Original article

The epidemiology, control and cause of sooty blotch of carambola, *Averrhoa carambola* L., in South Florida

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The epidemiology, control and cause of sooty blotch of carambola, *Averrhoa carambola* L., in South Florida.

Abstract — Introduction. Carambola, *Averrhoa carambola*, produces a fruit that is an important commodity in South Florida (USA). A newly recognized disease in South Florida, sooty blotch, caused by the epiphytic growth of fungi, results in fruit cosmetic damage. **Materials and methods**. Disease incidence and severity were monitored in seven commercial groves from 1994 to 1996 to examine the influence of grove attributes, fruit size/maturity and season on sooty blotch development. Various fungicides were evaluated for control of the disease on calendar (1 and 3 weeks) and rainfall-driven application schedules. To identify the causal fungi, fungal colonies on fruit (thalli) and in culture were compared with those that have been reported on apple. **Results and discussion**. Disease incidence and severity were significantly greater in groves with older vs younger trees, N–S vs E–W row orientations, and windscreens vs no wind protection. The disease developed predominantly on mid- to late-stage fruit, and continued to increase as fruit matured. Moderate, but significant, control was obtained with certain fungicides. Based on the morphology of thalli on affected fruit, the anatomical and morphological characteristics of the fungi in culture, and their response to fungicides, the disease appears to be a disease complex similar to sooty blotch on apple. The most common agent on carambola resembles, but is distinct from, *Peltaster fructicola*. In the absence of a formal description, we call the fungus *Peltaster* sp. carambola. **Conclusion**. This is the first report on the epidemiology, control and cause of the sooty blotch disease on carambola in South Florida. Previous reports indicating that the disease was either sooty mold or was caused by *Leptothyrium* sp. or *Gloeodes pomigena* are incorrect. © Éditions scientifiques et médicales Elsevier SAS

USA / Florida / *Averrhoa carambola* / disease symptoms /disease surveillance / pathogens / *Peltaster*

Épidémiologie, contrôle et cause des taches fuligineuses du carambolier, *Averrhoa carambola* L., dans le sud de la Floride.

Résumé — Introduction. La carambole est un fruit important pour la Floride du sud (États-Unis). Cependant, dans cette région, la maladie nouvellement identifiée des taches fuligineuses, provoquées par la croissance épiphyte de champignons, affecte significativement l'aspect du fruit. **Matériel et méthodes**. L'incidence et la sévérité de la maladie ont été observées de 1994 à 1996 dans sept plantations commerciales pour évaluer l'influence des caractéristiques du verger, de la taille / maturité du fruit et de la saison sur le développement de ces taches fulgineuses. Divers fongicides ont été évalués vis-à-vis du contrôle de la maladie à partir d'un calendrier d'application donné (1 et 3 semaines) ou basé sur les pluies. Pour identifier les champignons en cause, des colonies fongiques sur fruit (thalles) et en culture ont été comparées à celles connues sur la pomme. **Résultats et discussion**. L'incidence et la sévérité de la maladie ont été significativement plus importantes sur les vieux arbres que sur les jeunes, sur les orientations d'arbres N–S que sur des rangs E–W, et sur des arbres protégés du vent que sur ceux sans protection. La maladie, développée surtout sur des fruits en milieu ou en fin de maturité, a continué d'augmenter au fur et à mesure que le fruit mûrissait. Un contrôle modéré, mais significatif, a été obtenu avec de certains fongicides. En se basant sur la morphologie des thalles sur le fruit affecté, les caractéristiques anatomiques et morphologiques des champignons en culture et leur réponse aux fongicides, il semblerait que la maladie soit un complexe semblable à celui de la tâche fuligineuse de la pomme. Sur le carambolier, l'agent le plus commun ressemble à, mais est distinct de, *Peltaster fructicola*. En l'absence d'une description formelle, il a été appelé *Peltaster* sp. carambola. **Conclusion**. Cet article est le premier publié sur l'épidémiologie, le contrôle et la cause de la maladie des tâches fuligineuses du carambolier en Floride du sud. Les rapports précédents indiquant que la maladie était une moisissure fuligineuse ou était due à *Leptothyrium* sp. ou à *Gloeodes pomigena* sont incorrects. © Éditions scientifiques et médicales Elsevier SAS

États Unis / Floride / *Averrhoa carambola* / symptôme de maladie des plantes / surveillance epidémiologique / agent pathogène / *Peltaster*

