Research Note

HORTICULTURAL EVALUATION OF 'FHIA-21' (AAAB) PLANTAIN IN PUERTO RICO[1,2]

Carlos E. Ortiz[3]*, Manuel Díaz-Rivera*[4]*, Agenol González-Vélez*[5]*, Luis E. Rivera*[6]*, Evelyn Rosa-Márquez*[5]*, Jesús M. Cardona*[7] *and Martha C. Giraldo-Zapata*[8]

J. Agric. Univ. P.R. 103 (2):189-196 (2019)

Control of black Sigatoka disease in plantains is imperative for adequate yield. Black Sigatoka is caused by the fungus *Pseudocercospora fijiensis* (Morelet) Deighton, formerly known as *Mycosphaerella fijiensis* Morelet. The disease does not immediately kill the plants, but by reducing the effective leaf area it interferes with photosynthesis (Churchill, 2011). If not controlled, the disease has the potential to devastate plantain fields.

In Puerto Rico, the main plantain cultivar is 'Maricongo', a false-horn clone which is susceptible to black Sigatoka. Locally, a combination of synthetic pesticides and the sanitary removal of leaves, or parts of them, are used to control the disease. As suggested by Goenaga and Irizarry (2006), the use of French-type plantain clones may result in increased yield via increased production of fruits and by the tolerance of these clones to black Sigatoka. Resistance to this disease appears to be associated with French-type parents as the source of resistance in Musaceae breeding programs (Goenaga and Irizarry, 2006).

A French-type tetraploid (AAAB) plantain cultivar, 'FHIA-21' was developed by the "Fundación Hondureña de Investigación Agrícola" (FHIA) at La Lima, Honduras. Major attributes of this cultivar are its high tolerance to black Sigatoka and higher yields than false-horn clones (Rowe, 1997; Hauser, 2010; Calvo, 2010); details for the plant characteristics of 'FHIA-21' were summarized in its patent (Rowe, 1997). However, 'FHIA-21' is susceptible to the Banana Streak Virus (Martínez et al., 2015), a virus that limits plant development and consequently reduces its yield potential

[1]Manuscript submitted to the Editorial Board 15 March 2019.

[2]This work was supported by the Department of Agriculture of Puerto Rico – FIDA Grant identified as project ZFIDA-15. Authors express thanks to Dr. Raúl E. Machiavelli for the statistical analyses.

[3]Professor, Department of Agroenvironmental Sciences, University of Puerto Rico, Mayagüez Campus. Agricultural Experiment Station at Gurabo, P.O. Box 1306, Gurabo, PR 00778. Corresponding author: carlos.ortiz35@upr.edu

[4]Professor and Starchy Crops Specialist, Department of Agroenvironmental Sciences, University of Puerto Rico, Mayagüez.

[5]Retired Professor, Department of Agroenvironmental Sciences, University of Puerto Rico, Mayagüez.

[6]Researcher, Department of Agroenvironmental Sciences, University of Puerto Rico, Mayagüez.

[7]Retired Research Associate, Agricultural Experiment Station, University of Puerto Rico, Mayagüez.

[8]Associate Professor, Department of Agroenvironmental Sciences, University of Puerto Rico, Mayagüez.

(González-Vélez, 2014; Hausser, 2010). The Banana Streak Virus infection in Musaceae is characterized by discontinuous chlorotic areas that turn into necrotic streaks on leaves and the split of the pseudostem (Lockhart, 1995). Nonetheless, because of its high yield potential, 'FHIA-21' continues to be used for processed plantain products especially in the Dominican Republic (Garming et al., 2013). Thus, the Department of Agriculture of Puerto Rico was interested in evaluating 'FHIA-21' to increase local raw material for processed plantain products. This study was conducted to evaluate 'FHIA-21' for plant characteristics, susceptibility to important diseases, and its production potential in four agricultural zones of Puerto Rico as compared to the local cultivar 'Maricongo'.

Field trials were conducted between 2013 and 2015 at the Corozal, Gurabo, Isabela and Juana Díaz research farms of the Agricultural Experiment Station of the University of Puerto Rico. Locations differ in geographical conditions and in soil characteristics (Table 1).

Soil in the planting area was prepared conventionally (University of Puerto Rico, 1995). Planting corms were obtained from sword suckers weighing 0.45 to 1.81 kg. Prior to planting, suckers with similar weight were arranged as replicates. Each plot consisted of a bed 3.05 m wide and 10.97 m long containing six 'FHIA-21' and two 'Maricongo' plants. The plot accommodated three bunch-pruning treatments for 'FHIA-21' plants. 'Maricongo's bunches were not pruned. Thus, within the plot, two plants represented each treatment. The number of replicates varied by location as follows: Corozal, 25; Isabela, 35; Juana Díaz, 20. At Gurabo the experiment was planted three times with 30, 25 and 12 replicates.

