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Diversity of the Development Cycle Duration and Production Parameters in the Plantain Bananas Collection of Ivory Coast

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Abstract

The production of plantain bananas is threatened in Ivory Coast due to the irregularly of the rainfall and the water scarcity. Matching the sensitive steppes of the development cycle with the rainfall periods by shortening or lengthening the development cycle duration could be an appropriate strategy to increase the plantain yield. Therefore, better knowledge about the diversity of the fructification time and the parameters of production is required. Hence forty-two (42) cultivars of the plantain germplasm were studied. The development cycle duration was splited into two steppes: vegetative, from planting to blooming and fructification, from blooming to harvest. Some production parameters such as the bunch weight, the number of hands per bunch, the number of fruits per hand and per bunch and the fruits weight and diameter were scored. A great variability was recorded for all analyzed parameters. Three groups of the plantain cultivars consisting of early (269 days), intermediate (360 days) and late (390 days) cultivars were found. These groups corresponded respectively to the Cooking bananas cultivar of ABB type, the Horn type (False or True) and the French type. Three modal distribution was observed as well as for the development cycle as for the number of hands per bunch and the number of fruits per hand suggested major genes effect. The development cycle duration had an impact on the production parameters. The late cultivars produced bigger bunch than the early and intermediate groups. However, their fruits were small size contrarily to those of the early and intermediate groups. Since the relationship found was not strong enough, a real opportunity for improving the plantains bananas production by the variability existed. Within and between groups hybridation could allowed at once a combination between bigger bunch and bigger fruit in cultivars exhibiting short, middle or long development cycle duration which fits well with the rainfall period.

Keywords: Plantain cultivar; Germplasm; Development cycle; Production; Ivory Coast.

Introduction

The banana plays a significant role in food safety and the worldwide economy. It constitutes in tonnage the fourth important harvest in the world after rice, wheat and corn. The production of banana is an important source of incomes and employment with an estimate of 102.687 million tons including 40 million for plantain in 2003 [1-3].

One distinguishes two groups of banana tree: the cultivars of the type serves, with consumed fruits raw and the cultivars of the Cooking bananas type for which the fruits were consumed after cooking [4]. The banana serves a long time occupied the first place in the publications because of export towards the developed countries [5]. However, the plantain plays also a significant role at the nutritional and socio-economic level [4,6].

In Ivory Coast, the plantain is strongly consumed [7]. Its culture knows a real passion in all the production zones. However, the production is far from meeting the food needs for the population which is in perpetual growth. The productivity of the plants is low since the bunch weight was generally weak, varying from 5 to 8 kg. Elsewhere, the plants are threatened by many diseases (Fusariose, Cercosporioses, the disease of Moko or bacterial fading of banana tree etc.) and parasitic pressures due to the nematodes Odoiporus longicollis and the Cosmopolites sordidus. In addition, in these five last years, the seasonal changes have a strong influence on the production throughout the water scarcity and the rainfall irregularity and bad distribution.

The creation of new performing cultivars and/or the valorization of some existing cultivars is necessary for optimizing the production. These new cultivars should combine productivity, resistance to diseases and pathogen and good organoleptic quality. In addition, they should also have a development cycle adapted to the context of the climate change defined by the perturbation of the rainfall regime. Thus, the main question still the possible to produce cultivars exhibiting short, middle or long development cycle duration which fits well with the rainfall period. Therefore, the recourse to the genetic resources is necessary.

The National Center of Agronomic Research (CNRA) of Ivory Coast has an important collection of plantain. This study focused on this collection. The main objective is to analyze the diversity of the development cycle duration and the parameters of production. Specifically, the genotypes were firstly characterized upon the bunch and the fruits (banana) and secondly the diversity structure of the collection was analyzed.

Materials and Methods

Materials

The plant material consisted of 42 cultivars of plantains bananas, including 28 cultivars collected from Ivory Coast, 7 from Congo, 3 from Cameroon, 2 from Nigeria, and 1 respectively from Ghana and Vietnam. These cultivars were ranged into five plantains cultivars groups designed French, True Horn, False Horn, Cooking bananas and Bastard. The Table 1 summarized the information's about the name of the cultivars, their country of origin and plantain groups. The evaluations concerned eight plants per cultivar resulting in a total of 336 plants. All these plants were obtained from rejections on the mother's feet in collection and planted in experimental field in 2015.

