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Banana diversity in the Oriental provinces, north-eastern Democratic Republic of Congo

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Abstract

Studies on banana diversity and distribution have been carried out in the Democratic Republic of Congo (DR Congo) since the 1950s. However, there are still insufficient data on the distribution of diversity in large areas of the Congo basin. The present study was conducted in the surrounding region of Kisangani (Lubuya Bera sector) and in 24 territories of the Oriental province. Three villages were randomly selected in the Lubuya Bera sector and in each territory, totalling 75 villages. In each village, a group discussion was conducted to assess farmers' knowledge of banana diversity. Ten farmers per village (750 in total), each having at least 20 banana mats, were randomly selected for a diagnostic survey focusing on banana germplasm diversity, criteria that influence the selection of planting material and cultivar preference. Morphological descriptors were recorded and photos taken of each cultivar. In total, 92 cultivars were characterized consisting of 70 Plantains (AAB genome), 11 dessert bananas (AAA, AAB, and AABB genome), 10 cooking bananas (AAA-EA and ABB genome) and 1 ABB cultivar ('Kayinja') used for brewing. Fruit pulp quality, availability of planting material, marketing potential and bunch size were the main criteria used by farmers for selection. The five most appreciated Plantains were 'Libanga Likale', 'Litete', 'Amakake', 'Yumba' and 'Chwachwa', while 'Gros Michel', 'Kamaramasenge', 'Grande Naine', 'Petite Naine' and 'Yangambi Km 5' were the most appreciated dessert bananas. Future efforts should also be focused on agronomic, post-harvest and molecular aspects for enhanced knowledge, use and conservation of banana diversity across DR Congo.

Keywords: Congo basin, morphological diversity, *Musa* characterization, selection criteria.

INTRODUCTION

Banana, and especially Plantain, with a production of 1.5 million t/year, is the second most important staple food crop after cassava in the Democratic Republic of Congo (DR Congo) (Pemsl and Staver, 2014). In addition, the Congo basin is a centre of diversity for Plantains (De Langhe, 1969). However, banana production in DR Congo faces numerous biotic and abiotic constraints, such as soil depletion, lodging by wind, diseases and pests, and socio-economic constraints (Dhed'a et al., 2011). Such constraints call for the identification of the best on-farm performing cultivars. Thus, the objective of this study was to assess the morphological diversity of bananas across all districts and territories of the Oriental province, DR Congo. Knowledge of banana genetic diversity and their geographical spread will provide valuable information not only to breeders and taxonomists (Swennen and Vuylsteke, 1987) but also to agronomists. Indeed, agroecology begins by the identification of the most sustainable cultivars (i.e. needing less nutrients, being less pest and disease

sensitive) in the agro-ecological zones where farmers cultivate bananas. In addition, breeding programs should take into account farmer objectives and selection criteria which affect cultivar acceptance and distribution. Knowledge of the current cultivar diversity and farmers' selection criteria is therefore urgently needed to formulate strategies for the conservation of threatened cultivars with promising yield, marketing or breeding qualities. An additional objective was the establishment of a collection of all the banana cultivars collected across different agro-ecological zones of the Oriental province for their better morphological characterization. With the disappearance of the *Musa* collections established in the 1950s at the Institut National des Etudes Agronomique au Congo (INEAC) Yangambi, Bambesa Lubarika and Mulungu stations (De Langhe, 1961a), the need for new collections in DR Congo became necessary. Thus, from January 2005 until May 2007, three missions were carried out by the University of Kisangani (UNIKIS) to collect Plantains in the Oriental province (Tshopo district- around Kisangani and Yangambi, Ituri district - around Kilo close to the border with Uganda, Haut Uele district - around Wamba close to the border with Sudan, and Bas Uele district - close to the border with the Central African Republic). These *Musa* collection missions recovered major parts of the extinct Plantain collection of INEAC Yangambi. A total of 65 Plantain cultivars were collected and planted at the UNIKIS *Musa* collection (Dhed'a *et al*., 2011). In order to collect additional cultivars and capture a larger fraction of the existing diversity in the wider Oriental province, an additional large-scale collection mission was carried out in 2009.

