ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
http://ansijournals.com/ja

JOURNAL OF AGRONOMY

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

OPEN ACCESS Journal of Agronomy

ISSN 1812-5379
DOI: 10.3923/ja.2016.151.164

Research Article
Assessment of Banana and Plantain Behavior under Natural Infestation by *Mycosphaerella fijiensis*, Morelet in Southern Côte d'Ivoire

[1]Tuo Seydou, [1]Amari Ler-N'ogn Dadé Georges Elisée, [1]Camara Brahima, [2]Soro Sibirina, [1]Sorho Fatogoma, [3]Abo Kouabenan, [4]Ouédraogo Somgnogdin Léonard and [1]Koné Daouda

[1]Laboratory of Plant Physiology, Department of Biosciences, University Félix Houphouët-Boigny of Cocody-Abidjan, 22 B.P. 582, Abidjan 22, Côte d'Ivoire
[2]Department of Agroforestry, University Jean Lorougnon Guédé of Daloa, B.P. 150 Dalo, Côte d'Ivoire
[3]Laboratory of Plant Pathology and Plant Biology, Department of Training and Research in Agriculture and Animal Resources, Institut National Polytechnique Félix Houphouët-Boigny, B.P. 1313 Yamoussoukro, Côte d'Ivoire
[4]Institute of Environment and Agricultural Research, 01 B.P. 910 Bobo Dioulasso, Burkina Faso

Abstract

Background and Objective: An assessment trial on the behavior of five varieties of banana and plantain cultivars under natural infestation by *Mycosphaerella fijiensis* was carried out in Azaguié-Ahoua in Southern Côte d'Ivoire, in 2013 and repeated in 2014 for selecting varieties that are productive and tolerant to Black Sigatoka (BLSD). **Methodology:** The trial was set up in split-plot with three repetitions. The banana tree suckers were planted, with a density of 1,600 plants per hectare, that is a spacing of 2.5 and over 2.5 m. In the 4th month after planting, observations and measurements focused on agronomic and phytopathological descriptors so as to assess yield components and sensitivity of the varieties to BLSD. **Results:** The results indicated that hybrids PITA 3 and FHIA 21 introduced were the most tolerant and productive and the local cultivar "Orishele", the most sensitive and least productive. These hybrids PITA 3 and FHIA 21 presented respective gross yields of 18.50 and 21.22 t ha^{-1} in the first crop cycle and 10.62 and 14.98 t ha^{-1} in the second crop cycle with a high tolerance to BLSD. Whereas, the local cultivar "Orishele" presented a gross yield of 11.49 and 5.63 t ha^{-1} in the first and second crop cycle, respectively with a high sensitivity to BLSD. **Conclusion:** In order to improve the performance of the local cultivar "Orishele" appreciated by consumers it seems appropriate to continue research in an agronomic approach focusing on its cultivation in combination with tolerant hybrids for an integrated management of Black Sigatoka.

Key words: Banana and plantain, behavior, sensitivity, *Mycosphaerella fijiensis*, Côte d'Ivoire

Received: July 02, 2016 Accepted: August 15, 2016 Published: September 15, 2016

Citation: Tuo Seydou, Amari Ler-N'ogn Dadé Georges Elisée, Camara Brahima, Soro Sibirina, Sorho Fatogoma, Abo Kouabenan, Ouédraogo Somgnogdin Léonard and Koné Daouda, 2016. Assessment of banana and plantain behavior under natural infestation by *Mycosphaerella fijiensis*, Morelet in Southern Côte d'Ivoire. J. Agron., 15: 151-164.

Corresponding Author: Tuo Seydou, Laboratory of Plant Physiology, Department of Biosciences, University Félix Houphouët-Boigny of Cocody-Abidjan, 22 B.P. 582, Abidjan 22, Côte d'Ivoire

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Banana tree (*Musa* spp.) is essentially a food plant cultivated for its fruit consumed as fresh banana (dessert banana) or cooked (plantain and other cooking bananas) or even consumed as fries. About 400 million people worldwide depend on this crop, by its consumption and its marketing[1,2]. Thus, plantain tree is a subsistence crop in Côte d'Ivoire and in many countries of the humid tropics. It is suitable for low-labor regions since using less labor and resulting in a high yield. It is a crop grown by small farmers in West and Central Africa with 50% of world production of plantain[3]. The cultivation is made on concessions, that are farms practicing small-scale mixed cropping or mono cropping and is a significant source of income in both rural and urban areas[4]. In Côte d'Ivoire, plantain tree cultivation is characterized by a traditional production system. Approximately 85% of plantations are family owned and in 92% of cases, plantain tree is grown in combination with other food crops[4]. In Côte d'Ivoire, with a yield estimated at 1.624 million tons per year, plantain is ranked 3rd in food crops after yam and cassava[5]. This yield makes Côte d'Ivoire the 3rd producer of plantain in West Africa, after Nigeria and Ghana[5,6]. In 2013, the plantain tree area cultivated[5] in Côte d'Ivoire was estimated at 430 000 ha. However, whatever the areas and production methods, the past few decades showed a decrease in yield of the different varieties of banana and plantain trees grown. This decrease in yield is related on the one hand to the non-compliance with phytosanitary practices, declining soil fertility, use of inappropriate farming techniques, lack of resistant cultivars and degeneration of cultivars and on the other hand, to the explosion of pests and diseases[7]. According to Camara[2], pests and diseases are a growing threat to small and large producers and can cause catastrophic losses. According to the same author, many banana and plantain production systems are threatened by epidemics caused by plant pathogenic fungi. Among these, Black Leaf Streak Disease (BLSD) or Black Sigatoka caused by the ascomycete fungus *Mycosphaerella fijiensis* Morelet appears as the main foliar disease of banana and plantain trees in Côte d'Ivoire[8,2]. It is the most damaging due to its virulence and its impact on a wide range of cultivars worldwide[9]. It attacks leaves and causes leaf surface deterioration and decrease of photosynthetic capacities resulting in reduced plant growth and productivity with early ripening of bananas. Crop losses[10] are estimated between 20 and 50% and can reach 100% from the second crop cycle[11,12].

In order to reduce the use of synthetic fungicides, the use of material resistant to Black Sigatoka is advised for building a barrier that would prevent and/or minimize disease spreading[13]. Indeed, Black Sigatoka control is relatively difficult and it is necessary to use all available weapons[8,14]. One strategy for solving this problem is to create new resistant varieties, in breeding programs that help get superior genotypes[15]. Thus, new cultivars of dessert banana and plantain showing partial resistance vis-a-vis Black Sigatoka and Yellow Sigatoka obtained in breeding programs are under assessment in Côte d'Ivoire[16]. Note that the use of resistant varieties is one of the most efficient alternatives for disease control.

This study aims at assessing, over 2 crop cycles, growth and yield performance of local cultivars of dessert banana (AA) and plantain (AAB) and introduced cultivars of plantain (AAAB) under natural infestation by *Mycosphaerella fijiensis*, Morelet in Southern Côte d'Ivoire.

MATERIALS AND METHODS

Area of study: The experiments were carried out in Azaguié-Ahoua. It is a town located Southern Côte d'Ivoire in the region of Agnéby-Tiassa, at 05°37′ North latitude, 04°02′ West longitude and 76 m altitude. It has an average annual temperature oscillating between 26 and 29°C, a relative 94% humidity and an average annual 1545 mm rainfall. These agroecological conditions correspond to those of the subtropical rainforest. The climate is tropical humid, characterized by a mixed rainfall pattern in four seasons, including two dry seasons and two rainy seasons: A short dry season (July-August), a long rainy season (March-June), a long dry season (December-February) and a short rainy season (September-November)[17]. The two sites used for conducting this experiment were previously fallow lands. The physicochemical composition of their soil was determined.

Plant material: The plant material used consisted of sword suckers of banana and plantain trees from five varieties. They include: Three local cultivars "Figue Sucrée" (AA), "Orishele" (AAB) and "Corne 1" (AAB) and two tetraploid hybrids PITA 3 (AAAB) and FHIA 21 (AAAB), cultivars under dissemination to producers[17].

