fruit drop in 1988 were selected for fungicide timing tests. Two orchards were located near Arcadia, FL—one was navel orange (*Citrus sinensis* (L.) Osbeck) on sour orange (*C. aurantium* L.) rootstock; the other was Valencia orange on the same rootstock. The third orchard, located near La Belle, was navel orange on Swingle citrumelo (*Poncirus trifoliata* (L.) Raf. × *C. paradisi* Macfady.) rootstock.

Fungicide application. The following five fungicide application schedules were evaluated in the three orchards from 1989 to 1991: 1) untreated control—no fungicide application during bloom; 2) a single application at midbloom; 3) one application at early bloom and one at midbloom; 4) a discretionary program based on stage of bloom, disease incidence, and recent rainfall; and 5) a weekly or 10-day schedule during the bloom period. Not all applications were made in every orchard in all 3 yr. Program variations and all application dates are presented in Tables 1–3.

Benomyl, formulated as 50WP or 50DF, was applied in the two orchards near Arcadia at 1.14 kg a.i./ha using an airblast sprayer delivering 1,660 L/ha. Captafol, formulated as 80 Sprills, was applied to the orchard near La Belle at 4.54 kg a.i./ha using an airblast sprayer delivering 950 L/ha.

Application schedules were arranged in a randomized complete block design and replicated five times on four-tree plots at each site. Trees within each plot were in the same row and an unsprayed guard tree was located between plots. Unsprayed guard rows were left between treated rows of each experiment.

Evaluations of disease. PFD incidence was determined by inspecting all blossoms that were open or about to open on each tree from early bloom to petal fall. If more than 100 blossoms were present, only 100 were inspected around the periphery of the canopy. Unsprayed control plots were inspected biweekly and all plots were evaluated if disease incidence was greater than 5%. The average percentage of bloom affected in each of the five plots was calculated and graphed over the bloom periods. Data for each replicate were plotted individually and the area under the curve (AUC) was determined by passing plots through a leaf area meter (LI-3000, Li-Cor, Inc., Lincoln, NE).

The number of persistent buttons and fruit on 12 branches per tree, three selected at random in each quadrant of the tree, were counted in June of each year after normal physiological drop was complete. Total fruit yields in the navel orange orchard near Arcadia, the site where disease was most severe, were determined at harvest in November 1989 and October 1991.

Data on AUC, numbers of buttons and fruit, and yields were subjected to analysis of variance and means separated using Duncan's multiple range test to compare application schedules. The relationship between the number of fungicide applications and the AUC and the number of buttons was analyzed using curve-fitting programs. Only exponential curves showed consistently significant relationships, and results are not presented for other types of curves. All statistical analyses were conducted using SAS Version 6.04 (7).

RESULTS

1989. Disease was moderate in the navel oranges near Arcadia with up to 30% of the blossoms blighted at times. All spray schedules that included benomyl reduced blossom blight and the persistent buttons compared with the untreated control, but there were few differences among the four application schedules tested (Table 1). However, regression analysis showed a significant negative exponential relationship between the number of applications and AUC for blossom blight ($R^2 = 67.8\%$, $P = 0.055$) and the number of buttons ($R^2 = 90.6\%$, $P = 0.008$). Despite appreciable blossom blight and the large number of buttons formed, there was no effect of treatment schedule on fruit counts or total yield at harvest.

Little disease was observed in the Valencia orange orchard near Arcadia. Analysis of variance indicated no difference among spray schedules that included benomyl in blossom blight, button formation, or fruit counts (Table 1). However, regression analysis indicated a significant negative exponential relationship between the number of sprays and the AUC ($R^2 = 87.7\%$, $P = 0.012$).

Disease incidence also was low in the navel orange experiment near La Belle. The early bloom and midbloom and the weekly schedules of captafol significantly reduced the AUC for blossom blight (Table 1). The weekly spray schedule significantly reduced the number of buttons compared with the unsprayed

Table 1. Effect of fungicide application schedules on control of postbloom fruit drop of citrus in 1989

Benomyl application schedule[t]	No. of applications	AUC[u]	Buttons per 12 branches[v]	Fruit per 12 branches[v]	Yield (kg/tree)
Navel oranges—Arcadia[w]					
Control	0	28.0 a[x]	68 a	12.6	119
Midbloom	1	13.4 b	38 b	12.2	147
Early and midbloom	2	8.3 b	26 bc	10.0	127
Discretionary	3	6.1 b	15 bc	12.0	131
Weekly	9	3.6 b	5 c	12.6	139
				NS	NS
Valencia oranges—Arcadia[y]					
Control	0	5.3	4.6	22	...
Midbloom	1	3.4	2.8	21	...
Early and midbloom	2	3.4	3.4	22	...
Discretionary	1	2.4	3.8	22	...
Weekly	9	0.7	2.2	23	...
		NS	NS	NS	
Navel oranges—La Belle[z]					
Control	0	3.1 a	7.0 a	22	...
Midbloom	1	2.5 ab	2.6 ab	21	...
Early and midbloom	2	1.5 b	3.4 ab	22	...
Discretionary	1	2.3 ab	6.4 ab	22	...
Weekly	9	1.5 b	1.8 b	22	...
				NS	