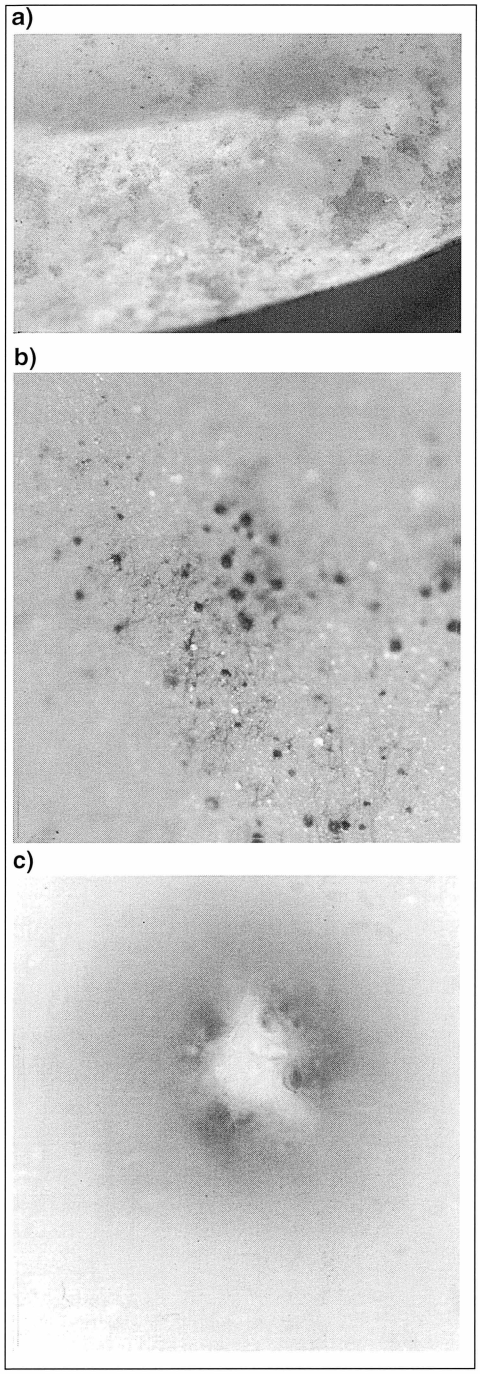

Figure 1.
Symptoms and signs of sooty blotch on the surface of a ripe (class 7) fruit of carambola cultivar Arkin.
a) Close-up of ramose thalli. Note the gray, diffuse appearance of individual thalli.
b) Sparse plectenchymal bodies (pycnothyria) in ramose thalli (40×).
Note the fernlike, arborescent growth of hyphae within the thalli.
c) Ruptured, dimidiate shield on a mature pycnothyrium that has exposed single-celled conidia of *Peltaster carambola* (1 000×).

1. introduction

Carambola, *Averrhoa carambola* L., is a member of the Oxalidaceae. It is a small tree, usually less than 10 m in height, that produces a conspicuously ribbed, ellipsoidal yellow to light orange fruit [1, 2]. The fruit's unique appearance and taste have recently made it a popular commodity outside its native range of Southeast Asia.

A significant carambola industry has developed in South Florida (USA) during the last decade [3]. This is due, in large part, to the region's mild subtropical climate, the recent introduction of sweet, more widely accepted cultivars into the local trade, and aggressive marketing by local producers. During the 1995–1996 season, a crop valued at ca. US$17.5 million was harvested, 98 % of which were shipped to markets outside the area [4].

Carambola is nonseasonal in the tropics and usually yields three to five crops of fruit per year. However, in subtropical areas such as South Florida, there are usually only two fruiting seasons per year due to the impact of cool, winter temperatures. Fruit development in South Florida is not synchronized, but one peak season generally begins with the onset of the rainy season in June, and another starts in October or November. Fruit mature ca. 70 d after they are set [5].

One of the most important, but poorly understood, production problems in South Florida is a fruit blemish [6, 7]. It does not affect the edibility of fruit, but packing houses either reject severely blemished fruit, or wash and re-wax them when demand is high. Thus, the problem results in either direct losses or increased packing costs. It is most prevalent during the area's hot, humid summers, can usually be removed from the fruit surface by hand, and is caused by the epiphytic growth of fungi. In general, symptoms appear on the fruit and leaf surface as smoky grey to black, irregular splotches of varying intensity (*figure 1a*). They are finely webbed networks of fungal hyphae of the causal agents that, in severe cases, cover 50 % or more of the fruit surface. They possess diverse, microscopic, hyphal morphologies that are most often aborescent and fernlike.

The identity and cause of this disorder has been confused in Florida. It was initially reported as 'sooty mold' caused by *Leptothyrium* sp. [8, 9], a genus that has been erroneously indicted as the cause of flyspeck on apple, carnation and other hosts [10]. *Leptothyrium* sp. was later recovered from a leafspot of an *Averrhoa* species other than carambola (not specified) [11], and *Microthyrium* sp. was implicated as the cause of the fruit disorder (G. Simone, personal communication).

When the senior author of the present paper began to examine the fruit blemish in 1994, it was clear that it was not sooty mold but resembled sooty blotch, a common, late season disease on apple and many other host species [6, 12]. Not only were the symptoms on carambola distinct from those of sooty mold, but also there was no evidence that insect or aphid excreta were intimately associated with the problem, a prerequisite for sooty mold development. Based on these observations, the carambola disease was subsequently referred to as sooty blotch, rather than sooty mold [6].

The identity and nomenclature of the causal agent(s) of sooty blotch of apple have changed several times during the long time the disease has been recognized. Originally, Schweinitz [13] determined that flyspeck and sooty blotch were both caused by a highly variable fungus, *Dothidea pomigena* Schw. Saccardo [14] recognized that flyspeck and sooty blotch actually had different causal agents, and transferred the sooty blotch agent to another genus, *Phyllachora*. Colby [15] later erected a new genus, *Gloeodes*, to accommodate the sooty blotch agent, and Groves [16] then described four thallus types of *G. pomigena* (Schwein.) Colby, fuliginous, punctate, ramose and rimate, to account for the diverse signs the fungus produced on apple fruits.

Johnson et al. [17, 18] recently reported that at least three of Groves' [16] thallus types represented species of fungi other than *G. pomigena*. They associated the ramose thallus with either *Geastrumia polystigmatis* Bautista & M.L. Farr or *Peltaster fructicola* Johnson, the fuliginous type with *Leptodontium elatius* (G. Mangenot) De Hoog, and the punctate type with a fungus that resembled, but was distinct from, *P. fructicola*. The cause(s) of the rimate thallus type was not determined. Importantly, the authors did not observe fungi on apple that fit Colby's [15] original description of *G. pomigena*.

