Comparison of Sanitation and Fungicides for Management of Botrytis Fruit Rot of Strawberry

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ABSTRACT

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To determine the effects of sanitation on yield and incidence of Botrytis fruit rot (*Botrytis cinerea*) in annual strawberry, replicated experiments were conducted during the 1995-96, 1996-97, and 1998-99 seasons. Leaf sanitation (removal of senescent and necrotic leaves) and fruit sanitation (removal of unmarketable fruit from alleys between beds) were compared to a standard fungicide control program (weekly applications of captan plus four bloom applications of iprodione) and combined sanitation and fungicide treatments. Leaf sanitation reduced Botrytis fruit rot incidence from 12.6 to 8.2% over the entire 1996-97 season, and from 17.6 to 11.8% during the latter half of the 1998-99 season, compared to untreated controls. However, sanitation did not increase marketable yield. Supplementing fungicides with leaf sanitation or leaf and fruit sanitation did not improve disease control and frequently reduced yield. Fruit sanitation had no significant effect on Botrytis incidence or yield. Losses to Botrytis fruit rot in the sanitation treatments were significantly higher ($P \leq 0.05$) than in the fungicide treatments each season; marketable yields were significantly lower in 1996-97 and 1998-99. Under Florida conditions, fungicides control Botrytis fruit more effectively and economically than does sanitation.

Additional keywords: cultural control, *Fragaria* × *ananassa*

Florida is the principal source of fresh market strawberries (*Fragaria* × *ananassa* Duchesne) for the eastern United States from December to March. Strawberries are grown in west central Florida as an annual crop on plastic-mulch beds with drip irrigation. The growing season is characterized by long periods of leaf wetness, periodic rains, and mild temperatures, which are conducive to Botrytis fruit rot caused by *Botrytis cinerea* Pers. In experimental trials, preharvest losses to Botrytis fruit rot ranged from 0.5 to 13% in a standard captan-rovral treatment, and up to 35% in untreated plots (14–16). Postharvest losses also can be significant (5,13,19)

In perennial strawberries, *B. cinerea* overwinters as sclerotia and mycelium in leaves, petioles, crop debris, straw mulches, and weeds (1,10,27). Young leaves are highly susceptible to infections, which become latent. As the leaves senesce and die, the fungus colonizes the tissues and sporulates (1,2). Conidia formed on dying and necrotic leaves are the principal source of inoculum for Botrytis fruit rot epidemics (1). Fruit lesions usually appear at the stem end of green or ripe fruit and often originate from infected petals, stamens, and other floral parts (3,22). Under favorable conditions, *Botrytis* sporulates profusely on diseased fruit and adjoining infected peduncles (10; J. C. Mertely, *unpublished data*). Conidia formed on these tissues contribute to fruit rot epidemics in perennial ever-bearing and annual strawberries (27). Healthy fruit touching these tissues may also become infected.

Commercial strawberry cultivars are moderately to highly susceptible to Botrytis fruit rot (17,18,21). For this reason, growers rely on fungicides to protect susceptible flowers and fruit. In Florida, fungicides are applied more intensively to strawberries than to any other food crop (23). The standard control program consists of up to 24 applications of captan or thiram at weekly intervals for broad-spectrum disease control. Benomyl and sulfur are applied as needed to control powdery mildew. Iprodione and other fungicides are applied during peak bloom periods to improve control of Botrytis fruit rot. Even with such intensive spray programs, Botrytis fruit rot can be severe when susceptible cultivars are grown (17).

The costs associated with a reliance on fungicides have encouraged testing of cultural methods for Botrytis control. Sanitation, i.e., the physical removal or destruction of infected plant parts and crop debris, is recommended for *Botrytis* management in greenhouse-grown flowers (9) and may reduce *Botrytis* incidence in other crops. In lowbush blueberries, *B. cinerea* colonized fruits from sites pruned by mowing more frequently than by biennial burning (12). In onion, periodic removal of necrotic leaves reduced the spore load in experimental plots and delayed the progress of a leaf spot caused by *B. cinerea* (11). In perennial strawberry, mechanical harvesting followed by removal of foliage and fruit from the field suppressed spore production and reduced Botrytis fruit rot the following season (28).

