Ecología

REACTION OF BANANA AND PLANTAINS CULTIVARS TO BLACK SIGATOKA DISEASE CAUSED BY *MYCOSPHAERELLA FIJENSIS* MORELET. EPIDEMIOLOGICAL COMPONENTS OF THE RESISTANCE

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ABSTRACT

The reaction of a group of cultivars (cvs) of the banana and plantain germplasm of Cuba and synthetic hybrids from the breeding program of the Federación Hondureña de Investigaciones Agrícolas (FHIA) to black Sigatoka disease caused by Mycosphaerella fijiensis *Morelet, was studied in naturally infected plots without protection with fungicides. Most of the Cuban germplasm were highly susceptible. The highest resistance levels were observed in the cvs Yangambi Km. 5, Paka, Bungulan and Burro CEMSA. The cultivar UCRS which is highly resistant to yellow Sigatoka (*Mycosphaerella musicola *Leach ex Mulder) showed intermediate resistance to black Sigatoka. Of the FHIA cvs, the highest resistance were expressed by the cultivars FHIA 18, FHIA 2, FHIA 3 and SH 3436 and lastly the FHIA 23. The resistance is expressed through the lengthening and eventual detention of symptom evolution and the reduction of pseudothecia formation in the spot in relation to the cultivar Grand Nain (AAA, highly susceptible).*

Key words: Black Sigatoka, Mycosphaerella fijiensis, cultivar resistance, mechanisms of resistance

INTRODUCTION

Sigatoka leaf spots diseases of banana and plantains caused by *Mycosphaerella fijiensis* Morelet (Mf), (causal agent of black Sigatoka/black leaf streak) and *M. musicola* Leach ex Mulder (causal agent of Sigatoka), can be considered from the economic point of view the two most serious diseases of *Musa spp.* The *M. fijiensis* (Mf) pathogenicity on banana and plantains cultivars (cvs) formerly resistant to *M. musicola* (Mm), has had a strong social impact among the small farmers due to the production infrastructures (small parcels in towns, mixed cropping systems) and the cost of agrochemicals used for the control.

Although a considerable progress has been achieved in black Sigatoka (BS) control by the implementation of an integrated management program based on a bio-climatic forecast for timing the treatments with systemic fungicides [Pérez *et al.*, 1998], the only rational, ecologically safe and suitable strategy of disease management for small farmers, is to growth resistant cultivars and the adoption of cultural practices to reduce the inoculum availability and to create unfavourable condition to Mf infections [Pérez, 1998].

The resistance of banana and plantains to (Mm) was widely studied [Brun, 1962; Simmonds, 1966; Vakili; 1968 Chessman and Wardlaw according Wardlaw, 1972 and Pérez *et al.*, 1981]. Vakili (1968) and Pérez *et al.* (1981) found an increment of the resistance levels to the fungus in function of the participation of *M. balbisiana* in the cvs's genome. The 80% of the AAA triploids cvs studied in Cuba [Pérez *et al.*, 1981], showed a high susceptibility to the disease while the plantains (AAB), and the cooking bananas (ABB) cvs showed an intermediate and high level of resistance respectively, making unnecessary the protection with fungicides. The resistance was expressed as a delay of the infection process, due to the lengthening of the period of transition of lesions from the streaks to necrosis stages and to a reduction of the size of the lesions.

Different studies have been carried out on the resistance of banana and plantains cultivars to BS [Meredith and Lawrence, 1970; Firman, 1972; Fouré *et al.*, 1984; Fouré *et al.*, 1990]. The present study was carried out to determine the resistance to BS and the mechanisms of its expression, on different banana cvs of the germplasm present in Cuba and in a group of synthetic FHIA hybrids [Rowe and Rosales, 1993a, 1993b], that have been introduced in the country.

MATERIALS AND METHODS

Reaction to BS of some cultivars existent in the Cuban germplasm

A study of the reaction to BS was carried out in a banana and plantain cvs collection garden not subjected to treatments of protection at the Experimental Station of the INISAV in the locality of Alquízar. The plots were constituted by two rows of ten plants each one. The relation of cvs included in the study appears in the *Table 1*.

