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Morphological Diversity of Plantain (*Musa* sp. L. AAB Group) in Cameroon: Relationships to Farmer's Cultural Practices

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ABSTRACT

Managing diversity or releasing new varieties into existing farming landscapes require a good understanding of farmers' practices. This study was carried out to assess the extent and cause of intra-field morphological diversity in plant communities of plantain farmers in Cameroon. Vegetative propagules ascribed by farmers to the popular varieties 'Assang-Da', 'Ebang', 'Elat', and 'Essong' were field established at the research stations of the International Institute of Tropical Agriculture for phenotypic evaluation. None of the varieties appeared to be a community of unique morphotypes with average similarity indices of 46.5% for 'Assang-Da', 48.3% for 'Ebang', 49.4% for 'Elat' and 55.8% for 'Essong', confirming the mixture nature of the varieties. Inter-variety phenotypic similarity coefficients ranged from 41.7% ('Ebang' vs 'Elat') to 45.0% ('Ebang' vs 'Essong'), equally showing considerable overlaps, yet sufficient phenotypic differentiation, between the varieties. Many migrants, being more distantly related to individuals in their respective assigned groups than to individuals ascribed to other groups, were identified in all variety groups, except 'Ebang'. In the absence of gene flow among plantain varieties, we attributed this pattern of diversity to farmer's inability to distinguish varieties when acquiring planting materials, or more likely, to a deliberate decision by farmers to distribute risk across different types. Testing and releasing new varieties, such as those derived from breeding, may have to conform to the mixture principle, in order to increase prospects for adoption by small-holder farmers.

Keywords: diversity, migration, morphological markers, plantain, seed systems

INTRODUCTION

Banana and plantain (*Musa* sp. L.) are important cash and subsistence crops in most tropical and subtropical regions of the world (Robinson 1996). The cultivated bananas are predominantly triploid (2n=3x=33) varieties derived from the species *M. acuminata* (genome A) and *M. balbisiana* (genome B), which are native to South East Asia. A morphological method for determining the relative genomic contribution of the two species to the existing cultivars has been developed by Simmonds and Shepherd (1955), but molecular tools are becoming available with recent developments in DNA technology (Pillay *et al.* 2000). The cultivated varieties are usually classified into three major groups, AAA, AAB, and ABB (Robinson 1996; Simmonds 1962; Stover and Simmonds 1987).

The plantains belong to the AAB group and were introduced into Africa 3000 years ago (De Langhe 1961; Wilson 1987). The plantains have become prominent features in the agricultural landscape of western and Central Africa, where over seventy percent of the world crop of plantains is grown and consumed, with increasing quantities being exported to the U.S.A. and Europe. Western and Central Africa harbor the world's greatest variability of plantains, therefore, this region is now considered as the secondary center of diversification (Simmonds 1995; Swennen *et al.* 1995; De Langhe 1964). These plantains display considerable diversity, with morphological variation occurring for inflorescence type, plant size, fruit orientation, fruit shape, pseudostem and fruit colour (Tézenas du Montcel *et al.* 1983; Swennen 1990). Using the criterion of inflorescence morphology, plantains are usually sorted into four categories, i.e., French plantain, French Horn plantain, Horn and False Horn plantain, which are further divided into giant, medium and small types (De Langhe 1964).

Commensurate with the geographical dispersion of the plantains, many local names and synonyms exist among the accessions, due to indiscriminate assignment of names by different language groups across and within countries (Rossel 1998). For example, in Nigeria, several plantains are referred to as 'Ntanga' (which means plantains), without consideration of their morphological differences (Swennen and Vuylsteke 1987). Likewise, in Cameroon, the most commonly grown plantain landraces are 'Assang-Da' (Horn), 'Ebang' (False horn), 'Elat' (Small French), and 'Essong' (Medium French), but it is not uncommon to observe morphological differences within a landrace. In contrast, individuals assigned to different landraces may appear closer than they are to other individuals in their group. In fact, farmers often give the same name to several similar looking cultivars, which suggests that popular names describe populations rather than accessions. This superimposes linguistic diversity to genetic and ecological diversity.

These varieties are often grown perennially whereby successive crops are derived from shoots (also called suckers) emerging from lateral buds located at the base of the main plant in the previous crop (De Langhe 1961). Suckers constitute the planting materials that farmers use for establishment of new fields or replacement of lost stands in old fields. Since there is no formal seed production schemes in most countries, farmers resort to acquiring suckers on an *ad hoc* basis, from neighbors or rural markets. Thus, suckers of putative varieties are collected only based on popular names, resulting in intra-field diversity that may be unintended,

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Table 1 Characteristics of the local plantain varieties used in this study.

Variety group	Classification	Synonyms	Source of planting material used in study	Farmer descriptors (proportion of 112 farmers identifying variety with listed characteristics)
Assang-Da	True Horn	'Messang mebe', 'Messang melé', 'Avot-Mbegle', 'Asumbegle'	Pa Joe Akonia (Bilik), Mr. Omgba (Nkolguet)	Variety with 1-3 hands (100%), deciduous neutral flowers (89%), and deciduous male inflorescence (91%)
Ebang	False Horn	'Ebang Mboé', 'Ebang tige rouge', 'Osseu Ebang', 'Mbimi', 'Zoaba', 'Popolo'	Mr. Manga Ndi (Bilik), Mrs Mengue Helen (Bilik)	Variety with about 5-7 hands (100%), persistent neutral flowers (87%), and deciduous male inflorescence (82%)
Elat	Small French	'Osseu Elat', 'Elat tige rouge'	Mr. Omgba (Nkolguet), Mr. Manga Ndi (Bilik)	Variety with about 6-8 hands (100%), persistent neutral flowers (92%), and persistent male inflorescence (91%)
Essong	Medium French	'Essong Mboé', 'Alou Vini', 'Ndoan', 'Obel Ekwan', 'Ekwan mekie', 'Koé Ekwan', 'Amoung'	Pa Joe Akonia (Bilik), Mrs Mengue Helen (Bilik)	Variety with about 6-8 hands (100%), persistent neutral flowers (100%), and persistent male inflorescence (96%)

since homonymous suckers may not be identical varieties. Indeed, contamination of the desired variety by suckers from other varieties may cause heterogeneity in morphological and phenological attributes of the plant community, preventing crop uniformity and potentially causing a nuisance in economic terms.