In addition to applying fungicides, Florida strawberry growers use various cultural practices to improve disease control. These practices are based on microclimate modification and sanitation. For example, most growers have changed from overhead sprinkler irrigation systems to drip tape. Some growers have adopted wider plant spacing, which has been shown to improve disease control (17). Shortly after plant establishment, necrotic and senescent leaves are frequently trimmed and left in the alleys between beds. Although this operation costs approximately $750/ha, growers believe that potential gains in disease control offset the additional expense. During harvest operations, unmarketable fruit are removed from the plant canopy and dropped in the alleys. Some growers completely remove these fruit from the production field. Our study evaluated the effects of two sanitation practices (the removal of senescent leaves and unmarketable fruit), standard fungicide programs, and combined sanitation and fungicide programs on Botrytis fruit rot incidence and marketable yield. Preliminary findings have been published (13,20).

MATERIALS AND METHODS

Horticultural practices. Field experiments were carried out in 1995-96, 1996-97, and 1998-99 at the University of Florida's Gulf Coast Research and Education Center in Dover. During each growing season, land preparation began in September with a broadcast application of a 6:2:8 starter fertilizer (570 kg/ha) and rotovation. Beds measuring 15 to 18 cm tall and 75 cm wide were formed, fumigated with methyl bromide/chloropicrin (98:2) at 350 kg/ha, and covered with black plastic mulch over drip irrigation tape. In mid-October, greentop, bare-root plants from Canadian nurs-

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eries were transplanted into the beds and irrigated by overhead sprinklers for 10 days to facilitate establishment. After establishment, irrigation and fertigation were provided twice weekly through drip tape, and freeze protection was provided by overhead sprinklers when necessary. Spider mite and insect populations were monitored by a scouting program and controlled by the application of predatory mites, miticides, and insecticide sprays. The experiments were hand-harvested twice weekly from November or December to March.

Experimental design. The experiments were arranged in a randomized complete block design with three replications in 1995-96 and four replications in 1996-97 and 1998-99. The experiments were conducted in raised beds, 1.2 m apart center to center. Each bed contained two staggered rows of plants, 30 cm apart. Each plot extended across three beds. In 1996-97 and 1997-98, the plots were 3.3 m long by 3.6 m wide and contained 48 plants set 41 cm apart within the rows. The plots were separated by unplanted buffer areas 2 m wide between plots and 1.2 m wide between blocks. In 1998-99, the plots were 3.8 m long by 3.6 m wide and contained 78 plants set 29 cm apart. Adjacent plots were separated by 1.2-m-wide unplanted buffer area. To maintain uniform environmental conditions and promote disease development, a moderately susceptible cultivar (Camarosa) was planted in a single-bed bordering each block and in 3-m-long plots capping the ends of each block.

Treatments. In the 1995-96 experiment, fungicide, sanitation, and a combined fungicide and sanitation treatment were evaluated using the cultivars Oso Grande and Sweet Charlie in a 3 × 2 factorial experiment (Table 1). The fungicide treatment consisted of captan (3.4 kg a.i./ha) applied weekly from 1 November 1995 through 26 March 1996. Iprodione (1.1 kg a.i./ha) was tank mixed with captan and applied twice (7 days apart) during each of the first two peak bloom periods, for a total of four applications. The fungicides were suspended in water and applied by a tractor-mounted boom sprayer at 690 kPa pressure in 940 liters/ha. This treatment simulated the standard commercial spray program for Florida strawberries. Leaves and/or unmarketable fruit were removed in the sanitation treatments. Necrotic and senescent leaves were trimmed once each month from November to March and removed from the plots. Small, deformed, and diseased fruit were harvested twice weekly along with the marketable fruit to obtain harvest data and returned to the alleys of the fungicide but not the sanitation treatments. The combined treatment integrated the standard fungicide program with the removal of senescent leaves and unmarketable fruit.

In the 1996-97 experiment, 11 treatments were evaluated, including an untreated control (Table 1). Cultivar Sweet Charlie was used exclusively due to its high susceptibility to Botrytis fruit rot (17). The fungicide treatments included the standard fungicide program tested the first season and a reduced-rate program consisting of weekly captan and four iprodione bloom applications at 2.2 and 1.1 kg a.i./ha, respectively. The fungicides were applied from 1 November to the end of the season as described previously. Four sanitation treatments were evaluated: (i) a one-time removal of necrotic and senescent leaves immediately following plant establishment, (ii) monthly removal of necrotic and senescent leaves beginning immediately after plant establishment, (iii) removal of unmarketable fruit from the plot alleys during each harvest, and (iv) a combination of treatments ii and iii. The latter treatment was identical to a treatment carried out in 1995-96. The remaining treatments combined fungicide programs with leaf and/or fruit sanitation to evaluate the potential for additional disease control by sanitation practices.

