Distribution of Thiabendazole-Resistant *Colletotrichum musae* Isolates from Guadeloupe Banana Plantations

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ABSTRACT

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In Guadeloupe, anthracnose of bananas, caused by *Colletotrichum musae*, is commonly controlled by postharvest thiabendazole treatments. A survey was conducted in 45 banana packing stations of Guadeloupe to determine the proportion of isolates that were resistant to thiabendazole. Isolates resistant to thiabendazole concentrations of 1 µg/ml (R1), 5 µg/ml (R5), and 50 µg/ml (R50) were detected. Most of the resistant isolates were R1 or R5, and of 1,350 isolates, the proportion of resistant isolates (R1 + R5 + R50) was 23%, ranging from 0 to 70% depending on the location. The presence of resistant isolates was correlated with the exclusive use of benomyl as foliar aerial sprays from 1972 to 1982 to control Sigatoka disease. Isolates resistant to concentrations of 1 and 5 µg/ml were as pathogenic as the susceptible isolates and were not controlled satisfactorily by postharvest thiabendazole treatments. Alternative control measures and the importance of resistance in terms of anthracnose control in Guadeloupe are discussed.

Additional keywords: cross-resistance, postharvest disease, postharvest treatments

Anthracnose, caused by *Colletotrichum musae* (Berk. & M.A. Curtis) Arx, is the main postharvest disease affecting bananas from the French West Indies, causing brown fruit rot during ripening. In Guadeloupe, the disease is particularly severe from September to February in the lowland banana plantations where fruit growth is very fast, and anthracnose is considered to be the main factor affecting fruit marketability.

The pathogen is easily isolated from rotten fruits (12,14,17,22). Conidia germinate rapidly on fruits and form "quiescent" infections through appressoria that remain inactive until fruit ripening (4,19). During ripening, appressoria form penetration hyphae that colonize the underlying tissues and lead to anthracnose lesions. Fruit injuries promote rot development (16) and increase fruit losses.

Anthracnose is controlled through postharvest fungicide treatments with thiabendazole (10,21). Thiabendazole-resistant isolates of *C. musae* have been recently isolated on bananas exported from Martinique (14) and from the Windward Islands (15). Nevertheless, the status of resistance

to thiabendazole was unknown in Guadeloupe. The objective of this study was to evaluate thiabendazole resistance in different geographic and climatic areas of this island in order to determine whether the detection of resistant isolates in vitro could be related to anthracnose control failures (20). Thus, an outbreak of resistant isolates might explain severe anthracnose in bananas exported from some areas of Guadeloupe, especially in the lowland plantations where anthracnose is regularly severe.

Slabaugh and Grove (23) suggested that aerial sprays of benomyl for Sigatoka disease control lead to a build-up of benzimidazole-resistant isolates of crown rot pathogens, among which is *C. musae*. In Guadeloupe, benomyl was used exclusively as aerial foliar sprays from 1972 to 1982 to control the disease, which led to resistance in *Pseudocercospora musae* (Zimm.) Deighton populations (3,7). After 1982, benomyl use was reduced, and this fungicide was alternated with sterol inhibitors. Because there is positive cross-resistance between benomyl and thiabendazole, another purpose of this work was to evaluate whether resistance to thiabendazole is related to benomyl aerial foliar sprays for Sigatoka control.

MATERIALS AND METHODS

Sampling. Samples were collected in 1992 from 45 banana plantations corresponding to different Sigatoka control spraying zones where climatic conditions differed substan-

tially (Table 1). At each location, 50 untreated fruits were arbitrarily sampled in the packinghouse station before the postharvest treatment with thiabendazole to evaluate the proportion of resistant isolates in the field. Fruits were treated with ethephon (Ethrel) to accelerate their maturation, and stored in boxes at 24°C in the laboratory for 1 week. Typical orange acervuli developed on ripe fruits, and 30 acervuli, 1 from each of 30 different fruits, were spread on 30% agar for single-spore isolation. Single-spore isolates were transferred to potato dextrose agar (PDA) and incubated for 3 days. For each location, 30 single-spore isolates were collected; a total of 1,350 isolates were collected for the study.

