Early Season Indicators of Postbloom Fruit Drop of Citrus and the Relationship of Disease Incidence and Fruit Production

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ABSTRACT

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Postbloom fruit drop (PFD) is caused by the slow-growing orange (SGO) strain of *Colletotrichum gloeosporioides*. When citrus flowers are infected, the fruitlet abscises, leaving persistent calyces (buttons) that remain into the following season. The following three factors were evaluated as early season indicators of postbloom fruit drop for the upcoming season on navel and Valencia oranges at 4 to 11 locations from 1992 to 1994: (i) the number of buttons remaining from the previous season as determined in January; (ii) the number of propagules of the pathogen recovered from mature leaves in January to February; and (iii) the percentage of diseased flowers on early bloom in January to February. There was a strong positive correlation between the number of buttons remaining from the previous season and the number in the current season, especially in 1992 and 1994. Buttons from the previous season were negatively but weakly correlated with fruit counts in the current season. Propagule numbers of the SGO strain of *C. gloeosporioides* from mature leaves were not correlated or were only weakly correlated with current season button or fruit counts. Where early season flowers developed, there was usually a positive correlation between the disease incidence on flowers and the number of buttons formed in the current season. Thus, the number of buttons from the previous year provided the best indication of disease potential in the upcoming season. There was a strong negative linear correlation between the number of buttons in the current year and the number of fruit set on navels and Valencias. It is estimated that about five to six fruit are lost for each 100 buttons formed as a result of PFD.

Postbloom fruit drop (PFD) of citrus is caused by the slow-growing orange (SGO) strain of *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc. in Penz. (3,5,7). The fungus infects flower petals, producing necrotic, orange-brown lesions and blight of entire inflorescences. Subsequently, the fruitlets abscise, but the floral disks and calyces persist, forming structures commonly called buttons. These buttons often persist as long as the twig to which they are attached. The pathogen survives between flowering periods as appressoria and/or quiescent infections on buttons, leaves, and twigs (2,9).

A model has been developed based on available inoculum and total rainfall for the last 5 days, which predicts disease severity 3 to 4 days in advance (11,12). Use of the model aids in timing of fungicide applications but requires considerable monitoring of the status of the bloom and disease incidence. Given the large size of plantings of citrus in Florida and the sporadic nature of the disease, intense scouting of all blocks of trees is difficult and costly. Plantings and blocks of trees with the highest probability of developing disease problems must be identified early in the season to reduce the amount of scouting required.

Some information is available on the relationship of disease severity to fruit production and yield from fungicide timing experiments (10). However, there are no definitive data on the relationship between the number of buttons formed and fruit production. We have speculated (6,8) that, since the percentage of flowers that actually set fruit is about 1.0% (4), a like percentage of flowers that form buttons would have produced fruit.

Thus, the purpose of the present study was to find indicators of potential disease problems at individual locations in order to help growers focus disease monitoring efforts. Three factors were examined to assess the potential disease severity prior to the major bloom period, which usually occurs from mid-February to mid-April depending on cultivar and location in the state: (i) the number of buttons remaining from the previous season; (ii) the number of propagules of the SGO strain recovered in leaf washes; and (iii) the incidence of disease on scattered early bloom. These factors were later correlated with the disease severity that actually developed on each tree in the subsequent bloom period. In addition, the number of buttons produced was related to the fruit production in the same year.

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MATERIALS AND METHODS

All studies were conducted in commercial groves of navel and Valencia sweet oranges (*Citrus sinensis* (L.) Osbeck) because these cultivars are the most seriously affected by the disease in Florida (6,8). Groves chosen were in full production and ranged in age from 8 to 25 years old. Sites were selected initially to represent a range of disease severities from rare to extremely severe as well as a range of locations in central, eastern, and southwestern areas of the state. From one to three plots of 10 contiguous trees were selected at each location for determinations of disease incidence and assays. Sites selected in 1992: navel oranges—Arcadia (one plot), Frostproof (one plot), and LaBelle (two plots); Valencia oranges—Arcadia (one plot), Indiantown-1 (three plots), Indiantown-2 (two plots), and Lake Placid-1 (two plots). Sites selected in 1993: navel oranges—Arcadia (one plot), Ft. Pierce-1 (two plots), Ft. Pierce-2 (two plots), Frostproof (two plots), Vero Beach (two plots), and Lake Placid-2 (one plot); Valencia oranges—Arcadia (one plot), Indiantown-1 (three plots), Indiantown-2 (two plots), Lake Placid-1 (two plots), Lake Placid-2 (one plot), and Lake Placid-3 (two plots). Sites selected in 1994 were the same as in 1993 except only one plot was used in the navel oranges at the Frostproof site. No fungicide sprays were applied to the plots during the bloom period.