In the 1998-99 experiment, eight treatments were evaluated using cv. Sweet Charlie (Table 1). The chemical treatments included the standard fungicide program and a reduced rate program using captan at the lowest recommended rate of 1.7 kg a.i./ha. In both treatments, captan was applied weekly from 9 November to the end of the season. Due to the reduced distance between the plots, fungicides were applied to individual beds using a CO_2 backpack sprayer at 310 kPa pressure in 940 liters/ha using a two-nozzle wand. The sanitation treatments included the removal of senescent leaves, unmarketable fruit, or both, as in 1996-97. Leaf sanitation was carried out in November and February, rather than once monthly, to test a more economically feasible practice. Treatments combining leaf and fruit sanitation with standard and reduced-rate spray programs were also evaluated, as well as an untreated control.

Data collection and analysis. In each experiment, fruit were harvested twice weekly from the middle bed of the three beds comprising each plot. Marketable fruit were counted and weighed. Unmarketable fruit were enumerated by category,

Table 1. Treatments evaluated in annual strawberry during the 1995-96, 1996-97, and 1998-99 seasons

Trt	Cultural control	Chemical control	Treatments tested[u]		
			1995-96	1996-97	1998-99
1	None	Captan weekly (full rate) + four bloom sprays of iprodione[v]	X	X	X
2	Leaf sanitation (1×)[w]	Captan weekly (full rate) + four bloom sprays of iprodione	…	X	…
3	Leaf sanitation (n×)[w]	Captan weekly (full rate) + four bloom sprays of iprodione	…	X	…
4	Fruit sanitation[x]	Captan weekly (full rate) + four bloom sprays of iprodione	…	X	…
5	Leaf (n×) and fruit sanitation[y]	Captan weekly (full rate) + four bloom sprays of iprodione	X	X	X
6	None	Captan weekly (reduced rate)[z], without iprodione	…	X	X
7	Leaf (n×) and fruit sanitation	Captan weekly (reduced rate)[z], without iprodione	…	X	X
8	Leaf sanitation (n×)	None	…	X	X
9	Fruit sanitation	None	…	X	X
10	Leaf (n×) and fruit sanitation[y]	None	X	X	X
11	None	None	…	X	X

[u] In 1995-96, three treatments were tested with two cultivars (Sweet Charlie and Oso Grande) in a 3 × 2 factorial experiment. In 1996-97 and 1998-99, 'Sweet Charlie' was the sole test cultivar.

[v] In treatments 1 through 5, captan (3.4 kg a.i./ha) was applied weekly from November through March for a total of 20 to 24 applications. In addition, iprodione (1.1 kg a.i./ha) was applied twice during the early stages of each of the first two flowering periods, i.e., 6 December, 13 December, 30 January, and 6 February for 'Oso Grande' and 29 November, 6 December, 23 January, and 30 January for 'Sweet Charlie' in 1995-96; 2 December, 6 December, 10 January, and 17 January in 1996-97; and 17 November, 25 November, 23 December, and 30 December in 1998-99.

[w] Leaf sanitation = old, senescent, and necrotic leaves were trimmed from the plants and removed from the plots once after plant establishment (1×) or two or more times during the growing season (n×).

[x] Fruit sanitation = diseased and unmarketable fruit were removed from alleys between the plots during each harvest. In treatments without fruit sanitation, culls were returned to the alleys of their respective plots after grading.

[y] For treatments 5 and 10, leaf sanitation was carried out two or more times during a season, and fruit sanitation was carried out during each harvest.

[z] In 1997-98, treatments 6 and 7 received weekly applications of captan at 2.2 kg a.i./ha and four bloom sprays of iprodione at 1.1 kg a.i./ha. In 1998-99, treatments 6 and 7 received captan alone at 1.7 kg a.i./ha.

i.e., small (<10 g), deformed, or diseased. Diseased fruit were categorized and enumerated by causal agent (e.g., *Botrytis* sp., *Colletotrichum* sp., etc.). After grading, unmarketable fruit from treatments that did not require fruit sanitation were returned to the alleys of their respective plots. The two outer beds in each plot were harvested on the same schedule as the middle bed. Unmarketable fruit from these beds were dropped in the alleys, or collected and removed from the field according to treatment protocol.