Physicochemical characterization of the soil of experimental sites

Sampling and preparation of soil samples: Given the fact that changes in farming systems are faster in the surface layer[18], soil sampling for physicochemical analysis were made in the layer from (0-20 cm). Four composite soil samples were

taken at well-separated points on each of the two plots, with a small planting shovel. A total of 8 samples were collected for laboratory analysis. The amount of soil collected was about 1 kg^{-1} sample. Such soil samples collected were dried in the open air in a well ventilated room, ground and sieved using a square mesh sieve of 2 mm for analysis. The <2 mm fraction was then stored in polyethylene plastic bags labeled with a permanent marker and sent to the Soil and Plant Laboratory of the National Polytechnic Institute Houphouët-Boigny (INPH-B) in Yamoussoukro for analysis.

Physicochemical analysis: The different analysis were conducted only on the samples of the surface layer located between 0 and 20 cm as the banana tree roots have shallow growth in soil. Previously dried soil samples were used for particle size analysis of the soil at 5 fractions without decarbonation. The densitometric method using the Robinson-Köln pipette was practiced[19,20]. According to standard NF X 31-107, the proportions of the following classes of particles: Coarse (20-50 µm) and fine (2-20 µm) silt, clay (0-2 µm), fine (50-200 µm) and coarse (200-2000 µm) sand were determined. The particle size was measured after oxidation of the organic matter with hydrogen peroxide (H_2O_2) followed by dispersion with a solution of sodium hexametaphosphate [$(NaPO_3)_6$+Na_2CO_3] after prior separation of fine sand and coarse sand by sieving[21]. For each sample, the analysis was repeated 3 times. For result analysis, the sand fractions as well as the silt fractions were grouped. This lead to three particle size classed for determining soil texture. This texture was determined using the texture triangle[22] proposed by Lagatu in 1904 by adding sand, silt and clay percentages determined. The determination of soil pH was made according to the electrometric method[23]. The measurement of water pH was carried out by direct reading on the pH m, in 1/2.5 soil/water suspension. Organic carbon (C) was determined by the Walkley and Black method[24], the result was converted into Organic Matter (OM) using the factor 1.724 (OM = C × 1.724). As for total nitrogen it was determined by the Kjeldahl method[25]. Total phosphorus was determined by colorimetry after extraction with perchloric acid[26].

Establishment of plots

Experimental design: The experiment was conducted under natural infestation of field banana by *Mycosphaerella fijiensis*. The implementation of the trial was made in 2013 and repeated in 2014. The main factor studied was the varietal factor with five levels of variation (5 monovarietal plots). The experimental unit was the banana tree plant. The adopted experimental design was a split-plot, with 3 repetitions (3 blocks). Each variety ("Orishele", "Corne 1", "Figue Sucrée", PITA 3 and FHIA 21) represented a treatment. Each block was composed of 5 plots to which were allocated the treatments. The block was represented by the treatment (procedures). The trial was thus made up of 5 plots per block.

On these plots, banana suckers were planted, with a density of 1,600 plants per hectare, that is, a spacing of 2.5 and over 2.5 m. The different treatments within the same block were bordered by 2 rows of suckers of cultivar "Orishele" so as to favor conditions for stronger pressure of Black Sigatoka. Each monovarietal plot was composed of 24 banana (24 repetitions of the experimental unit over 4 rows at the rate of 6 feet per line) of the same variety. Five plants of each variety were assessed per block, that is 15 plants per variety. A total of 75 plants were assessed in each trial.

In each trial, the plants were monitored in the same way, with standard cultivation techniques and did not receive fungicide-based treatment against black leaf streak disease. However, fertilization management was performed using dry and well decomposed chicken manure, taken from poultry farms. It was used at doses of 2 kg^{-1} plant during sucker planting. Subsequently, five other applications of 2 kg each were made monthly from the 4th month after planting, up to total of 12 kg at flowering.

Agronomic observations

Growth and development parameters of plantain during the vegetative phase: Disease development and cultivar sensitivity were assessed 6th and 8th months after planting during the vegetative phase of banana trees and plantain trees before the first flowering of the first production cycle.

Agronomic descriptors were used for this assessment during the first production cycle. These include the number of emerged leaves (NEL), pseudo stem height and girth. Pseudo stem height (Hp) was measured from the collar to the top of the plant at the V formed by the last two functional leaves. The pseudo stem girth was assessed at 10 cm above ground (C10). As for the number of emerged leaves, it was determined by counting from bottom to top as early as sucker planting up to the first flowering.

Agronomic parameters assessed at flowering and harvesting: Agronomic descriptors were used during both production cycles. The intervals expressed in days (d) between planting and flowering (IPF) or time elapsed between planting and emergence flower at the top of pseudo-stem; then

between flowering and harvest (IFH) or time elapsed between the appearance of the flower and coppicing and finally between planting and harvesting (IPH) or duration of the development cycle were calculated.

The bunch was cut when the distal end of the fruit turned black, the fingers became obviously well filled, without ridges and/or at the first curved finger stage.

At harvest, the assessment of the physical characteristics of bunches and fruits focused on the following parameters:

- The average bunch weight (BW) in kilogram of each cultivar was determined by weighing each bunch on precision balance (compact Baxtran DSN30) (±1 g) and the yield per hectare was calculated from the average weight of bunches multiplied by the density of plants
- The number of hands (NHB) and fingers (NFB) by bunch were counted
- The mass (MFH), the outer length (ELFH) and grade or class (GFH) of reference fruits (middle fingers) of the second were determined. For these last two parameters, the measurements concerned the distance from the distal end to the proximal end of the outer arc where the pericarp ends and the girth in the middle portion

Phytopathological observations

Phytopathological parameters assessed during the vegetative phase: The phytopathological parameters assessed at the 6th and 8th months for Black Sigatoka, during both production cycles were:

- The Youngest Leaf Affected (YLA), that is to say, by counting the leaves from top to bottom, the youngest leaf showing the early symptoms of Black Sigatoka, with at least 10 streaks of stage 1 of its evolution[27]
- The youngest leaf at stage 3 (YL3) mentioned by Meredith and Lawrence[28]
- The Youngest Leaf Spotted (YLS), which corresponds to the rank of the youngest leaf showing 10 necroses of stage 5 or 6 of Black Sigatoka[27,29]
- The Youngest Leaf Completely Spotted (YLCS), which enables to compare the severity of the disease by the loss of the functional activity of the leaf[30]
- The number of leaves affected (NLA), which corresponds to the number of leaves capable of doing photosynthetic activities, starting from the YLA to the YLCS

The Severity Index (SI), which is an estimation of the percentage of necrotic leaf area per plant was also calculated in the 4th, 6th and 8th month according to the method described by Gauhl[31]:

$$\text{Severity Index (SI)} = \frac{\sum \text{nb} \times 100}{(\text{N}-1)\text{T}}$$

where, n is the number of leaves of each level, b is the index (0 = no symptoms, 1 = less than 1% of leaf area affected (only streaks and/or 10 lesions maximum), 2 = 1-5% leaf area affected 3 = 6-15% of leaf area affected, 4 = 16-33% of leaf area affected, 5 = 34-50% of leaf area affected and 6 = 51-100% of leaf area affected), N is the number of index used in the scale (7) and T is the total number of leaves assessed.

This index was used by Krishnamoorthy *et al.*[32] as an expression of resistance/tolerance of varieties of banana trees and plantain trees to Black Sigatoka. These researchers propose the following scale:

- SI = 0: Varieties showing total resistance
- SI≤10%: Resistant varieties
- 10%<SI<30%: Tolerant varieties
- SI≥30%: Sensitive varieties

Phytopathological parameters assessed at flowering and harvesting: Phytopathological descriptors were used to assess the seedlings of each cultivar during both production cycles. At flowering and harvesting, the pathological descriptors of black leaf streak disease considered were: The NFL and the ratio between the numbers of leaves at flowering and harvesting (NFLH/NFLF)[17,33].

The leaves were counted from top to bottom for determining the number of functional leaves (NFL) erected. The last fully unrolled leaf (located just past the cigar or the bunch formed) is marked number 1. The leaf is considered functional when more than a third of its surface is green. Broken leaves due to senescence or cut at the petiole are not taken into account. The ratio (NFLH/NFLF) between the number of functional leaves at flowering (F) and the number of functional leaves at harvesting (H) was calculated. This ratio helped assess the performance of the sensitivity or tolerance of cultivars.

Statistical analysis of data: The collected data were submitted to analysis of variance (ANOVA), using the software Statistica 7.1. In case of significant difference, the multiple comparison test of Newman-Keuls, at 5% threshold was used to classify the averages in homogeneous groups.