Evaluation of in vitro resistance to thiabendazole. Sensitivity to thiabendazole was evaluated by an inhibition test of mycelial growth. Four 4-mm² plugs removed from the edges of 3-day-old colonies were each transferred to 20% agar amended with thiabendazole concentrations of 1, 5, and 50 µg/ml, and 20% agar without thiabendazole was used as a control. Stock solutions of thiabendazole were prepared the same day from Mertect 20 S (220 g a.i./liter), MSD AGVET. Colony diameter was measured 3 days after incubation at room temperature (24°C) for each concentration and compared to that in the control media. Isolates were classified into four groups: S, susceptible (no growth with a thiabendazole concentration of 1 µg/ml); R1, isolates resistant to a thiabendazole concentration of 1 µg/ml (but no growth at 5 µg/ml); R5, isolates resistant to a thiabendazole concentration of 5 µg/ml (but no growth at 50 µg/ml); and R50, isolates resistant to a thiabendazole concentration of 50 µg/ml (growth on 50 µg/ml). Some isolates grew only slightly (2 to 3 mm) on thiabendazole-amended media and were not considered resistant. Resistant isolates always had growth superior to 50% of the control.

Pathogenicity tests and in vivo resistance to thiabendazole. Five isolates of the different categories (S, R1, and R5) were used for pathogenicity tests and evaluation of thiabendazole control. Fruits for inoculations came from the second cluster (from the top) of fruits coming from bunches collected in the same banana plot at the CIRAD-FLHOR experimental station of

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Neufchâteau, Guadeloupe. Ten replicates from ten bunches were used, and fruits were grouped in batches for use as control or for thiabendazole treatment. All isolates were cultured on PDA for 10 days, conidia were removed by flooding the plates with sterile distilled water, and spore concentrations were adjusted to 10^6 conidia per ml. Fruits were surface-sterilized with 50% ethanol before wounding. A cork borer was used to make an annular wound, 10 mm in diameter, on each fruit. After wiping the exuded latex from the wound, the cork borer, previously dipped in the spore solution, was applied to the wound. Thiabendazole treatment was carried out by dipping the fruits in a 500 µg/ml bath for 2 min. Fruit were kept in room conditions before the thiabendazole treatment, which was applied 4 h after inoculation to enable germination of

conidia and to prevent them from being washed from the fruit surface. Control fruits were dipped in water for 2 min. After treatment, fruits from different batches were placed in commercial boxes and stored at 21°C. The diameter of the rot was recorded 13 days after inoculation when the fruits were ripe; the 10 mm diameter of the wound was subtracted. Data were analyzed by analysis of variance, and the Student-Newman-Keuls comparison test was used to compare differences of treatment means.

Statistical analysis of the resistance distribution. The proportion of resistant isolates (%RT = %R1 + %R5 + %R50) was related with five putative explanatory factors (Table 1), as follows:

(i) The annual sprays for Sigatoka control (ASC), which is the mean number of annual aerial fungicide sprays for Sigatoka

Table 2. Lesion diameter (in millimeters) of wounded bananas inoculated with sensitive or resistant isolates^y of *Colletotrichum musae*

Treatment	S	R1	R5
Control	31.98 a ^z	32.88 a	35.4 a
Mertect 20S	1.14 b	20.6 b	29.5 a

^y Means of 5 isolates inoculated on 10 fruits each. S = sensitive isolates, R1 = isolates resistant to a thiabendazole concentration of 1 µg/ml, and R5 = isolates resistant to a thiabendazole concentration of 5 µg/ml. Bananas were dipped for 2 min in a thiabendazole (Mertect 20S) concentration of 500 µg/ml or in water (control) and incubated 13 days at 21°C.