S.No.	Name of the Cultivars	Origin	Plantain groups
1	Corne 1	Ivory Coast	False Horn
2	Orishélé	Nigeria	False Horn
3	Red Ebanga	Congo	False Horn
4	M'Bomo	Congo	True Horn
5	3 Vert	Congo	Bastard
6	Corne 5	Ivory Coast	False Horn
7	French 2	Ivory Coast	French
8	18 Rouge french	Congo	False Horn
9	Laknao	Cameroon	Cooking bananas
10	Zakoi	Ivory Coast	Cooking bananas
11	Glowa	Ivory Coast	French
12	French sombre	Cameroon	French
13	N'zelouka	Congo	French
14	Corne bout rond	Ivory Coast	False Horn
15	N'gletia	Ivory Coast	French
16	Assouba	Ivory Coast	True Horn
17	Corne tâcheté	Ivory Coast	False Horn
18	Iba	Nigeria	True Horn
19	Lorougnon	Ivory Coast	False Horn
20	Bindi-Mossendjo	Congo	French
21	Aboisso	Ivory Coast	True Horn
22	Ghana	Ghana	Cooking bananas
23	Big Ebanga	Cameroon	False Horn
24	Agninin 1	Ivory Coast	French
25	Kaptrègnon	Ivory Coast	True Horn
26	Afoto 2	Ivory Coast	False Horn
27	Ninglinnin	Ivory Coast	French
28	Foua	Ivory Coast	French
29	M'bindi	Congo	French
30	Banaboi 1	Ivory Coast	False Horn
31	Agninin 2	Ivory Coast	French
32	Eniaba	Ivory Coast	False Horn
33	Banadiè 2	Ivory Coast	False Horn
34	Banablé	Ivory Coast	False Horn
35	Ehô	Ivory Coast	False Horn
36	Corne 4	Ivory Coast	False Horn
37	French clair	Ivory Coast	French
38	Oleakotoi 1	Ivory Coast	True Horn
39	Saci 1	Ivory Coast	Bastard
40	Kokoida	Ivory Coast	False Horn
41	N'doria	Ivory Coast	True Horn
42	Monthan	Vietnam	Cooking bananas

Table 1: Name, origin and plantain group of the studied cultivars.

Methods

Experimental design and crops management: The experimental design was a randomized complete block. The classical density of 1667 plants/ha was applied: 2 m between the seedlings and 3 m between the lines. The fertilization consisted at once of 250 g of dolomite and 150 g of phosphorus before planting. Thereafter, urea and potassium were brought in the proportions going from 25/50 at 3rd month to 50/100 at the 9th month. The weeding was removed either manually or using chemical herbicide containing glyphosate of brand "KALASH". At blooming a staking was carried out using bamboos to support the bunch preventing hence the banana tree from falling.

Evaluation of the duration of development cycle duration (DCD) of the banana trees: Three traditional steppes characterized the development cycle of the banana tree: vegetative, blooming and fructification. However, in the framework of this study, two steppes were considered: vegetative, from planting-to-blooming (DPB) and fructification, going from blooming-to-harvest (DBH). The sum DPB and DBH corresponds to the duration of the development cycle (DCD). Two synthetics variables, CDPB and CDBH were calculated to consider the relative importance or contribution of each steppes (DPB and DBH) in the development cycle as followed: CDPB = DPB/DCD and CDBH = DBH/DCD.

Evaluation of the parameters of production: Seven production parameters were evaluated. They concerned the bunch weight, the number of hands per bunch, the number of fruits per hand, the length, diameter and weight of the fruits and the thickness of the fruit skin. In addition, a synthetic variable corresponding to the load factor (fruits filling) of the fruits (FF) expressed in g/day was computed as followed: FF = fruit weight/DBH. It corresponds to the relationship between the fruit weight and the duration from blooming-to-harvest.