However, intra-field diversity may also originate from deliberate mixing of different accessions. This is because intra-field diversity may be viewed as an ecosystem-stabilizing factor that operates like an insurance allowing for greater resilience of the ecosystem in the face of stressful conditions (Kahmen *et al.* 2005) while offering growers diversity of diet, stability of income, and reduced losses to pests (Smithson and Lenne 1996). When the grower's objective is to manage risk with diversity, unintended intra-field homogeneity, resulting from purchase of suckers from synonymous varieties, could also constitute a nuisance.

Managing diversity in farmers' fields requires a good understanding of the pattern of variation among popular varieties, particularly in juvenile plants. This in turn determines to what extend plant breeding may succeed in releasing new varieties into existing production schemes. Therefore, the objective of this study was to examine (i) the extent of phenotypic diversity and (ii) the phenetic relationships among accessions of the most popular plantain landraces grown in Central Africa.

This study will show that variation occurs within relative accessions. Identifying landraces at early stages is important for industrial farmers to set up homogenous fields from the varieties in their fields with different names (**Table 1**).

MATERIALS AND METHODS

Study sites

This study was carried out at the research farms of the International Institute of Tropical Agriculture (IITA), located at Mbalmayo (lat. 3° 25′ N, long. 11° 28′ E, alt. 640 m asl) and Nkolbisson (lat. 3° 21′ N, long.11° 30′ E, alt. 700 m asl), near Yaoundé, in the humid forest margins of southern Cameroon (IITA 1988; Gockowski and Ndoumbé 1999).

The Mbalmayo station has an average annual rainfall of approximately 1500 mm, bimodally distributed from February–June and September–November. The soil is classified as a clayey, kaolinitic, isohyperthermic, Typic Kandiudult (USDA classification) and is acid in the subsoil, with pH between 5 and 6 (De Cauver *et al.* 1995; Hulugalle and Ndi 1994). The climatic characteristics of Nkolbisson are very similar to those of Mbalmayo, but the soil type is a Rhodic Kandiudult (USDA classification), with well-drained sandy clay soil in the top 30 m layer (Ambassa-Kiri 1990).

Plant materials

Sampling procedure

A participatory rapid appraisal based on questionnaire and field visits was utilised to obtain farmers' perception of differences between the major plantain variety groups, on the basis of which, suckers representing such groups were purchased from some of the farmers. Briefly, we appraised 112 plantain growers near Mbalmayo, consisting of 52% men and 48% women, with an age range of 18 to 65 years, 55% being under 30 years, 18% aged 31 to 40 years, and 23% older than 40 years. Plantain occupied either the first or the second position in terms of importance in monetary value as well as satisfaction of farmer's subsistence needs. Farmers use a combination of criteria to classify the varieties, but the most consistent discriminants were inflorescence traits (**Table 1**).

One hundred and thirteen accessions of the commonly grown varieties were collected from farmers' fields. This consisted of 29 accessions of 'Assang-Da', 31 of 'Ebang', 23 of 'Elat', and 30 of 'Essong' as identified by the farmers. To minimize heterogeneity arising from morphogenetic, i.e., ontogenic causes, suckers of similar size were purchased from the farmers and prepared for planting as described by Swennen (1990).

Phenotypic variation

A field experiment was carried out at Mbalmayo to examine the extent of phenotypic differences among adult plants, within and across accessions. Planting was done on 28 September 2001 following an unbalanced completely randomized design whereby the collected specimens were assigned to non-replicated single plant plots. Plant spacing was 3 m between rows and 2 m within rows to achieve a population density of 1667 plants ha^{-1}. Field maintenance was carried out as described by Swennen (1990), except that no fertilizer was applied.

The plants were grown to maturity and data were collected on 11 growth habit traits and seven yield characteristics. The growth habit traits included time to flowering (days), time to harvest (days), fruit filling time (days), i.e., the period elapsed from flowering to harvest, plant height at flowering (cm), plant girth at flowering (cm) measured at 100 cm above the soil line, time to emergence of the first sucker (days), number of suckers at flowering, and height of tallest sucker at flowering (cm). Also recorded were leaf emission and retention status of the plants at flowering, i.e., total number of leaves, the number of standing leaves (NSL), the youngest leaf spotted (YLS), and the index of non-spotted leaves (INSL), which was derived from the former two as INSL=100*(YLS-1)/NSL. The leaf characteristics are typically used to assess host plant response to the defoliating effects associated with black leaf streak (caused by *Mycosphaerella fijiensis* Morelet), which is considered as the most serious constraint to cultivation of plantains (Stover 1980). Yield traits included bunch weight (kg), number of hands per bunch, number of fruits per bunch, average fruit length (cm) and girth (cm), average fruit weight (g), and dry matter content of the fruit (%).

The data were subjected to statistical analysis using the GLM procedure in SAS (SAS Institute 2003) to partition phenotypic variation into inter- and intra-variety components, in order to test for differences between varieties. The UNIVARIATE procedure of SAS was used to explore further phenotypic variation within each variety.

Table 2 Phenotypic means and variation in adult plant attributes among accessions of popular landraces of plantain in Cameroon.