We report work on the epidemiology, control and cause of sooty blotch on carambola in South Florida. Specific objectives during these studies were to: 1) identify factors that influence disease development; 2) identify control measures for the disease; and 3) compare and contrast sooty blotch thallus types and the associated fungi on carambola with those that have been reported on apple.

2. materials and methods

All studies that are described below were conducted either at the University of Florida's Tropical Research & Education Center, in Homestead, or in local commercial carambola production groves.

2.1. epidemiology

The development of sooty blotch was monitored in groves that differed in tree age, planting density, wind protection, irrigation practice and row orientation (*table I*). Groves were planted to the standard commercial cultivar, Arkin, with one exception, a Kary grove.

Disease was monitored in seven groves every 1–2 weeks, from June 1994, to February 1995, and in four of the same groves every 2–4 weeks, from June 1995, to April 1996 (*table I* and *figures 2–5*). In each grove, 12 trees were identified in random locations and marked for future reference. On each sample date, flower phenology was recorded for each tree as: 1 = flower initials and/or buds present, and 2 = flower buds open; and fruit class as: 3 = >1 cm long, 4 = 1–3 cm long, 5 = >3 cm long but

Table I.
Sooty blotch development in, and descriptions of, studied carambola groves in South Florida[a].

Grove	Cultivar	Age (years)	Density	Wind protection	Row orientation	Irrigation[b]	1994–1995[c]	
							Incidence	Severity
1	Arkin	7	high	windscreen	N–S	overhead	48.5 b	3.5 bc
2*[d]	Arkin	2	high	windscreen	N–S	overhead		
3	Kary	3	mod.	none	E–W	overhead	40.9 c	2.9 c
4*	Arkin	10	high	none	E–W	overhead	48.8 b	4.3 b
5*	Arkin	15	mod.	none	N–S	drip/over.	48.2 b	2.6 c
6	Arkin	7	high	windscreen	E–W	drip/over.	61.5 a	3.5 bc
8*	Arkin	10	mod.	windscreen	N–S	over./micr.	51.2 b	9.4 a

Disease summary, 1994–1995[e], regarding grove characteristics.

Response	Wind protection			Row orientation			Grove age			Density		
	+		–	N–S		E–W	>7 years		<7 years	Moderate		High
Incidence	54	*	46	49	ns	51	49	ns	51	47	ns	53
Severity	5	*	3	5	*	4	3	*	5	5	ns	4

[a] Commercial carambola groves were monitored every 1–2 weeks for sooty blotch incidence and severity from June 1994, to February 1995. Groves with asterisks were included in a second disease progress study and were monitored every 2–4 weeks from June 1995 to April 1996. Results from both studies are illustrated in *figure 2*.
[b] Either overhead (over.), high-volume, drip, or microjet, undertree irrigation was used in study orchards.
[c] Disease means are for all dates of the study. Within a column, means followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($p < 0.05$). Analyses are for commercially mature, class 6 fruit.
[d] Grove 2 was excluded from these analyses because few susceptible fruit were present for much of the first season.
[e] Paired means within a column are significantly different if separated by an asterisk according to *t*-tests ($p < 0.05$, ns: not significant).

green, 6 = full size with color break (commercial maturity), and 7 = ripe. Sooty blotch incidence and severity was recorded for each class of fruit. Incidence for a tree was the percentage of a given class that were symptomatic, and for the grove was the mean incidence on fruit for all trees that had fruit of a given class. Likewise, disease severity for a given class was the mean surface area that was covered by sooty blotch, and, for the grove, was the mean severity on fruit for all trees that had fruit of a given class.

2.2. sooty blotch control

Three studies were conducted to identify control measures for the disease. Each was conducted in a different part of grove 1 from that used for the above epidemiological studies. During the first two trials, three fungicides were identified that were somewhat effective (resulted in lower disease incidence and severity than the water control): Copper-count N, a copper-based fungicide that does not impart a blue color when it is applied to fruit; Manzate 200DF, a standard, economical mancozeb (EBDC) fungicide; and Benlate 50 WP, a systemic benomyl (benzimadizole) fungicide that has activity against a wide range of fungal pathogens but against which resistance can develop.

For resistance management purposes, Benlate 50 WP was applied in combination with Manzate 200DF during the third trial. Three basic treatments were tested on application schedules of every week, every third week, or the week after at least two measurable rainfall evens occurred: Coper-