Ten mature not flowered plants of each cv were weekly sampled. Observations were carry out of: a) the youngest leaf with BS symptoms (YLStr); b) the youngest leaf with BS spots (YLS) on stages 4th to 6th according the description of Fouré *et al.* (1984) and c) the infection severity according the international scale proposed by Stover (1971) and modified by Pérez (1978) for estimating the severity of Sigatoka at the moment of maximum disease incidence and frequency (%) of leaves in the highest degrees of disease severity. The formula of Towsend and Heuberger according to Unterstenhoefer (1963), were used to transform the degrees of severity in an index (%) of leaf infection ($II\ \% = (\Sigma a.n/5N)100$ where a = value of severity of scale, n = number of leaves rated in each value and N = total number of leaves rated).

Table 1. List of the cultivars evaluated belonging to the germplasm of Cuba

Cultivars	Cultivars
Valery (AAA)	Macho de Santa Lucía (AAB)
Robusta (AAA)	Zanzíbar (AAB)
Giant Cavendish (AAA)	Criollo 70 (AAB)
Similar al Rey (AAA)	UCRS (AAA?)
Grand Nain (AAA)	Yangambi Km 5 (AAA)
CEMSA ¾ (AAB)	Paka (AA) [Stover y Simmonds, 1987]
Macho ¾ (AAB)	Horn (AAB)
Mzuzu Green (AAB)	Burro CEMSA (ABB)

Reaction of FHIA hybrids cultivars to BS. Epidemiologic components of the resistance

In a field of the farm La Cuba in Ciego de Ávila province, plots of the cvs FHIA 23 (SH 3444, AAAA; Prata Ana x SH 3142: Rowe and Rosales, 1993a); FHIA 2 (SH 3486, AAAA; Williams Cavendish x SH 3393; Rowe and Rosales, 1993a), FHIA 3 (SH 3565, AABB; SH 3386 x SH 3320; Rowe and Rosales, 1993a), FHIA 18 (AAAB), SH 3436 [AAAA; Highgate x SH 3142; Jones, 1994], and Grand Nain [AAA, subgroup Cavendish], were planted. Three furrows between the plots were planted of the cv. Grand Nain, highly susceptible to BS. The plots were maintained without fungicide treatments, during the time that lasted the observations. Ten plants were marked in each plot to carry out the assessments.

The maximum period of incubation were determined following the procedure used by Brun (1963) and Pérez *et al.* (1981), in the months of February (mother plants) and June (first follower). Observations were carried out every other day, to determine the first indication of BS stage 1 symptoms [according to the description of Fouré *et al.*, 1984]. In a similar way observations were carried out every other day, to determine the date of the change of stages of symptoms, in every one of the marked leaves in the different cvs. It was determined the average duration in days of the change of each symptom stage to the following one and the average duration of the transition period (duration in days of symptoms evolution from stage 1 to 6) in each cv. There were also determined in each cv. the average of the number of order of the leaf in which each stage of symptom appeared.

Two hundred spots at the 5th and 6th stages of evolution were sampled, measured the length in mm and counted the number of pseudothecia/spot. For this last, the spots were cleared with lactophenol in a boiling water bath during 5-6 minutes and the total pseudothecia present in the spots were counted under a binocular microscope with transmitted light.

It was determined weekly in the mother plants and the first follower, the severity of infection on the way pre-

viously explained. At harvest, the number of functional leaves and the weight of bunches were recorded and calculated the yields.

Previously to be submitted to statistical analysis, all data were adequately transformed for normality. Data in % were transformed to arsin$\sqrt{x}$. Data were submitted to ANOVA and the means compared by the test of Student.

RESULTS AND DISCUSSIONS

Reaction of some cultivars of the Cuban germplasm

All Cavendish banana cultivars (AAA) and plantains (AAB), showed a high BS susceptibility characterized by high values of the index of disease and a high proportion of the leaves rated in the highest severity values (*Table 2*).