^z Numbers within columns followed by the same letter are not different according to the Student-Newman-Keuls comparison test ($P < 0.05$).

Table 1. Description of banana plantations in Guadeloupe sampled for thiabendazole-resistant isolates of *Colletotrichum musae*

Plantation	Name	%R1 ^y	%R5	%R50	%RT	ASC ^z	NBT	Alt	Piche	Wind
1	Bonne mère	16	10	0	26 (2)	8.1	14	35	25.2	15
2	Prise d'eau	23	0	0	23 (3)	6.1	22	80	20.3	15
3	Fénetau	30	0	0	30 (3)	6.7	16	150	19.6	15
4	Montebello	30	7	0	37 (2)	8	10	180	19.6	15
5	La rose	4	4	0	8 (5)	3.4	11	10	27.2	20
6	Rivière morin	20	47	3	70 (1)	8.7	25	160	19.6	15
7	Moreau	20	10	0	30 (3)	7.1	11	170	19.6	15
8	Christophe	10	30	3	43 (3)	5.1	23	110	27.2	15
9	Richebois	10	3	0	13 (4)	7.4	12	190	17.7	15
10	Changy	3	3	3	9 (5)	2.6	11	30	22.1	15
11	Besnard bisson	19	6	3	28 (3)	4.4	19	100	22.1	15
12	Bois rouge	6	26	0	32 (2)	7.6	10	380	17.7	15
13	Digue	20	13	0	33 (3)	5.4	10	230	22.1	15
14	Cambrefort	7	13	0	20 (3)	4.9	31	110	22.1	15
15	Lotissement féfé	27	23	0	50 (2)	8.1	25	380	17.7	15
16	Sarde basse	27	3	0	30 (3)	3.7	16	45	27.2	20
17	Grand rivière	0	0	0	0 (5)	1.3	11	45	34.2	20
18	Bois brûlé	0	10	0	10 (3)	5	14	80	28.5	15
19	Concession	13	17	0	30 (4)	7.3	12	320	17	15
20	Manceau	7	21	4	32 (3)	5.6	12	200	21.3	15
21	Blondinière	26	3	0	29 (3)	4.7	22	100	21.3	15
22	Dumanoir	0	17	0	17 (3)	5.9	19	210	21.3	15
23	Bois debout	3	3	3	9 (5)	3.4	10	110	28.8	20
24	Montbelley	10	0	20	30 (4)	5.9	12	240	17.1	15
25	Moulin à eau	7	3	3	13 (5)	2.9	11	45	34.2	20
26	Mineurs	0	0	0	0 (5)	1	4	50	43.2	20
27	St. Sauveur	3	0	0	3 (5)	2.9	12	50	28.8	20
28	Grand étang	0	14	0	14 (2)	8	14	300	17.1	25
29	Habituée	0	0	3	3 (4)	6.7	22	200	17.1	25
30	Tabaco	0	3	7	10 (4)	6.4	37	270	17.1	30
31	Montplaisir	0	0	0	0 (4)	3.9	30	100	14.5	30
32	Haute plaine	0	16	3	19 (4)	5.9	37	220	11.6	30
33	Lafitte bunel	23	19	0	42 (1)	7.9	34	420	11.6	35
34	Savane buissonnet	10	0	0	10 (5)	3.6	24	100	22.5	30
35	Gd fond Jaqmel	39	3	0	42 (4)	6.1	41	450	11.6	40
36	Regrettée	3	30	3	36 (3)	5	20	250	22.5	30
37	Dolé	23	3	3	29 (3)	5.3	30	300	22.5	25
38	Gillardin	10	0	0	10 (4)	4.9	31	210	14.5	25
39	Moscou	19	35	0	54 (1)	8	48	650	9.5	45
40	St. Claude	3	3	0	6 (4)	5.7	35	400	18.9	25
41	Matouba	0	0	0	0 (4)	6.9	44	500	13.2	25
42	Haut Matouba	3	0	0	3 (4)	6.1	38	650	13.2	35
43	Gd Marigot haut	33	0	0	33 (4)	7	27	600	13.2	35
44	Gd Marigot bas	17	13	0	30 (3)	3.9	15	470	26.4	20
45	Mont val	0	30	0	30 (3)	5	31	550	21.1	35