At planting, each plant received 50 g of triple superphosphate. Each plant was individually side-dressed with 57 g of 12-5-20 fertilizer applied approximately at two, five and eight months after planting. Weeds were controlled by hoeing around the plant and the use of registered herbicides for the rest of the field. Nematodes and soil-borne insects were controlled by following current recommended practices. Drip irrigation was used. Because a major objective of this study was to evaluate 'FHIA-21' for its tolerance to black Sigatoka, no practices were carried out to control this disease.

At flowering (inflorescence apical emission) functional leaves were counted, and the height of the plant and diameter of the pseudostem were measured. The height was measured as the distance from the ground to the point where the flower emerged. The diameter of the pseudostem was measured at one meter above ground.

At six months after planting, and at flowering, plants were evaluated for susceptibility to black Sigatoka following procedures summarized by Carlier et al. (2003) and by Viljoen et al. (2017). Evaluations were made at Corozal, Gurabo and Isabela considering plantings made on similar dates. At each location, plots at the center of the field were selected, and among these plots 12 plants per cultivar were marked for sampling. For each of the 12 plants, the youngest leaf spotted (YLS) was identified, number of functional leaves and number of standing leaves (NSL) were counted, and the index of non-spotted leaves (INSL) calculated. The youngest leaf spotted is the first (youngest) leaf from the top of the plant having at least ten black Sigatoka necrotic lesions. Functional leaves were those with an erect petiole and more than 50% free of black Sigatoka lesions. The INSL refers to the proportion of standing leaves without the typical late-stage symptoms of black Sigatoka and was calculated as INSL = (YLS – 1) / NSL x 100. This index provides an estimation of available photosynthetic leaf area prior to fruit filling and is an estimate of black Sigatoka tolerance for cultivated Musaceae (Viljoen et al., 2017).

Plants with symptoms associated with the Banana Streak Virus were identified and counted throughout the crop cycle. Symptoms included necrotic streaks on the

Table 1.—*Eco-geographical and soil characteristics of the locations used to evaluate 'FHIA-21' plantain.*

Location[1]	Geographical Zone	Soil Series and Soil Properties								
		Series	Family	pH	EC[2]	OM[3]	CEC[4]	P	K	Ca	Mg
					µS/cm	%	meq/100g	mg/kg			
Corozal	Eastern humid mountains	Corozal	Typic Haplohumults	5.5	147.0	2.6	1.1	3.7	25.8	177.0	12.4
Gurabo	Caguas Valley	Toa	Fluventic Hapludolls	6.5	105.6	1.7	1.8	16.2	10.8	213.4	71.6
Isabela	Northern coastal plains, subhumid section	Coto	Typic Hapludox	6.5	86.5	1.9	0.6	7.8	11.4	90.8	8.0
Juana Díaz	Alluvial southern plains (subarid)	San Antón	Cumulic Haplustolls	8.4	206.8	1.8	25.5	37.0	309.8	4393.0	212.5

[1]Research farms of the Agricultural Experiment Station of the University of Puerto Rico.
[2]Electrical Conductivity
[3]Organic Matter
[4]Cation Exchange Capacity

leaves, stunted plants, splitting of the pseudostem, cigar leaf necrosis, absence of bunch or underdeveloped (abnormally-shaped) bunch. Many of these symptoms were described by Lockhart (1995).

Yield results were from the three plantings at Gurabo. Treatments for bunch pruning were applied between the second and third week after bunch emergence. Pruning consisted in the removal of the male floral bud and the apical hands. The pruning of hands in 'FHIA-21' was done so that their bunches retained six, five and four hands. Bunches for the 'Maricongo' plants were not pruned because this cultivar has an inflorescence that disintegrates as the bunch matures. Bunches were harvested when estimated ready for market. Freshly harvested bunches were weighed and fruits counted. The number of hands of 'Maricongo' were counted. For yield, analysis of variance was carried out using a mixed model. Aleatory effects were planting and replicates within planting. Fixed effects were 'FHIA-21' with bunches pruned at six, five and four hands and unpruned 'Maricongo'. To compare the number of fruits per bunch and yield, two analyses were made. The first analysis included all plants whether or not the plant yielded or was unproductive. In this analysis yield was zero for unproductive plants. The second analysis included yield for plants that were productive and harvested. Means were compared by using the least significant difference at the 0.05 probability level.