[t] Navel and Valencia oranges in Arcadia were sprayed with benomyl; navel oranges in La Belle were sprayed with captafol.
[u] Area under the curve for percent flowers affected by blossom blight.
[v] Average number of persistent buttons or fruit on three branches in the four quadrants of each tree counted in June of each year after normal physiological fruit drop.
[w] Application dates for benomyl: early bloom, 16 February; midbloom, 23 March; discretionary, 23 February, 2, 23, March; weekly, 9, 16, 23 February, 2, 9, 16, 23, 30 March, and 6 April.
[x] Mean separation by Duncan's multiple range test, $P \leq 0.05$. NS = not significant.
[y] Application dates for benomyl: early bloom, 16 March; midbloom, 30 March; discretionary, 16 March; weekly, 9, 16, 23 February, 2, 9, 16, 23, 30 March, and 6 April.
[z] Application dates for captafol: early bloom, 9 February; midbloom, 24 March; discretionary, 9 March; weekly, 9, 16, 23, February, 2, 9, 16, 23, 30 March, and 5 April.

Table 2. Effect of fungicide application schedules on control of postbloom fruit drop of navel oranges in La Belle, FL, in 1990

Captafol application schedule[w]	No. of applications	AUC[x]	Buttons per 12 branches[y]	Fruit per 12 branches[y]
Control	0	2.5 a[z]	5.6 a	32
Midbloom	1	0.2 b	4.2 ab	34
Early and midbloom	2	0.4 b	2.0 bc	35
Discretionary	1	0.2 b	1.8 bc	30
Weekly	3	0.2 b	0.6 c	35
				NS

[w] Application dates: early bloom, 1 February; midbloom, 12 February; discretionary, 22 February; weekly, 1, 12 February, and 9 March.
[x] Area under the curve for percent flowers affected by blossom blight.
[y] Average number of persistent buttons or fruit on three branches in the four quadrants of each tree counted in June of each year after normal physiological fruit drop.
[z] Mean separation by Duncan's multiple range test, $P \leq 0.05$. NS = not significant.

control, but there was no difference in fruit counts among the application schedules. There was no significant relationship between the number of sprays and AUC or number of buttons.

1990. A freeze in December 1989 caused some defoliation at all experimental sites but did not produce appreciable twig or wood damage. As a consequence of defoliation and warm weather in January 1990, the bloom was profuse, early, and of short duration. Thus, complete application schedules were not possible.

In the navel orange orchard near Arcadia, blossom blight never exceeded 5% in the control. An average of 2.8 buttons per 12 branches were formed on the control, and a single application of benomyl made on 15 February significantly reduced the number of buttons compared with the untreated control. Fruit counts per 12 branches ranged from 69 to 74 in the different plots but were not significantly affected by the application.

In the Valencia orange orchard near Arcadia, disease incidence was low and only a single application of benomyl was made on 15 February. Button counts ranged from 1.6 to 4.5 per 12 branches and fruit counts from 63 to 75 per 12 branches, but the application did not significantly affect either variable.

Some disease occurred in the navel orange orchard near La Belle, and all application schedules that included captafol significantly reduced blossom blight (Table 2). All schedules except the single spray at midbloom reduced button formation. No schedule increased fruit counts over the unsprayed control. There was a significant exponential relationship between the number of sprays and the number of buttons formed ($R^2 = 83.3\%$, $P = 0.03$).

1991. Disease was exceptionally severe in the navel orange orchard near Arcadia with up to 80% of the flowers blighted at some times. Schedules where one or two applications of benomyl were made reduced the AUC for blossom blight, and five applications on a 10-day schedule nearly eliminated blossom infection (Table 3). However, the schedules with one or two applications reduced button counts only slightly if at all. The program of five applications had seven times more fruit and three times greater total yield than the unsprayed control but was the only schedule that increased the fruit counts or yield. There was a significant negative relationship between the number of sprays and AUC ($R^2 = 87.1\%$, $P = 0.013$).