Plant attributes	'Assang-Da' (N=30)		'Ebang ' (N=31)		'Elat ' (N=28)		'Essong ' (N=24)		Difference between accessions	
	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	P value	R^2
Time to flowering (days from planting)	385.3	18.3	340.9	8.2	342.5	11.7	379.5	10.8	0.0002	0.161
Fruit filling time (flowering to harvest interval, days)	95.7	15.5	102.4	16.6	105.9	16.1	88.7	12.1	0.0096	0.132
Time to harvest (days)	459.0	7.9	441.3	6.5	430.8	4.2	452.6	6.7	0.0148	0.122
Plant height at flowering (cm)	327.0	10.2	321.6	9.0	316.3	10.8	325.8	10.0	0.5905	0.017
Plant girth at flowering (cm)	55.6	13.9	54.2	12.2	53.0	11.6	58.4	11.4	0.0325	0.077
Time to first sucker emergence (days from planting)	176.1	17.4	162.6	14.4	166.3	19.8	163.3	11.4	0.2103	0.040
Number of suckers at flowering	1.2	87.0	2.6	54.7	2.5	52.8	3.3	47.4	<.0001	0.233
Height of tallest sucker at flowering (cm)	85.9	49.3	105.2	50.3	87.7	59.0	94.6	38.1	0.4171	0.028
Total number of leaves at flowering	42.1	3.4	40.5	4.6	39.4	8.1	43.2	5.1	<.0001	0.292
Number of standing leaves at flowering	9.8	19.8	10.5	16.6	9.7	20.1	9.4	24.7	0.1739	0.044
Youngest leaf spotted at flowering	5.6	25.3	5.9	18.7	5.2	26.8	5.0	27.1	0.0755	0.061
Index of non-spotted leaves at flowering (%)	45.9	16.7	46.4	11.0	42.5	18.2	42.3	19.2	0.0544	0.067
Bunch weight (kg)	6.0	36.1	8.6	42.6	12.3	31.4	12.0	22.3	<.0001	0.385
Number of hands per bunch	1.5	49.4	6.0	20.8	5.9	17.8	7.0	10.9	<.0001	0.820
Number of fruits per bunch	18.0	37.2	28.8	24.4	75.3	23.0	87.2	16.0	<.0001	0.858
Average fruit length (cm)	28.1	22.3	23.9	17.1	21.8	11.6	18.8	17.1	<.0001	0.352
Average fruit girth (cm)	14.8	10.8	14.4	14.4	12.4	10.9	11.9	12.9	<.0001	0.331
Average fruit weight (g)	166.5	34.9	175.0	38.5	82.7	31.9	62.9	26.5	<.0001	0.476
Dry matter content (%)	41.0	13.0	42.0	9.8	42.4	4.1	41.9	5.8	0.7006	0.017

Phenetic relationships

Landraces typically require 15-24 months to reach reproductive stages where distinctive features of their inflorescence can be used to unambiguously identify them. Whether phenotypic discrimination could be achieved at an earlier growth stage had not been previously investigated. Therefore, a second experiment was designed to examine phenetic relationships among juvenile plants, within and across accessions. This experiment was established on 15 April 2003 at Nkolbisson, using sword suckers taken from each plant of the first experiment. Hence, the experimental design was a completely randomized design without replications. Planting density and field maintenance were the same as for Mbalmayo.

We carried out phenotypic evaluation four months after planting, when plants had fully established and recovered from post-transplanting shock. Twelve plants did not survive to evaluation, including one plant of 'Assang-Da', three of 'Elat', and four each of 'Ebang' and 'Essong'.

Data were collected on twenty-three qualitative morphological characters to explore their discriminatory power between and within varieties. Therefore, each morphological character was used as a descriptor for which several descriptor states were defined using reference guidelines of the *Musa* Germplasm Information System (MGIS http://mgis.inibap.org/). The descriptors were classified as non-discriminatory, when only one of their potential states was observed and discriminatory otherwise.

The data were subjected to chi-square analysis to test for departure from monomorphic distribution of the discriminatory descriptors in each variety. Thereafter, data were coded, whereby each descriptor state was given a value of "1" when present and "0" otherwise, generating a data matrix with descriptor states as rows and individuals as columns.

The phenotypic similarity between individuals was estimated with Jaccard's index (Jaccard 1908) implemented by the JACCARD option of the DISTANCE procedure of SAS (SAS Institute 2003). Similarity indices were calculated on the basis of shared presence of phenotypic descriptor states, which allowed for subsequent separation of individuals into distinct clusters within and across varieties, using the CLUSTER and TREE procedures of SAS (SAS Institute 2003).

RESULTS

Phenotypic variation

Expectedly, considerable phenotypic variation was observed for all traits both within and between accessions (**Table 2**). However, inter-accession differences were not statistically significant for several traits, including plant height, time to emergence of the first sucker, height of the tallest sucker at flowering, and dry matter content of the fruit. There was no difference for the number of standing leaves, youngest leaf spotted, and index of non spotted leaves, despite significant differences in the number of leaves produced at flowering. This suggests that the photosynthetic capacity of the accessions was the same at flowering, indicating unequal susceptibility to defoliating effects of black leaf streak between the accessions.

Of the 19 variables analysed, 12 showed significant variation between varieties, suggesting that they may be used to discriminate among varieties, particularly for experienced farmers. Differences between varieties accounted for less than 5% of the observed variation in most traits, leaving large fractions of the variation attributable to differences within varieties. Model adequacy, i.e., the proportion of variation explained by differences between varieties was less than 30% for growth habit traits, indicating that they may not provide reliable discrimination. In contrast, model adequacy was much higher for yield traits, the R^2 exceeding 80% in some cases, e.g., the number of hands and the number of fruits per bunch. This was not surprising, since bunch characteristics are known to be relatively reliable for varietal discrimination, and have been used for this purpose by taxonomists (De Langhe 1964; Tézenas du Montcel *et al.* 1983; Swennen 1990).