Across locations, 'FHIA-21' consistently flowered later in the crop cycle and had more leaves at flowering than 'Maricongo' (Table 2). The latter observation is consistent with previous reports indicating that 'FHIA-21' flowers later than commercial false-horn clones (González-Vélez, 2014; Calvo, 2010). This result also indicates that the crop cycle for 'FHIA-21' is longer than that of 'Maricongo'. The INSL for 'FHIA-21' was 93 or higher, indicating that the available photosynthetic leaf area prior to fruit filling was high (Table 3). These observations confirm that 'FHIA-21' is highly tolerant to black Sigatoka. 'Maricongo' had an INSL from 91 to 73 at six months. However, this index went from 35 to 52 at flowering. Thus, results indicated 'Maricongo' was more susceptible to black Sigatoka than 'FHIA-21' (Table 3).

At all locations 'FHIA-21' plants showed symptoms associated with Banana Streak Virus (Table 4). Common symptoms were the necrotic streaks on the leaves, stunted plants, cigar leaf necrosis, splitting of the pseudostem, absence of bunch and abnormally shaped bunch. 'Maricongo' plants did not present symptoms of this virus. Percentage of 'FHIA-21' plants showing symptoms of the Banana Streak Virus and becoming unproductive varied from 54% at Corozal to 26% at one of the Gurabo plantings (Table 4). Even though our results confirmed 'FHIA-21' is highly tolerant to black Sigatoka, the relatively high percentage of unproductive plants associated with Banana Streak Virus reduces the chances this cultivar will become commercial under the current agricultural system for plantain production in Puerto Rico. Local cost for plantain production is high; thus, a high percentage of productive plants is necessary to recover investment and to generate adequate returns.

In this study, the number of hands per bunch of 'FHIA-21' plants was set to six, five and four through bunch pruning. Unpruned 'Maricongo' bunch had on average 6.8 hands (Table 5). ***Yield analysis counting all plants whether or not plants yielded or were unproductive*:** Under this analysis, 'FHIA-21' plants with their bunches pruned to six hands had more fruits and higher bunch weight than 'FHIA-21' plants pruned to four and five hands, and more than 'Maricongo' (Table 5). ***Yield analysis counting plants that were productive and harvested*:** Under this analysis, the higher the number of hands in 'FHIA-21' bunches, the higher the number of fruits (Table 5). 'FHIA-21' plants pruned to six and five hands did not differ in bunch weight, and bunches from both treatments weighed significantly more than those from 'FHIA-21' plants pruned to four hands, and also more than 'Maricongo'.

TABLE 2.—*Plant height and diameter, days to flower and leaves at flowering for 'FHIA-21' and 'Maricongo' planted at various locations.*

Location	Cultivar	Plants sampled no.	Height m	Diameter cm	Days to flowering no.	Leaves at flowering no.
Corozal	FHIA-21	125	3.37	18.4	352	9.9
	Maricongo	51	3.60	17.6	295	8.7
Gurabo first planting	FHIA-21	141	3.20	18.0	258	13.7
	Maricongo	59	3.38	16.3	237	10.3
Gurabo second planting	FHIA-21	103	3.21	18.3	265	14.2
	Maricongo	46	3.30	16.3	252	10.9
Gurabo third planting	FHIA-21	50	3.03	16.5	256	13.2
	Maricongo	21	3.09	15.5	234	9.9
Isabela	FHIA-21	144	2.89	15.9	314	—*
	Maricongo	58	2.99	16.1	256	—
Juana Díaz	FHIA-21	91	3.53	19.5	290	—
	Maricongo	24	3.41	17.8	246	—

*—Missing results.

TABLE 3.—*Total and functional leaves and index of non-spotted leaves for 'FHIA-21' and 'Maricongo' plantains sampled at six months after planting and at flowering at various locations.*

		'FHIA-21' leaves			'Maricongo' leaves		
		Total	Functional	Index of non-spotted leaves	Total	Functional	Index of non-spotted leaves
Sampling date	Location	no.			no.		
Six months after planting	Gurabo	9.9	9.9	100	9.4	9.2	91
	Corozal	10.7	10.7	100	11.1	9.4	61
	Isabela	9.0	9.0	100	7.7	6.3	73
At flowering	Gurabo	12.2	12.2	100	10.3	10.1	51
	Corozal	9.8	9.6	93	7.6	6.1	52
	Isabela	6.7	6.7	97	8.4	7.3	35