Yield and disease incidence data from both harvests each week were combined for analysis. Weekly data for the early season extending from the first harvest to the end of January, for the late season from February 1 to the final harvest, and for the whole season were analyzed by two-way ANOVA using SAS (SAS Institute, Cary, NC). Disease incidence (the number of diseased fruit expressed as a percentage of the total number of marketable and unmarketable fruit) data were transformed by arcsine square root prior to analysis. Mean separations were made using Fisher's protected least significant difference ($P \leq 0.05$). Linear contrast analyses were performed on selected a priori comparisons of whole season means for disease incidence and yield.

RESULTS

Natural epidemics of Botrytis fruit rot developed in the experiments during each of the three growing seasons. Losses to Botrytis were significant each season, whereas losses to other fruit rot pathogens did not exceed 1%. Across all treatments, Botrytis fruit rot incidence ranged from 0.1 to 8.1% in 1995-96, 2.8 to 12.6% in 1996-97, and 11.8 to 21.4% in 1998-99 (Table 2). During all three seasons, disease levels were lowest in the fungicide treatments and highest in the sanitation and untreated controls.

In 1995-96, Botrytis fruit rot incidence in the untreated control increased slightly in December and January and more significantly in February and March, producing a bimodal pattern (Fig. 1). In 1996-97 and 1998-99, the disease progress curves were generally more bell shaped (Fig. 1). Disease incidence was low after planting, increased to epidemic levels as the seasons progressed, and declined sharply before the final harvests in March. Losses to Botrytis fruit rot remained at high levels during calendar weeks 3 to 9 in 1997 and 1 to 7 in 1999. In 1995-96 and 1996-97, the incidence of Botrytis fruit rot peaked at the same time among all treatments over the entire season. In 1998-99, however, disease incidence in the fungicide treatments increased more slowly and peaked later than in the non-fungicide treatments. Nevertheless, disease incidence declined simultaneously in all treatments at the end of the 1996-97 and 1998-99 harvest seasons.

The incidence of Botrytis fruit rot on susceptible cultivar Sweet Charlie differed significantly among treatments during each of the three seasons (Table 2). In 1995-96, when cv. Oso Grande was also tested, Botrytis incidence was less than 1% for that cultivar. On Sweet Charlie, however, disease incidence in the leaf and fruit sanitation treatment (8.1%) was significantly higher than in the full fungicide treatment (0.5%). In 1996-97, leaf sanitation and combined leaf and fruit sanitation reduced disease incidence during the February to March late period, but not the December to January early period (Table 2). Over the whole season, disease incidence was reduced from 12.6% in the control to 8.2% in the leaf sanitation treatment and 8.3% in the combined leaf and fruit sanitation treatment. However, disease incidence in

Table 2. Effects of fungicide and sanitation treatments on Botrytis fruit rot and marketable yield in annual strawberry during the 1995-96, 1996-97, and 1998-99 seasons