Intra-variety differences accounted for a large proportion, i.e., > 50%, of the variation in most traits, exceeding 95% for several traits. Intra-variety fluctuations, as indicated by the coefficient of variation, were lowest for the total number of leaves and the number of days from planting to harvest, and highest for the number of suckers and height of tallest sucker at flowering for all four varieties (**Table 2**).

Whether this within-variety heterogeneity is solely attributable to micro-environmental factors is unlikely, but equally unlikely is an entirely genetic basis for the observed variation, given the vegetative propagation nature of this crop. We could not resolve this matter, due to the lack of replications.

A rapid survey in the collection area showed that different farmers used different criteria for variety identification, but the most common criteria included vegetative characteristics (colour of the pseudostem, colour of the sap), bunch characteristics (number of hands, fruit length and insertion angle, persistence of the male bud) and sensorial characteristics (firmness and taste of the pulp) of mature

Table 3 Descriptor status of some morphological attributes used for phenotypic classification of juvenile plants of popular plantain accessions in Cameroon.

Morphological attributes	Number of descriptor states	Prevalent phenotypic classes
Leaf habit	1(3)[a]	Intermediate
Pseudostem aspect	3(3)	Slender, normal, robust
Pseudostem colour	4(11)	Medium green, green, green yellow, red green
Pigmentation in the pseudostem	2(3)	Brown black, brown/rusty brown
Pseudostem appearance	1(2)	Shiny
Predominant underlying colour of the pseudostem	2(7)	Light green, medium green
Sap colour	1(3)	Watery
Sap dripping on cutting the leaf's petiole	1(2)	Drips
Wax on leaf sheaths	2(3)	Moderately waxy, few wax
Blotches colour	3(4)	Brown, dark brown, brown black
Petiole canal leaf III	3(5)	Margins curved inwards, straight with erect margins, margins overlapping
Wing type	2(2)	Dry, not dry
Petiole margin colour	2(3)	Green, pink/purple to red
Edge of petiole margins	2(2)	Coloured, colourless
Colour of leaf upper surface	2(6)	Medium green, green
Appearance of leaf upper surface	1(2)	Shiny
Wax on leaf	3(4)	Waxy, moderately waxy, very little or no wax
Insertion point of leaf blade base	1(2)	Symmetric
Shape of leaf blade base	2(3)	Both sides rounded, both sides pointed
Leaf corrugation	1(3)	Even/smooth
Leaf tips	2(2)	Twisted, not twisted
Colour of midrib dorsal surface	3(6)	Light green, pink purple, green
Colour of cigar leaf dorsal surface	1(2)	Green

[a] Numbers in parentheses are expected number of descriptor states, based on Musa Descriptors (MGIS http://mgis.inibap.org).

Table 4 Statistical tests for discriminatory value of some morphological attributes used for phenotypic classification of juvenile plants of popular plantain accessions in Cameroon.

Morphological attributes	**Chi-square test for departure from monomorphic distribution of descriptor states within varieties** [a]				**χ^2 test for no preferential variety-trait association** [b]
	'Assang-Da'	**'Ebang'**	**'Elat'**	**'Essong'**	
Pseudostem aspect	0.255 ns	0.642 ns	0.434 ns	0.382 ns	0.631 ns
Pseudostem colour	9.837 *	10.585 *	9.120 *	8.681 *	15.277 ns
Pigmentation in the pseudostem	0.050 ns	1.210 ns	0.180 ns	0.107 ns	5.376 ns
Predominant underlying colour of pseudostem	0.654 ns	1.21 ns	0.08 ns	2.000 ns	0.8539 ns
Wax on leaf sheaths	0.092 ns	0.025 ns	0.320 ns	0.426 ns	1.466 ns
Blotches colour	0.971 ns	4.740 ns	1.140 ns	0.990 ns	2.302 ns
Petiole canal leaf III	1.523 ns	3.630 ns	2.383 ns	0.648 ns	3.930 ns
Wing type	0.010 ns	0.990 ns	0.980 ns	0.296 ns	1.027 ns
Edge of petiole margin	0.041 ns	0.990 ns	1.280 ns	0.296 ns	1.184 ns
Colour of leaf upper surface	1.469 ns	0.990 ns	0.980 ns	0.580 ns	0.593 ns
Wax on leaf	1.477 ns	2.074 ns	1.546 ns	10.731**	1.373 ns
Shape of leaf blade base	0.163 ns	0.134 ns	0.320 ns	0.189 ns	0.763 ns
Leaf tips	2.000 ns	0.069 ns	1.620 ns	1.704 ns	6.700 ns
Colour of midrib dorsal surface	3.268 ns	2.543 ns	3.120 ns	2.460 ns	10.022 ns

[a] Indicates no (ns) or significant departure from monomorphic distribution of descriptor at the probability levels of 5% (*) and 1% (**)

[b] "ns" indicates no preferential association of descriptor states with varieties

plants.

Would it be possible for farmers to identify varieties at a juvenile stage? We examined the discriminatory potential of twenty-three botanical characters, which are normally little affected by environmental conditions. As many as eight of these descriptors only displayed one state across accessions, and were classified as non-discriminatory. The monomorphic descriptors included pseudostem appearance, sap colour, sap viscosity, leaf habit, appearance of leaf upper surface, insertion point of leaf blade base, leaf blade corrugation, colour of cigar leaf dorsal surface (**Table 3**). The maximum number of known descriptor states was observed for only four attributes, including pseudostem aspect, petiole wing type, edge of petiole margins, and shape of leaf tips, while the remaining traits displayed several descriptor states without reaching the potential number (**Table 3**).