MATERIALS AND METHODS

This study was conducted in 2009 in the Bas Uele, Haut Uele, Ituri and Tshopo districts of the Oriental province, north-eastern DR Congo. One can note that the Oriental province has been divided into four different provinces since 2006 (Bruneau, 2009), each district becoming a self-ruling province. The *Musa* germplasm surveys took place in 6 territories of Bas Uele district (Aketi, Ango, Bombesa, Bondo, Buta and Poko), 6 territories of Haut Uele district (Dungu, Faradje, Niangara, Rungu, Wamba and Watsa), 5 territories of Ituri district (Aru, Djugu, Irumu, Mahagi and Mambasa) and the 7 territories of Tshopo district (Bafwasende, Banalia, Basoko, Isangi, Opala, Ubundu, Yahuma). In addition, the surrounding region of Kisangani town (Lubuya Bera sector) was also surveyed. Hence the surveys were carried out in 24 territories of the Oriental province and the surroundings of Kisangani town (Figure 1). Three villages were randomly selected per territory giving a total of 75 villages across the Oriental province. In each village, a focus group discussion was conducted with a group of at least 30 men, and with a separate group of 30 women, to assess farmers' knowledge of banana diversity. A list of banana cultivar names was compiled per village and 10 farmers, each having at least 20 banana mats, were randomly selected per village for the subsequent household diagnostic survey. Household surveys were carried out on 750 farms in the Oriental province.

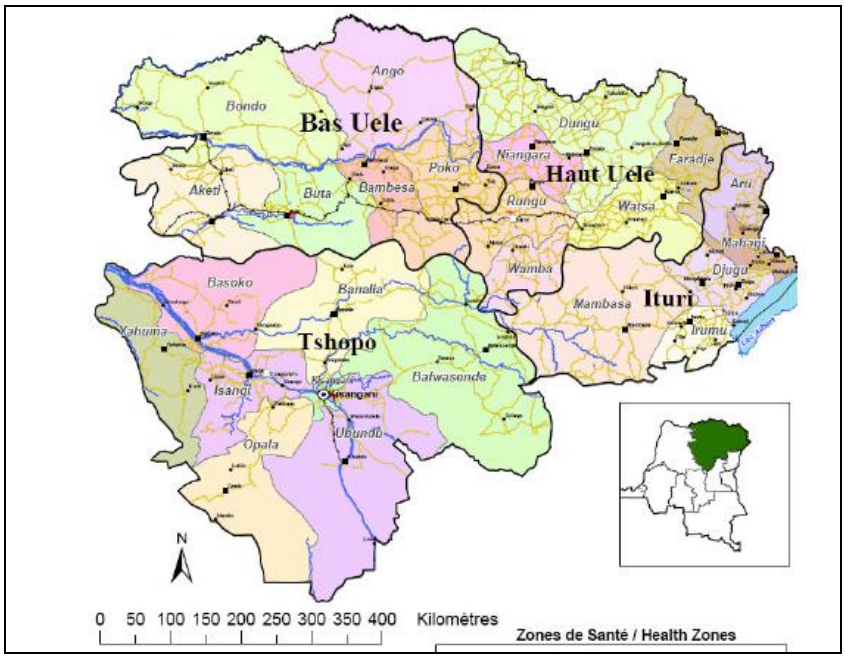

Figure 1. Districts (Bas Uele, Haut Uele, Ituri and Tshopo) and territories of the Oriental province in DR Congo

The household surveys focused on banana germplasm diversity, criteria that influence the selection of planting material, and on cultivar preference. On each farm, interviews were conducted with the person responsible for the maintenance of the banana field (mainly women). The respondents named first all the banana cultivars they cultivate and estimated the proportion of each cultivar. A list of 9 criteria (availability of planting material; bunch size; drought tolerance; flavour/taste/juice quality; market demand and price; resistance to pests and diseases; production cycle; sustainable production; tolerance to low soil fertility) were proposed to farmers and they were asked to choose criteria they considered most important in selecting cultivars they grow in their agro-ecological zone. Respondents were allowed to add other important criteria to the initial list. The germplasm was characterized by descriptors for banana (IPGRI-INIBAP/CIRAD, 1996) as well as by photos of different plant parts for each representative sampled cultivar. Suckers were collected of each putative new cultivar and planted in the UNIKIS, Kisangani or the Université Catholique du Graben (UCG), Butembo *Musa* collections for subsequent and additional characterization. A cultivar was considered new if it was met for the first time during the survey and hence needed to be collected.

RESULTS AND DISCUSSION

Banana cultivar diversity in the Oriental province

A total of 92 cultivars, including 70 Plantains and 22 other bananas (including brewing, cooking and dessert types) were collected across Bas Uele, Haut Uele, Ituri and Tshopo districts (Tables 1-2). The Plantains (AAB genome) dominated largely, demonstrating their importance as a food crop in the province. Within the Plantain subgroup, the French Plantains were the most numerous with 48 different cultivars. False Horn Plantains ranked second with 16 cultivars and Horn Plantains were represented by 6 cultivars (Table 2). These proportions were also reflected in the existing UNIKIS collection, with French Plantains being most numerous (67%), followed by False Horn (23%) and Horn Plantains (10%) (Dhed'a et al., 2011).