Data analysis: The plantain cultivars had compared each other for each parameter using the analysis of variance at a 5% significance level. Moreover, the relationships between the duration of the development

cycle and the parameters of production were studied through regression analysis. Finally, the structure of the diversity in the plantain collection was analyzed by mean of a principal component analysis. All computations were carried out on the Statistica software, version 7.1. (2005).

Results

Duration of the development cycle of the banana trees

The development cycle of the plantain's bananas required on average 269.12 ± 5.37 to 395.75 ± 3.37 days according to the cultivars. The distribution of this parameter revealed three groups (Figure 1): GI including one cultivar, the GII, 24 cultivars and the GIII, 17 cultivars. For the first group, the duration of the cycle was an average around 269 days, the second around 360 days and the third 390 days. The cultivar Zakoi (GI) appeared earliest contrary to the one of Agninin 2 (GIII) which was the latest. The cultivar Lorougnon with an average of 360.87 ± 3.35 days, presented an intermediate development cycle. The differences observed between the cultivars were highly significant ($p<0.000$).

We found that the DBP steppe (Planting - blooming) demanded 206 to 306 days versus 63 to 92 days for DBH. It was remarkable to observe that whatever the cultivars, the DPB was the longest steppe. It required on average 76.26% (variation: 74.72% to 78.05%) of the development cycle duration. Thus, this steppe lasted on average three times more than the blooming - harvest steppe and strongly determined the total duration of the development cycle of the banana trees. A significant positive correlation was calculated between these two steppes: r=0.568; p=0.000. Hence longer DPB seemed to be associated with longer DBH.

The three groups (GI, GII and GIII) identified above for the development cycle duration were also found as well as for DPB as for DBH steppe.

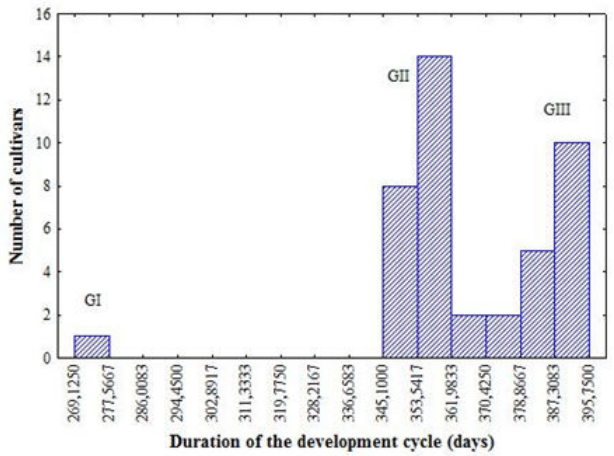

Figure 1: Distribution of the development cycle duration in the plantain collection of the National Center for Agronomic Research.

Characteristics of the bunches

The results showed that for all cultivars only one bunch was produced per plant. The bunch weight ranged between 8.62 ± 1.06 kg and 24.5 ± 1.06 kg according to the cultivar. The distribution of the trait was continuous (Figure 2). The smallest bunches were found for the cultivar Ehô while the biggest one was recorded for the cultivar Monthan.

The number of hands per bunch varied also considerably between the cultivars from one to 15. The distribution revealed three groups: cultivars exhibiting one or two hands per bunch, the one carrying 3 to 11 hands per bunch and those bearing more than 13 hands per bunch (Figure 3). The cultivars Assouba, Iba and N'doria an average had one or two hands per bunch whereas the cultivar Monthan carried 15 hands per bunch.

For each hand on average of 3.5 ± 0.2 to 18.8 ± 1.5 fruits were counted. The distribution of the trait revealed also three types of cultivars (Figure 4). One distinguished the cultivars bearing low number of fruits per hand (3 to 6 fruits), the one with intermediate number, 7 to 13 fruits per hand and those with many fruits per hand, more than 16 fruits. The largest numbers of fruits per hand were found for the cultivars Assouba (18.87) and Iba (16.37) which had one or two hands per bunch. Ultimately within the collection we counted on average 7.37 ± 0.52 to 192.12 ± 2.80 fruits per bunch. The cultivar N'doria scored an average the smallest number of fruits per bunch (7.37) contrary to the cultivar Monthan (192.12).