Table 2. Black Sigatoka development in different cultivars of the Cuban germplasm

Cultivars	YLstr (Number of order)	YLS of leaves (%)	Frequency index (%) rated 4-6	Infection (Number of order)
Valery (AAA)	2.8	5.2	55.1	34.3
Giant Cavendish (AAA)	2.7	5.2	33.7	40.9
Robusta (AAA)	2.7	5	38.5	42.0
S. al Rey (AAA)	2.96	5	48.2	45.7
Grand Nain (AAA)	2.8	5.3	43	48.6
CEMSA ¾ (AAB)	2.9	4.1	16.9	35.9
Macho ¾ (AAB)	3.8	6.7	19.1	29.5
Horn (AAB)	3.1	5	28.6	39.3
Macho Santa Lucía (AAB)	3.4	6.5	13.2	26.4
Mzuzu Green (AAB)	2.3	4.8	10.5	30.4
Zanzíbar (AAB)	3.7	6.9	17.1	30.4
Criollo 70 (AAB)	3.6	6.6	12.2	28.7
UCRS (AAA?)	2.8	6.4	2.6	23.1
Bungulan (AAB)	3.2	8.8	2.6	9.8
Yangambi Km 5 (AAA)	2.9	9	3.3	9.8
Paka (AA)	3.1	8.4	1.8	6.9
Burro CEMSA (ABB)	4.1	8.2	2.0	7.3

Among the Cavendish, the highest severity rates were observed in the cvs Valery, Similar al Rey and Grand Nain. Among the plantains, Horn showed the highest values of susceptibility to BS with a high frequency of leaves in the highest severity values, followed by CEMSA ¾ and the rest of the AAB cvs, with little differences among them.

The cultivar UCRS (AAA) which is highly resistant to yellow Sigatoka, showed a lower BS susceptibility than Cavendish cvs, although it was more affected than the cvs. Bungulan (AAB), Yangambi Km 5 (AAA), Paka (AA) and Burro CEMSA (ABB).

The differences in relation to the youngest leaf with symptoms were not very marked among the different cvs. (*Table 2*). The highest difference observed among the cvs. was in relation to the YLS that showed a better correlation with the diseased leaf area. These suggest that resistance is fundamentally expressed by a lengthening of the period of lesion transition from streaks to spots. In Yangambi Km 5 we do not observe the hypersensitive reaction and the blockade of the lesion evolution from the 1rst. to 2nd stage reported by Fouré (1988); in our study, Yangambi and Paka did show a strong delay of symptom evolution in relation to what happen in Cavendish bananas and plantains.

Reaction of FHIA hybrids cultivars to BS. Epidemiologic components of the resistance

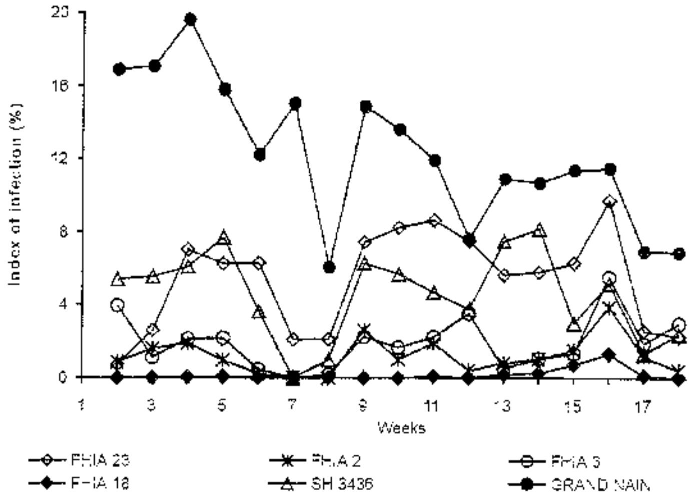

Figure 1. Reaction of FHIA hybrids to black Sigatoka. Leaf area affected in moteher plants.

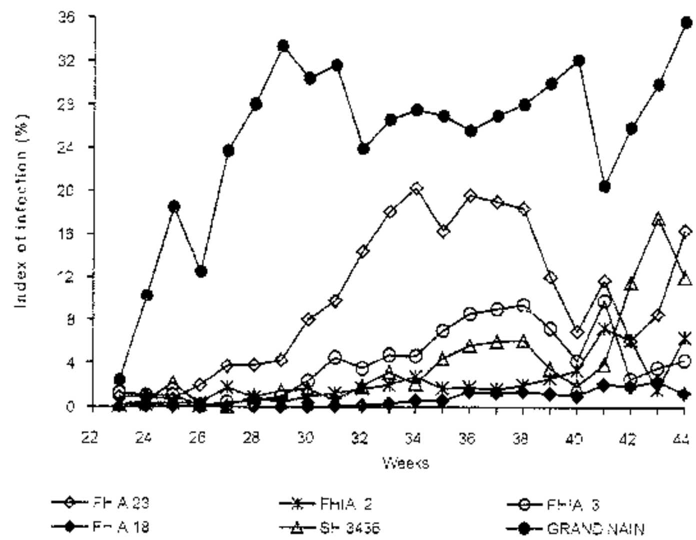

Figure 2. Reaction of FHIA hybrids to black Sigatoka. Leaf area affected in first follower.