RESULTS

Physicochemical characteristics of the soils of experimental sites: The physicochemical analysis of studied soils, before planting, is presented in Table 1. The results in Table 1 show the existence of a significant difference between the particle sizes of each soil at both experimental sites. However, it can note that there is no textural difference between the soils of these sites. Indeed, the soils of these experimental sites of Azaguié-Ahoua are significantly richer in sands (73.84 and 70.78%) and silt (21.26 and 24.46%) and are generally poor in clay (3.38 and 4.23%). However, the soil of site 1 is well endowed with very coarse sand (40.38%). Thus, the soil of Azaguié-Ahoua has sandy-silt texture overall, predominantly consisting of coarse sand. Table 1 also shows that the soils of the study area are acidic (5.5 pH ≤6) with values oscillating between 5.59 and 5.83. Organic carbon contents (CO) range from 1.97-3.33 g kg^{-1} and those of total nitrogen from 0.15-0.28 g kg^{-1}. This indicates that the total nitrogen content is very low (N<0.5 g kg^{-1}) in the study area of Azaguié-Ahoua. However, on site 2, the soil is relatively more endowed with nitrogen (0.28 g kg^{-1}) than that of site 1 (0.15 g kg^{-1}). Concerning the total organic material, its content ranges between 5.75 and 3.5 g kg^{-1} (MO<14 g kg^{-1}) but is relatively more significant in the soil of site 1 (5.75 g kg^{-1}) compared to that of site 2 (3.40 g kg^{-1}). All these soils are thus very poor in organic matter. As for the carbon/nitrogen ratio (C/N), it ranges between 7 and 23. The C/N ratio is below 15 for the soil of site 2 and superior to 20 for the soil of site 1. Accordingly, the decomposition rate of organic matter is fast in the soil of site 2 except that for mineralization of the organic matter, nitrogen requirements are not covered (C/N<15). These needs are not covered either for the soil of site 1 where the decomposition rate of organic matter is slow. The results also show that the total phosphate content (Pt) ranges between 0.48 and 0.60 cmol kg^{-1}. The soils of the experimental sites of Azaguié-Ahoua are poorly endowed with magnesium (0.15 and 0.19 cmol kg^{-1}). The low contents of nitrogen, phosphorus and potassium, essential minerals for proper growth of crops, reflect the poverty of the soils of experimental sites.

Agronomic characteristics of varieties

Growth and development parameters of banana tree plants

Number of emerged leaves: The results in Table 2 show that there is no statistical difference in the evolution of leaf emergence for the 5 varieties in the 4th month after planting during the first crop cycle. However, in the 8th month, statistically significant differences were observed between cultivars regarding the number of emerged leaves. These include the cultivars "Orishele", "Corne 1" and PITA 3 that gave the largest number of emerged leaves whose average ranges from 30.75-31.35 leaves, followed by cultivar FHIA 21 with an average of 29.80 leaves. The smallest number of emerged leaves was observed with the cultivar "Figue Sucrée" (29 leaves).

Average height of plants: The analysis of Table 2 shows that there is no statistical difference between cultivars in the 4th month after sucker planting regarding plant height in the first crop cycle. However, in the 8th month of cropping, statistical differences were observed between cultivars. The hybrid PITA 3 had the highest pseudostems (251.88 cm) and hybrid PITA 3 had the highest pseudostems (251.88 cm) and

Table 1: Physicochemical characteristics of the soils of experimental sites

		Samples (Horizon 0-20 cm)	
Types of analysis	Parameters	Site 1	Site 2
Physical analysis	Coarse sand (%)	40.38±0.21[a]	34.92±0.17[b]
	Fine sand (%)	33.46±0.22[b]	35.86±0.98[a]
	Coarse silt (%)	10.28±0.24[b]	11.18±0.10[a]
	Fine silt (%)	10.98±0.22[b]	13.28±0.12[a]
	Clay (%)	3.38±0.25[b]	4.23±0.13[a]
Physicochemical analysis	C (g kg^{-1})	3.33±0.17[a]	1.97±0.18[b]
	N (g kg^{-1})	0.15±0.02[b]	0.28±0.03[a]
	C/N	22.20±1.68[a]	7.04±0.85[b]
	MO (g kg^{-1})	5.75±0.21[a]	3.40±0.17[b]
	P (mg kg^{-1})	0.60±0.01[a]	0.48±0.07[b]
	pH water	5.83±0.06[a]	5.59±0.03[a]
Adsorption complex	Mg (cmol kg^{-1})	0.15±0.02[b]	0.19±0.05[a]
	K (cmol kg^{-1})	0.08±0.01[a]	0.04±0.02[b]
	Conductivity (mS cm^{-1})	0.14	0.02

Average values on the same line followed by the same lower-case letters are not significantly different according to the Newman-Keuls average comparison test at 5% probability

Table 2: Agronomic characteristics during the vegetative and phytopathological phases at flowering and harvesting in cultivars of banana trees and plantain trees in the first and second production cycles

		Pseudostem						No. of leaves		
		Height (cm)		Girth (cm)		Number of emerged		No. of functional leaves at flowering	No. of functional leaves at harvesting	Ratio
Crop cycles	Cultivars	4 months	8 months	4 months	8 months	4 months	8 months	(NFLF)	(NFLH)	NFLH/NFLF
First cycle	Figue Sucrée	70.69±6.05^{a}	198.41±12.85^{b}	22.81±2.05^{a}	53.33±2.34^{b}	11.45±0.72^{a}	29.00±0.46^{b}	13.65±0.25^{a}	6.30±0.30^{a}	0.46±0.02^{a}
	PITA 3	85.26±8.04^{a}	251.88±6.98^{a}	28.29±2.62^{a}	65.25±1.78^{a}	11.55±0.76^{a}	30.75±0.38^{a}	13.05±0.50^{a}	4.55±0.22^{b}	0.36±0.02^{b}
	FHIA 21	77.28±7.04^{a}	210.78±10.24^{ab}	27.70±2.96^{a}	63.64±2.77^{a}	13.15±0.62^{a}	29.80±0.48^{ab}	13.40±0.39^{a}	6.35±0.42^{a}	0.48±0.03^{a}
	Corne 1	73.00±6.13^{a}	237.23±12.63^{ab}	22.96±1.79^{a}	59.58±2.40^{ab}	12.45±0.55^{a}	31.35 ±0.68^{a}	10.85±0.18^{b}	2.30±0.22^{c}	0.21±0.02^{c}
	Orishele	77.35±7.47^{a}	233.48±12.37^{ab}	23.96±2.27^{a}	57.53±2.20^{ab}	12.45±0.59^{a}	31.25±0.41^{a}	9.15±0.25^{c}	1.00±0.13^{d}	0.11±0.01^{d}
	Overall average	76.71±3.10	226.35±5.29	25.14±1.07	59.86±1.10	12.21±0.29	30.43±0.23	12.02±0.23	4.10±0.25	0.32±0.02
	CV (%)	40.44	23.36	42.44	18.44	23.91	7.72	19.07	60.29	53.85
	p-value	0.6395	0.0082	0.2979	0.0033	0.3198	0.0037	<0.0001	<0.0001	<0.0001
Second cycle	Figue Sucrée	-	-	-	-	-	-	11.70±0.56^{a}	5.10±0.28^{a}	0.44±0.02^{a}
	PITA 3	-	-	-	-	-	-	8.50±0.50^{b}	3.80±0.20^{b}	0.45±0.02^{a}
	FHIA 21	-	-	-	-	-	-	8.40±0.31^{b}	4.10±0.23^{b}	0.49±0.03^{a}
	Corne 1	-	-	-	-	-	-	6.40±0.27^{c}	1.60±0.31^{c}	0.24±0.04^{b}
	Orishele	-	-	-	-	-	-	4.60±0.45^{d}	0.50±0.17^{d}	0.09±0.03^{c}
	Overall average	-	-	-	-	-	-	7.92±0.39	3.02±0.26	0.34±0.03
	CV (%)	-	-	-	-	-	-	34.49	61.85	52.26
	p-value	-	-	-	-	-	-	<0.0001	<0.0001	<0.0001

- : Data not available, NFLH/NFLF: Ratio of No. of functional leaves at harvesting over No. of functional leaves at flowering for a given crop cycle, the average values in the same column followed by identical lower-case letters are not significantly different according to the Newman-Keuls comparison test at 5% probability

cultivar "Figue sucrée" the lowest (198.41 cm). The plant height of the different cultivars ranged from 198.41-251.88 cm for an overall average of 226.35 cm. It should be noted that these differences in the 8th month were kept until flowering and harvesting when the pseudo stems of the plants of variety PITA 3 were the highest. The plants of cultivar "Figue Sucrée" showed the lowest pseudostems.