^y %R1, %R5, and %R50, are the proportions of isolates resistant to thiabendazole concentrations of 1, 5, or 50 µg/ml, respectively; %RT is the proportion of all resistant isolates (R1 + R5 + R50). Letters in parentheses correspond to the groups determined by regression-tree analysis.

^z ASC is the mean number of annual aerial sprays for Sigatoka disease control from 1972 to 1982; NBT is the number of benomyl treatments from 1983 to 1991; Alt is the elevation of the plantation in meters; Piche is the Piche evaporation in millimeters; and Wind is the annual aeolian energy available at a height of 60 m ($\times 100$ Kwh/m²).

disease control carried out between 1972 and 1982 when benomyl was used exclusively. Data before 1972 were not available, and they were estimated from 1983 to 1991. Effectively, the number of annual sprays for Sigatoka control is quite constant for a single location; decisions to spray are based on a bioclimatic forecasting sys-

tem. There is little between-year variation for the same area (2). So, ASC represents fungicide selection pressure with benzimidazole products from 1972 to 1982 when benomyl was used exclusively.

(ii) The number of benomyl treatments (NBT), which is the number of benomyl aerial sprays carried out from 1983 to 1991,

and represents the fungicide selection pressure with benzimidazole products exerted during this period. During this period, benomyl was alternated with propiconazole and tridemorph.

(iii) The altitude (Alt), which is the elevation of the plantation in meters. This parameter might be important because cli-

Fig. 1. Regression-tree analysis of the proportion of thiabendazole-resistant *Colletotrichum musae* isolates (%RT [proportion of all resistant isolates]) based on: ASC, the average number of annual aerial sprays for Sigatoka control from 1972 to 1982; NBT, the number of benomyl treatments from 1983 to 1991; Alt, the elevation of the plantation in meters; Piche, the Piche evaporation in millimeters; and Wind, the annual aeolian energy available at a height of 60 meters ($\times 100 \text{ Kwh/m}^2$). %RT is represented in 14 classes from 0 to 70%, with an increment of 5% between each class. N is the size of the groups, m is the mean %RT in the groups, and s is the standard deviation of %RT within each group. The code number of the plantations is shown at the bottom of the class distribution of %RT within each final group (solid portion of columns) compared to the whole sample (open portion of columns). Classification was stopped if $N < 8$. Splits producing less than four objects in a subgroup were rejected, and the maximum number of levels in the tree was four.

matic conditions are very dependent on the elevation. Moreover, in highland plantations aerial spraying of bananas is affected by air turbulence, and by a high flight altitude caused by the irregularity of topography and the presence of many natural obstacles.

(iv) Piche, which is the mean weekly Piche evaporation in millimeters. This climatic factor takes into account the temperature, humidity, and wind and is used to describe the hydric status of the leaf surface and to forecast aerial sprays for Sigatoka control (11).

(v) Wind, which is the annual aeolian energy available at a height of 60 m ($\times 100$ Kwh/m²) and represents the air turbulence (9) that might affect aerial spraying of bananas.