Treatment description[y]	Cultivar	Botrytis fruit rot incidence (%)[x]			Yield (kg/ha)
		Early	Late	Whole	
1995-96 season					
Full fungicide (FF)	Oso Grande	0.0	0.2 a[z]	0.2 a	17,756
FF+ leaf (n×) and fruit sanitation	Oso Grande	0.0	0.1 a	0.1 a	15,922
Leaf (n×) and fruit sanitation	Oso Grande	1.1	0.6 a	0.7 a	17,721
Full fungicide	Sweet Charlie	0.3	0.5 a	0.5 a	17,073
FF + leaf (n×) and fruit sanitation	Sweet Charlie	0.4	0.5 a	0.5 a	17,631
Leaf (n×) and fruit sanitation	Sweet Charlie	2.3	9.6 b	8.1 b	13,179
1996-97 season					
Full fungicide	Sweet Charlie	4.5 a	2.6 a	2.8 a	24,360 ab
FF + leaf sanitation (1×)	Sweet Charlie	7.7 ab	4.2 a	4.6 a	24,037 abc
FF + leaf sanitation (n×)	Sweet Charlie	4.0 a	2.7 a	2.9 a	21,839 c
FF + fruit sanitation	Sweet Charlie	4.2 a	3.7 a	3.8 a	25,061 a
FF + leaf (n×) and fruit sanitation	Sweet Charlie	6.4 a	2.8 a	3.4 a	22,528 bc
Reduced fungicide (RF)	Sweet Charlie	5.1 a	3.2 a	3.5 a	24,054 abc
RF + leaf (n×) and fruit sanitation	Sweet Charlie	6.7 a	2.7 a	3.3 a	23,355 abc
Leaf sanitation (n×)	Sweet Charlie	14.6 c	7.0 b	8.2 b	18,905 d
Fruit sanitation	Sweet Charlie	16.5 c	10.1 cd	11.0 bc	19,369 d
Leaf (n×) and fruit sanitation	Sweet Charlie	12.8 bc	7.5 bc	8.3 b	18,602 d
Control	Sweet Charlie	19.7 c	11.3 d	12.6 c	18,526 d
1998-99 season					
Full fungicide	Sweet Charlie	10.3 ab	14.8 ab	13.4 ab	21,334 a
FF + leaf (2×) and fruit sanitation	Sweet Charlie	7.9 a	14.2 ab	11.8 a	19,673 abc
Reduced fungicide	Sweet Charlie	14.4 bc	15.9 bc	15.6 bc	20,021 abc
RF + leaf (2×) and fruit sanitation	Sweet Charlie	18.0 c	15.0 ab	16.2 bc	19,179 bc
Leaf sanitation (2×)	Sweet Charlie	28.4 d	11.8 a	17.9 cd	17,308 d
Fruit sanitation	Sweet Charlie	25.9 d	19.8 c	21.4 d	17,889 cd
Leaf (2×) and fruit sanitation	Sweet Charlie	26.1 d	14.0 ab	18.3 cd	16,127 d
Control	Sweet Charlie	26.9 d	17.6 bc	20.7 d	16,891 d

[x] Botrytis fruit rot incidence = (number of diseased fruit/total number of fruit) × 100. Botrytis incidence was calculated from the first harvest through 31 January (early), from 1 February through the last harvest (late), and for the entire season (whole).

[y] Full fungicide (FF) = captan applied at the full label rate of 3.4 kg a.i./ha; reduced fungicide (RF) = captan applied at 1/2 to 2/3 of full label rate. Leaf sanitation = old, senescent, and necrotic leaves were trimmed from the plants and removed from the plots once after plant establishment in November (1×), once in November and February (2×), or once monthly beginning in November (n×). Fruit sanitation = diseased and unmarketable fruit were removed from the alleys between the plots during each harvest. In treatments without fruit sanitation, culls were returned to the alleys of their respective plots after grading.

[z] Within a column and growing season, valued followed by the same letter are not significantly different according to a Fisher's protected LSD test. Mean separations were not carried out when P (F test) > 0.05, and are indicated by missing letters.

the fruit sanitation treatment (11.0%) was not significantly different from the control. The incidence of Botrytis fruit rot in the fungicide treatments (2.8 to 4.6%) was significantly lower than in the sanitation treatments or the control. In 1998-99, leaf sanitation, but not leaf and fruit sanitation, significantly reduced disease incidence in the late period (Table 2). Over the entire season, no significant differences were found between the sanitation treatments and the control. However, disease incidence in the fungicide treatments was significantly less than in the control.

Combining fungicides with sanitation did not improve control of Botrytis fruit rot. In 1995-96 and 1996-97, Botrytis incidence was low in all the fungicide treatments. No significant differences were found between fungicide treatments and those combining fungicides with leaf