Girth of banana tree plants at 10 cm above ground: Like plant height in the 4th month of cropping, no statistical difference was observed for the girth. However, highly significant differences were observed in the eighth month of cropping. The PITA 3 and FHIA 21 were statistically equal and showed the largest girths whose averages were respectively 65.25 and 63.64 cm (Table 2). The cultivar "Figue Sucrée" showed the smallest girths with an average of 53.33 cm. The girth of the plants in the 8th month of cropping ranged from 53.33-65.25 cm and the average was 59.86 cm.

Yield and performance parameters

Production cycles of plants: The results in Table 3 show that the time interval between planting and flowering (IPF) in plants ranged from 257.30-301.05 days in the first cycle for an overall average of 284.55 days and from 517.90-580.10 days in the second cycle for an overall average of 540.16 days. The plants of hybrid PITA 3 started flowering earlier than the other varieties during both production cycles and those of cultivar "Orishele" started flowering later. Significant differences were observed for the IPF.

The time interval between flowering and cutting or harvesting of the first bunch (IFH) was longer in hybrid PITA 3 (93.95) and FHIA 21 (93.10 days) in the first production cycle although no significant difference was observed between the IFH of cultivars. This parameter ranged from 82.85 (Corne 1) to 93.95 days (PITA 3). The overall average was 88.06 days for fruit filling. In the second production cycle, no significant difference was also observed between the IFH of the different cultivars. However, the IFH ranged from 73.80 days (PITA 3) to 81 days (FHIA 21) in the second cycle and was generally shorter with an average of 77.86 days for fruit filling.

The duration of production cycle showed no significant difference in the first crop cycle between cultivars. As for the time interval between the planting and harvesting of the first bunch (IPH1), no significant difference was observed between cultivars. This IPH varied for all cultivars, from 351.25-389.25 days for an average of 372.61 days (Table 3). The time interval between banana trees sucker planting and bunch cutting was therefore identical between the plants of all cultivars involved. However, in the second production cycle a statistical difference was observed in the duration of the production cycle of cultivars. Indeed, the

Table 3: Agronomic characteristics of cultivars of banana trees and plantain trees in the first and second production cycles

		Time intervals (days)					Average number			Second hand of bunch		
Crop cycles	Cultivars	Planting-flowering	Flowering-harvesting	Planting-harvesting 1st bunch	Planting-harvesting 2nd bunch	Average bunch weight (kg)	Hands per bunch	Fruits per bunch	No. of fruits	Average fruit weight (g)	Average fruit length (cm)	Average fruit grade (cm)
First cycle	Figue Sucrée	283.9 5±7.84^{ab}	82.20±4.44^{a}	366.15±11.63^{a}	-	8.22±0.27^{c}	6.20±0.19^{a}	110.55±6.45^{a}	18.00±0.89^{a}	63.50±3.33^{d}	12.23±0.41^{c}	8.82±0.31^{d}
	PITA 3	257.30±11.24^{b}	93.95±1.90^{a}	351.25±11.48^{a}	-	11.56±0.57^{b}	5.35±0.15^{b}	57.70±2.41^{c}	12.10±0.33^{b}	159.00±6.02^{c}	22.87±0.28^{b}	12.91±0.17^{b}
	FHIA 21	283.00±11.50^{ab}	93.10±2.49^{a}	376.10±12.72^{a}	-	13.26±0.62^{a}	6.15±0.15^{a}	71.65±3.05^{b}	12.60±0.36^{b}	152.00±9.56^{c}	24.07±0.35^{b}	11.83±0.15^{c}
	Corne 1	297.45±11.37^{a}	82.85±3.08^{a}	380.30±12.88^{a}	-	7.54±0.44^{c}	5.35±0.38^{b}	23.05±2.37^{d}	6.40±0.67^{c}	264.25±16.04^{a}	28.54±0.55^{a}	13.74±0.23^{a}
	Orishele	301.05±10.18^{a}	88.20±4.81^{a}	389.25±14.02^{a}	-	7.18±0.50^{c}	6.05±0.37^{a}	33.45±3.52^{d}	7.15±0.65^{c}	221.25±10.88^{b}	28.25±0.67^{a}	13.10±0.30^{ab}
	Overall average	284.55±4.86	88.06±1.62	372.61±5.66	-	9.55±0.33	5.82±0.12	59.28±3.53	11.25±0.50	172.00±8.17	23.19±0.63	12.08±0.20
	CV (%)	17.08	18.42	15.20	-	34.10	21.20	59.63	44.62	47.51	27.17	16.94
	p-value	0.0364	0.0517	0.2620	-	<0.0001	0.0399	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Second cycle	Figue Sucrée	526.10±11.81^{b}	78.30±4.08^{a}	-	604.40±13.33^{b}	5.58±0.65^{bc}	6.20±0.33^{ab}	119.50±11.14^{a}	19.60±1.19^{a}	48.00±3.09^{d}	10.67±0.16^{c}	9.29±0.20^{c}
	PITA 3	520.30±14.65^{b}	73.80±2.93^{a}	-	594.10±15.18^{b}	6.64±0.79^{b}	6.20±0.49^{ab}	65.00±6.13^{c}	12.40±0.37^{b}	145.00±8.69^{c}	24.07±0.68^{b}	11.99±0.20^{b}
	FHIA 21	517.90±11.67^{b}	81.00±5.09^{a}	-	598.90±13.00^{b}	9.36±1.02^{a}	7.10±0.23^{a}	90.50±7.07^{b}	13.30±0.26^{b}	165.50±12.12^{bc}	23.81±0.74^{b}	12.20±0.18^{b}
	Corne 1	556.40±10.32^{ab}	75.40±4.33^{a}	-	631.80±12.57^{b}	5.38±0.34^{bc}	6.10±0.23^{ab}	32.80±2.09^{d}	6.20±0.29^{c}	221.00±11.40^{a}	28.46±0.60^{a}	13.82±0.18^{a}
	Orishele	580.10±8.27^{a}	80.80±4.26^{a}	-	669.90±8.13^{a}	3.52±0.19^{c}	5.30±0.26^{b}	30.10±1.97^{d}	6.70±0.37^{c}	187.00±11.74^{b}	26.70±1.22^{a}	12.65±0.26^{b}
	Overall average	540.16±6.04	77.86±1.97	-	619.82±6.76	6.09±0.40	6.18±0.16	67.58±5.69	11.64±0.75	153.30±9.37	22.74±0.95	11.99±0.23
	CV (%)	7.91	17.49	-	7.71	46.06	18.40	59.12	45.45	43.23	29.66	13.61
	p-value	0.0010	0.0778	-	0.0005	<0.0001	0.0085	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

For a given crop cycle, the average values in the same column followed by identical lower-case letters are not significantly different according to the Newman-Keuls comparison test at 5% probability

duration of crop cycle of cultivar "Orishele" was longer (669.90 days) in contrast to other cultivars whose duration was almost identical to each other. The time interval between the planting and harvesting of the second bunch (IPH2) ranged from 594.10-699.90 days for all cultivars. The overall average production cycle from sucker planting, to second bunch harvesting was 619.82 days (Table 3).

Characteristics of bunches and fruits at harvest: The comparison of plant yield parameters between the different cultivars was performed for both crop cycles. The yield components are influenced by the cultivar (Table 3).

In the first production cycle as well as the second one, the banana trees of hybrids FHIA 21 and PITA 3 yielded bunches with higher weight. Bunch weight ranged from 7.18 kg "Orishele" to 13.26 kg (FHIA 21) in the first cycle and 3.52 kg ("Orishele") to 9.36 kg (FHIA 21) in the second production cycle. If in the first production cycle, local cultivars ("Orishele", "Corne 1" and "Figue Sucrée") gave statistically identical weight, ranging between 7.18 and 8.22 kg in the second cycle some differences were observed between them. Cultivar "Orishele" yielded bunches having the lowest weight (3.52 kg).

The average number of hands per bunch was statistically different in both production cycles. The number of hands per bunch ranged from 5-6 in the first cycle and 5-7 in the second production cycle for all cultivars (Table 3).

Regarding the average number of fruits (fingers), per bunch, statistical differences were observed in both production cycles. This number statistically ranged from 33-111 fingers in the first cycle and from 30-120 fingers in the second cycle (Table 3). It is clear from this analysis that the local cultivar "Figue Sucrée" which is a dessert-type banana tree yielded more fruits and the local cultivar "Orishele" which is a plantain tree yielded less fruits in both cycles.