This strengthens the assumption that French Plantains were the first introduced Plantains in Africa (De Langhe, 2007), of which part underwent somatic mutation to the False Horn type and finally to the Horn type. The same trend was also observed in other collections in humid Africa (Swennen, 1990; Swennen and Vuylsteke, 1987; Tezenas de Montcel et al., 1983). From the 56 Plantain accessions collected by Edmond De Langhe mainly in the Oriental Province during the 1950s and established in the Yangambi collection, 34 were French Plantains while there were only 13 and 9 False Horn and Horn Plantains, respectively (De Langhe, 1964). Two surveys conducted in Southern Cameroon in late 1999 and in late 2001 showed that among the 32 Plantain cultivars reported, 18 were classified as French Plantains, 7 as False Horn and 6 as Horn Plantains (Hauser and Amougou, 2010).

The other most important groups cultivated in the Oriental province were dessert (11 cultivars) and cooking bananas other than Plantains (10 cultivars). The dessert bananas comprised AAA (7 cultivars), AAB (3 cultivars) and a AABB cultivar (1 recent hybrid from FHIA). The cooking bananas consisted of AAA-EA (8 cultivars) and ABB cultivars (2 cultivars) (Table 2). In the Oriental province, only 1 cultivar 'Kayinja' (ABB genome) was recorded exclusively as a brewing banana (Table 1). Some cultivars had different uses according to the districts. 'Figue Rose' was essentially used as dessert banana in Bas Uele, Haut Uele and Tshopo, while in Ituri district it was used as a brewing banana. 'Yangambi Km 5' was consumed either as dessert or as brewing banana in all the districts. In the Yahuma territory (Tshopo district), even Plantains are used for brewing. Plantain processing into an alcoholic drink is mainly carried out to prevent post-harvest losses. The Yahuma territory is far from major cities like Kisangani and the roads are in a very poor state.

A comparative description study of all the collected banana cultivars with previous collection data in Oriental province (De Langhe, 1961; Dhed'a et al., 2011) identified 24 never-before-recorded cultivars (Table 1). Most of those new cultivars were Plantains (23 out of 24). The new Plantain cultivars were recorded in Bas Uele (13), Haut Uele (2), Tshopo (3), Ituri (1), Bas Uele and Haut Uele (2), Bas Uele and Ituri (2), Bas Uele, Haut Uele and Ituri (1).

The highest numbers of cultivars were reported respectively in Bas Uele (58) and Tshopo (54 cultivars) districts, while the Haut Uele (46 cultivars) and Ituri (34 cultivars) districts had the lowest number of cultivars (Figure 2). Although the Ituri district displayed the lowest diversity, it nevertheless contained the largest AAA-EA diversity in the Oriental province, its altitude being typical for the highlands of East-Africa where these bananas dominate (Table 1).

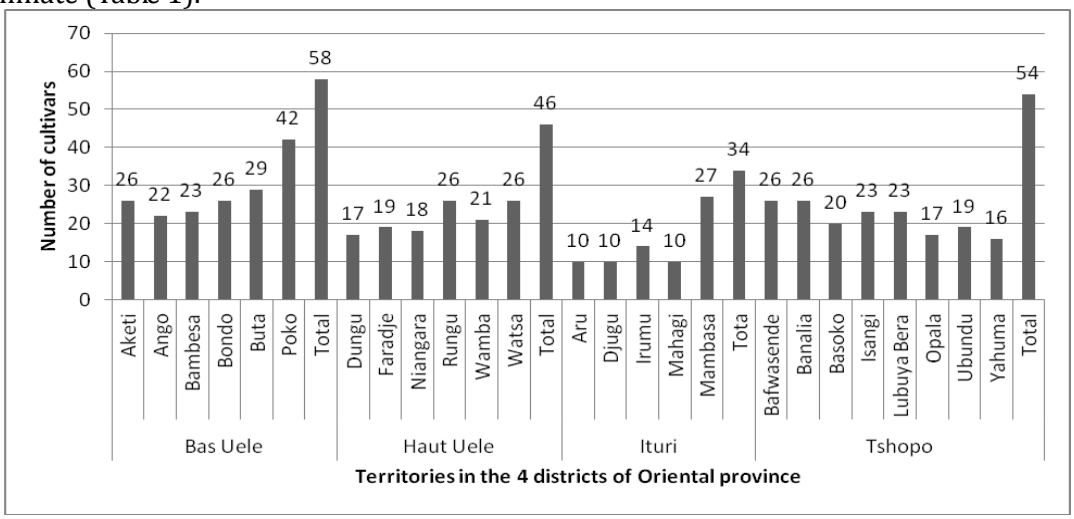

Figure 2. Number of cultivars sampled per territory in the districts of Tshopo, Bas Uele, Haut Uele and Ituri districts.