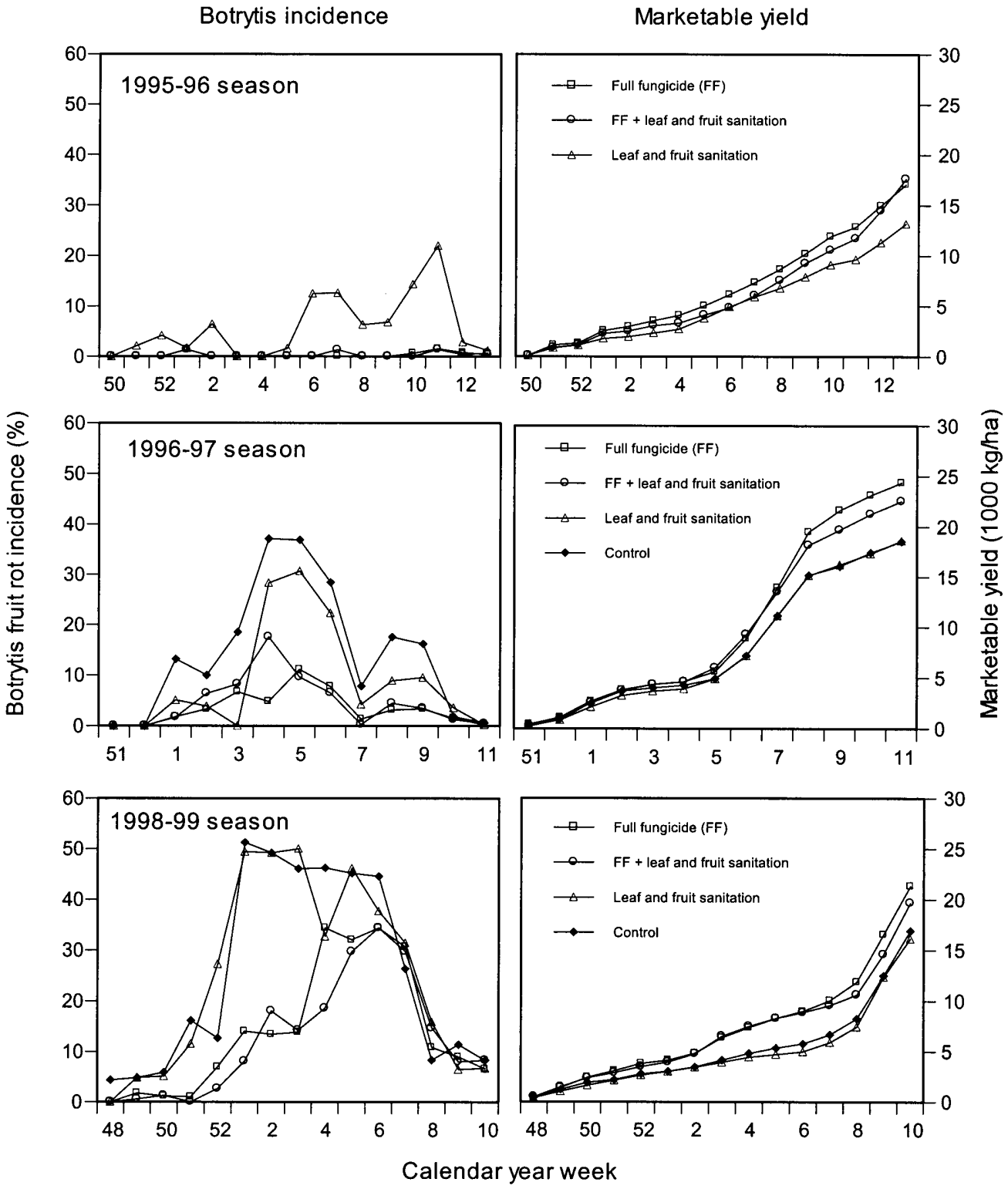

Fig. 1. Weekly incidence of Botrytis fruit rot and cumulative marketable yield for fungicide and sanitation treatments in annual strawberry during the 1995-96, 1996-97, and 1998-99 seasons in Dover, FL.

and/or fruit sanitation (Table 2). Similar results were obtained in 1998-99, when disease pressure was severe. The incidence of Botrytis fruit rot in the full- and reduced-rate fungicide treatments was not statistically different from corresponding treatments combining fungicides with leaf and/or fruit sanitation. In addition, linear contrast analysis revealed no significant differences ($P = 0.6026$) between fungicide treatments alone, and combined fungicide and sanitation treatments (Table 3).

Marketable yields in the sanitation treatments were generally lower than in the fungicide and combined fungicide and sanitation treatments (Table 2). In 1995-96, however, yields among treatments were not significantly different ($P = 0.1608$). In 1996-97, three sanitation treatments and the untreated control yielded 18,526 to 19,369 kg/ha of marketable fruit. In contrast, seven fungicide or combined fungicide and sanitation treatments produced significantly higher yields (21,839 to 25,061 kg/ha). In 1998-99, the sanitation treatments and the untreated control yielded 16,127 to 17,889 kg/ha, whereas the fungicide and combined treatments yielded 19,179 to 21,334 kg/ha. Marketable yield in the leaf sanitation treatment was less than in the standard fungicide treatment but statistically equivalent to three other fungicide treatments in 1998-99. However, none of the sanitation treatments produced significantly greater yields than the control in 1996-97 or 1998-99.