Also, for the average number of fruits of the second hand of the bunch (median fruit), statistical differences were observed. The cultivar "Figue Sucrée" yielded more fruits in the first and second production cycles (18 and 19, respectively). However, local cultivars "Orishele" and "Corne 1" had the lowest number of fruits (6 and 7 for "Orishele" and 6 for "Corne 1") during both production cycles (Table 3).

Statistically significant differences were observed between varieties, in the average weight of finger of the second hand of bunch (median fruit). This average weight varied depending on the cultivar (Table 3). It was higher in the local cultivar "Corne 1" (264.25 g in the first cycle and 221 g in the second cycle) and lower in the cultivar "Figue Sucrée" (63.50 and 48 g, respectively in the first and second cycle).

Apart from the dessert-type banana tree ("Figue Sucrée"), all other plantain tree cultivars (local and introduced) yielded fruits of more than 20 cm long (Table 3). However, local cultivars "Orishele" and "Corne 1" yielded the longest fruits (more than 26 cm long) compared to hybrids PITA 3 and FHIA 21 (length inferior or equal to 24 cm) over both production cycles. The highest grades (classes) of fruits were obtained with cultivar "Corne 1" and the lowest ones with "Figue Sucrée" in both production cycles. The grade ranged from 8.82-13.74 cm in the first cycle and 9.29-13.82 cm in the second cycle. Hybrids PITA 3 and FHIA 21 had grades ranging between 11 and 13 cm on both cycles. Statistical differences were observed for this parameter between cultivars.

The average potential yield per hectare varied from one cultivar to another and from one production cycle to another. This potential yield was higher in hybrids than in local cultivars whatever the crop cycle. Cultivar "Orishele" was the least productive (Fig. 1).

Phytopathological descriptors

Disease development during the vegetative phase: Concerning resistance to BLSD, apart from the YLA in the fourth crop month of both cycles; statistically significant differences were observed between cultivars regarding the variables NLA, YLS, YL3 and YLCS (Table 4). Hybrids FHIA 21 and PITA 3 showed low sensitivity to this disease, characterized by a slow or even very slow development of symptoms; with rows of YLA between 2 and 4; rows of Youngest Leaves Spotted (YLS) between 3 and 7. In addition, the rows of YL3 ranged between 3 and 6 while those of youngest leaves completely spotted (YLCS) ranged between 6 and 11 in the first and second production cycle.

Regarding cultivar "Orishele", it was very sensitive with rows of YLA ranging between 1 and 2 during both cycles, followed by cultivar "Corne 1". The number of spotted leaves showed highly significant differences depending on cultivars. This number ranged between 3 and 9 during the assessment periods of both cycles (Table 4).

Severity Index of black leaf streak disease (SI): The severity index measures at a given time the rate of leaf area destroyed by the disease on a banana tree. Figure 2 and 3 show the value of this index in both production cycles. The severity index was significantly different depending on cultivars. Local cultivars "Orishele", "Corne 1" and "Figue Sucrée" showed the highest index values compared to hybrids FHIA 21 and PITA 3 in both production cycles. In the 4th month of cropping, this index ranged from 10.87-22.29% and from 14.19-30% of leaf area

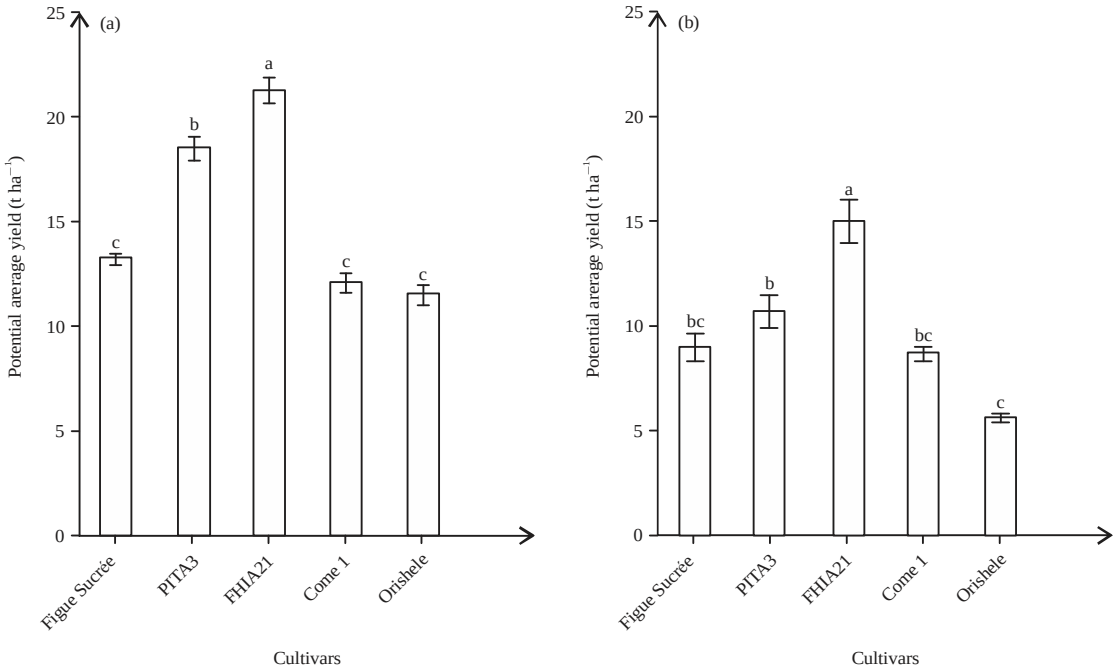

Fig. 1(a-b): Potential average yield of the different cultivars during both crop cycles, (a) First cycle and (b) Second cycle

Table 4: Pathological parameters of black leaf streak disease on the leaves of banana and plantain trees under natural infestation in the first and second production cycles

		Pathological parameters									
		NLA		YLA		YLS		YL3		YLCS	
		4	8	4	8	4	8	4	8	4	8
Crop cycles	Cultivars	(Months)									
First cycle	Figue Sucrée	6.50±0.41^{ab}	7.65±0.35^{a}	3.15±0.24^{a}	3.05±0.17^{a}	5.90±0.32^{a}	5.45±0.35^{b}	5.15±0.28^{a}	5.00±0.29^{ab}	9.20±0.47^{a}	10.70±0.40^{ab}
	PITA 3	6.30±0.50^{b}	7.40±0.47^{a}	2.55±0.29^{a}	2.85±0.18^{a}	6.05±0.59^{a}	6.80±0.50^{a}	4.90±0.46^{a}	5.80±0.28^{a}	8.70±0.67^{a}	10.25±0.42^{b}
	FHIA 21	8.25±0.61^{a}	8.75±0.66^{a}	2.65±0.25^{a}	3.05±0.17^{a}	7.25±0.72^{a}	7.50±0.51^{a}	5.00±0.53^{a}	5.70±0.28^{a}	10.95±0.83^{a}	11.80±0.65^{a}
	Corne 1	7.20±0.41^{ab}	5.05±0.17^{b}	2.45±0.17^{a}	2.70±0.12^{a}	5.85±0.45^{a}	4.80±0.19^{bc}	4.70±0.41^{a}	4.65±0.17^{b}	9.10±0.41^{a}	7.60±0.26^{b}
	Orishele	6.90±0.49^{ab}	4.90±0.25^{b}	2.40±0.24^{a}	2.10±0.12^{b}	5.45±0.37^{a}	4.15±0.15^{c}	4.60±0.22^{a}	3.95±0.18^{c}	9.00±0.62^{a}	7.15±0.20^{b}
	Overall average	7.03±0.22	6.75±0.24	2.64±0.11	2.75±0.08	6.10±0.23	5.74±0.21	4.87±0.18	5.02±0.13	9.39±0.28	9.50±0.26
	CV (%)	32.01	35.32	42.05	28.01	38.03	35.77	31.14	25.32	30.14	27.16
	p-value	0.0508	<0.0001	0.2052	0.0002	0.1395	<0.0001	0.8693	<0.0001	0.0900	<0.0001
Second cycle	Figue Sucrée	5.80±0.29^{ab}	4.50±0.50^{a}	1.70±0.15^{a}	4.20±0.20^{a}	3.70±0.30^{bc}	6.00±0.26^{a}	3.10±0.18^{ab}	5.80±0.36^{a}	7.50±0.37^{b}	8.70±0.54^{a}
	PITA 3	4.80±0.39^{b}	5.10±0.48^{a}	1.80±0.13^{a}	3.50±0.22^{a}	3.90±0.28^{b}	6.20±0.42^{a}	3.10±0.31^{ab}	5.50±0.37^{a}	6.60±0.40^{c}	8.60±0.52^{a}
	FHIA 21	6.40±0.31^{a}	4.20±0.33^{a}	1.60±0.22^{a}	4.00±0.33^{a}	4.90±0.31^{a}	6.20±0.29^{a}	3.50±0.28^{a}	5.60±0.34^{a}	8.00±0.47^{a}	8.20±0.25^{a}
	Corne 1	4.80±0.25^{b}	4.40±0.27^{a}	1.40±0.16^{a}	2.00±0.26^{b}	3.20±0.13^{bc}	4.40±0.43^{b}	2.60±0.16^{b}	3.40±0.27^{b}	6.20±0.25^{d}	6.40±0.37^{b}
	Orishele	3.70±0.21^{c}	3.90±0.18^{a}	1.30±0.15^{a}	1.60±0.16^{b}	2.80±0.25^{c}	3.30±0.33^{c}	2.40±0.22^{b}	2.20±0.13^{c}	5.00±0.21^{e}	5.50±0.17^{b}
	Overall average	5.10±0.18	4.42±0.17	1.56±0.08	3.06±0.18	3.70±0.15	5.22±0.23	2.94±0.12	4.50±0.24	6.66±0.21	7.48±0.25
	CV (%)	25.44	27.08	34.65	42.49	29.02	30.55	27.84	38.42	22.62	23.74
	p-valus	0.0001	0.241828	0.2080	<0.0001	<0.0001	<0.0001	0.0151	<0.0001	<0.0001	<0.0001