Humid rainforest covers the territories with the highest Plantain diversity. Thus for example, the territory of Ituri district with the highest diversity of Plantains, even of banana, was Mambasa, with 27 cultivars. The largest part of this territory is located in the rainforest zone and its banana diversity is similar to its neighbouring territory, Bafwasende, with 26 cultivars (Figure 2), a territory of the Tshopo district. Thus, Plantain cultivation largely occurs in the lowland rainforest zone where they require a humid-warm climate without major temperature/rainfall oscillations. The plant suffers heavily from a long dry period, and a dry season of more than 3 months is detrimental (De Langhe, 2007). The underground parts eventually perish as well, contrary to many other bananas, such as in the ABB group, where the corm survives to produce a new sucker after a long drought or cold period.

Plantains can nevertheless survive under protected growing conditions at elevations between 1000 and 1600 masl, i.e. on the highland parts of the Haut Uele and Ituri districts, thereby displaying a very different plant growth. A typical case had been extensively studied in altitudinal Kivu province (De Langhe, 1964). Cultivars from the lowland Yangambi collection were grown at the collection of Mulungu, near Lake Kivu (1460 masl). With the exception of giant cultivars (e.g. 'Bosua') which grew very poorly, they produced smaller bunches after a longer vegetative period, but the pseudostem was shorter, with less foliage leaves before flowering. While in the lowlands, most suckers were reduced to dormant buds till flowering, they quickly developed as multiple ratoons at Mulungu, thus eventually producing a stool with many bunches. The maintained multiple ratooning per stool led to the assumption that such plants had acquired a perennial character (instead of dying out like in the lowland conditions). Interestingly, accessions from Mulungu, when grown at Yangambi, quickly showed again the typical lowland habit. This altitudinal ecotype-effect has recently been confirmed, and even slightly different altitudes have similar effects (Turner et al., 2016). These findings indicate how the Plantain reached the lowlands from the East after crossing altitudinal East-Africa (De Langhe, 2007).

The proportion of banana mats (per cultivar) in the field differed from one district to another. The district with the highest proportion was Ituri (51.19%), while the Tshopo district had the lowest proportion of mats (13.11%) (Table 1). The cultivars which dominated the landscape in the Oriental province were respectively 'Libanga Likale' (False Horn Plantain with 8.7% of mats in the fields), 'Yumba' (French Plantain with 6.6%), 'Kayinja' (brewing banana with 6.6%), 'Bisamunyo' (AAA-EA cooking banana with 6.4%), 'Gros Michel' (AAA dessert banana with 5.8%) and 'Kamaramasenge' (AAB dessert banana with 5.7%). The other cultivars had less than 5% of mats in fields. There were even cultivars with less than 0.5% of mats in the fields. This means that these cultivars were rare, hence the need for their conservation.

Table 1. Name, genome group, banana type and number of mats for cultivars encountered in the four surveyed districts of the Oriental province, DR Congo

N°	Cultivar name	Genome group	Banana type#	Numbers of mats per district				Total	%
				Bas Uele	Haut Uele	Ituri	Tshopo		
1	Adili	AAB	F	3	6		8	17	0.24
2	Afati	AAB	F				5	5	0.07
3	Afati Black	AAB	F	18				18	0.26
4	Afati 'Red Wine'	AAB	F	3	2	2	1	8	0.11
5	Akodje*	AAB	F	1	16	72		89	1.27
6	Akoto	AAB	FH		7	9	17	33	0.47
7	Akoy*	AAB	F		32			32	0.46
8	Akpasi	AAB	F	1	26		4	31	0.44
9	Aleke	AAB	F	9	14		2	25	0.36