The apparently polymorphic descriptors were subjected to a chi-square analysis to test for departure from monomorphic distribution, i.e., to examine the likelihood that the observed variation was not fortuitous. Thus, pseudostem colour was the only descriptor that appeared to discriminate individuals within all four varieties, while the extent of waxiness of the leaf was another discriminatory descriptor, albeit in one variety (**Table 4**). Whether each variety could be traced to specific attributes was equally examined by chi-square analysis, revealing the non-preferential occurrence of descriptor states across varieties, hence overlaps between varieties, regardless of the trait under consideration (**Table 4**).

Phenetic relationships

Whether simultaneous consideration of several descriptors would prove more satisfactory for variety discrimination was examined through multivariate analysis, generating similarity coefficients summarized in **Table 5**. Clearly, intra-variety diversity was quite important with average similarity of 46.5% for 'Assang-Da', 48.3% for 'Ebang', 49.4% for 'Elat' and 55.8% for 'Essong', confirming the mixture nature of the varieties. Inter-variety phenotypic similarity coefficients ranged from 41.7% ('Ebang' vs 'Elat') to 45.0% ('Ebang' vs 'Essong'), equally showing that there was considerable convergence and overlaps, yet sufficient phenotypic differentiation, between the varieties.

Table 5 Average phenotypic similarity within and between popular plantain variety pools from Cameroon.

Comparison	Jaccard's similarity coefficients		
	Mean ± SE	**Minimum**	**Maximum**
'Assang-Da' vs 'Assang-Da'	0.465 ± 0.010	0.111	1.000
'Assang-Da' vs 'Ebang'	0.428 ± 0.005	0.111	0.875
'Assang-Da' vs 'Elat'	0.418 ± 0.006	0.071	0.875
'Assang-Da' vs 'Essong'	0.418 ± 0.006	0.071	0.765
'Ebang' vs 'Ebang'	0.483 ± 0.010	0.071	1.000
'Ebang' vs 'Elat'	0.417 ± 0.006	0.035	0.875
'Ebang' vs 'Essong'	0.450 ± 0.005	0.111	0.875
'Elat' vs 'Elat'	0.494 ± 0.015	0.154	1.000
'Elat' vs 'Essong'	0.449 ± 0.007	0.071	0.875
'Essong' vs 'Essong'	0.558 ± 0.010	0.111	1.000

Average–linkage analysis based on the similarity indices produced six clusters, none of which was specific to, or dominated by, a particular variety. Nonetheless, one would assume that individuals belonging to the same "variety" would be closer to each other than to individuals assigned to other varieties. Our data show that this was not always the case (**Fig. 1-4**). Thus, about one third of individuals ascribed to 'Assang-Da' had greater average similarity to individuals outside their assigned group (**Fig. 1**). Likewise, five 'Ebang' (**Fig. 2**) and one 'Essong' (**Fig. 4**) accessions were more distantly related to individuals in their respective assigned groups than to individuals ascribed to other groups. Only individuals assigned to the 'Elat' variety by the farmers appeared closer to each other than they were to individuals of the other variety groups (**Fig. 3**).

DISCUSSION

The observed variations in this study could be partly attributed to morphogenetic heterogeneity of the suckers used as planting materials, although care was taken to select suckers of identical size based on the postulate that they would have the same physiological age. The most common alternative to suckers is *in-vitro* derived seedlings obtained by tissue culture. *In-vitro* derived seedlings are more uniform, but their use in this tudy would have departed from farmers' practice and would not have provided appropriate conditions for understanding the practical causes of variation in the farmer's fields.

The name of a variety essentially is a short descriptive of its most distinctive features. Hence, the name 'Assang-Da' means one hand, which points to the characteristic small number of hands (1-3) of this variety. Likewise, 'Ebang' means big, which identifies a variety with big fruits, 'Elat' means union because hands are apparently joined together, having arised from a common insertion level on the peduncle, while 'Essong' (big bunch) is distinguished by a very large number of fruits (Rossel 1998; Tezenas du Montcell 1979). This phenomenon is not restricted to central Africa. In Ghana for example, some plantain accessions have derived their native names from their propensity to produce two (e.g. 'Abomienu') or three (e.g. 'Abomiensa') bunches (Hemeng *et al.* 1995; Schill *et al.* 1997).

Understandably, this naming system is prone to inter-individual variations in subjective perception, often causing inexperienced growers to conclude that name differences, resulting from differences in dialects or intonation, reflect differences between varieties when in fact they are synonyms. Likewise, similar intonations may cause exactly the reverse, with different varieties being considered identical when in fact they are merely homonyms. Rossel (1998) provide substantial accounts of these incongruities, also reported by Efanden *et al.* (2003).

Biocultural interactions constitute driving forces in the maintenance of relatively high levels of genetic diversity in traditional agriculture, with the potential of reinforcing or tempering with evolutionary forces, as has been shown for many sexually propagated crop species. For example, Alvarez *et al.* (2005) examined the patterns of local diversity of sorghum (*Sorghum bicolour* [L.] Moench) in northern Cameroon and attributed the apparent lack of bottleneck effects to the structure of farmer-to-farmer seed transactions, whereby fields of older farmers serve as sources of diversity that supply the fields of younger farmers (who typically start farms with a small number of varieties), in a recurrent mode as younger farmers age. Gene flow occurs between individuals within and across sorghum varieties, under-