NB: NLA: Number of leaves affected, YLA: Youngest leaf affected, YLS: Youngest leaf spotted, YL3: Youngest leaf at stage 3, YLCS: Youngest leaf completely spotted, for a given crop cycle, the average values in the same column followed by identical lower-case letters are not significantly different according to the Newman-Keuls comparison test at 5% probability

spotted, respectively in the first and second production cycle. In the 6th month the leaf area spotted varied from 11.03-29.34% in the first cycle and 7.53-24.09% in the second production cycle. However, in the 8th month, this index ranged from 9.73-25.46% and from 8.45-24.76%, respectively in the first and second production cycle. Generally, the plants of cultivar "Orishele" presented the highest severity index during both production cycles with an average value of leaf area spotted oscillating between 22 and 30%. Nevertheless, cultivar FHIA 21 had the lowest severity indices on both production cycles.

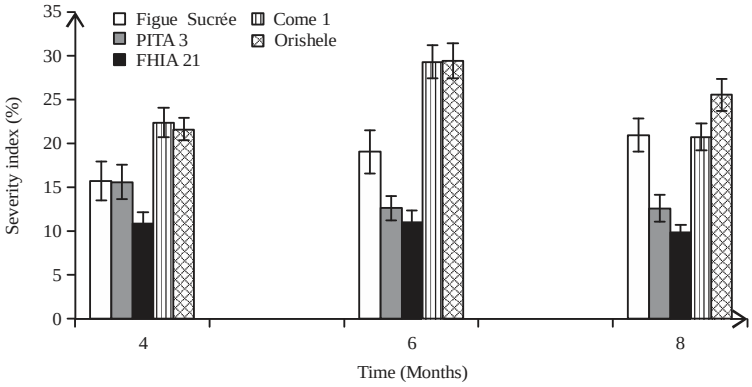

Fig. 2: Severity index of black leaf streak disease depending on the cultivar in the first production cycle

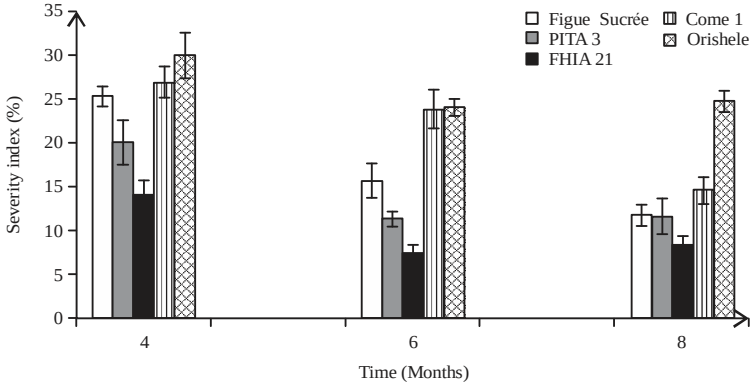

Fig. 3: Severity index of black leaf streak disease depending on the cultivar in the second production cycle

Number of functional leaves at flowering and harvesting: The performance at flowering and harvesting is presented in Table 2. The number of functional leaves at flowering and harvesting (NFLF and NFLH) shows significant differences depending on cultivars. At flowering as well as at harvesting during both production cycles, cultivar "Figue Sucrée" held the highest number functional leaves followed by cultivar FHIA 21 (Table 2). Cultivar "Orishele" held the least functional leaves. In the first production cycle, the number of functional leaves switched from 13.65 at flowering to 6.30 leaves at harvesting in cultivar "Figue Sucrée" and from 13.40-6.35 leaves in cultivar FHIA 21. As for cultivar "Orishele", it switched from 9.15-1 leaf. In the second crop cycle, the number of functional leaves switched from 11.70-5.10 leaves; from 8.40-4.10 leaves and from 4.60 to less than one leaf respectively in cultivars "Figue Sucrée", FHIA 21 and "Orishele". Also, for the H/F ratio that is to say, the rate of disappearance of the leaves due to Black Sigatoka, significant differences were observed between treatments (cultivars) regardless of the production cycle. In the first cycle as well as the second cycle, in all varieties ("Orishele", "Corne 1", "Figue Sucrée", FHIA 21 and PITA 3) less than half of the leaves at flowering (R/F <0.5) was present at harvesting (Table 2). However, the R/F ratio of banana trees of cultivar "Figue Sucrée" (0.46 and 0.44) and hybrids FHIA 21 (0.44 and 0.49) and PITA 3 (0.36 and 0.45) presented the highest values, respectively the first and second cycle. However, in cultivar "Orishele", the loss of leaves was faster (0.11 and 0.09) in both production cycles.

DISCUSSION

Soil characterization of experimental sites of Azaguié-Ahoua in southern Côte d'Ivoire showed the sandy-silt nature of the latter (textural triangle), mainly composed of coarse sand. This strong richness in coarse sand makes the soil permeable and light and this gives it a low structural stability, inducing a high sensitivity of this soil to physical (erosion) and chemical degradation. Chemically, the results of the pH show that the soil of experimental plots of Azaguié-Ahoua is acidic. According to Muche *et al.*[34] at low pH values it occurs in the soil, many negative phenomena in plant growth such as reducing nitrification, phosphorus deficiency,

aluminum and manganese toxicity. The soil acidity of Azaguié-Ahoua would thus be responsible for the low decomposition of organic matter. The soil analysis of experimental sites shows organic matter contents at 5.75 and 3.40%. Now according to Balbin and Zapata[35], in soils having appropriate organic content comparable to about 4%, the proliferation of the root system is stimulated, resulting in an increase in water absorption and nutrients. Therefore, we might get stronger plants having a higher number of functional leaves that will thus be less damaged by the disease.

The analysis of the vegetative characteristics and some characteristics of bunches depending on cultivars, showed significant differences from one cultivar to another.

The average number of functional leaves at flowering was superior to eight leaves in all varieties tested in the first production cycle, which enabled good fruit filling overall. However, in the second production cycle, that number was inferior to eight leaves in local cultivars "Orishele" and "Corne 1" and superior or equal to eight in hybrids PITA 3 and FHIA 21 and the local cultivar "Figue Sucrée". Lassoudiere [36] indicated that the vegetative growth of banana and plantain trees ceases at the emergence of the bunch and at this stage the plant must have a minimum of 8 functional leaves. The leaf area available in the plant at that moment is a decisive parameter for crop productivity[37].

The number of functional leaves over time is a function of leaf emission and abscission rates, which in turn determine the number of leaves that the plant can keep at flowering since it did not suffer from drought, disease or under nutrition[38].