N°	Cultivar name	Genome group	Banana type#	Numbers of mats per district				Total	%
				Bas Uele	Haut Uele	Ituri	Tshopo		
10	Amakake	AAB	FH	20	43	183	48	294	4.20
11	Amakoko I	AAB	F		4	256		260	3.71
12	Amuku	AAB	F		10		5	15	0.21
13	Angbongbolia*	AAB	F	18				18	0.26
14	Apoka	AAB	FH	25	9		3	37	0.53
15	Apoka Magbuge	AAB	FH		13		2	15	0.21
16	Bakpala*	AAB	F	1				1	0.01
17	Belegi	AAA	D	5				5	0.07
18	Bhegisi*	AAB	F		27			27	0.39
19	Bisamunyo	AAA-EA	C	8	37	397	4	446	6.37
20	Bitabe ngay	AAA	D	1				1	0.01
21	Bluggoe	ABB	C	5	23	38		66	0.94
22	Bogo	AAB	F		35		7	42	0.60
23	Bokangasoku	AAB	H	3				3	0.04
24	Bokpeta	AAB	FH	36	1		3	40	0.57
25	Bolomaise	AAB	F	2	22		1	25	0.36
26	Boofo	AAB	F	1	4	52	1	58	0.83
27	Boofo Black	AAB	F	2	8		13	23	0.33
28	Bosakaraka I	AAB	F		7		2	9	0.13
29	Bosakaraka II	AAB	F		1		10	11	0.16
30	Bosua	AAB	F		17	115	26	158	2.26
31	Buambala*	AAB	F	1				1	0.01
32	Cardaba	ABB	C	65	82		8	155	2.21
33	Chwachwa	AAB	F	115	76		20	211	3.01
34	Egbe-O-Mabese I	AAB	FH	63	42	3	7	115	1.64
35	Egbe-O-Mabese II	AAB	F		8		9	17	0.24
36	FHIA-03	AAAB	D				1	1	0.01
37	Figue Pome	AAB	D	20			4	24	0.34
38	Figue Rose	AAA	D	22	32	31	20	105	1.50
39	Grande Naine	AAA	D	33	10	285	9	337	4.81
40	Gros Michel	AAA	D	67	107	154	76	404	5.77
41	Gwekwele*	AAB	F	16				16	0.23
42	Ifelete ya Bolome*	AAB	F				1	1	0.01
43	Ikpolo	AAB	H	30	18	23	48	119	1.70
44	Ikpolo Black	AAB	H		8		1	9	0.13
45	Ikpolo Red	AAB	H	1	10		1	12	0.17
46	Inekeleikumi	AAB	F				1	1	0.01
47	Kamaramasenge	AAB	D	57	102	222	21	402	5.74
48	Kambolokoso	AAB	F	1				1	0.01
49	Kayinja	ABB	B	4		456		460	6.57
50	Kodje*	AAB	F			22		22	0.31
51	Kpoolo*	AAB	F	4				4	0.06
52	Lese*	AAB	FH	14				14	0.20
53	Libanga Black	AAB	FH	11	40	12	3	66	0.94
54	Libanga Dark Green	AAB	FH		24		2	26	0.37
55	Libanga Liaboelabokoy	AAB	F	31	28	64	21	144	2.06
56	Libanga Lifombo	AAB	FH	95			18	113	1.61
57	Libanga Likale	AAB	FH	105	112	127	267	611	8.73

N°	Cultivar name	Genome group	Banana type#	Numbers of mats per district				Total	%
				Bas Uele	Haut Uele	Ituri	Tshopo		
58	Libanga Multiple	AAB	FH	5			1	6	0.09
59	Lindimama*	AAB	F	12		88		100	1.43
60	Lingu	AAB	FH		33		8	41	0.59
61	Litete	AAB	F	80	67	9	117	273	3.90
62	Lokoka	AAB	F	3			11	14	0.20
63	Maboto*	AAB	F	3	6			9	0.13
64	Magoma I	AAB	F		10	14	2	26	0.37
65	Mangweangwea*	AAB	FH	5				5	0.07
66	Mani mani*	AAB	F				1	1	0.01
67	Masekpe *	AAB	F	13				13	0.19
68	Matoke	AAA-EA	C			28		28	0.40
69	Mobwete*	AAB	FH	8				8	0.11
70	Moikili*	AAB	H				1	1	0.01
71	Mokomboso	AAB	F	2				2	0.03
72	Momuwiliagbia*	AAB	FH	2				2	0.03
73	Mongele*	AAB	F	1				1	0.01
74	Mudjuva	AAA-EA	C			29		29	0.41
75	Ngondima*	AAB	F	2				2	0.03
76	Nguku	AAB	F	12	5			17	0.24
77	Nyakisangani	AAA-EA	C			67		67	0.96
78	Ongua	AAB	F				1	1	0.01
79	Pakuma	AAA-EA	C			63		63	0.90
80	Petite Naine	AAA	D			190	4	194	2.77
81	Prata	AAB	D				3	3	0.04
82	Sika	AAB	F	8		16		24	0.34
83	Sira*	AAA-EA	C			38		38	0.54
84	Sira Rouge	AAA-EA	C			9		9	0.13
85	Sugbe*	AAB	F	4	1			5	0.07
86	Tala Lola	AAB	H	16	28		5	49	0.70
87	Vulambya	AAA-EA	C			52		52	0.74
88	Wilingwa*	AAB	F	4				4	0.06
89	Yangambi Km 5	AAA	D	65	116	4	52	237	3.38
90	Yelola	AAB	F				1	1	0.01
91	Yumba	AAB	F			454	10	464	6.63
92	Yumba Noir	AAB	F	9			1	10	0.14
Total				1171	1329	3584	918	7002	100
%				16.72	18.98	51.19	13.11	100	

*: Newly found cultivar

#: B: Brewing banana, C: Cooking banana, D: Dessert banana, F: French Plantain, FH: False Horn Plantain and H: Horn Plantain.