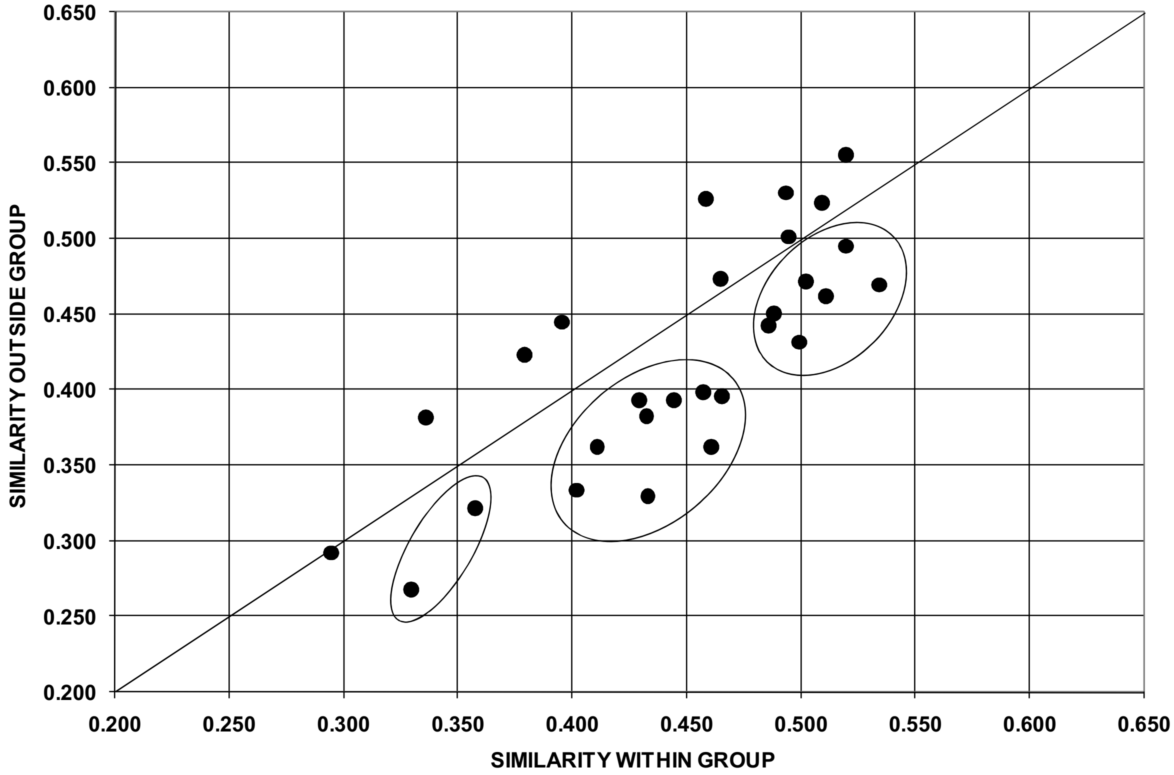

Fig. 1 Pattern of variation within the 'Assang-Da' Horn plantain variety pool. Individuals that have a greater similarity to others in the variety pool (below diagonal) are considered more descriptive of the variety pool than those that have greater similarity to individuals of other variety pools.

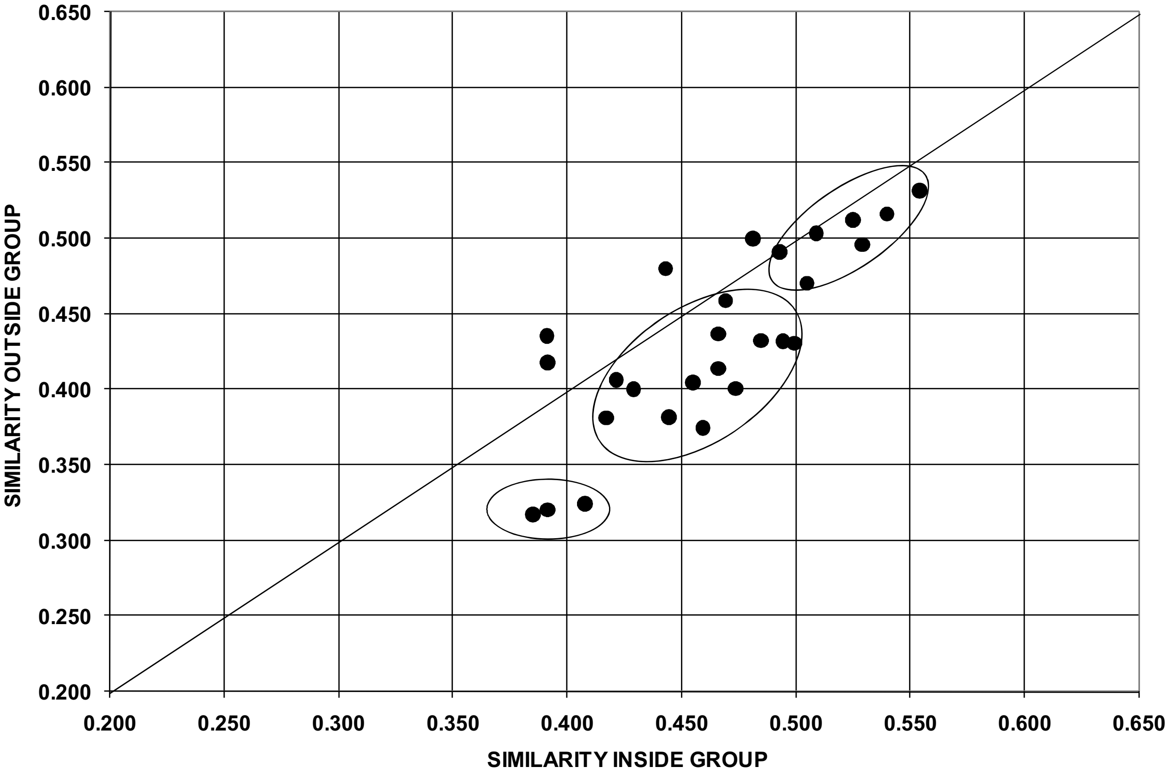

Fig. 2 Pattern of variation within the 'Ebang' False Horn plantain variety pool. Individuals that have a greater similarity to others in the variety pool (below diagonal) are considered more descriptive of the variety pool than those that have greater similarity to individuals of other variety pools.