TABLE 4.—*'FHIA-21' plants with Banana Streak Virus (BSV) before and after flowering and percentage of unproductive plants at various locations.*

	'FHIA-21' Plants			
	Planted	With BSV symptoms and dead before flowering	With BSV symptoms and with underdeveloped bunch	Unproductive
Location	no.			%
Corozal	150	16	65	54
Gurabo first planting	180	25	21	26
Gurabo second planting	150	28	21	33
Gurabo third planting	72	10	12	31
Isabela	210	29	—*	—
Juana Díaz	148	14	27	27

*—Missing results

TABLE 5.—*Average number of fruits per bunch and bunch weight for 'FHIA-21' and 'Maricongo' plants, counting dead and unproductive plants, and plants completing crop cycle.*[1]

		Counting dead and unproductive plants		Counting plants that completed the crop cycle	
Cultivar	Hands in the bunch	Fruits	Bunch Weight	Fruits	Bunch Weight
		--- no. ---	--- kg ---	--- no. ---	--- kg ---
FHIA-21	6	57.8 a[3]	15.8 a	72.1 a	19.6 a
FHIA-21	5	41.7 b	12.9 b	63.7 b	19.6 a
FHIA-21	4	35.1 b	12.5 b	51.8 c	18.3 b
Maricongo	6.8[2]	40.3 b	12.7 b	44.0 d	13.8 c

[1]These results are averages of plantings at Gurabo.
[2]Average number of hands for unpruned bunch.
[3]Within columns means followed by the same letter are not significantly different at $P < 0.005$.

LITERATURE CITED

Calvo, A.V., 2010. Efecto del desmane y de la modalidad de cosecha sobre las características y producción de racimos de plátano tipo Francés FHIA-21. *Tropicultura* 28 (1): 16-23.

Carlier, J., D. De Waele and J.V. Escalant, 2003. Evaluación global de la resistencia de los bananos al marchitamiento por Fusarium, enfermedades de las manchas foliares causadas por *Mycosphaerella* y nematodos. Guías técnicas INIBAP 7. Red Internacional para el Mejoramiento del Banano y el Plátano, Montpellier, Francia. 58 pp.

Churchill, A.C., 2011. *Mycosphaerella fijiensis*, the black leaf streak pathogen of banana: Progress towards understanding pathogen biology and detection, disease development, and the challenges of control. *Molecular Plant Pathology* 12(4): 307-328.

Garming, H., J. Espinosa, S. Guardia and R. Jimenez, 2013. Large-scale adoption of improved plantains: The impact of FHIA-21 in the Dominican Republic. *Acta Horticulturae* 986: 259-265.

Goenaga, R. and H. Irizarry, 2006. Yield performance of two French-type plantain clones subjected to bunch pruning. *J. Agric. Univ. P.R.* 90 (3-4): 173-182.

González-Vélez, A., 2014. Comportamiento de los clones de plátano 'Maricongo' y FHIA-21 en presencia de la Sigatoka negra en la zona de altura húmeda en Puerto Rico. *J. Agric. Univ. P.R.* 98(1): 21-30.

Hauser, S., 2010. Growth and yield response of the plantain (*Musa* spp.) hybrid FHIA 21 to shading and rooting by *Inga edulis* on a southern Cameroonian Ultisol. Proceedings International Conference on Banana and Plantain in Africa. *Acta Horticulturae* 879: 487-494.

Lockhart, B.E., 1995. Banana streak badnavirus infection in *Musa*: Epidemiology, diagnosis and control. Food and Fertilizer Technology Center, Technical Bulletin 143.

Martínez, R.T., X. Cayetano, I.N. Acina Manbole, C. Dubois, X. Perrier and P.Y. Teycheney, 2015. Risk assessment of spreading Banana streak viruses in the Dominican Republic through large scale cultivation of plantain cultivars and hybrids harbouring infectious eBSVs. (Abstract) P 48. 15èmes Rencontres de Virologie Végétale, 18 to 22 January 2015. Aussois, France.

Rowe, P.R., 1997. U.S. Patent PP 9791, Plantain Plant 'FHIA-21'. University of Puerto Rico, 1995. Conjunto tecnológico para la producción de plátanos y guineos., University of Puerto Rico-Mayagüez. Publication 97 (rev.). 46 pp.

Viljoen, A., G. Mahuku, C. Massawe, R. T. Ssali, J. Kimunye, G. Mostert, P. Ndayihanzamaso and D. L. Coyne, 2017. Banana diseases and pests: Field guide for diagnostics and data collection. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. 96 pp.