Table 2. Sampled number of banana cultivars by type or genome group

Plantain			
French	False Horn	Horn	Total
48	16	6	70
Dessert			
AAA	AAB	AAAB	Total
8	3	1	11

Cooking			
AAA-EA	ABB		Total
8	2		10
Brewing			
ABB	-	-	Total
1			1

Farmers' cultivar selection criteria and cultivar preference

Of the 9 criteria investigated, 4 criteria were mainly used by farmers when selecting a banana type across the 4 surveyed districts of the Oriental province: crop taste/flavour/juice quality, availability of planting material, market demand/price and bunch size. For Plantain, most farmers selected cultivars for their taste (29.9%), the availability of their planting material (27.2%), the market demand (20.5%) and bunch size (12.2%) (Table 3). Thus 'Libanga Likale' was the most appreciated Plantain cultivar due to availability of its planting material and its high market demand, while 'Litete' ranked second for its taste and market demand. The three other most appreciated Plantain cultivars were 'Amakake', 'Yumba' and 'Chwachwa' (Table 7).

Table 3. Farmer's selection criteria for plantain cultivars across Bas Uele, Haut Uele, Ituri and Tshopo districts.

Selection criteria	Bas Uele		Haut Uele		Ituri		Tshopo		Total	
	Number	%	Number	%	Number	%	Number	%	Number	%
Availability of planting material	90	55.9	33	23.4	25	17.2	46	17.3	194	27.2
Big bunch size	0	0.0	11	7.8	40	27.6	36	13.5	87	12.2
Drought tolerance	0	0.0	10	7.1	0	0.0	1	0.4	11	1.5
Flavour, taste, juice quality	19	11.8	39	27.7	35	24.1	120	45.1	213	29.9
Market demand and high price	52	32.3	19	13.5	34	23.4	41	15.4	146	20.5
Resistance to pests and diseases	0	0.0	6	4.3	5	3.4	1	0.4	12	1.7
Short production cycle	0	0.0	3	2.1	3	2.1	5	1.9	11	1.5
Sustainable production	0	0.0	10	7.1	1	0.7	15	5.6	26	3.6
Tolerance to low soil fertility	0	0.0	10	7.1	2	1.4	1	0.4	13	1.8
Total	161	100.0	141	100.0	145	100.0	266	100.0	713	100.0

For dessert bananas, the main selection criteria was the taste (58.7% of farmers). Market demand (18.6%) and availability of planting materials (14.2%) were also important for farmers when selecting cultivars (Table 4). The four most appreciated dessert banana cultivars ('Gros Michel', 'Kamaramasenge', 'Grande Naine' and 'Petite Naine') have good taste and a high market price. The 5th most appreciated dessert banana, 'Yangambi Km 5' (Table 7), performs well under poor soil fertility conditions and planting material of this genotype is largely available due to its vigorous suckering behaviour.

Table 4. Farmers' selection criteria for dessert banana cultivars across Bas Uele, Haut Uele, Ituri and Tshopo districts.

Selection criteria	Bas Uele		Haut Uele		Ituri		Tshopo		Total	
	Number	%	Number	%	Number	%	Number	%	Number	%
Availability of planting material	3	1.7	5	7.7	23	15.3	24	16.6	55	14.2
Big bunch size	0	0.0	0	0.0	31	20.7	4	2.8	4	1.0
Drought tolerance	0	0.0	0	0.0	3	2.0	1	0.7	1	0.3
Flavour, taste, juice quality	114	64.4	26	40.0	38	25.3	87	60.0	227	58.7

Market demand and high price	53	29.9	0	0.0	28	18.7	19	13.1	72	18.6
Resistance to pests and diseases	0	0.0	0	0.0	7	4.7	0	0.0	0	0.0
Short production cycle	0	0.0	0	0.0	12	8.0	0	0.0	0	0.0
Sustainable production	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Tolerance to low soil fertility	0	0.0	16	24.6	4	2.7	5	3.4	21	5.4
Total	177	100.0	65	100.0	150	100.0	145	100.0	387	100.0

For the cooking bananas other than plantains, taste (40.9 % of farmers), availability of planting material (18.4%), bunch size (17.4%) and market demand or price (14. 4%) were the most important criteria that influenced selection (Table 5). The 3 most appreciated cooking bananas were, respectively, 'Bisamunyo', 'Kayinja' and 'Bluggoe' (Table 7).