In the *Figures 1* and *2*, appear the curves of BS development in the mother plant and first follower of the cvs FHIA 23, FHIA 2, FHIA 3, FHIA 18, SH 3436 and Grand Nain respectively. The levels of infection at the most favourable period of the year are shown in *Table 3*. The cvs FHIA 18 and FHIA 2, showed a high resistance to BS in both the mother plant (coincident with the driest and coolest time of the year) and followers (coincident with the rainy and hottest part of the year). The infection index in these cvs did not surpass in any moment 7%, and showed the highest values of active leaves. The cultivar FHIA 3 shows also a high resistance to BS. FHIA 23 and SH 3436 show a lower level of resistance than FHIA 18, FHIA 2 and FHIA 3, but much higher than Grand Nain.

Tabla 3. Infection index in the different cultivars in the most favorable period for black Sigatoka development

Cultivars	Infection index (%)[1] [October, 1996]
FHIA 23	16.4 b
FHIA 2	6.4 a
FHIA 3	4.3 a
FHIA 18	1.3 a
SH 3436	12.1 b
Grand Nain	35.7 c

[1] According de International Stover's scale modified by Pérez (1978).

The temperature has a marked effect on the incubation and evolution of BS symptoms as it can be appreciated from the data recorded in the months of February and June in *Table 4*. The incubation period of BS in Grand Nain was a 40% shorter in June than in February were temperature are frequently under 20°C.

The FHIA hybrids showed a statistically significant lengthening of the duration in days between the emergency of the leaves and the appearance of the first symptoms (maximal incubation period) in relation to the susceptible Grand Nain (*Table 4*).

The main effect of resistance was however linked to the transition of the symptoms from streaks to necrosis (*Tables 5* and *6*) and the number of fructifications/spot (*Table 7*). The lengthiness of symptom evolution combined with the drastic reduction of the formation of fructifications in leaf spots results (when there are not aloinfections from other external sources), in an important number of functional leaves at harvest even in the absence of fungicide protection.

Table 4. Maximum incubation period (from stage A of the development of unfurled leaf according Brun, 1963), to apparition of stage 1 symptoms according Fouré *et al.*, 1984 description), the transition period from stage 1 (streaks) to stage 6 (spots) of symptom evolution and number of functional leaves at harvest in the different cultivars

Cultivars	Duration in days				Active leaves at harvest	
	Incubation		Transition			
	Feb.	June	Feb.	June	Feb.	June.
FHIA 23	43.5 b	28.2 a	76.4*	75.5	9	8
FHIA 2	46.9 b	31.0 a	>150.0*	86.6	8	10
FHIA 3	60.4 a	24.1 a	>150.0*	107.7	10	8
FHIA 18	52.8 ab	28.7 a	>150.0*	119.0	12	9
SH 3436	35.2 c	28.0 a	84.3*	80.2	10	7
Grand Nain	27.9 c	16.7 b	36.6	43.0	1	0

[1] Different letters indicate significative differences at 95% of probability

* Most lesions stopped its evolution at stage 3.

Table 5. Media of the number of order of the leaf in which the different stages of black Sigatoka symptoms appears (Jan.-Jun. /96)

Cultivars	Number of the leaf at stage of symptoms					
	S_1	S_2	S_3	S_4	S_5	S_6
FHIA 18	4.6	6.6	8.8	10.1*	**	**
FHIA 2	5.0	7.2	9.1	11.7*	**	**
SH 3436	2.9	4.1	5.6	7.1*	9.1	9.8
FHIA 3	3.7	4.7	5.5	8.1*	**	**
FHIA 23	3.1	4.5	6.3	8.1*	8.1*	10.2*
Grand Nain	2.5	3.4	4.2	5.2	5.6	6.0

* Symptoms stopped evolution in the 50 % of samples at the previous stage.