In the Valencia orange orchard near Arcadia, blossom blight incidence was very low except for near the end of the bloom in late March and early April. The AUC was not calculated. Disease occurrence was localized with none in some plots and moderate disease in others. Most benomyl application schedules reduced button counts, and there was a significant relationship between the number of sprays and the number of buttons ($R^2 = 81.8\%$, $P = 0.022$). The discretionary program with a single early bloom spray had higher button and lower fruit counts (Table 3), but this was probably attributable to coincidental location of these plots in areas with high disease. In the other schedules, fruit counts were not different from the unsprayed plots.

Disease incidence was low in the navel orchard near La Belle, and a full program of sprays was not completed. Three applications of captafol on a 10-day schedule or a single application at early bloom reduced button counts (Table 3). A single application at very first bloom (discretionary) was ineffective. The relationship between the number of sprays and number of buttons was not significant.

Table 3. Effect of fungicide application schedules on control of postbloom fruit drop of citrus in 1991

Benomyl application schedule[t]	No. of applications	AUC[u]	Buttons per 12 branches[v]	Fruit per 12 branches[v]	Yield (kg/tree)
Navel oranges—Arcadia[w]					
Control	0	86.1 a[x]	258 a	1.9 b	26 b
Midbloom	1	49.1 b	249 ab	3.0 b	44 b
Early and midbloom	2	49.5 b	246 ab	1.2 b	28 b
Discretionary	2	44.2 b	217 b	2.3 b	38 b
10-day	5	1.8 c	62 c	13.7 a	77 a
Valencia oranges—Arcadia[y]					
Control	0	...	49 b	24.1 ab	...
Midbloom	1	...	25 c	21.3 bc	...
Early and midbloom	2	...	13 cd	26.1 ab	...
Discretionary	1	...	70 a	17.7 c	...
10-day	6	...	3 d	29.6 a	...
Navel oranges—La Belle[z]					
Control	0	...	3.1 a	...	...
Midbloom	0	...	2.5 ab	...	...
Early and midbloom	1	...	1.5 b	...	...
Discretionary	1	...	2.3 ab	...	...
10-day	3	...	1.5 b	...	...

[t] Navel and Valencia oranges in Arcadia were sprayed with benomyl; navel oranges in La Belle were sprayed with captafol.
[u] Area under the curve for percent flowers affected by blossom blight.
[v] Average number of persistent buttons or fruit on three branches in the four quadrants of each tree counted in June of each year after normal physiological fruit drop.
[w] Application dates for benomyl: early bloom, 1 March; midbloom, 11 March; discretionary, 7 February, 20 March; 10-day, 7, 18 February, and 1, 11, 30 March.
[x] Mean separation by Duncan's multiple range test, $P \leq 0.05$.
[y] Application dates for benomyl: early bloom, 11 March; midbloom, 29 March; discretionary, 7 February; 10-day, 7, 18 Feburary, and 1, 11, 20, 29 March
[z] Application dates for captafol: early bloom, 1 March; midbloom, not applied; discretionary, 8 February; 10-day, 8, 18 February, and 1 March.

DISCUSSION

Benomyl and captafol were highly effective in reducing blossom blight incidence and formation of buttons, confirming results on sweet orange in Belize (4) and on limes in south Florida (5). In the fungicide trial in Belize (4), a single application of a benomyl-captafol mixture was effective in reducing blossom blight and button formation. But when these fungicides were used singly, four applications at 8-day intervals were required to significantly reduce disease incidence. McMillan (5) found that four applications of various fungicides reduced button formation on limes in south Florida. Bloom periods are more extended on limes than on other citrus, and in tropical areas such as Belize, bloom periods are longer than in more temperate areas. No attempt was made in these previous studies to time sprays according to bloom stages.

In the present study, when the same number of fungicide applications were made on different schedules, there seldom were significant differences among the schedules. The number of applications, however, had a significant impact with AUC and button formation decreasing exponentially with increasing numbers of sprays. Thus, precise timing of applications may not be necessary to obtain disease control. Where disease incidence was low, one to two applications were sufficient to significantly reduce the AUC and button formation. However, where disease was severe, as in the navel orchard near Arcadia in 1991 (Table 3), one to two applications had little effect. In this case, only the five-spray program on a 10-day schedule provided a high degree of control.

Previous research with fungicides has demonstrated reductions in PFD (4,5), but there are no previous reports of yield increases in response to fungicide applications for PFD control. In the studies reported here, fungicide applications rarely affected fruit counts. Where disease incidence was low, as in all 3 yr in the Valencia orange orchard near Arcadia and the navel orange orchard near La Belle, loss in fruit yield was not discernible. Citrus trees normally set fruit on less than 2% of the blossoms (2), and many of the fruit lost to PFD would never have set in any case. Thus, the presence of some buttons on citrus trees does not necessarily indicate that yield losses have occurred.