The study of the relations between the characteristics of the bunch showed that the weight of the bunch was significantly correlated with the number of hands per bunch (r=0.806; p=0.000) and at lesser extent with the number of fruits per hand (r=0.355; p=0.023). By contrast any significant correlation was found between the number of hands per bunch and the number of fruits per hand (r=-0.063; p=0.689).

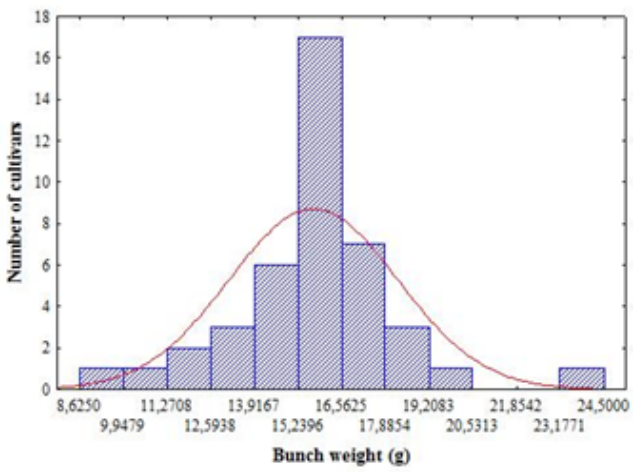

Figure 2: Distribution of the bunch weight in the plantain collection of the National Center for Agronomic Research.

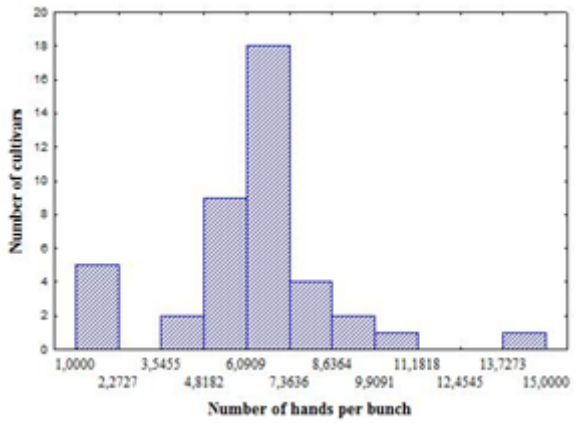

Figure 3: Distribution of the number of hands per bunch in the plantain collection of the National Center for Agronomic Research.

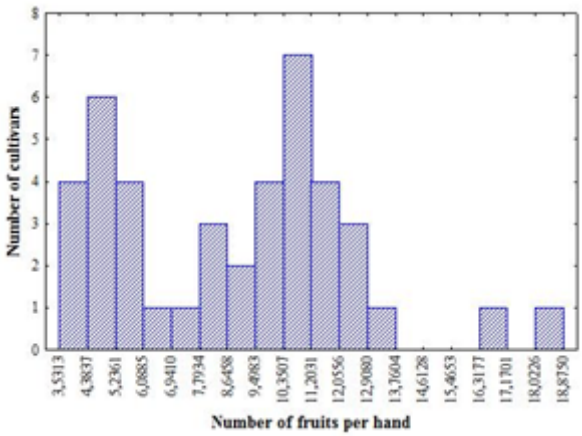

Figure 4: Distribution of the number of fruits per hand in the plantain collection of the Centre National Center for Agronomic Research.

Characteristics of the fruits

The fruits characteristics also differed strongly between the cultivars. The recorded average length varied from 14.62 ± 0.74 cm to 50.75 ± 1.48 cm, the diameter oscillated between 3.63 ± 2.6 cm and 5.66 ± 1.4 cm and the weight ranged between 122.25 ± 11.71 g and 652.25 ± 31.12 g. The cultivar Ngletia presented the smallest fruits while the cultivar Ndoria produced the biggest fruits.