The bunch was harvested when it reached physiological maturity. A lot of living leaves present on the plant from flowering to harvesting enables to have better fruit filling, heavier bunches and increased yield. At harvesting, the number of leaves was significantly different between cultivars. The local cultivar "Figue Sucrée" and hybrids FHIA 21 and PITA 3 showed on average more functional leaves at harvesting that local cultivars "Orishele" and "Corne 1" over both production cycles. However, none of these varieties reached maturity with half of the functional leaves counted at flowering. This could be due to the long duration of crop cycle. No fungicide treatment having been made in the conduct of trials, the partial resistance of plantain tree hybrids vis-a-vis black leaf streak disease was confirmed by the observation of a number of functional leaves at harvesting higher than those of local varieties.

The height of the pseudostem in banana and plantain trees is an important characteristic. All the studied varieties showed in general pseudostem heights inferior to 3 m during the vegetative phase of assessment before the first flowering. The plants which showed the lowest ports, had a significant advantage on sloping lands or in areas with strong winds. According to the study of Sadom *et al.*[39] and Smith *et al.*[40], the ideal height for a banana tree should be inferior to 3 m in order to reduce the risk of falls due to wind and to facilitate the management of the plantation. Indeed, easy staking and gradual harvesting of hands and fruits on parent plant are so many benefits relating to the stature of the plant[41].

The duration of production cycle showed no significant difference between cultivars in the first crop cycle. But in the second cycle, slightly significant differences were observed. During both cycles, hybrids FHIA 21 and PITA 3 flowered early compared to local cultivars but the time interval between flowering and harvesting was longer in the latter. These results are in accordance with those of Noupadja *et al.*[42] and Manzo-Sanchez *et al.*[43] and who worked on plantain tetraploid hybrids. According to these authors, early flowering of hybrids might not necessarily lead to an early harvesting to the extent that such time saving would be overridden by longer fruit filling time. Which would therefore partly explain the uniformity of harvest with local cultivars in the first production cycle under our experimental conditions. The duration of the production cycle is also influenced by cropping systems such as irrigation, plant material used, planting period and densities.

The synergy of the observed growth parameters has probably influenced positively the growth and development of bunches with better filled fruits, which helped gain bunch weight. Indeed, there is a positive correlation between these parameters and bunch weight[44]. A minimum of eight functional leaves at flowering is needed to achieve high yields. Plant height and bunch weight are positively correlated[45].

The trials carried out under natural infestation by *Mycosphaerella fijiensis* with varieties (local and hybrid) of banana and plantain trees showed varying degrees of severity of black leaf streak disease. Local cultivars "Orishele" and "Corne 1" and were characterized by the highest severity index values of the disease and hybrids FHIA 21 and PITA 3 and dessert "Figue Sucrée" had the lowest values. These high severity index values might express the sensitivity of banana cultivar *Mycosphaerella fijiensis*. The infection index best expresses the response of each genotype with respect to the disease. According to the study of Traore *et al.*[17] the sensitivity of a cultivar to Black Sigatoka is determined by the stomatal density at the proximal portion of the sheet. This would mean that each stoma might constitute a potential pathway to leaf tissues by infectious propagules of Black Sigatoka pathogen and a high number of stomata would accelerate the development of the disease by coalescence of the lesions.

CONCLUSION

The results of this study show the impact of BLSD on the yield of banana and plantain trees in Côte d'Ivoire, whose fruits are highly consumed in households. Considering these results, it can notice as many other researchers, the epidemic nature of Black Sigatoka under natural infestation in our cropping area. In this experiment, we could notice the varietal behavior of local and hybrid cultivars vis-a-vis this disease in the absence of any protective measures. At the end of this preliminary study, we can say that hybrids PITA 3 and FHIA 21 show a high tolerance to Black Sigatoka. Among the tested cultivars, the local cultivar, "Orishele" is the most vulnerable vis-a-vis Black Sigatoka followed by the local cultivar "Corne 1". The results obtained enable on the one hand to popularize hybrids PITA 3 and FHIA 21 on-farm. On the other hand, these results can help consider mixed cropping of tolerant hybrids with the local cultivar sensitive to Black Sigatoka so that they constitute a barrier to disease spreading and contribute to increased yield and food security.

ACKNOWLEDGMENTS

We sincerely thank the Interprofessional Fund for Agricultural Research and Consultancy (FIRCA) for the financing of this project thought WAAPP/PPAAO program and the honorable readers for their useful comments that helped improve this study. We also thank Mr Kangah Albert, banana and plantain producer in Azaguié for his advice and technical support during the trial.

REFERENCES

1. Mohiuddin, A.K.M., M.K. Saha, M.S. Hossian and A. Ferdoushi, 2014. Usefulness of Banana (*Musa paradisiaca*) wastes in manufacturing of bio-products: A review. Agriculturists, 12: 148-158.
2. Camara, B., 2011. Caracterisation des parasites fongiques foliaires et telluriques en Cote d'Ivoire chez les bananiers (*Musa* sp.) et recherche de methodes de lutte. Ph. D. Thesis, Universite Felix Houphouet-Boigny, Cote d'Ivoire.
3. Tripathi, L., A. Babirye, H. Roderick, J.N. Tripathi and C. Changa *et al*., 2015. Field resistance of transgenic plantain to nematodes has potential for future African food security. Sci. Rep., 5: 8127-8127.
4. Vawa, O.S.T, G.P. Gnonhouri, A. Adiko, N. Zakra and A. Otchoumou, 2015. [Annual replanting of plantain orchard: A strategy for the management of the endoparasitic nematodes, *Radopholus similis* and *Pratylenchus coffeae* in Cote d'Ivoire]. J. Applied Biosci., 92: 8659-8666.
5. FAO., 2015. FAOSTAT database. Food and Agriculture Organization of the United Nations, Geneva. http://faostat3.fao.org/home/index_fr.html?locale =fr# DOWNLOAD.
6. Kouame, N., A.E. Dick, N.E. Assidjo Nogbou and A.P. Anno, 2014. [Study of the growth plantain (*Musa* sp., AAB cultivar Horn 1) in the regions of Azaguie and Yamoussoukro (Cote d'Ivoire)]. J. Applied Biosci., 76: 6411-6424.
7. Nkuba, J., W. Tinzaara, G. Night, N. Niko and W. Jogo *et al*., 2015. Adverse impact of Banana *Xanthomonas Wilt* on farmer's livelihoods in Eastern and central Africa. Afr. J. Plant Sci., 9: 279-286.
8. Noorulla, H., M.K. Naik, G. Sunkad and Y.S. Amaresh, 2013. Prevalence of Sigatoka Disease of banana in major growing areas of Karnataka, India. Asian J. Sci. Technol., 4: 42-45.
9. Ngando, J.E., A. Rieux, O. Nguidjo, L. Pignolet and C. Dubois *et al*., 2015. A novel bioassay to monitor fungicide sensitivity in *Mycosphaerella fijiensis*. Pest Manage. Sci., 71: 441-451.
10. Kumakech, A., H.L. Jorgensen, R. Edema and P. Okori, 2015. Efficient screening procedure for Black Sigatoka disease of banana. Afr. Crop Sci. J., 23: 387-397.
11. Sahlan, S. and A. Soemargono, 2011. Distribution and incidence leaf diseases of banana in several banana production centers in north Sumatra, west Sumatra Bengkulu and west Java. Agrivita, 33: 174-181.
12. Peixouto, Y.S., C.A.D. Braganca, W.B. Andrade, C.F. Ferreira and F. Haddad *et al*., 2015. Estimation of genetic structure of a *Mycosphaerella musicola* population using inter-simple sequence repeat markers. Genet. Mol. Res., 14: 8046-8057.
13. Tuo, S., L.N.D.G.E. Amari, B. Camara, F.M. Kassi and S.L. Ouedraogo *et al*., 2015. Effet de l'association de differents cultivars de bananiers (*Musa* spp.) tolerants sur l'incidence de la cercosporiose noire chez le cultivar sensible Orishele en Cote d'Ivoire. Eur. Sci. J., 11: 70-94.
14. Ayala, A., M. Colina, J. Molina, J. Vargas and D. Rincon *et al*., 2014. Evaluacion de la actividad antifungica del quitosano contra el hongo *Mycosphaerella fijiensis* Morelet que produce la Sigatoka Negra que ataca el Platano. Revista Iberoamericana de Polimeros, 15: 312-338.
15. De Santana Neto, S.P., I.R. Silva and A.C. da Silva Pinto Bittencourt, 2016. Distribuicao DO lixo marinho e sua interacao com a dinamica de ondas e deriva litoranea no litoral Norte do estado da Bahia, Brasil. Sao Paulo UNESP Geociencias, 35: 231-246.
16. N'guetta, A., S. Traore, N.T. Yao, N. Aby and Y.D. Koffi *et al*., 2015. [Effect of planting density on growth and yield of plantain in Cote d'Ivoire: Case of two hybrids (PITA 3 and FHIA 21) and two local varieties (Corne 1 and Orishele)]. Agronomie Africaine, 27: 213-222.
17. Traore, S., K. Kobenan, K.E. Kendia, D. Kone and D. Traore, 2008. Relation entre densite stomatique et reaction a la maladie des raies noires chez differents genotypes de bananiers et de bananiers plantains. Agronomie Africaine, 20: 37-47.