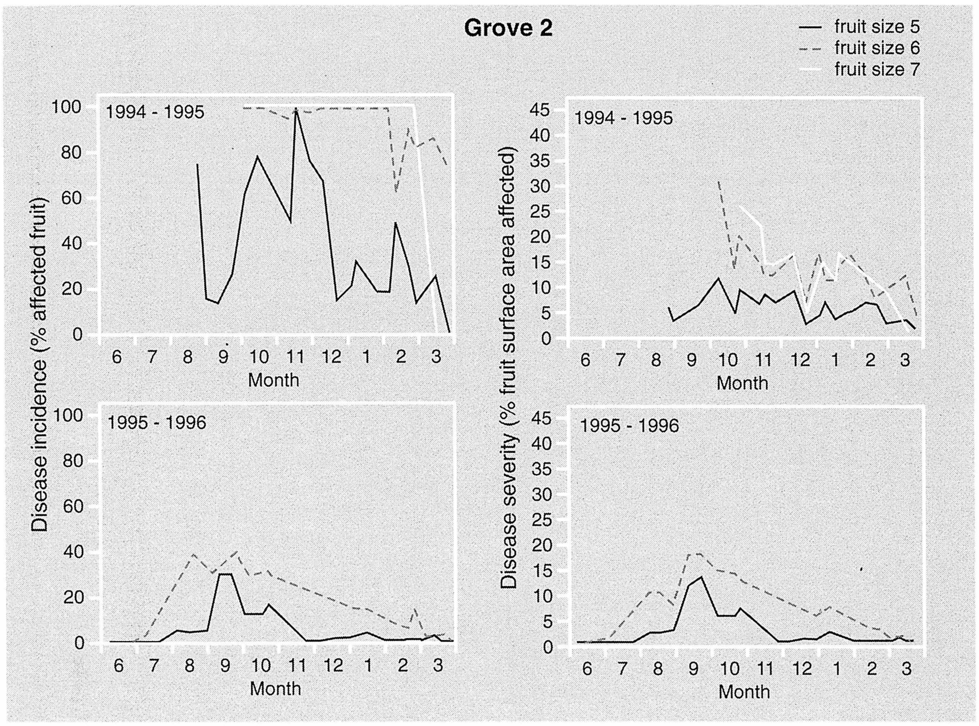

Figure 2.
Sooty blotch incidence and severity over two fruiting seasons (1994–1995 and 1995–1996) in grove 2 (see *table I* for attributes). In general, peak seasons in South Florida begin in June and October–November. Incidence and severity for class 7 fruit are not shown for 1995–1996 due to the low numbers of these fruit that were produced during those seasons.

count N (6 L·ha^{-1}), Manzate 200DF (2 kg·ha^{-1}), and Manzate 200DF (1 kg·ha^{-1}) + Benlate 50 WP (0.4 kg·ha^{-1}) (*table II*). Treatments were replicated eight times on single-tree replicates that were bordered by nontreated buffer trees, in a randomized complete block design. The trial began on 20 June 1995 and was stopped after the last application on 30 January 1996. Two fruiting cycles and a total of 33 weekly applications occurred during the study. Prior to every weekly application, ratings of disease incidence and severity were made on class 5, 6 and 7 fruit. Mean ratings in *table II* are from the first 14 weeks of the study, which coincided with the rainy season and the highest disease pressure that was observed during the trial.

2.3. sooty blotch etiology

Fruit from nontreated commercial groves of Arkin were examined to determine the thallus type(s) that predominated in South Florida. Comparisons were made between the observed thalli and Groves' [16] figures and descriptions, as well as thalli on apple fruit that were kindly identified and provided by Sharon Williamson (North Carolina State University, Raleigh NC, USA).

A variety of methods were used to recover fungi from affected fruit. Discrete thalli were excised, surface disinfested for different durations in 70 % ethanol and 0.525 % NaClO (respectively, 5–10 s and 0–2 min), and submerged in molten (45 °C) Difco potato dextrose agar amended with 100 mg·L^{-1} streptomycin sulfate, 50 mg·L^{-1} rifamycin, and 4 drops·L^{-1} of a commercial miticide, Danitol 2HEC (Chevron Corp., San Francisco, USA) (PDA-SRD). Alternatively, intact fruit were surface disinfested with different combinations of either 70 % or 95 % ethanol (10 s) and 0.525 % NaClO (2–3 min), and thalli were abraded with sterile cotton swabs that were then streaked on PDA-SRD.

A third approach was suggested by Turner Sutton (North Carolina State University, Raleigh NC, USA). Symptomatic fruit were rinsed in tap water and affected areas then washed with several changes of sterile cotton swabs and sterile water. Washed areas were blotted dry with sterile paper

Table II.
Results of the sooty blotch control treatments on fruit with different maturity classes[1]. Data are means for 14 weekly rating dates through 19 September 1995 that coincided with the rainy season and the highest disease pressure during the course of the study. Treatments were replicated eight times in a randomized complete block design.

Treatment	Quantity	Frequence[2]	Incidence[3]			Severity[4]		
			5	6	7	5	6	7
1. Nontreated control		n/a	19.5 a	59.6 a	78.7 a	9.4 a	23.6 a	34.2 a
2. Copper-count N	3 qts·a^{-1}	1 week	13.1 b	48.1 b	57.6 bc	5.3 b	15.2 bc	17.0 c
3. Manzate 200DF	2 lbs·a^{-1}	1 week	7.3 c	29.2 d	44.4 c	3.1 b	10.8 d	13.0 c
4. Manzate 200 DF, + Benlate 50 WP	1 lb·a^{-1} 0.2 lb·a^{-1}	1 week	7.0 c	33.5 cd	42.4 c	3.0 b	11.4 cd	13.2 c
5. Copper-count N	3 qts·a^{-1}	3 week	11.4 bc	47.9 b	67.9 ab	5.2 b	17.0 b	24.5 b
6. Manzate 200DF	2 lbs·a^{-1}	3 week	9.3 bc	34.4 cd	60.0 bc	3.8 b	13.2 bcd	19.6 bc
7. Manzate 200 DF + Benlate 50 WP	1 lb·a^{-1} 0.2 lb·a^{-1}	3 week	10.3 bc	37.6 cd	56.1 bc	4.7 b	14.5 bcd	18.7 bc
8. Copper-count N	3 qts·a^{-1}	rain	9.6 bc	39.6 bcd	52.1 bc	4.3 b	14.2 bcd	19.2 bc
9. Manzate 200DF	2 lbs·a^{-1}	rain	8.5 bc	32.7 cd	47.3 c	3.7 b	11.2 cd	14.0 c
10. Manzate 200 DF + Benlate 50 WP	1 lb·a^{-1} 0.2 lb·a^{-1}	rain	9.7 bc	41.6 bc	55.9 bc	4.6 b	13.2 bcd	15.1 c