The number of buttons from the previous year was assessed in January 1992, 1993, and 1994 by counting the total number of buttons on three branches about 0.75 m long in each quadrant of each tree. Data were expressed as the average number of buttons per 12 branches per tree.

The number of propagules of the SGO strain was assessed on a sample of 20 mature leaves collected from each tree. One-centimeter-diameter disks were cut from the leaves and a 0.5-g fresh weight sample was added to 20 ml of sterile distilled water in a 125-ml flask. After shaking for 15 min on a rotary shaker at about 150 rpm, 0.1-ml aliquots of the suspension were plated on each of five plates of the selective medium (1). After incubation for 4 days at 18°C and 1 day at 27°C, the number

of colonies was counted and the average number of propagules per gram fresh weight of leaf tissue was calculated.

The disease incidence (proportion of flowers affected) on scattered early bloom was determined by counting the open flowers and total number of diseased open flowers on each tree in the study. Propagule counts and early season disease evaluations were made twice prior to the main bloom in each year. The first sample from all plots was collected from 23 January to 11 February 1992, from 19 to 29 January 1993, and from 18 to 27 January 1994. The second sample was collected from 13 to 24 February 1992, from 1 to 11 February 1993, and from 2 to 14 February 1994.

Counts of buttons and fruit were made on all study trees to ascertain disease severity following the bloom in late May or June of each year. By that time of the year, the period of normal physiological fruit drop has passed and the majority of the fruit present should remain until harvest. Nearly all buttons produced by the disease in the recent bloom were still present, whereas most of those from the previous year had died, or aged to the point that they were readily distinguishable from current season buttons. Button and fruit counts were made on three branches about 0.75 m long in each quadrant of each tree and data were expressed as the number of buttons or fruit per 12 branches per tree.

The three prebloom factors were compared with the number of buttons and fruit counted after the bloom season in each year by linear regression analysis using the REG procedure of SAS Statistics (SAS Institute, Inc., SAS/STAT User's Guide, Vers. 6, 4th ed., Cary, N.C.). Data from the two sampling periods for disease prior to the main bloom and for propagule counts were analyzed separately. All analyses were based on individual tree data and results are presented as correlation coefficients.

The relationship between the number of buttons formed and the numbers of fruit set in the same season was assessed as an indication of yield loss. The numbers of fruit on all trees with 0 to 12 buttons per 12 branches were pooled and averaged. Similarly, average fruit counts were calculated for trees with 13 to 24, 25 to 36, 37 to 48 . . . 385 to 396 buttons per 12 branches per tree. The average fruit counts were plotted against the number of buttons on the same trees. Curve fitting was used to determine the relationship between the number of buttons formed and the fruit count. Data from all 3 years were pooled for this analysis and cultivars were assessed separately. The curve fitting procedure of SigmaPlot for Windows (Jandel Scientific Software, Transforms & Curve Fitting, San Rafael, Calif.) was used for regression analyses and curve fitting.

Table 1. Postbloom fruit drop incidence, flower counts, propagule densities of *Colletotrichum gloeosporioides* on mature leaves and fruit numbers in surveyed Florida citrus groves from 1992 to 1994

Location	No. of plots	Previous year's buttons[a]	First sample[b]		Second sample[c]		Current year's buttons[e]	Current year's fruit[e]
			Disease incidence[d]	Propagules per g	Disease incidence[d]	Propagules per g		
1992 navel oranges								
Arcadia	1	225	0	3	0.01	100	155	21
Frostproof	1	184	0	43	0.06	130	143	52
LaBelle	2	2	0	0	0	30	7	44
1993 navel oranges								
Arcadia	1	201	0.50	31,403	0.57	4,224	284	8
Ft. Pierce-1	2	57	0	131	0.03	0	188	10
Ft. Pierce-2	2	1	0.08	87	0.07	120	52	13
Frostproof	2	118	0.24	1,951	0.32	3,209	207	8
Vero Beach	2	4	0.50	3,855	0.67	11,720	235	11
Lake Placid-2	1	58	0	227	0.12	210	218	12
1994 navel oranges								
Arcadia	1	215	0	0	0	4	135	13
Ft. Pierce-1	2	150	0.02	3	0.07	10	101	11
Ft. Pierce-2	2	24	–	0	–	0	1	21
Frostproof	1	181	0	1	0	0	74	27
Vero Beach	2	77	0.01	1	0.06	3	127	16
Lake Placid-2	1	130	0	0	0	0	23	21
1992 Valencia oranges								
Arcadia	1	27	0	3	0.01	0	42	66
Indiantown-1	3	47	0	1	0	32	6	79
Indiantown-2	2	54	0	0	0.01	20	4	69
Lake Placid-1	2	197	0	7	0.01	75	139	35
1993 Valencia oranges								
Arcadia	1	5	–	39	0	0	273	23
Indiantown-1	3	2	–	0	–	0	3	19
Indiantown-2	2	4	0	0	0	0	175	23
Lake Placid-1	2	110	0	0	0	0	22	46
Lake Placid-2	1	148	–	39	–	0	133	27
Lake Placid-3	2	338	0	6	0	352	180	16
1994 Valencia oranges								
Arcadia	1	290	0	0	–	0	163	28
Indiantown-1	3	2	–	1	–	0	2	36
Indiantown-2	2	44	0	0	–	0	15	31
Lake Placid-1	2	27	–	0	0	0	9	29
Lake Placid-2	1	142	–	0	–	1	32	24
Lake Placid-3	2	130	–	1	–	1	54	26