18. Kone, W.A., 2009. Qualite des sols en zone de savane humide de Cote d'Ivoire: Utilisation des legumineuses herbacees comme alternative pour une valorisation des terres marginales et une agriculture durable. Ph.D. Thesis, Universite d'Abobo-Adjame, Cote d'Ivoire.
19. Van Quang, P., P.E. Jansson and V.T. Guong, 2012. Soil physical properties during different development stage of fruit orchards. J. Soil Sci. Environ. Manage., 3: 308-319.
20. Thiry, M., N. Carrillo, C. Franke and N. Martineau, 2013. Technique de preparation des mineraux argileux en vue de l'analyse par diffraction des Rayons X et introduction a l'interpretation des diagrammes. Rapport Technique No. RT131010MTHI, Centre de Geosciences, Ecole des Mines de Paris, Fontainebleau, France, pp: 34.
21. Van-Reeuwijk, L.P., 2002. Procedures for Soil Analysis. 6th Edn., ISRIC, USA., Pages: 120.
22. Hartemink, A.E., 2009. The depiction of soil profiles since the late 1700s. Catena, 79: 113-127.
23. Hassine, H.B., T. Aloui, T. Gallali, T. Bouzid, S. El Amri and R. Ben Hassen, 2008. Evaluation quantitative et role de la matiere organique dans les sols cultives en zones subhumides et semi-arides mediterraneennes de la Tunisie. Agrosolutions, 19: 4-17.
24. El Oumlouki, K., R. Moussadek, A. Zouahri, H. Dakak, M. Chati and M. El Amrani, 2014. [Study of physic-chemical quality of water and soil in the region Souss Massa (Case perimeter Issen), Morocco]. J. Mater. Environ. Sci., 5: 2365-2374.
25. N'guessan, K.A., N. Diarrassouba, B. Kone, K.A. Alui and A. Yao-Kouame, 2015. [Contribution of organic manure on the ground is necessary to allow the formation of a clay-humic complex that will provide structural stability]. J. Anim. Plant Sci., 24: 3814-3828.
26. Maghanga, K.J., L.J. Kituyi, K.F. Segor and O.P. Kisinyo, 2012. Comparison of soil phosphorous extraction by Olsen and double acid methods in acid soils of Western Kenya. East Afr. J. Pure Applied Sci., 2: 1-5.
27. Essis, B., K. Kobenan, S. Traore, J. Yatty, D. Kone, N. Aby and D.E.F. Thiemele, 2016. Pression d'inoculum de la maladie des raies noires (MRN) causee par *Mycosphaerella fijiensis* Morelet, dans les plantations industrielles de bananiers, en Cote d'ivoire. Eur. Sci. J., 12: 37-52.
28. Churchill, A.C.L., 2011. *Mycosphaerella fijiensis*, the black leaf streak pathogen of banana: Progress towards understanding pathogen biology and detection, disease development and the challenges of control. Mol. Plant Pathol., 12: 307-328.
29. Zandjanakou-Tachin, M., P.S. Ojiambo, I. Vroh Bi, A. Tenkouano, Y.M. Gumedzoe and R. Bandyopadhyay, 2013. Pathogenic variation of Mycosphaerella species infecting banana and plantain in Nigeria. Plant Pathol., 62: 298-308.
30. Traore, S., K. Kobenan, D. Kone, P. Gnonhouri, N.T. Yao and S. Ake, 2010. Distribution of *Mycosphaerella* spp. Diseases on Banana in Cote d'Ivoire. In: Contributions of Agricultural Sciences Towards Achieving the Millenium Development Goals, Mwangi, M. (Ed.). FaCT Publishing, Nairobi, Kenya, pp: 49-54.
31. Forero, S.E.A., N.V.P. Gambasica and J.C.M. Flores, 2012. [Relationship between soil and edaphoclimatic properties and the Black Sigatoka incidence (*Mycosphaerella fijiensis* Morelet) in the Banana Region of Magdalena-Colombia]. Revista de Investigacion Agraria y Ambiental, 3: 13-25.
32. Krishnamoorthy, V., N. Kumar, K. Angappan and K. Soorianathasundaram, 2004. Evaluation of new banana hybrids against black leaf streak disease. InfoMusa, 13: 25-27.
33. Amari, L.N.D.G.E., 2012. Strategies d'evaluation et de gestion par stimulation des defenses naturelles des bananiers a l'infection de la maladie des raies noires causee par *Mycosphaerella fijiensis* Morelet (Mycosphaerellaceae) en Cote d'Ivoire. Ph.D. Thesis, Laboratoire de Physiologie Vegetale, UFR Biosciences, Universite de Cocody-Abidjan.
34. Muche, M., A. Kokeb and E. Molla, 2015. Assessing the physicochemical properties of soil under different land use types. J. Environ. Analytical Toxicol., Vol. 5. 10.4172/2161-0525.1000309
35. Balbin, L.A.G. and J.C. Zapata, 2001. Lutte integree contre les cercosporioses noire et jaune chez la variete de bananier plantain cv. Africa. InfoMusa, 10: 3-7.
36. Lassoudiere, A., 2011. Le bananier, un enjeu mondial. Revue Pour la Science, 400: 78-85.
37. Hernandez, J.J., J.M. Maican and L. Serrano, 2008. [Development *Musa* AAB of Harton plantain in 3 growing densities under irrigation]. Produccion Agropecuaria, 1: 15-20.
38. Aristizabal, L.M. and C.G. Jaramillo, 2010. [Identification and description of the growth stages of Dominico Harton plantain (*Musa* AAB)]. Agron., 18: 29-40.
39. Sadom, L., K. Tomekpe, M. Folliot and F.X. Cote, 2010. [Comparison of the effectiveness of two vegetative propagation methods for banana trees from the study of the agronomic characteristics of a hybrid of plantain (*Musa* spp.)]. Fruits, 65: 3-9.
40. Smith, M.K., P.W. Langdon, K.G. Pegg and J.W. Daniells, 2014. Growth, yield and Fusarium wilt resistance of six FHIA tetraploid bananas (*Musa* spp.) grown in the Australian subtropics. Sci. Hortic., 170: 176-181.
41. Dzomeku, B.M., A.A. Ankomah, M.D. Quain, J.N.L. Lamptey, F.O. Anno-Nyako and A. Aubyn, 2007. Agronomic evaluation of some IITA Musa hybrids in Ghana. Afr. Crop Sci. Conf. Proc., 8: 559-562.

42. Noupadja, P., K. Tomekpe and E. Youmbi, 2007. [Evaluation of plantain tetraploid hybrids (*Musa* spp.) resistant to Black Sigatoka disease in Cameroon]. Fruits, 62: 77-88.
43. Manzo-Sanchez, G., M.T. Buenrostro-Nava, S. Guzman-Gonzalez, M. Orozco-Santos, M. Youssef and R.M.E.G. Medrano, 2015. Genetic Diversity in Bananas and Plantains (*Musa* spp.). In: Molecular Approaches to Genetic Diversity, Caliskan, M., G.C. Oz, I.H. Kavakli and B. Ozcan (Eds.)., In Tech, Rijeka, Croatia, ISBN: 978-953-51-2042-1, pp: 93-121.
44. Hernandez, R., T. Ramirez, J.C. Noa-Carrazana, R. Rodriguez-Fernandez and M.J. Canal *et al*., 2007. Generation of five new *Musa* hybrids with resistance to Black Sigatoka and high yield. Am. J. Agric. Biol. Sci., 2: 43-48.
45. Singh, W.R., S.S. Singh and K. Shrivastava, 2014. Analysis of banana genome groups of wild and cultivated cultivars of Manipur, India using sScore card method. Adv. Applied Sci. Res., 5: 35-38.