Means within a column that are followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($p < 0.05$).
[1] Fruit classes were: 5 = 1½" to full size, but green; 6 = fullsize with color break (market maturity); 7 = ripe.
[2] Treatments were applied either every week, every third week, or the week after at least two measurable rainfall events occurred.
[3] Incidence = the percentage of fruit of a given class that had symptoms of sooty blotch.
[4] Severity = the percentage of the fruit surface area for a given class that was symptomatic.

towels and sterile transfer loops or wet or dry sterile swabs were used to abrade the area and then streaked on PDA-SRD.

On nonamended PDA, cultural characteristics of single-conidium isolates from carambola that were recovered with each of the above methods were compared with those from apple that were provided by Sharon Williamson (North Carolina State University, Raleigh NC, USA).

2.4. artificial inoculations

Representative strains of fungi that were recovered from Arkin fruit were tested in eight different trials to confirm that they were sooty blotch agents and to identify a reliable means by which symptoms could be reproduced. In general, disease-free Arkin fruit from either field or greenhouse plants were washed in tap water and blotted dry before inoculation. Fruit were immersed in aqueous or sucrose suspensions of various concentrations of conidia for 15 s and placed immediately on screens that were suspended above water in transparent plastic boxes on a laboratory bench. Fruit for different treatments were arranged in completely randomized designs in all studies.

On a weekly basis, fruit were rated for disease incidence (yes or no) and severity on the following scale: 1 = no symptoms; 2 = <5 thalli per fruit; 3 = 5–10 thalli; 4 = 11–20 thalli; 5 = >20 thalli. Since most studies utilized mature, class 6 fruit, they could be conducted for only 2 to 3 weeks before fruit rotted and had to be discarded.

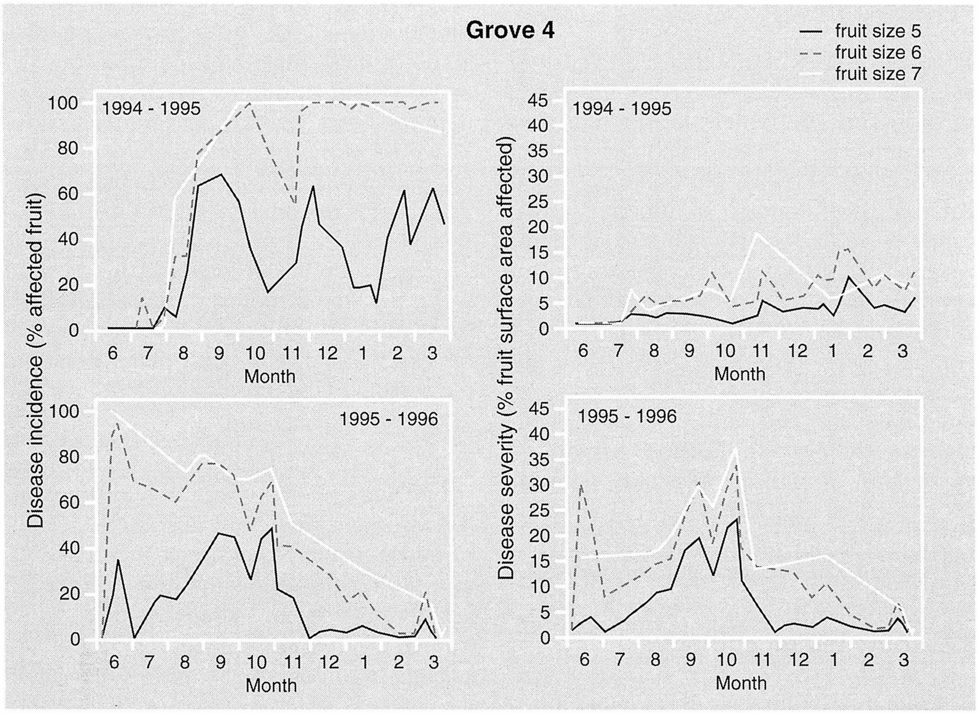

Figure 3.
Sooty blotch incidence and severity over two fruiting seasons (1994–1995 and 1995–1996) in grove 4 (see *table I* for attributes).

2.5. analyses

Graphs of incidence and severity data were created with Harvard Graphics 2.0. Arcsine square root transformations of the data were performed before mean separations and regression analyses were conducted with the General Linear Models (GLM) procedure of SAS for Windows (SAS Institute, Inc., Cary, NC, USA).

3. results and discussion

3.1. epidemiology

Sooty blotch symptoms developed predominantly on the two largest (oldest) classes of fruit during both field studies. Regardless of the grove, overall disease severity, and the time of year that data were collected, symptom development occurred on fewer mid-size fruit (class 5), and virtually no smaller fruit (classes 3 or 4) (*figures 2–5*). In both studies, disease incidence and severity increased significantly as fruit class (maturity) increased ($p < 0.0001$) (data not shown).