The load factor of the fruit filling ranged significantly between the cultivars from 1.45 ± 0.12 g/day for the cultivar Monthan to 7.57 ± 0.44 g/day for N'doria. This load factor did not depend on the length of DBH. Indeed, the DBH of the cultivar Zakoi was 63 days and the one of the cultivars M'bindi, 92 days, nevertheless the load factor of their fruits did not differ significantly: 3.31 g/day versus 2.26 g/day respectively. In addition, for similar DBH 84 and 86 days the cultivar Monthan showed the lowest load factor (1.45 g/jour) while the cultivar N'doria presented the highest load factor (7.57 g/day). The False and True Horn showed the highest load factor of fruits filling 4.60 ± 0.62 g/day and 5.40 ± 2.06 g/day respectively against 2 to 2.4 g/day for the other plantain's groups.

Another important characteristic is the thickness of the skin of the fruit. This trait distinguished appreciably the cultivars. It measured from 1.12 ± 0.35 mm for the cultivar Assouba to 6.25 ± 0.46 mm for the cultivar Ndoria. This thickness of the skin was positively correlated with the size of the fruit: r=0.41; p=0.006.

The relationships between the fruit's parameters indicated that the fruit weight was negatively correlated with that of the bunch (r=-0.7595; p=0.000) and with the number of the fruits per bunch (r=-0.861; p=0.000). In fact, the weight of the fruit fitted a logarithmic curve (Figure 5) with the number of fruits of the bunch: Weight fruit=1052.4366-439.4476*log10 (X). Thus, the large number of fruits on the bunch resulted in small fruits.

When considering the characteristics of the bunches and the fruits, the three groups, GI, GII and GIII of the development cycle duration strongly differed by the number of fruits per hand, the diameter, the weight and the load factor of the fruits (Table 2). The group II, including the cultivars with an intermediate duration development cycle (350.62 to 368.87 days) was opposed to the two other groups. Indeed, in group II, the cultivars bore few fruits per hand, 7.63 against 11.44 and 10.35 for GI and GIII respectively. Their fruits presented high load factor and were large (Table 2). The other characteristics of the bunch and the fruits did not distinguish statistically the three groups.

Parameters of production	Development cycle duration		
	GI	GII	GIII
Development cycle duration (days)	269.12 ± 0.00^{a*}	356.41 ± 4.76^{b}	386.91 ± 6.45^{c}
Fruits number per hand	11.44 ± 0.00^{a}	7.63 ± 4.12^{b}	10.35 ± 1.89^{a}
Diameter of the fruit (mm)	39.87 ± 0.00^{a}	49.23 ± 4.58^{b}	42.40 ± 4.70^{ab}
Fruit weight (g)	208.37 ± 0.00^{a}	382.85 ± 137.00^{b}	242.00 ± 82.48^{c}
Fruits load factor (fruits filling)	3.31 ± 0.00^{ab}	4.42 ± 1.56^{b}	2.73 ± 1.01^{a}
Fruits number per bunch	68.62 ± 0.00^{a}	46.05 ± 40.19^{b}	69.72 ± 19.96^{a}
Hands number per bunch	6.00 ± 0.00^{a}	6.29 ± 3.12^{a}	6.65 ± 1.37^{a}
Bunch weight (kg)	14.87 ± 0.00^{a}	15.00 ± 2.86^{a}	16.70 ± 1.74^{a}
Fruit lenght (cm)	19.87 ± 0.00^{a}	26.49 ± 7.02^{a}	22.69 ± 4.16^{a}
Skin thickness (mm)	3.50 ± 0.00^{a}	3.71 ± 1.10^{a}	3.52 ± 0.80^{a}

Table 2: The parameters of production of the three groups GI, GII and GIII identified for the development cycle duration in the plantain collection of the National Center for Agronomic Research.