** All lesions stopped evolution in the sample.

Table 6. Media of the number of order of the leaf in which the different stages of Black Sigatoka symptoms appears (Jun.-Oct. /96)

Cultivars	Number of the leaf ar stage of symptom					
	S_1	S_2	S_3	S_4	S_5	S_6
FHIA 18	3.86 a[1]	6.42 a	9.24 a	11.90 a	13.69 a	14.44 a
FHIA 2	3.83 a	5.91 a	9.18 a	10.50 a	11.90 a	12. 46 a
SH 3436	2.98 a	4.07 b	6.00 b	7.73 a	9.49 b	9. 98 b
FHIA 3	2.57 b	3.62 b	4.84 bc	5.76 c	6.76 c	7.56 bc
FHIA 23	2.53 b	3.20 b	4.04 c	5.11 c	6.50 c	7.90 bc
Grand Nain	2.20 b	3.18 b	4.16 c	4.75 c	5.02 c	5.66 c

[1] Different letters indicate significative differences at 95% of probability.

Table 7. Size of the spots and number of *M. fijiensis* pseudothecia /spot

Cultivars	Size of spots (mm)	Number of *M. fijiensis* pseudothecia/spot
FHIA 23	17.3 n.s.	15.9 a[1]
FHIA 2	13.3 n.s.	34.8 b
FHIA 3	15.5 n.s.	31.6 b
FHIA	14.3 n.s.	35.0 b
SH 343618	12.7 n.s.	9.5 a
Grand Nain	17.5 n.s.	173.6 c

[1] Different letters indicate significative differences at 95% of probability.

The FHIA hybrids showed a high productivity in spite of not beeing protected against BS; this is evident when comparing the second crop cycle harvest data with the one of Grand Nain (*Table 8*). However, some of these cultivars as FHIA 23 and SH 3436 in the presence of external sources of inoculum could require some treatments with fungicides in the most favourable months of the year to disease development.

Fouré *et al.* (1990), classified the BS sensibility of 50 cvs from diverse genetic groups, in four different types: very resistant or type 1, characterized by a blockade of symptoms evolution from the 1st to the 2nd stage; partial resistance or type 2, because the lesions evolve from the stage 1 to 6 but in a slow way and because the number of functional leaves at harvest in these cvs is high; sensitive or type 3, due to that the evolution of the BS lesions is fast from the stage 1 to 6 and the number of functional leaves at harvest is not very high; very sensitive banana trees or type 4, in which the disease evolution is very fast and show very few functional leaves (if any) at harvesting.

In our experiment the banana and plantains cultivars shown the following types of reaction:

- *Partial resistant or type 2*: Paka, Yangambi km 5; Bungulan, Burro CEMSA, FHIA 23, FHIA 2, FHIA 3, FHIA 18, SH 3436);
- *Sensible or type 3:* UCRS.
- *Very sensible or type 4*: Giant Cavendish, Robusta, Grand Nain, Valery, Similar al Rey, CEMSA ¾; Mzuzu Green, Horn, Zanzíbar, Macho Santa Lucía, Criollo 70.

In contrast with the case of the interaction *Musa* spp.-*M. musicola*, on which the presence of B genes of *M. balbisiana* in the genotype was correlated to the resistance to the disease [Vakili, 1963; Pérez *et al.*, 1981], in the interaction *Musa* spp.-*M. fijiensis* it is not.

There were not observed in Yangambi Km 5 the hypersensible reaction observed by Fouré *et al.* (1990). This cultivar and the cultivars Paka show a similar but stronger reaction than FHIA 18 and FHIA 2.

The FHIA hybrids are good alternative for banana and plantain production in areas where chemical treatments are not feasible or available as is the case of small farm productions. Their use should be combined with sanitation and adequate practices of sanitation. They have a better behaviour when are grown in compact fields far from sources of inoculum.

Table 8. Bunch weight and yield of the plots without fungicide protection

Cultivars	Bunch weight (kg)		Yield (t/ha)	
	Mother Plants	First Follower	Mother Plant	First Follower
FHIA 23	36.0	42.5	55.0	70.8
FHIA 2	37.5	34.0	62.5	56.6
FHIA 3	31.5	34.0	87.5	56.6
FHIA 18	28.5	26.5	79.2	44.1
SH 3436	37.5	26.0	57.3	43.3

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