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The morphological diversity of plantain in the Democratic Republic of Congo

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ABSTRACT

This work focused on the morphological characterization of plantain cultivars collected in the period 2005–2014 in 280 villages across 9 provinces of the Democratic Republic of Congo. These cultivars were established in two field collections at the University of Kisangani.Existing descriptors were adapted to better differentiate their variation to address better the taxonomic handicap and the synonymy handicap to improve future research on plantains.Most of the collected cultivars were French plantains (64 out of 98), followed by False Horn (23) and Horn (10) plantains. The bunch type was the main striking difference which allows the quick separation of plantain cultivars into three main types. Other striking differences within plantain were the size of the pseudostem (giant, medium-sized and small-sized) and the bunch orientation (which was generally pendulous or subhorizontal, and rarely horizontal and erect). These three descriptors were considered as main descriptors. Other descriptors (pseudostem colour, immature fruit peel colour, fruit shape, fruit apex, fruit position, number of hands, fruit size, number of fingers per hand and flower relicts at the fruit apex) allowed the differentiation of one cultivar from another within the same main group of bunch type, pseudostem size or bunch orientation. These descriptors are considered as secondary descriptors. Rare descriptors allowed to differentiate one cultivar from all the others in the subgroup.

This approach makes the cultivar description logical and faster because it moves from general to particular characteristics, and it offers a platform for reflections on the Pan-African scale of plantain diversity

1. Introduction

1.1. The significance of plantain as a staple food crop in Africa

In sub-Saharan Africa, it is estimated that over 30 million people subsist on bananas as the principal source of dietary carbohydrate. The vast majority of banana and plantain producers in the continent are small-scale farmers growing the crop mainly for home consumption or for local markets (Karamura et al., 1999). In west and central Africa, about two-thirds of the bananas cultivated and produced are plantains, of which the starchy fruits need culinary preparation for consumption. The other third consists of dessert and other cooking bananas (FAOSTAT, 2015). In Africa, plantain is cultivated from Guinea to the Democratic Republic of Congo (DR Congo) and the Central African Republic. The major producing countries are Cameroon, Ghana, Nigeria and Côte d'Ivoire. In these countries production of plantain ranks high (12.327.974 tonnes in 2014) among the starchy staples (FAOSTAT, 2015).

1.2. Two major handicaps for research on plantains

World banana and plantain production is hampered by many biotic (pests and diseases, shortage of clean and/or high-yield planting material…) and abiotic (soil fertility, water deficit…) constraints (Pemsl and Staver, 2014; Swennen et al., 2013). In DR Congo, the productivity of plantain in the traditional farming systems is seriously limited by soil depletion, lodging by winds, diseases and pests, and socio-economic constraints (Dhed'a et al., 2011). Such deficiencies/constraints calls for the selection of the best-performing cultivars and their genetic improvement. The estimated plantain diversity in Africa amounts to more

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than 120 cultivars (De Langhe, 1969; Swennen, 1990; Lescot, 2000). Consequently, research results on one or even a few cultivars cannot automatically be representative for all plantains, as there is not yet a correct taxonomic description of the vast plantain diversity. This is called *"the taxonomic handicap"*. There is the need for a taxonomic reference base that allows the univocal identification of a cultivar under investigation.

On top of the taxonomic problem comes the fact that each cultivar in a given area has a local vernacular name. Hence each popular cultivar has almost as many different names as there are tribes that cultivate it. Consequently research results on a cultivar, when published with its local name, can hardly be understood in other areas. This is called *"the synonymy handicap"*.

For resolving the taxonomic and the synonymy handicaps, one needs tools which differentiate cultivars from each other. Agro-morphological traits have been used over the past 70 years in *Musa* diversity studies. Morphotaxonomy was first complemented by chemotaxonomic studies involving isozyme and flavonoid analysis (Horry, 1989; Mandal et al., 2001; Reyes et al., 1998); subsequently molecular genetics used DNA-analysis techniques such as restriction fragment length polymorphism (RFLP), amplified fragment length polymorphism (AFLP), random amplified polymorphic DNA (RAPDs), and more recently the highly performing marker techniques of simple sequence repeats (SSR) and diversity arrays technology (DArT) (Christelová et al., 2016; De Langhe et al., 2005; Noyer et al., 2005; Ortiz and Swennen, 2014; Ude et al., 2002).