There were significant differences in disease development among the studied groves and between seasons ($p < 0.05$) (*table I*, *figures 2–5* and data not shown). For example, the onset of disease at the beginning of the 1994–1995 season in grove 2 occurred more than 2 months after that in grove 8, and, in grove 4, occurred 6 weeks earlier in 1995–1996 than in 1994–1995.

At least some of the variation in sooty blotch development among groves could be explained by different grove characteristics (*table I*). During 1994–1995, those with windscreens and N–S row orientations had higher disease severities than did groves without windscreens and E–W row orientations ($p < 0.05$). Likewise, old groves (>7 years old) had more severe sooty blotch than young groves (<7 years). Incidence data followed the same trends, but were not significant as often. Based on the above attributes, it is probable that free moisture was retained longer on fruit surfaces in the most severely affected groves in this study.

3.2. sooty blotch control

For each class of fruit that was evaluated, clear trends were evident on individual sample dates and when data for consecutive sample dates were combined (*table II* and data not shown). With one exception, each of the fungicide treatments significantly reduced sooty blotch incidence and severity when compared to the nontreated control. In general, treatments that contained Manzate 200DF, either alone or in combination with Benlate 50WP, were the most effective. Statistically, there was no difference between ratings for any of the Manzate 200DF application schedules; application of Manzate 200DF or Manzate 200DF + Benlate 50WP was no more effective on a weekly basis than when applied every three weeks or after rainfall ($p < 0.05$).

3.3. sooty blotch etiology

Thalli on carambola fruit in South Florida were similar or identical in appearance to ramose thalli on apple that were illustrated and described by Groves [16], observed on intact apple fruit from North Carolina, and reported to be caused by *P. fructicola* by Johnson et al. [17, 18]. Most were light gray and diffuse with microscopic, sparse, radiate hyphae interspersed with sparse plectenchymal bodies (*figures 1a, 1b*). Some of these thalli had more plectenchymal bodies than others, but they were neither as frequent nor as large as those observed in the punctate thallus on apple. On carambola, the plectenchymal bodies mature to become pycnothyria, conidiomata that produce single-celled conidia on a raised dimidiate shield that are released when the shield ruptures (*figure 1c*) [(also see figure 10 in ref. 19)]. Far less frequent on carambola were thalli that resembled the punctate and ramose *G. polystigmatis*-generated thalli on apple.

The sooty blotch fungi are slow growing (ca. 0.5 $mm \cdot d^{-1}$). Thus, it is difficult to recover them from fruit that are also colonized by fast-growing fungi. When assessing different isolation methods, we relied heavily on reference strains of these fungi from apple in order to identify sooty blotch isolates from carambola, and to determine the success of a given approach. Sooty blotchlike fungi were recovered rarely from carambola with methods that utilized relatively harsh disinfestants, i.e. ethanol and NaClO, but were recovered much more frequently when sterile water and cotton swabs were used to clean thalli prior to abrading and streaking on PDA-SRD.

Table III.
Salient features of sooty blotch agents from apple and carambola.

Species (host)	Thallus type	Features	Pycnidium and conidium features and dimensions
Peltaster fructicola Johnson (apple)	Ramose	Arborescent, rugose, radiate, fernlike, plectenchymal bodies, not abundant	Pycnidia: 81–113 µm Conidia: aseptate, 4–6 µm × 2 µm, borne from inverted hymenium, released through ruptures in dimidiate shield
Peltaster sp. (apple)	Punctate	Reticulate network of interconnecting hyphae, distinct margins, but not arborescent plectenchymal bodies conspicuous	Pycnidia: 57–94 µm Conidia: 3–4 µm × 0.5–0.7 µm, but otherwise similar to those for *P. fructicola*
Peltaster sp. carambola (carambola)	Ramose	Arborescent, rugose, radiate, fernlike plectenchymal bodies, not abundant	Pycnidia: 35–64 µm (50.3 µm) Conidia: aseptate, 1.5–2 µm × 3.2–4.8 µm (1.6 × 3.84 µm), released through ruptures in dimidiate shield

Data are from Johnson et al. [17, 18] and this paper.

Table IV.
Sooty blotch development after inoculation with Isolate GLE2B of *Peltaster* sp. carambola of cultivar Arkin greenhouse-grown carambola fruit in two trials. Final ratings for fruit in trial 1 were 19 d after inoculation, and, in trial 2, after 11 d.

Treatment / conidia concentration	Incidence according to fruit class in trial 1 (no. of fruit with symptoms / no. of fruit treated)			Incidence according to fruit class in trial 2 (no. of fruit with symptoms / no. of fruit treated)			Total
	5	6	7	5	6	7	
1. Control / 0	3 / 6	4 / 5	1 / 5	1 / 5	0 / 6	0 / 4	9 / 31
2. 10^3	5 / 6	4 / 6	2 / 3	0 / 6	3 / 6	4 / 5	18 / 32
3. 10^5	3 / 5	3 / 5	1 / 3	2 / 6	3 / 6	2 / 5	14 / 30
4. 10^7	2 / 5	4 / 5	1 / 4	1 / 6	4 / 6	6 / 6	18 / 32
Significance [1]	ns	ns	ns	ns	*	*	*

[1] Significance indicates whether sooty blotch incidence was statistically greater on inoculated vs control fruit: ns = nonsignificant and * = significant at $p < 0.05$.