Leaf sanitation reduced marketable yield, particularly when Botrytis fruit rot was controlled by fungicide applications. In 1996-97, the full fungicide treatment yielded 24,360 kg/ha of marketable fruit (Table 2). Treatments combining full fungicide applications with one cycle of leaf sanitation, monthly leaf sanitation, or fruit sanitation combined with monthly leaf sanitation produced 24,037, 21,839, and 22,528 kg/ha, respectively. Monthly leaf sanitation reduced yield significantly, while the other reductions were not significant. Fruit sanitation alone did not reduce yield. In 1998-99, two cycles of leaf and fruit sanitation reduced yields from 21,334 to 19,673 kg/ha in the full fungicide treatments and from 20,102 to 19,179 kg/ha in the reduced fungicide treatments. While these differences were not significant at the 5% level, when analyzed by a linear contrast, the two fungicide treatments produced higher yields than corresponding treatments combining fungicides with sanitation ($P = 0.0558$, Table 3).

DISCUSSION

Leaf sanitation, i.e., the removal of senescent and necrotic leaves from strawberry plants, reduced the incidence of Botrytis fruit rot in experiments carried out in 1996-97 and 1998-99. However, the reductions were relatively small compared to standard fungicide programs, and when fungicide treatments were supplemented with leaf sanitation, disease control was not improved. Leaf sanitation also reduced marketable yield, which offset gains from the reduction in Botrytis incidence. The removal of culled fruit from between the beds did not affect the incidence of Botrytis fruit rot.

At the beginning of this study, we hypothesized that leaf sanitation would reduce the incidence of Botrytis fruit rot. This hypothesis was based on research showing that canopy removal during machine harvest reduced potential sporulation of *B. cinerea* and incidence of Botrytis fruit rot in perennial strawberry (28). An alternate hypothesis was proposed for grapes, in which Botrytis bunch rot is significantly reduced by the removal of leaves around fruit clusters (6,25). English et al. attributed the reduction to changes in microclimate, and recorded increased wind speeds in the modified canopies (6). However, he was unable to find clear relationships between microclimatic variables and disease development. In our study, the strawberry plants were small and well separated when the first leaf sanitation operation was carried out. Later operations removed relatively small amounts of tissue compared to the total mass of foliage present. It is unlikely that leaf sanitation caused a significant change in microclimate. Nevertheless, leaf sanitation produced statistically significant reductions in disease incidence. These reductions were probably caused by the removal of substrate for inoculum production.

A polycyclic disease such as Botrytis fruit rot may be controlled by the suppression of initial or secondary inoculum. In annual strawberry, the primary sources of initial inoculum are the transplants themselves or alternative hosts outside of the field. *B. cinerea* is a ubiquitous necrotroph that colonizes a wide range of hosts (7,27). Conidia of *B. cinerea* are commonly found in the atmosphere (8). Windborne spores from exogenous sources could initiate an epidemic in a field of clean plants. However, strawberry transplants are usually infected in the nursery. In 1997, 12 to 66% of the transplants sampled from Canadian nurseries supported latent infections of *B. cinerea* in the leaves and petioles (4). In our experiments, senescent and necrotic leaves formed in the nursery were removed during the first leaf sanitation operation. In subsequent operations, senescent and necrotic leaves produced after planting (i.e., potential sources of secondary inoculum) were removed.

While leaf sanitation sometimes reduced Botrytis fruit rot incidence, the level of control was always less than that provided by the standard fungicide treatment. Two factors may account for the relatively low efficacy of leaf sanitation. One involves the timing of the sanitation operation. After the plants are set in October, the crop is irrigated heavily for 10 to 14 days by overhead sprinklers to facilitate establishment. This period is highly favorable to the spread of *B. cinerea*, since high humidity and free moisture promote sporulation and infection (2,24). As soon as 3 days after transplant, *B. cinerea* sporulated on necrotic leaves and petioles (J. Mertely, *unpublished data*). This inoculum is produced in close proximity to newly emerging leaves, which are highly susceptible to infection (2). After these new leaves senesce in February and March, another cycle of inoculum production begins, which coincides with an increase in fruit production and the incidence of

Table 3. Probability values for linear contrast analyses of marketable yield and incidence of Botrytis fruit rot in annual strawberry during the 1996-97 and 1998-99 seasons