The results of molecular detection of diversity have confirmed the morphological classification of *Musa* into groups and subgroups. For instance, at the group level, the identification of polymerase chain reaction (PCR) markers for detection of A and B genome sequences in *Musa* was already reported by Pillay et al. (2000). At the subgroup level, and in a study across 561 *Musa* accessions, the allelic distribution of each of 22 SSR loci was analyzed (Hippolyte et al., 2012). The analysis produced clusters that reflect the triploid subgroups, and in addition indicated the putative diploid parents in some cases. However, neither SSR nor DArT could differentiate the cultivars within the subgroups. Even the currently tried single nucleotide polymorphism (SNP) technique on plantains is apparently not able to differentiate the plantain cultivars (De Langhe, pers. comm.). Since the differentiation is not evident at the DNA level, the suggestion that somaclonal variation is of epigenetic origin (Risterucci et al., 2009), seems plausible.

Because molecular tools to differentiate plantain cultivars appear to be of no use in support of research in plantain taxonomy, the morphological identification of plantain cultivars remains of prime importance, considering that many cultivars are economically superior, both in terms of productivity and of market value.

1.3. Earlier characterization efforts in DR Congo

Research on plantain started in DR Congo in 1933 at the '*Institut National des Etudes Agronomiques au Congo*' (INEAC) at the research centre of Yangambi (Tshopo district, Oriental province). The focus was on cultivar screening for higher productivity using plant material grown by the tribes around Yangambi (Muller, 1947). The challenge was to deal with the different vegetative growth cycles of different cultivars varying between six and 15 months. That research was quickly confronted with the occurrence of duplicates with different names, as each tribe had its own name for a cultivar. Muller therefore systematically collected and characterized plantain cultivars in the 1940s to assess the synonymy in the Yangambi region. Muller's publication became a good reference for plantain cultivar characterization and classification during the 1950s. While the Yangambi collection reached more than 50 different plantain accessions, region-specific collections were also established during the 1950s in the INEAC stations of Bambesa (Oriental province), Mvuazi (Bas-Congo) and Mulungu (South Kivu). Plantains were mainly found in the Oriental province, while mainly east African highland bananas (EAHBs) were collected in the South Kivu Province. Unfortunately, and starting from the 1960s, social unrest, civil wars and political instability put this considerable work on plantain characterization on hold for several decades. Moreover, these early *Musa* collections progressively disappeared. Still, the characterization-focused studies during the 1950s were published (De Langhe 1961a, 1961b, 1964a, 1964b).

With the disappearance of the large field collection at Yangambi, the need of a new collection in DR Congo became necessary.

Table 1
Collecting missions in DR Congo between 2005 and 2014.

Time of collection	Province (District)	Villages	Cultivars collected
2005–2007	Oriental province (Tshopo)	17	67
	Oriental province (Bas Uele)	13	
	Oriental province (Haut Uele)	11	
	Oriental province (Ituri)	10	
2009	Oriental province (Tshopo)	24	57
2010–2012	Oriental province	63	88
	Katanga	15	
	Eastern Kasai	15	
	Western Kasai	15	
	Bandundu	15	
	Maniema	18	
	North Kivu	18	
	South Kivu	18	
	Equateur	18	
2013–2014	Oriental province (Bas Uele)	4	23
	Equateur province	6	

2. Materials and methods

2.1. Plantain collection missions and conservation at UNIKIS (University of Kisangani)

Over 9 years (2005–2014), plantains varieties were collected in 280 villages in 9 provinces of DR Congo (Table 1). The plantain cultivars were established in two field collections: (1) in the faculty of sciences of the UNIKIS at Kisangani, DR Congo containing 67 accessions and (2) near the administrative building of the UNIKIS containing 83 accessions. In both collections, each accession is represented by at least 5 plants planted in a single row, with a spacing of 2.5 × 2.5 m within and between rows. These collections were established with suckers planted in holes of 40 cm diameter and 60 cm depth. At planting and at subsequent 6-month intervals, approximately 30 kg of decomposed pig dung was applied to enhance soil fertility. In addition mulching was done twice a year with grass (mainly *Pennisetum purpureum* L.). Between plantain rows, a hedgerow of a tree legume (*Leucaena* spp.) was installed to maintain soil fertility. Neither pesticides nor chemical fertilizers are used. De-leafing and pruning are frequently practiced, leaving 9–12 live and green leaves per plant and three shoots per mat to restrict competition between plants.

2.2. Characterization

The descriptor guide 'Descriptors for bananas (*Musa* spp.)' (IPGRI-INIBAP/CIRAD, 1996) was used to describe the plantain cultivars at the UNIKIS collections (Adheka, 2014). New descriptors have however been introduced in this study as for example for the fruit apex. Instead of the states 'pointed, lengthily pointed, blunt-tipped, bottle-necked and rounded' as provided by 'Descriptors for bananas', only three states were found to be of value in the plantain subgroup: salient (the apex consists of two well-separated parts as the end of the parthenocarpic fruit and passes abruptly into an irregularly angulate tip, the acumen),

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