Data were processed by binary regression tree. This statistical method was first proposed by Morgan and Sonquist in 1963 (18) under the Automatic Interaction Detection (AID) algorithm. It investigates possible associations between a continuous dependent variable (Y) and a set of categorical predictors (X_i) by a stepwise procedure. Later, this method was to be adapted to the processing of any variable; more recently, Breiman et al. (1) added numerous theoretical developments to it and gave it a general configuration with the classification and regression trees (CART) methodology. The principle is, step after step, to split a set of objects into two subsets according to the values of a predictor X_i , such that objects within one subset are as homogenous as possible on the dependent variable Y , and as different as possible from the other subset objects. A categorical predictor with q ordered categories allows $q - 1$ different dichotomies of the set of objects. If X_i is a continuous predictor, each value is considered as a category. A criterion is defined to evaluate the discriminative capacity of the dichotomy on the dependent variable Y . In the AID method, this criterion is the between-groups sum-of-squares. Each predictor is examined for its most adequate dichotomy of the initial population. The best one is chosen, and data are subdivided according to this predictor. At the next step, the same procedure is applied independently to each subgroup in turn and is followed through each branch until matching

a predefined stopping rule. The gradual succession of these splits will generally be represented by a tree diagram. This method is a nonparametric alternative to multiple regression. Processing of each tree branch separately allows the detection of interactions even if complex, and when it would be difficult to express them with a linear model. The interest lies in the automatic detection, i.e., without previously defined specification. Moreover, the interpretation of results is more intuitive than with an algebraic model when it comes to describing the studied phenomenon: the way the studied population distribution varies along each branch stands out clearly. Last, the order in which relevant factors are sorted reveals their hierarchical importance. AID analysis was performed with SPAD.S package (SPAD.S version 2.5, Système Portable d'Analyse des Données. Segmentation. Centre International de Statistique et d'Informatique Appliquées. Saint-Mandé, France), using five continuous predictors. The minimum number of objects to divide a group was seven; splits giving less than four objects in a subgroup were rejected. The maximum number of levels in the tree was four.

RESULTS

Frequency of thiabendazole-resistant isolates in Guadeloupe banana plantations. Resistant (RT = R1 + R5 + R50) isolates ranged from 0 to 70% in the plantations (Table 1). Of the 1,350 *C. musae* isolates collected in the 45 plantations, 23% were resistant to thiabendazole, of which 11.7% belonged to the R1 group, 9.9% belonged to the R5 group, and 1.4% belonged to the R50 group.

Pathogenicity tests and in vivo resistance to thiabendazole. Resistant isolates of the R1 and R5 groups were as pathogenic as susceptible isolates (Table 2). No significant differences were observed for necrosis extension as compared on untreated bananas inoculated with isolates of the S, R1, and R5 groups using a Student-Newman-Keuls comparison test.

Reduction of rot extension by Mertect 20S on bananas inoculated with sensitive isolates was excellent (Table 2). Resistant isolates of groups R1 and R5 were not controlled satisfactorily by the fungicide. R1 isolates were controlled only partially by the

postharvest treatment, whereas R5 isolates were not significantly controlled (Table 2).

Distribution of thiabendazole resistance. The regression-tree analysis of the proportion of resistant isolates in the different banana plantations indicated that the main explanatory factor for this distribution was ASC. Plantations were first divided into two groups: A, with more than 7.5 sprays for Sigatoka disease control per year, and B, with 7.5 or fewer sprays per year (Fig. 1). Thus, the selection pressure exerted during the period of exclusive use of benomyl for Sigatoka control from 1972 to 1982 appears to be the main factor responsible for resistance to thiabendazole in *C. musae* populations.

Within plantations where the use of benomyl for Sigatoka disease control was more intensive from 1972 to 1982 (group A), the frequency of the use of benomyl during subsequent years had an affect on the levels of resistance to thiabendazole in *C. musae* populations. Group A split into two subgroups according to NBT, the number of benomyl sprays carried out from 1983 to 1991 (Fig. 1). Within subgroup A.1, 43% of aerial sprays for control of Sigatoka disease contained benomyl during this period, and 54.3% resistant isolates were observed compared to subgroup A.2, within which the use of benomyl was less intensive (only 16% of aerial sprays for control of Sigatoka disease contained benomyl during this period), and fewer (27.5%) resistant isolates were observed. No more division could be done on groups A.1 and A.2 because the minimum number of objects to divide a group was seven.