Where disease was moderately severe, as in the navel orange orchard in 1989, significant numbers of fruit that would normally have set may have been lost to PFD. However, in these cases, trees affected with PFD may shed less fruit during the period of normal physiological drop in May than unaffected trees. Thus, by harvest, moderately affected trees may have more buttons but about the same amount of fruit as the treated tree.

Only where disease was severe, as in the navel orchard near Arcadia in 1991, and fruit load was reduced below the carrying capacity of the tree were final yields affected significantly. In that case, fruit counts made in June were seven times higher in the five-spray schedule than in the unsprayed control, but total yield in October was only three times greater. Thus, on unsprayed trees with a light fruit load, fruit size partially compensated for the lack of fruit numbers. There also was a small June bloom on these trees, and a portion of the total yield consisted of immature fruit. Fruit on the unsprayed plots and most of those receiving one to two sprays consisted of oversized and off-bloom fruit unacceptable for fresh market use.

The value of fresh-market navel oranges during 1990–1991 was $11.25 per field box (41 kg) and for processing fruit was $2.51 per field box (11). Assuming a 75% packout, the gross return per hectare was estimated at $6,375 on the trees sprayed five times. On unsprayed trees, crop value was estimated at $593. Assuming a cost of about $100 per hectare for each benomyl application, the net return to the grower would have been large. However, with improper selection of orchards to be treated, the potential for wasted applications is great.

Although PFD causes only minor losses in many cases, the disease can rapidly become epidemic with devastating effects. Under favorable conditions, disease incidence can double every 3–4 days leaving growers little time to respond. Most Florida growers have sufficient equipment to spray their entire acreage only every 3–4 wk. Predictive systems being developed (L. W. Timmer and S. E. Zitko, *unpublished*) should be helpful identifying those orchards or blocks with potential of incurring serious disease losses. Aerial application has proven effective for control of PFD (4,10) and could be used should the disease become epidemic over large hectarages.

ACKNOWLEDGMENTS

We thank Orange-Co., Inc. and Duda & Sons, Inc. for use of their orchards for this research. We thank Jerry Newlin and Fred Hensley of Orange-Co., Inc. and Tom Obreza, Mark Sommerfeld, Gary England, and Danny Jones of Duda & Sons, Inc. for their cooperation and assistance in the application of fungicides and data collection. We also thank Hilary Sandler and Becky King for their technical assistance.

LITERATURE CITED

1. Denham, T. G. 1988. Postbloom fruit drop diseases. Pages 24-25 in: Compendium of Citrus Diseases. J. O. Whiteside, S. M. Garnsey, and L. W. Timmer, eds. American Phytopathological Society, St. Paul, MN.
2. Erickson, L. C. 1968. The general physiology of citrus. Pages 86-126 in: The Citrus Industry. W. Reuther, L. D. Batchelor, and H. J. Weber, eds. Univ. Calif. Div. Agric. Sci., Berkeley, CA.
3. Fagan, H. J. 1979. Postbloom fruit drop of citrus, a new disease of citrus associated with a form of *Colletotrichum gloeosporioides*. Ann. Appl. Biol. 91:13-20.
4. Fagan, H. J. 1984. Postbloom fruit drop of citrus in Belize. II. Disease control by aerial/ground spraying. Turrialba 34:179-186.
5. McMillan, R. T., Jr. 1991. Evaluation of fungicides for control of postbloom fruit drop of 'Tahiti' limes caused by *Colletotrichum gloeosporioides*. Proc. Fla. State Hortic. Soc. 104:160-161.
6. McMillan, R. T., Jr., and Timmer, L. W. 1989. Outbreak of citrus postbloom fruit drop caused by *Colletotrichum gloeosporioides* in Florida. Plant Dis. 73:81.
7. SAS Institute, Inc. 1985. SAS Procedures Guide for Personal Computers. Version 6 Ed. SAS Institute, Inc., Cary, NC. 373 pp.
8. Sonoda, R. M., and Pelosi, R. R. 1988. Characteristics of *Colletotrichum gloeosporioides* from lesions on citrus blossoms in the Indian River area of Florida. Proc. Fla. State Hortic. Soc. 101:36-38.
9. Timmer, L. W. 1990. Status of postbloom fruit drop in Florida citrus. Citrus Ind. 71(2):30, 33.
10. Timmer, L. W., and Zitko, S. E. 1991. Aerial application of fungicide for control of postbloom fruit drop. Citrus Ind. 72(12):26-27.
11. United States Department of Agriculture. 1991. Citrus production and value and production by counties. USDA Natl. Agric. Stat. Serv. 4 pp.