Table 5. Farmer's selection criteria for cooking banana cultivars across Bas Uele, Haut Uele, Ituri and Tshopo districts.

Selection criteria	Bas Uele		Haut Uele		Ituri		Tshopo		Total	
	Number	%	Number	%	Number	%	Number	%	Number	%
Availability of planting material	7	11.5	44	25.0	20	13.3	2	22.2	73	18.4
Big bunch size	0	0.0	16	9.1	51	34.0	2	22.2	69	17.4
Drought tolerance	0	0.0	0	0.0	3	2.0	0	0.0	3	0.8
Flavour, taste, juice quality	43	70.5	82	46.6	36	24.0	1	11.1	162	40.9
Market demand and high price	7	11.5	17	9.7	32	21.3	1	11.1	57	14.4
Resistance to pests and diseases	0	0.0	0	0.0	5	3.3	1	11.1	6	1.5
Short production cycle	3	4.9	8	4.5	2	1.3	0	0.0	13	3.3
Sustainable production	1	1.6	9	5.1	1	0.7	1	11.1	12	3.0
Tolerance to low soil fertility	0	0.0	0	0.0	0	0.0	1	11.1	1	0.3
Total	61	100.0	176	100.0	150	100.0	9	100.0	396	100.0

Juice quality (40.9% of farmers) was the most important selection criterion for brewing bananas (Table 6). The other most important criteria were, respectively, availability of planting material (18.4 %), bunch size (17.4%) and market demand (9.8%). The most appreciated brewing bananas were 'Yangambi Km 5', 'Kayinja', 'Bluggoe' and 'Cardaba' (Table 7).

Primary criteria used by farmers in selecting planting material were flavour/taste/juice quality, availability of planting material, market demand/high price and big bunch size. Other interesting criteria is sustainable production (longevity of cultivar). Cultivars with extended longevity, such as 'Yangambi Km 5' or 'Kayinja', present good tolerance to low soil fertility, drought tolerance, resistance to pests and diseases.

Table 6. Farmer's selection criteria for brewing banana cultivars across Bas Uele, Haut Uele, Ituri and Tshopo districts.

Selection criteria	Bas Uele		Haut Uele		Ituri		Tshopo		Total	
	Number	%	Number	%	Number	%	Number	%	Number	%
Availability of planting material	7	11.5	44	25.0	20	13.3	2	22.2	73	18.4
Big bunch size	0	0.0	16	9.1	51	34.0	2	22.2	69	17.4
Drought tolerance	0	0.0	0	0.0	3	2.0	0	0.0	3	0.8
Flavour, taste, juice quality	43	70.5	82	46.6	36	24.0	1	11.1	162	40.9
Market demand and high price	7	11.5	17	9.7	32	21.3	1	11.1	57	14.4
Resistance to pests and diseases	0	0.0	0	0.0	5	3.3	1	11.1	6	1.5
Short production cycle	3	4.9	8	4.5	2	1.3	0	0.0	13	3.3

Sustainable production	1	1.6	9	5.1	1	0.7	1	11.1	12	3.0
Tolerance to low soil fertility	0	0.0	0	0.0	0	0.0	1	11.1	1	0.3
Total	61	100.0	176	100.0	150	100.0	9	100.0	396	100.0

Table 7. Most preferred banana cultivars in Oriental province, north-eastern DR Congo.

Ranking	Plantain (AAB)	Dessert banana (AAA)	Cooking banana (ABB and AAA-EA)	Brewing banana (ABB and AAA-EA)
1	Libanga Likale	Gros Michel	Bisamunyo	Yangambi Km 5
2	Litete	Kamaramasenge	Cardaba	Kayinja
3	Amakake	Gande Naine	Bluggoe	Bluggoe
4	Yumba	Petite Naine		Cardaba
5	Chwachwa	Yangambi Km 5		

CONCLUSION

This study shows that the Oriental province contains a large banana diversity, consisting of 92 cultivars of plantain and other cooking bananas, dessert bananas and brewing bananas. With 70 cultivars, Plantains form the largest group. The diversity of banana depends on the location in the Oriental province. Plantains were mainly recorded in the districts completely covered by the forest (Bas Uele and Haut Uele), while AAA-EA banana were found in Ituri district, its altitude being typical for the highlands of East Africa where these bananas dominate. Part of the observed Plantain diversity is rare elsewhere (found only in one or two villages and never in other villages of the country or in other collections in Africa) and needs to be conserved for breeding purposes. The rest of banana diversity apart from these rare Plantains needs also to be conserved considering the interesting agro-ecological aspects (tolerance to low soil fertility, drought tolerance, resistance to pests and diseases…) presented by some varieties. Farmers select cultivars especially because of their taste and market value, and less because of high yield.