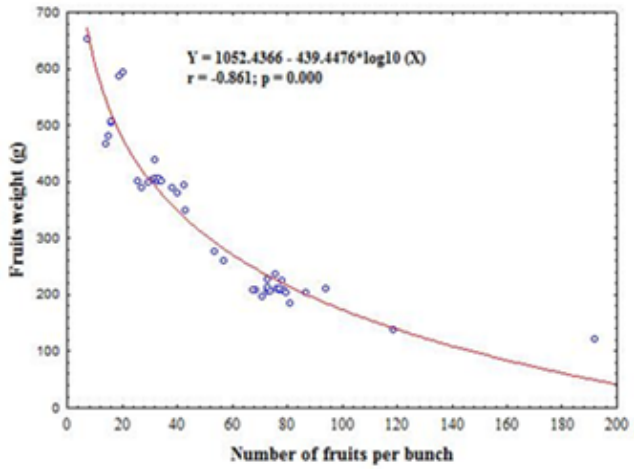

Figure 5: Relation between the number of fruits per bunch and the fruits weight in the plantain collection of the National Center for Agronomic Research.

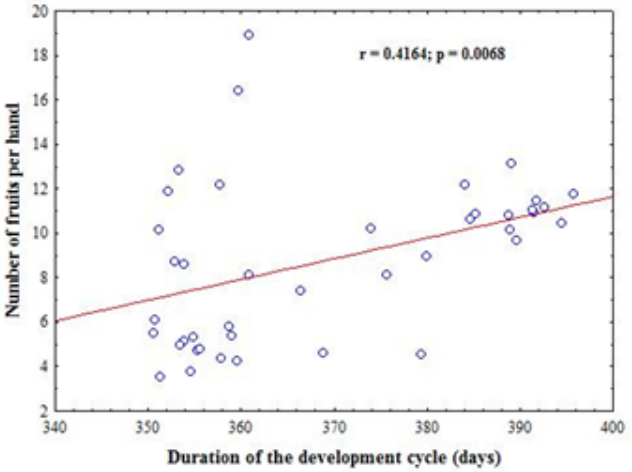

Figure 6: Relation between the development cycle duration and the number of fruits per hand in the plantain collection of the National Center for Agronomic Research.

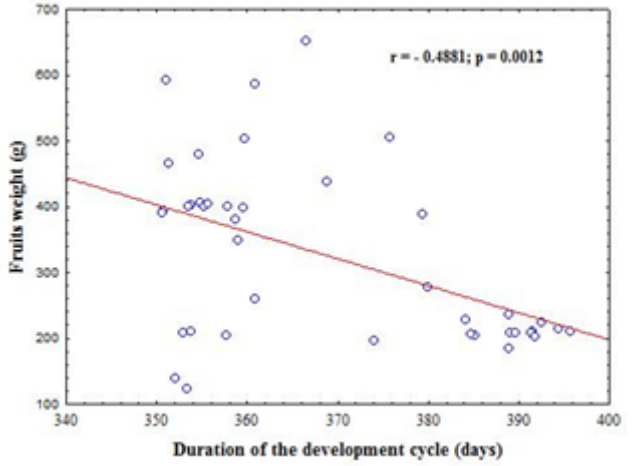

Figure 7: Relation between the development cycle duration and the fruits weight in the plantain collection of the National Center for Agronomic Research.

Relation between the duration of the development cycle and the characteristics of the bunches and the fruits

The analysis was conducted without the cultivar Zakoi which was the only one early cultivar. It arised from the results that the number of fruits per bunch, fruits per hand and the weight of the bunchs showed a significant positive correlation with the duration of the development cycle. That resulted in an increase in the values of these parameters with the lengthening of the duration of development cycle (Figure 6). By contrast, the weight of the fruit, was negatively correlated with the duration of the development cycle (Figure 7). Ultimately, these relations indicated that the plants presenting a long development cycle duration produced big bunches which carried much hands, high number of fruits per hand and many fruits on the whole bunch. However, these fruits were small (low length, diameter and weight). The data revealed that the variations of the duration of the development cycle, explained 10 to 24% of the variations of the characteristics of the bunches and the fruits.

The DBH steppe did not showed any significant correlation with the production's parameters. While the DPB steppe had the same trend as the whole development cycle.

Concerning the height of the plants and the production of rejections per plant, any significant correlation was recorded with the duration of the development cycle.