Table V.
Effect of sucrose concentration on sooty blotch incidence on carambola fruit: isolate GLE2 of *Peltaster* sp. carambola and field-grown, class 6 fruit of Arkin, were used in both studies. Ratings are from 2 weeks after inoculation.

Treatment / conidia concentration	Sucrose concentration	Trial 7 (no. of fruit with symptoms / no. of fruit treated)	Trial 8 (no. of fruit with symptoms / no. of fruit treated)
1. Control / 0	5 %	–	3 / 4
2 . 10^6	2 %	4 / 7	–
3. 10^6	5 %	2 / 5	–
4. 10^6	10 %	4 / 5	–
5. 10^6	20 %	1 / 5	–
6. 10^5	2 %	–	3 / 6
7. 10^5	5 %	–	1 / 6
8. 10^5	10 %	–	4 / 6
9. 10^5	20 %	–	1 / 6

On PDA, isolates that were recovered from carambola most often resembled, but clearly differed from, *P. fructicola*. Salient features for these fungi and *Peltaster* sp. from apple (cause of punctate thalli) are listed in *table III*. Based on their resemblance to *P. fructicola*, the most common isolates from carambola are hereafter referred to as *Peltaster* sp. carambola.

3.4. artificial inoculations

Only isolates of *Peltaster* sp. carambola were used in these studies.

Surprisingly, neither inoculum concentration nor fruit class had an effect on disease development (*table IV*). Thus, only class 6 fruit were used in subsequent work in which different concentrations of sucrose were tested as diluents for conidial suspensions. When a 5 % sucrose solution was used, a significantly higher incidence of sooty blotch developed on inoculated vs noninoculated fruit; however, comparable levels of disease developed when both 5 % sucrose and water were compared as diluents (data not shown). Different sucrose

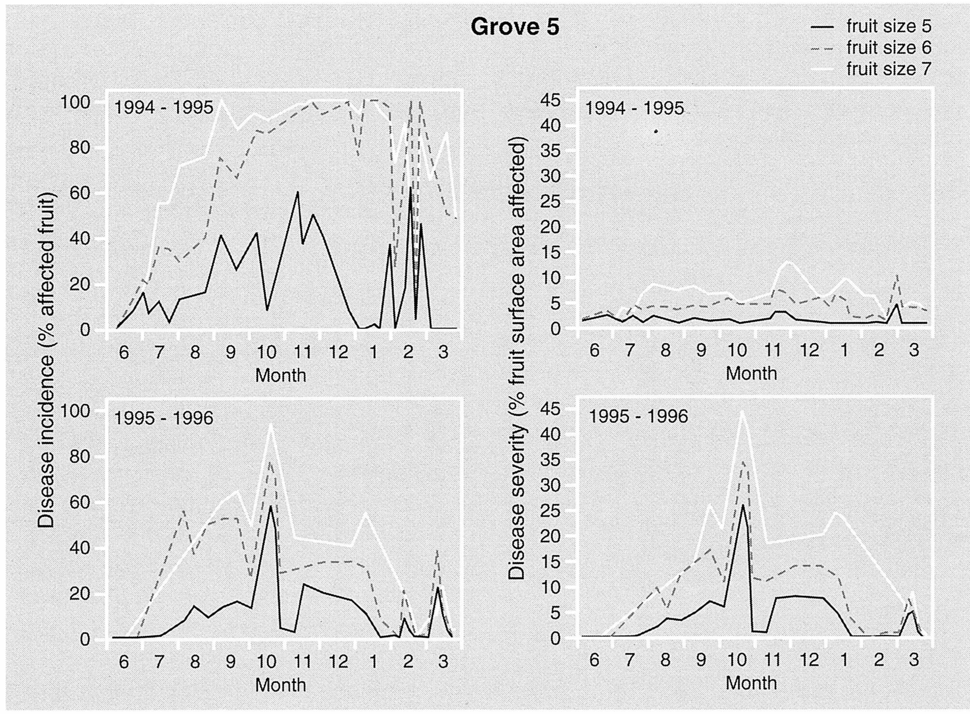

Figure 4.
Sooty blotch incidence and severity over two fruiting seasons (1994–1995 and 1995–1996) in grove 5 (see *table I* for attributes).

concentrations also did not have an effect on disease development (*table V*). In all cases, fungi that appeared to be identical to those that were used in artificial inoculations were recovered from symptomatic fruit.