The information generated in this study can be used as a baseline for further studies on Plantain diversity and as a basis for a more detailed banana germplasm characterization in other provinces of the Congo Basin. The assessed information on farmers' selection criteria is useful not only for breeders but also for agronomists involved in the agroecology which begins with the choice of the most sustainable varieties.

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Literature cited

Bruneau, J-C. 2009. Les nouvelles provinces de la République Démocratique du Congo : construction territoriale et ethnicités. *L'Espace Politique 7.* DOI : 10.4000/espacepolitique.1296

De Langhe, E. 1961. La taxonomie du bananier plantain en Afrique Equatoriale. Journal d'Agriculture Tropicale et de Botanique Appliquée 8, 418-453.

De Langhe, E. 1964. The origin of variation in the plantain banana. Gent, Belgium, State Agricultural University of

Gent 39, 45-80.

De Langhe, E. 1969. Bananas (*Musa* spp.). In: Ferwada, F.P. and F. Wilt (eds.). Outlines of perennial crop breeding in the tropics, Miscellaneous Papers N° 4, Agricultural University, Wageningen, The Netherlands, pp. 53-78.

De Langhe, E. 2007. The establishment of traditional plantain cultivation in the African rain forest: a working hypothesis. Pp. 361-70 in Rethinking Agriculture: Archaeological and Ethnoarchaeological Perspectives. T.P. Denham, J. Iriarte & L. Vrydaghs (eds.). Left Coast Press, Walnut Creek.

Dhed'a, D.B., Nzawele, B.D., Roux, N., Ngezahayo, F., Vigheri, N., De Langhe, E., Karamura, D., Picq, C., Mobambo, P., Swennen, R. and Blomme, G. 2011. *Musa* collection and characterization in central and eastern DR Congo: a chronological overview. Acta Horticulturae 897, 87–94.

Hauser, S. and Amougou, D. 2010. Plantain (*Musa* spp.) Cropping systems of Southern Cameroon. In Dubois T. *et al.* (ed.), *Banana & Plantain in Africa*. Acta Horticulturae 879, 495-508.

IPGRI-INIBAP/CIRAD 1996. Descriptors for Banana (*Musa spp.*) International Network for the Improvement of Banana and Plantain, Montpellier, France/Centre de Coopération International en Recherche Agronomique pour le Développement, Montpellier, France.

Janssens, M. 2001. Cassava (*Manihot esulenta* Crantz). Root and tuber crops. p.165-187**.** In: Crop production in Tropical Africa. RH Raemaekers ed. DGCD, Brussels, Belgium.

Root and tuber crops. p.165-187. In: R.H. Raemaekers (ed.), Crop Production in Tropical Africa. DGCD, Brussels, Belgium.

Muller, J. 1947. Amélioration du bananier indigène. Comptes rendus de la semaine agricole de Yangambi (du 26 février au 5 Mars 1947), Communication N° 21, 343-373

Pemsl, D.E. and Staver, C. 2014. Strategic Assessment of Banana Research Priorities. Lima (Peru). CGIAR Research Program on Roots, Tubers and Bananas (RTB). RTB Working Paper 2014-2. Available online at: www.rtb.cgiar.org

Stover, R.H. and Simmonds, N.W. 1991. Bananas. Tropical Agriculture Series. Third edition.

Swennen, R. 1990. Limits of morphotaxonomy: names and synonyms of plantain in Africa and elsewhere. The identification of genetic diversity in the genus Musa. Proceedings of an International Workshop. Los Baños, Philippines. 5-10 September 1988. 172-210.

Swennen, R., and Vuylsteke, D. 1987. Morphological taxonomy of plantain (*Musa* cultivars AAB) in West Africa. Banana and Plantain Breeding Strategies Proceedings of an International Workshop. ACIAR Proceedings No. 21. Cairns, Australia. 13-17 October 1986. 165-171.

Tezenas de Montcel, H., De Langhe, E., and Swennen, R. 1983. Essai de classification des bananiers plantains (AAB). Fruits, 38 (6), 461-474.

Turner, D.W., Fortescue, J.A., Ocimati, W. and Blomme, G. 2016. Plantain cultivars (Musa spp. AAB) grown at different altitudes demonstrate cool temperature and photoperiod responses relevant to genetic improvement. Field Crops Research 194: 103-111. http://dx.doi.org/10.1016/j.fcr.2016.02.006