Group B split again into two subgroups (B.1 and B.2) according to ASC, the selection pressure exerted during the period of exclusive use of benomyl for Sigatoka control from 1972 to 1982, confirming the importance of this factor in explaining resistance to thiabendazole in *C. musae* populations. The proportion of resistant isolates was very low in subgroup B.2 (6.8%), and less than 3.6 sprays per year are done in these plantations for Sigatoka disease control (Fig. 1). The analysis was stopped within subgroup B.2 because splits producing less than four objects in a subset were rejected.

B.1 split into two subgroups according to Piche evaporation. It is striking that

Table 3. Characteristics of the different groups (1 to 5) of the banana plantations with decreasing levels of resistance of *Colletotrichum musae* to thiabendazole, as determined by tree-structure analysis

Characteristic ^a	Mean value (min.–max.)				
	1	2	3	4	5
%RT	54.2 (42–70)	27.5 (14–37)	28.3 (10–43)	15.2 (0–42)	6.8 (0–13)
ASC	8.2 (7.9–8.7)	7.9 (7.6–8.1)	5.2 (3.7–7.1)	6.2 (3.9–7.4)	2.6 (1–3.6)
NBT	33 (25–48)	12 (10–14)	19.4 (10–31)	29.1 (12–44)	11.8 (4–24)
Alt	403 (160–650)	224 (35–380)	197 (45–550)	335 (100–650)	55 (10–110)
Piche	14.6 (9.5–19.6)	19.9 (17.1–25.2)	22.8 (19.6–28.5)	15.1 (11.6–28.5)	30.1 (22.1–43.2)
Wind	27.5 (15–45)	17.5 (15–25)	18.4 (15–35)	26.5 (15–40)	20.6 (15–30)

^a %RT is the proportion of all resistant isolates (R1 + R5 + R50); ASC is the mean number of annual aerial sprays for Sigatoka disease control from 1972 to 1982; NBT is the number of benomyl treatments from 1983 to 1991; Alt is the elevation of the plantation in meters; Piche is the Piche evaporation in millimeters; and Wind is the annual aeolian energy available at a height of 60 m ($\times 100$ Kwh/m²).

within group B.1.2, where Piche is lower, disease development is faster, and ASC is higher than in group B.1.1 (Table 3), the proportion of resistant isolates is lower (15.2%) than in group B.1.1 (28.3%).

All plantations, thus, were divided into five groups with decreasing levels of resistance: A.1 (54.3%), A.2 (27.5%), B.1.1 (28.3%), B.1.2 (15.2%), and B.2 (6.8%). These five groups were renamed 1, 2, 3, 4, and 5, respectively. Their characteristics are summarized in Table 3, and they have been represented on a correlation chart between ASC and the proportion of resistant isolates (Fig. 2). The strikingly low proportion of resistance in some plantations of group 4, including 29, 30, 32, 40, 41, and 42, is clearly shown in this chart.

DISCUSSION

The results of this study clearly show that resistance to thiabendazole is widespread in banana plantations of Guadeloupe, as 23% of all isolates evaluated were resistant to a thiabendazole concentration of at least 1 µg/ml, which is sufficient to result in control failure of post-harvest treatments with this fungicide. Resistance to benzimidazole products in *C. musae* populations has also been reported in the Windward Islands for benomyl (13) and thiabendazole (15), in Central America (23), in the Philippines for benomyl (20), and in Martinique for thiabendazole (14).