[a] Number of buttons per 12 branches per tree remaining from the previous year as counted in January of the current year.
[b] Evaluations made from 23 January to 11 February 1992, 19 to 29 January 1993, and 18 to 27 January 1994.
[c] Evaluations made from 13 to 24 February 1992,1 to 11 February 1993, and 2 to 14 February 1994.
[d] Proportion of flowers affected; – = no flowers present.
[e] Number of buttons or fruit per 12 branches per tree as counted in May or June of the current year.

RESULTS

The average number of buttons from the previous year ranged from a low of one to a high of 338 per 12 branches per tree (Table 1). Thus, a range of disease incidences was observed across locations and

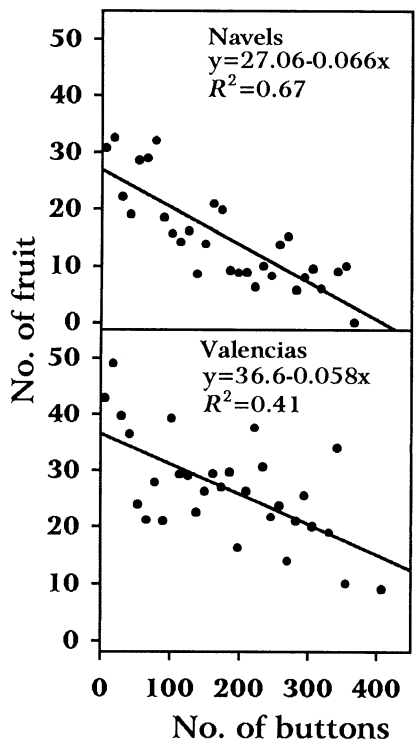

Fig. 1. The relationship between the number of buttons formed in the current season to the number of fruit produced on the same bloom in navel and Valencia oranges over the period 1992 to 1994.

years. The average number of flowers per tree at the first sampling ranged from 0 to 82 on navels and 0 to 5 on Valencias. At the second sampling, the average number of flowers ranged from 0 to 179 on navels and 0 to 27 on Valencias.

High propagule numbers were detected in leaf washes in some locations in 1993 (Table 1). This occurred when a large amount of bloom was present and the disease incidence was high (>0.10). The propagules probably represented secondary inoculum produced on infected petals rather than residual propagules that had overwintered on the leaf surface.

Disease severity was greatest in 1993 as evidenced by high button and low fruit counts, but even in that year some plots had low levels of disease. Postbloom fruit drop severity ranged from low to moderate at most sites in 1992 and 1994.

The number of buttons formed in each year often was correlated positively with the previous season's buttons, but only occasionally correlated with the number of propagules from the leaf surface and the disease incidence on early season bloom (Table 2). The number of buttons formed was strongly related to the number of buttons from the previous season on both cultivars in 1992 and 1994, but the correlation was lower on navels and not significant on Valencias in 1993. The number of propagules recovered from mature leaves was only weakly related to final button counts with few significant correlations. The disease incidence on early bloom was correlated significantly with the final button counts on navel oranges, but there was usually insufficient bloom on Valencias to make an assessment.

In most cases, the number of fruit was related negatively to most early season factors, but correlations were often not significant (Table 2). Of the three factors evaluated, the previous season's buttons appeared most strongly related to fruit production.

There was a significant negative relationship between the number of buttons formed and the number of fruit produced in the same bloom period (Fig. 1). The relationship was stronger with navel oranges ($R^2 = 0.67$, $P \leq 0.0001$) than with Valencia oranges ($R^2 = 0.41$, $P \leq 0.0001$). This would suggest that with navel oranges 6.6 fruit are lost for each 100 buttons formed and that with Valencias 5.8 fruit are lost for each 100 buttons. Other functions also significantly fit the observed data. R^2 values for exponential, logarithmic, and power functions were 0.71, 0.66, and 0.55, respectively, for navel oranges and 0.40, 0.44, and 0.42, respectively, for Valencia oranges. Thus, several functions produced relatively good fits to the data. However, many of the curves defined differed only slightly from the linear function.