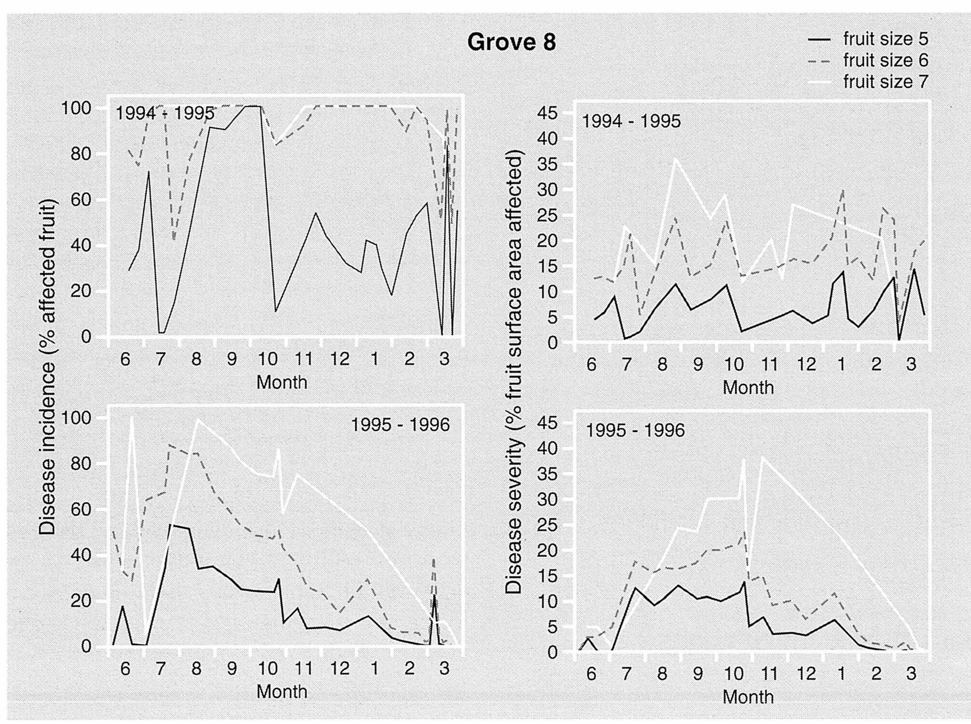

Figure 5.
Sooty blotch incidence and severity over two fruiting seasons (1994–1995 and 1995–1996) in grove 8 (see *table I* for attributes).

Thus, no highly reliable method for reproducing symptoms of sooty blotch was identified (*tables IV, V*). In two studies, no disease developed on either inoculated or noninoculated fruit, and, in two others, similar levels of disease developed on both noninoculated and inoculated fruit (*tables IV, V*, and data not shown). Despite these erratic results and the low levels of disease that resulted after inoculation with *Peltaster* sp. carambola, the results clearly indicate that the fungus produces thalli of the ramose type on carambola fruit. GLE2, an isolate that was used in most of the above artificial inoculation studies, is deposited with the American Type Culture Collection (Manassas, VA, USA) under the accession number ATCC 96595.

4. conclusions

Sooty blotch of carambola and apple are similar diseases that are caused, at least in part, by related fungi. In addition to the aforementioned thallus and cultural characteristics that *P. fructicola* and *Peltaster* sp. carambola share, the respective diseases on apple and carambola are also controlled by the same fungicides and require high moisture conditions in order to develop ([12] and this paper). However, many things remain unclear about the disease on carambola. For example, whether the steady increase in disease that was observed as fruit matured was the result of a greater susceptibility of older fruit or a long latent period is not known. Although symptoms began to develop on artificially inoculated fruit within 7 to 10 d after treatment (data not shown), at least some of the fruit that were used in these studies were probably latently infected (*tables IV, V*).

Results from the above studies add greatly to our rudimentary understanding of this cosmetic, but important problem on carambola fruit. Further work on its epidemiology, control and etiology is warranted, not only in Florida but also in other locations in which this disease apparently occurs [20].

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Epidemiología, control y causa de manchas fuliginosas de la carambola, *Averrhoa carambola* L., en el sur de Florida.

Resumen — Introducción. La carambola es una fruta importante para el sur de Florida (Estados Unidos). No obstante, en esta región, la enfermedad nuevamente identificada de manchas fuliginosas, provocadas por el crecimiento epifito de hongos, afecta significativamente el aspecto de la fruta. **Material y métodos**. Se observaron, de 1994 a 1996, la incidencia y de la gravedad de la enfermedad en siete plantaciones comerciales. Se examinó la influencia de las características del vergel, de la talla/madurez de la fruta y de la temporada sobre el desarrollo de estas manchas fuliginosas. Se examinó también diversas fungicidas respecto al control de la enfermedad, a partir de un calendario de aplicación dado (de una a trés semanas) o basado en las lluvias. Para los hongos en causa, se compararon colonias fúngicas en las frutas (talos) y en culturas conocidas en las manzanas. **Resultados y discusión**. La incidencia y la gravedad de la enfermedad han sido significativamente más importantes primero en los árboles más viejos, y no tanto en los jóvenes; segundo en las orientaciones norte/sur de los árboles, y no tanto en la orientación este/oeste y, tercero, en los árboles protegidos del viento, y no en los no protegidos. La enfermedad, desarrollada sobre todo en las frutas en una fase de madurez media o final, ha seguido aumentando a medida que la fruta maduraba. Se ha obtenido con ciertas fungicidas un control moderado, aunque significativo. Basándose en la morfología de los talos de frutas afectados, en las características anatómicas y morfológicas de los hongos en cultura y en su reacción a las fungicidas, se podría decir que la enfermedad es un complejo parecido al de la mancha fuliginosa de la manzana. En la carambola, el agente más común tiene semejanzas con *Peltaster fructicola*, aunque sea distinto. En ausencia de una descripción formal, se le ha llamado *Peltaster* sp. *carambola*. **Conclusión**. Este artículo es el primero en publicar la epidemiología, el control y la causa de la enfermedad de las manchas fuliginosas de la carambola en el sur de Florida. Los informes precedentes indicando o bien que la enfermedad era un moho fuliginoso, o bien que se debía a *Leptothyrium* sp. o a *Gloeodes pomigena*, son incorrectos.

Eua / Florida / *Averrhoa carambola* / síntomas de enfermedades / vigilancia de enfermedades / organismos patógenos / *Peltaster*