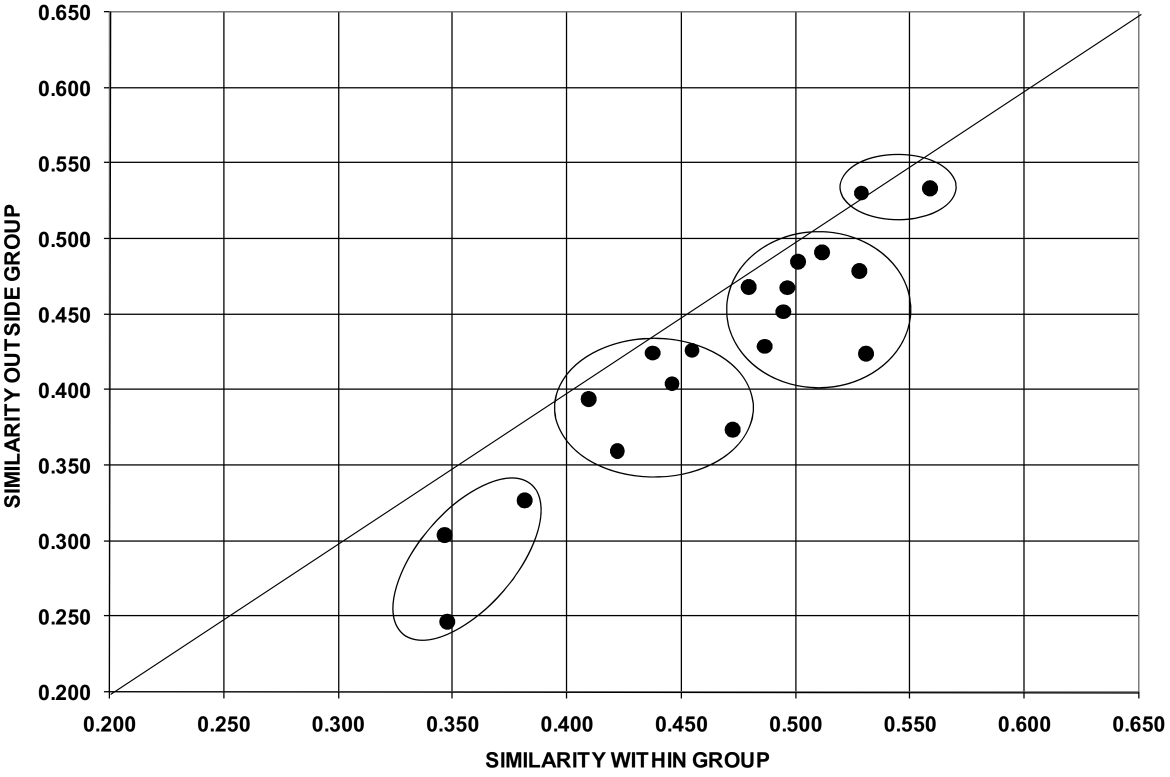

Fig. 3 Pattern of variation within the 'Elat' Medium French plantain variety pool. Individuals that have a greater similarity to others in the variety pool (below diagonal) are considered more descriptive of the variety pool than those that have greater similarity to individuals of other variety pools.

scoring the role of deliberate choices by farmers in the maintenance of substantially distinct and inbred landraces, with intra-landrace genetic variation accounting for nearly one third of the total variation (Barnaud *et al.* 2007). Therefore, it may be stated that landraces consist of mixtures of agronomically different sub-populations that display some ecological convergence, which lends support to the concept of ecotypes that some authors use.

Elias *et al.* (2001) examined the determinants of morphological and genetic variability of cassava (*Manihot esculenta* Crantz) in a traditional agro-ecosystem, and reported high intra-variety diversity, which could cause confusion between phenotypically similar varieties. The predominant mode of propagation of cassava is through vegetative cuttings, but seed-propagation also occurs, contributing to genetic diversification when viable seeds result from cross-