DISCUSSION

Clearly, the best indicator of disease for the forthcoming season was the number of buttons present on trees prior to the bloom. Correlations of these two factors were very high in 1992 and 1994, but lower in 1993. In that year, rainfall was high during bloom in many areas resulting in severe disease. Thus, disease incidence was often high even in some groves that had low levels in 1992, resulting in lower correlation coefficients. On navel oranges, correlation coefficients were often significant between disease levels on early season bloom and disease severity the coming year. On Valencia oranges, there was seldom enough bloom to examine this factor. Propagule densities of the pathogen overwintering on the mature leaves did not appear to be a good indicator of disease in the forthcoming bloom. Propagule densities were often low and erratic and much more intensive sampling would probably be needed to establish such a relationship.

Although the presence of high numbers of buttons from the previous year does not always predict severe disease in the upcoming season, it is the best indicator available. Growers can focus attention on those blocks with high numbers of buttons and look for disease on the early bloom as a secondary indicator. Once sufficient bloom has developed to represent an economically significant portion of the crop, the model developed earlier (11,12) can be applied. Sampling leaves for propagules of the pathogen would be costly and not provide additional useful information in estimating prospects for the coming season.

Previous fungicide tests (10) have given some idea of crop loss due to PFD under different conditions. However, growers would like to be able to estimate yield loss in individual blocks to evaluate the efficacy of past fungicide programs and to do cost/benefit analyses. Apparently, about six fruit are lost per 100 buttons present on the tree after the bloom season, which is much higher than our earlier estimates of less than 1%. Those estimates were based on data from California (4). More recent information from Florida indicates that the percentage of fruit set may be as high as about 1.5 to 2.0% on navel oranges and 4 to 5% on Valencia oranges (L. G. Albrigo, *unpublished data*). These data are more consistent with our results on losses due to PFD.

In severely affected groves in this study, button counts averaged 300 to 400 per 12 branches and the total number of buttons per tree ranged well into the thousands. Thus, losses can easily reach more than 100 fruit per tree. The amount invested in control programs will depend somewhat on the cultivar involved and its potential value in the market.

Table 2. Correlation coefficients between early-season indicators of postbloom fruit drop and the number of buttons and fruit produced after the bloom each year

				Propagules per g		Disease incidence	
Factor	Cultivar	Year	Previous season's buttons	First sample[a]	Second sample[b]	First sample[a]	Second sample[b]
Buttons[c]	Navel	1992	+0.84***[d]	-0.14^{NS}	-0.12^{NS}	ND[d]	+0.46**
		1993	+0.37***	$+0.12^{NS}$	$+0.11^{NS}$	+0.29**	+0.40**
		1994	+0.51***	+0.18*	$+0.06^{NS}$	+0.20*	+0.20*
	Valencia	1992	+0.75***	$+0.15^{NS}$	$+0.08^{NS}$	ND	+0.38**
		1993	$+0.05^{NS}$	+0.23*	$+0.07^{NS}$	IB[d]	IB
		1994	+0.56***	$+0.07^{NS}$	+0.27**	IB	IB
Fruit[c]	Navel	1992	-0.26^{NS}	$+0.06^{NS}$	-0.02^{NS}	ND	$+0.16^{NS}$
		1993	−0.31**	-0.01^{NS}	-0.04^{NS}	-0.04^{NS}	-0.08^{NS}
		1994	-0.05^{NS}	−0.23*	-0.17^{NS}	−0.26**	−0.26**
	Valencia	1992	−0.47***	-0.14^{NS}	-0.09^{NS}	ND	-0.015^{NS}
		1993	$+0.06^{NS}$	-0.05^{NS}	-0.02^{NS}	IB	IB
		1994	−0.29**	-0.06^{NS}	-0.05^{NS}	IB	IB

[a] Evaluations made from 23 January to 11 February 1992, 19 to 29 January 1993, and 18 to 27 January 1994.

[b] Evaluations made from 13 to 24 February 1992, 1 to 11 February 1993, and 2 to 14 February 1994.

[c] Evaluations made after bloom and after the period of normal physiological drop in May or June of each year.

[d] ***, **, * = correlations significant at $P \leq 0.001$, 0.01, and 0.05, respectively; NS = not significant, ND = no data; IB = insufficient bloom to evaluate disease incidence.

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