Variability of the plantain cultivars in the collection

The principal component analysis performed indicated that two factors explained approximately 60% of total variability within the plantain collection. The factor 1 with 42.12% of inertia, expressed the production of the cultivars through the size of the bunch and fruit (Figure 8). The factor 2, 17.80% of inertia, corresponded to the duration of the development cycle. The projection of the 42 cultivars on the axis 1-2, showed a good regrouping of the cultivars following the plantains groups: False Horn, True Horn, Bastard, French and Cooking bananas (Figure 8). When projecting the name of the cultivars on the graphic we observed that the True Horn cultivars such as N'doria, M'bomo, Iba Ehô and Assoba produced small bunches and big fruits in contrast to the cultivar Monthan (Figure 9). We could see

that two True Horn cultivars Aboisso and Oleakotoi line up rather towards French, False Horn and Cooking bananas. In the same way, the cultivar Saci and 3 Vert, recognized Bastard group merged in French group.

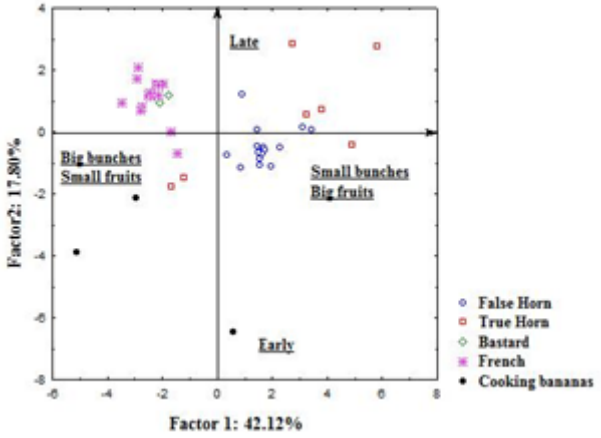

Figure 8: Representation of the plantain cultivars groups according to the two factors of the principal component analysis. The five plantain groups (False Horn, True Horn, Bastard, French and Cooking bananas) were clearly distinguished.

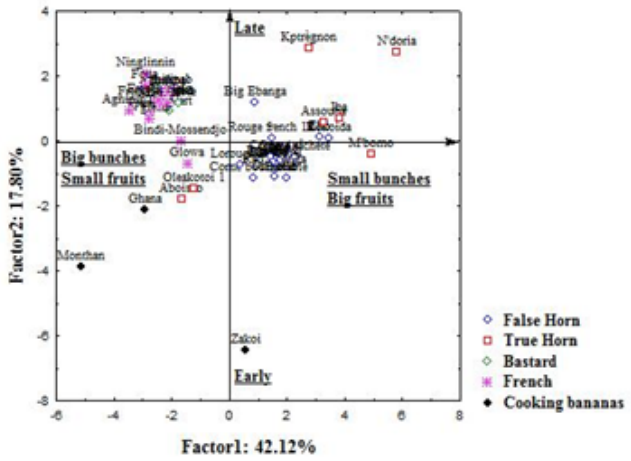

Figure 9: Projection of the name of the cultivars on the factors 1-2 of the principal component analysis. * The numbers bearing the same letter on the line were not different at 5% significance level.

Discussion

The impact of the seasonal changes on the production of the plantains in Ivory Coast is further accentuated in this past five years. That requires to better know about the duration of the development cycle of the banana trees to make coincide the significant periods of development cycle with the periods of rains. In addition, the relations between the duration of the development cycle and the parameters of production deserve to be known also to better direct the programs of improvement aiming to a shortening or a lengthening of the cycle. For all these concerns, a study was conducted in the plantain collection of the Centre National de Recherche Agronomique of Ivory Coast.

The evaluation of the duration of the development cycle revealed the existence of three groups of cultivars: Early, intermediate and late. The early group included one cultivar named Zakoi for which the development cycle required 269 days against 360 and 390 days for the intermediate and late cultivars respectively. The intermediate cultivars corresponded to the False and True Horn type while the late one included the French, Bastard and Cooking bananas (ABB type) except the cultivar Zakoi. In addition it is reported that the Cooking bananas exhibited long development cycle, 11 to 18 months. Therefore, the cultivar Zakoi appeared an exception [8-11].