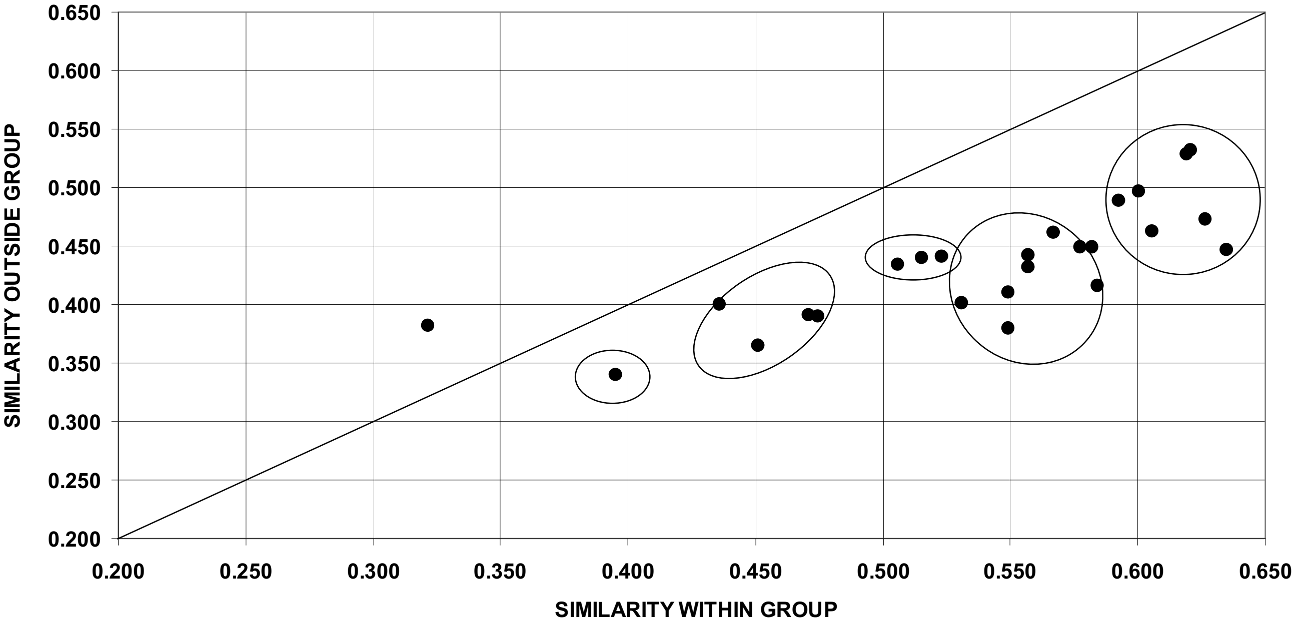

Fig. 4 Pattern of variation within the 'Essong' Tall French plantain variety pool. Individuals that have a greater similarity to others in the variety pool (below diagonal) are considered more descriptive of the variety pool than those that have greater similarity to individuals of other variety pools.

hybridization of distinct varieties that often co-exist in the same fields. What mechanisms are responsible for the maintenance of the phenotypic distinctiveness of varieties are not all known, but it appeared that farmers deliberately employ diversifying selection to manage risks over the long term (Elias *et al.* 2001).

Misclassification of varieties by their assignment to a group they are not, or little, genetically related to can be described as a migration event. This apparently occurs routinely for banana and plantain with farmers exchanging suckers of putative varieties, due to the lack of a formal seed system, and the difficulty of distinguishing among varieties solely based on vegetative characteristics, particularly in juvenile plants. It appears that even when planting materials are obtained from mature plants, there is still a high probability of variety mixtures, because homonyms might actually be different varieties.

Phenetic relationships

Sensory attributes such as the color of plant organs usually constitute the most discriminant features that saliently distinguish varieties. In this study, it was expected that each variety should have a specific pseudostem colour and that the colours should be unique for the different varieties, as described by Daniell *et al.* (2001). They distinguished degrees of greenness in pseudostem colour, classifying 'Essong' as green red, 'Ebang' as green yellow, and 'Elat' as medium green. Instead, we observed intra-variety diversity for this trait for all four varieties, which we attributed to inadvertent or deliberate mixture by farmers when obtaining planting materials.

That no particular descriptor state was characteristic of a given accession suggested that phenotypic discrimination could not be achieved at the juvenile stage or that the commonly accepted descriptors might not be suitable for juvenile plants. For example, it is not known whether pseudostem colour is under developmental regulation, with the fixation of a definite colour being reached only in adult plants, but this could as well explain the discrepancy between our results and those of Daniell *et al.*'s (2001). This could pose a problem for quality control, by phenotypic means, of field multiplication operations for the production of seedlings or the maintenance of field collections using *in-situ* approaches.

This study showed that plant communities in farmers' fields appeared to be systematic mixture of several varieties. Under such circumstances, the term variety may be inappropriate to collectively designate a population of plants grown by any farmer. Rather, caution would dictate a careful inventory of the available morphotypes in order to extract holotype varieties for conservation or use in breeding programs.

CONCLUSION

This study aimed to assess the extent of phenotypic variation among popular varieties of plantain grown by farmers in Central Africa, where intra-field diversity routinely occurs. It appeared that each variety as designated by the farmers was actually a mixture of different biological forms. In crop species that have an exclusive or facultative sexual mode of reproduction, a considerable fraction of the variability may be due to genetic recombination as modulated by mating patterns.

The cultivated banana and plantain varieties display high levels of andro- or gynosterility or both and essentially reproduce by asexual means, ruling out genetic recombination as the likely cause of intra-field variety for this crop. Rather, variety mixtures could have resulted from insufficient discriminatory power of the criteria used by farmers for variety classification. Mixture could also have derived from bulk purchase of detached suckers of putative varieties, i.e., at a time when phenotypic discrimination may not be possible. However, the most likely cause of the mixture is a deliberate decision by farmers to distribute risk across different types, since intra-field diversity may offer growers diversity of diet, stability of income, and reduced losses to pests (Smithson and Lenne 1996). Genetically, mixing varieties is analogous to migration, the consequences of which are to maintain intra-population diversity, particularly when genetic recombination does not occur.

Under these circumstances, it is hypothesized that adoption prospects for new varieties, such as hybrids with resistance to black Sigatoka, would increase if the new varieties were introduced into the farmers' cropping system through association with their own landraces. Furthermore, plant diversity, such as occurs in a mixture, has the potential of increasing the productivity and stability of the mixture, but it depends on the success of each individual in the mixture composition, which in turns depends on the extent of competition among individuals in the mixture. Neighbors can beneficially change the situation of a plant, most commonly when the neighbors contribute to alleviation of environmental conditions that are unfavorable to the survival, growth and reproduction of the plant (Bertness and Hacker 1994). Thus, an appropriate mixture regime would allow resistant hybrids to serve to reduce inoculum spread to plants of the susceptible plantain landraces. While this mechanism would help increase the yield of the landraces (preferred for their culinary properties), it would also preserve genetic diversity while exposing farmers to new, high-yielding, hybrids.

We conclude that the release of new varieties, such as those derived from cross-breeding, may have to conform to the mixture principle, in order to increase prospects for adoption by small-holder farmers.

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