In the Windward Islands and Martinique, there are reports of similar levels of resistance through 50% effective dose measurement, because three classes of resistant isolates were observed using similar limits (14, 15). In Martinique, of 29 isolates evaluated, 76% were resistant (14), and in the Windward Islands, only 17% of 54 isolates were resistant (15). Nevertheless, in these two studies carried out in Martinique and the Windward Islands, fruits were sampled in exported boxes after fungicide treatment with thiabendazole, and thus, the percentage of resistant isolates was over-estimated, because most susceptible isolates were controlled by the postharvest treatment and could not be isolated. In our study, samples were collected before thiabendazole treatment to evaluate the proportion of resistant isolates present in the field and to determine resistance distributions. However, in some areas fruits were treated with Mertect 20S before isolating, and the proportion of resistant isolates was very high (70 to 100%; data not shown). The results from Guadeloupe and Martinique, therefore, revealed higher proportion of resistant isolates than those from the Windward Islands.

The regression-tree analysis of the distribution of resistance shows that the aerial sprays of benomyl for Sigatoka disease control are the primary factor associated with thiabendazole resistance in *C. musae*

populations. Although Slabaugh and Grove (23) suggested that sprays for Sigatoka disease control could account for resistance to benzimidazole products in crown rot pathogens, our research is the first to demonstrate the probable role played by this practice.

Despite relatively high ASC and NBT values, we observed a low percentage of resistant isolates in the group 4 plantations (especially 29, 30, 32, 40, 41, and 42), which could be explained by the difficulty of aerial spraying over these areas. The quantity of fungicide reaching targets can be altered by drift and interception of droplets by natural obstacles. In addition, pilots consider these areas dangerous to spray. This interpretation can be supported by the case of the Windward Islands, where bananas are commonly interplanted with coconuts, the topography is often irregular, and banana plantations are similar to those of group 4. Similarly, less fungicide could reach targets, which would account for the lower levels of resistance to thiabendazole observed in the Windward Islands. Moreover, no resistance of *Pseudocercospora musae* to benomyl has been reported in the Windward Islands (6), when at the same time it was widely distributed in Guadeloupe (3,7), whereas the use of benomyl was more intensive in the Windward Islands (8 to 10 sprays per year).

Where resistant isolates are common, there is probably a failure of control of postharvest treatments, because these isolates are pathogenic and uncontrolled by thiabendazole treatments. Quimio (20) observed such a loss of efficacy of benomyl on resistant isolates in the Philippines. Nevertheless, anthracnose is regularly severe at the end of the year in lowland plantations of group 5, whereas the proportion of resistant isolates is very low in this area. Thiabendazole resistance, thus, cannot account for the higher anthracnose severity in this area of Guadeloupe banana plantations, and other factors might explain this situation. Recent results have pointed to the fact that fruit from these lowlands is more susceptible to mechanical damage, the preclimatic life is lower, and anthracnose development is faster on fruit artificially inoculated after harvest than on fruit coming from higher elevations (5). In addition, there was less postharvest control of anthracnose with thiabendazole on lowland fruit inoculated 15 days after bunch emergence and wounded at harvest, as compared to fruit coming from the highlands (L. de Lapeyre de Bellaire and M. Chillet, unpublished data).

In conclusion, postharvest control of anthracnose is faced with quite widespread thiabendazole resistance in *C. musae* populations in banana plantations of Guadeloupe. Imazalil, the only other fungicide approved for postharvest treatment of bananas, cannot be considered as a replacement because of its very low efficacy for

Fig. 2. Relationship between the proportion of thiabendazole-resistant *Colletotrichum musae* strains (%RT = %R1 + %R5 + %R50 [%R1, %R5, and %R50, are the proportions of isolates resistant to thiabendazole concentrations of 1, 5, or 50 µg/ml, respectively; %RT is the proportion of all resistant isolates]) and the mean number of annual aerial sprays for Sigatoka disease control (ASC) in the 45 banana plantations studied. Each plantation is represented by a number corresponding to one of the five groups determined by regression-tree analysis.

anthracnose control (8). Some sterol biosynthesis inhibitor fungicides are very effective for postharvest control of banana anthracnose, but are not registered for use in the French West Indies. Moreover, these results emphasize the need for new control strategies involving lower pesticide use, which would be in line with consumer requirements.

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