The three-modal distribution of the development cycle duration could be due to the presence of major genes. These genes should be responsible for the plantain's groups Horn and French since the three groups (early, intermediate and late) overlapped these plantains groups. However, some other genes should be involved regarding the within variability of each plantain's groups.

The characteristics of the bunches revealed that in the collection all the cultivars produced one bunch per plant. These bunches weighted between 8 to 24 kg per bunch and developed 7 to 192 fruits. The fruits length measured from 14 to 51 cm. Nevertheless, it is reported that bunch weight could reached 70 kg in some French cultivars. Such plantains were not present in our collection. Like as all cultivars of the collection in Ivory Coast produced only one bunch per plant while in Togo [11] reported that the plants of the cultivar Taévé (Cooking bananas) developed each two bunches. This cultivar could be introduced in Ivory Coast to enrich the collection [11-17].

On other hand the bunches were composed by one to 15 hands bearing each 3 to 19 fruits. The total number of fruits per bunch varied from 7 to 192 according to the cultivars. The fruits length measured from 14 to 51 cm. In some hybrids the number of fruits per bunch varied from 268 to 296 significantly larger than that we recorded in the collection [11,13,15,18,19].

Fine analysis revealed three groups of cultivars as well as for the number of hands per bunch s for the number of fruits per hand. Regarding the grouping about the number of hands per bunch, it consisted of 1 to 2 hands, 3 to 11 hands and more than 13 hands. For the number of fruits per hand the regrouping was 3 to 6 fruits, 7 to 11 fruits and more than 13 fruits per hand. All these groups partially overlapped those of the development cycle. Such distribution as recorded for the development cycle duration could suggest the involving of major genes effect. More analysis should be engaged for a better understanding of the genetic control of these traits. What could help genetic improvement program as it has been done for FHIA plantain hybrids.

The studies on the relationships revealed that significant correlation occurred between the parameters of production and the development cycle duration. The number of fruits per bunch, of fruits per hand and the bunch weight increased with the lengthening of the development cycle duration. Whereas concomitantly the fruits weight decreased. On other terms the late cultivars seemed to produce bigger bunches with large number of hands. However, the fruits were small size in opposition to the early and intermediate cultivars. This data was the first published in our knowledge in plantains collection in Ivory Coast. This result was much surprising since in some literatures [12] it has been reported that the late cultivars produced big bunches and big

fruits. This trend was also the same in Coffea species for which the beans and seeds size were positively correlated with the fructification duration [20]. Finally, it was interesting to know that the correlations obtained in this study between the development cycle duration and the production parameters were weak to moderate. Hence combining short, middle or long development cycle duration with big bunch comprising large number of hands which bore many big fruits should be possible. Such researches should be encouraging since it has been reported that the fruit units which weighted 270 g or more are considered marketable [21]. Within or inter plantains groups hybridations could be undertaken as it has been done for the FHIA hybrids. Therefore, mechanisms presented for producing hybrids in bananas trees could be applied. The structure of the diversity observed in this study could be helpful. The good regrouping of the cultivars suggested that few genes could be involved in the plantain's differentiation. The case of the True Horn cultivars Aboisso and Oleakotoi which merged with the French and the Cooking cultivars and that of the cultivars 3 Vert and Saci (Bastard type) which line up with the French remained surprising. Molecular analysis could highlight the plantain diversity [22].

Our data inferred that among the two steppes DPB and DBH, the first mainly determinate the development cycle duration: longer DPB seemed to be associated with longer DBH. However only DPB influenced significantly the parameters of production. Therefore, since water availability affected significantly the DPB steppe contrarily to the DBH as it was well documented as rainfall occurring during this steppe should be crucial for the plants yield [21]. Thus, selecting cultivars which DPB matched well with the rainfall period should be a best goal of genetic improvement. As the DPB steppe was long (206 to 306 days) it should be interesting to identify the right period to bring water and the best water requirement. Such a study should be applied also to the DBH steppe. The knowledge from these studies should allowed recommendations about the planting period to benefit to the water availability. Finally, programs should be engaged now for the selection of drought resistance cultivars.

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