	Probability (yield)		Probability (% Botrytis)	
Treatment comparisons	**1996-97**	**1998-99**	**1996-97**	**1998-99**
(Leaf sanitation[w] + leaf and fruit sanitation[x]) vs. control[y]	0.8238	0.8215	0.0068	0.1956
All sanitation treatments vs. control	0.6534	0.7634	0.0227	0.4485
All sanitation treatments vs. reduced fungicide[z]	0.0001	0.0005	0.0001	0.0465
All sanitation treatments vs. full fungicide	0.0001	0.0001	0.0001	0.0019
Full fungicide (FF) + reduced fungicide (RF) vs. FF with leaf and fruit sanitation + RF with leaf and fruit sanitation	0.1346	0.0558	0.8362	0.6026

[w] Leaf sanitation = old, senescent, and necrotic leaves were trimmed from the plants and removed from the plots once monthly after plant establishment in November (1996-97 season), or once in November and once in February (1998-99 season).

[x] Fruit sanitation = culled fruit were removed from alleys between the plots during each harvest. In treatments without fruit sanitation, culls were returned to the alleys of their respective plots after grading.

[y] Control plots were not sprayed with fungicides or subjected to leaf or fruit sanitation.

[z] Reduced fungicide = captan applied at 1/2 to 2/3 of full label rate of 3.4 kg a.i./ha.

Botrytis fruit rot. A similar disease cycle has been reported in North Carolina (4). To minimize infection of emerging leaves during the establishment period, it may be necessary to remove broken, necrotic, and senescent leaves just after transplanting rather than after establishment. Another problem associated with leaf sanitation involves production of inoculum on other plant parts. Flowers, fruit, peduncles, and crowns may also be infected (26,27) and serve as additional sources of inoculum. In these experiments, senescent leaves and cull fruit left in the alleys were removed from the field during leaf sanitation and fruit sanitation operations, respectively. The removal of other infected tissues (e.g., small, mummified fruit and blighted peduncles) was not attempted and would not be feasible in a commercial operation.

Yield reduction is another problem associated with the use of leaf sanitation to control Botrytis fruit rot. While leaf sanitation (or combined leaf and fruit sanitation) provided no additional disease control when fungicides were applied, they frequently depressed yields in the absence of high levels of Botrytis fruit rot. In a typical sanitation operation, many leaves were removed, including some which were in the early stages of senescence but still partially green. This loss of photosynthetically active tissues and potential reserves of mobile nutrients may explain the yield reductions. Frequent, selective pruning would have been more desirable, since the elimination of photosynthetically active tissues would be minimized. However, multiple leaf sanitation operations are impractical due to the costs involved, i.e., an estimated $750/ha for the initial leaf sanitation and higher amounts for subsequent operations when the plants are larger and labor is in short supply. Given these constraints, strawberry growers in most production areas seldom carry out more than a single leaf sanitation operation and rely on other cultural practices and fungicides for disease control.

In Florida, a number of growers trim senescent and necrotic leaves from their strawberry plants. Leaf sanitation is carried out shortly after plant establishment, a period usually coinciding with the initiation of regular fungicide sprays. In our study, Botrytis fruit rot control was not improved when leaf sanitation was combined with a standard fungicide spray program. In addition, marketable yields were depressed. A few growers also remove unmarketable fruit from the alleys between the beds in the production field. While fruit sanitation may reduce overall inoculum levels in the field, statistically significant reductions in Botrytis fruit rot incidence did not occur. Another sanitation practice, the removal of diseased fruit from plants within the beds, was routinely carried out in our study. These fruit were dropped in the alleys between the beds, simulating commercial harvest practices. Theoretical considerations, i.e., the proximity of the inoculum source to the infection court, support this practice. Further support comes from empirical observations of disease spread by fruit to fruit contact (27; D. Legard, *unpublished data*). However, the putative benefits of this practice should be evaluated experimentally.

In our study, a standard fungicide spray program costing approximately $1,400/ha (23) produced the lowest incidence of Botrytis fruit rot and the highest yield. When fungicides were applied, leaf sanitation did not improve disease control and often reduced yield. In the absence of fungicides, Botrytis incidence was reduced by two or more leaf sanitation operations costing an estimated $750/ha each. However, an expected increase in yield did not occur and may have been offset by the loss of photosynthetically active tissues. Fruit sanitation alone had no effect on Botrytis incidence or yield. Based on these results, neither leaf sanitation nor fruit sanitation can be recommended for Botrytis control in annual strawberry in Florida. However, leaf sanitation may have practical applications on organic farms, or in systems requiring reduced fungicide use. Further work is needed to quantify the benefits of leaf sanitation in these situations, and to determine the optimal number and timing of these operations.

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