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Research Paper

Morphological characterization and agronomic performances of cashew (*Anacardium occidentale* L.) accessions from Benin

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ABSTRACT. Cashew tree is a multi-purpose fruit species in Benin. The aim of this study was to evaluate the agro-morphological diversity of the cashew varieties for their better management and utilization in crop improvement. For this purpose, 120 cashew trees sampled from the three major production areas were characterized based on 36 (14 qualitative and 22 quantitative) agro-morphological descriptors developed by Bioversity International. Statistical tools such as Principal Component Analysis (PCA) and Hierarchical Clustering Analysis (HCA) tools have been used to describe the genetic variability. PCA results revealed that the parameters related to apple, nuts, kernel and inflorescence are the most important parameters that heavily contribute to overall diversity within the cashew species. Based on HCA of the quantitative variables, four phenotypic classes were distinguished within the sampled cashew trees. Significant correlations (positive or negative) were detected between variables such as the length and weight of the apple on one hand and the weight, length and width of the nut and inflorescence on the other hand. This preliminary work suggests the existence of an important genetic variability among Beninese cashew accessions that could be used in a breeding program.

Keywords: Agro-morphology, fruit tree, phenotypic diversity.

INTRODUCTION

Cashew (*Anacardium occidentale* L.) is a tropical species belonging to the family. It is a fruit tree that is adapted to a wide range of soils but, in general, it prefers fertile, well-drained, deep and sandy / clay, lateritic or rocky soils with a high content of organic matter. Cashew is a multipurpose tree which tolerates slightly acidic and neutral soils with a pH between 6.3 and 7.3 (Nambiar et al., 1990). Sometimes, the plant can also grow on soils with a pH between 4.5 and 6.5 (Aliyu, 2012), but it is sensitive to the high variation of temperature (Lautié et al., 2001). Wood from cashew tree is used for carpentry, firewood or turned into charcoal (Akinwale, 2000). Cashew resin is used in the manufacturing of plastics and natural insecticides. Various parts of the tree have medicinal value and they are used to treat various diseases (Cavalcante et al., 2003; Chabi Sika et al., 2013).

From 1950 to 1970, the African continent has provided about 70% of the world cashew nut production with the main producers being Mozambique and Tanzania. In Benin, cashew nut is the second largest exported crop after cotton. Indeed, the Benin national cashews trees acreage was estimated in 2003 to about 70 000 ha and is the 10th largest cashew nut producer with approximately 2% of the world exported volume and has the second best nut quality in West Africa after Guinea Bissau (ITC 2008). In Africa, and particularly in Benin, the cashew production is limited by many problems including the non-availability of improved seeds and the high sensitivity of plants to pests and diseases such as anthracnose (Aliyu and Awopetu, 2007). In addition, cashew accessions in cultivation in peasant plantations are not evaluated for their agronomic potential. To initiate a successful cashew breeding program in Benin, it is important to have knowledge on the species' genetic diversity with the aim to select elite trees that can be used in breeding schemes. Although morphological characteristics were known to be influenced by environmental factors, in plant characterization but they are still used for this purpose (Adoukonou-Sagbadja et al., 2007; Chipojola et al., 2009; Ahoton et al., 2011). The objective of this work was to study the morphological variability in Beninese cashew accessions and to evaluate their agronomic potentials for future genetic improvement of this important fruit species in Benin.

MATERIALS AND METHODS

Study area

The study area mainly covered the zones of high production of cashew in Benin. These zones are Center (zone 1), the Northeast (zone 2) and the Northwest (zone 3). For this study, three localities were surveyed by zone. In zone 1, data were collected in the districts of Bantè, Ouessé and Glazoué. In zone 2, the selected districts were Parakou, Nikki and Bembèrèkè whereas in zone 3, Djougou, Kouandé and Bassila districts were selected for the study. For this study, a total of 21 villages were selected based on their production and their accessibility (Figure 1).

Tree sampling

The trees were sampled in the period from December 2012 to March 2013. A total of 120 trees were sampled for all the study, within which 40 were selected per production area (Table 1). In each village, trees were selected in plantations of 9, 12 and 15 years old (10 nine years old trees and 15 twelve and fifteen years old). The trees were selected following the diagonal crossing method described by Chipojola et al. (2009). All these trees were marked and referenced by GPS (Global Positioning System). Furthermore, a distance of 10 m × 10 m between trees was considered within selected plantations. A floristic inventory of the main companion woody species and annual crops has been made in the selected plantations. In total, 22 quantitative and 14 qualitative traits were considered for data collection following the descriptors developed by Bioversity International (IBPGR, 1986) (Table 2).

Quantitative data collection

Measurement dendrometric characteristics

The diameter of tree DBH was determined from the circumference measured at 1.30 m over the ground using a tape meter. This parameter was calculated by the formula DBH = C/π, with C the circumference measured at 1.30 m on the top of the ground. To generate a single data per tree with more than one rod, the formula DBH $= \sqrt{(d1^2 + d2^2 + \ldots + dn^2)}$ was used (Saïdou et al., 2012). DBH is thus the square root of the sum of squares of the measured diameters of each stems.

To measure the total height of the tree (H), two sightings were made using a Suunto clinometer (Finland). The first was made at the foot of the tree (V1) and the second at the top of the tree (V2). These are referred as percentage of the distance (L) between the operator and the tree. The total height (H) of the measured tree is obtained using the Rondeux (1999) formula:

H = (V2 - V1) × L/100.

The average crown diameter was determined from the north-south and the east-west crown diameters that were measured using a decameter following the formula proposed by Rondeux (1999) and recently used by Saïdou et al. (2012):

$$D = \sqrt{\frac{(D1^2 + D2^2)}{2}} \tag{1}$$

with D = Average diameter of the crown, North-South diameter (D1) and East-West diameter (D2). In the case of several crowns for a single tree, the average diameter was estimated by calculating the quadratic mean of individual diameters measured.

The ground surface of the crown (S) was calculated

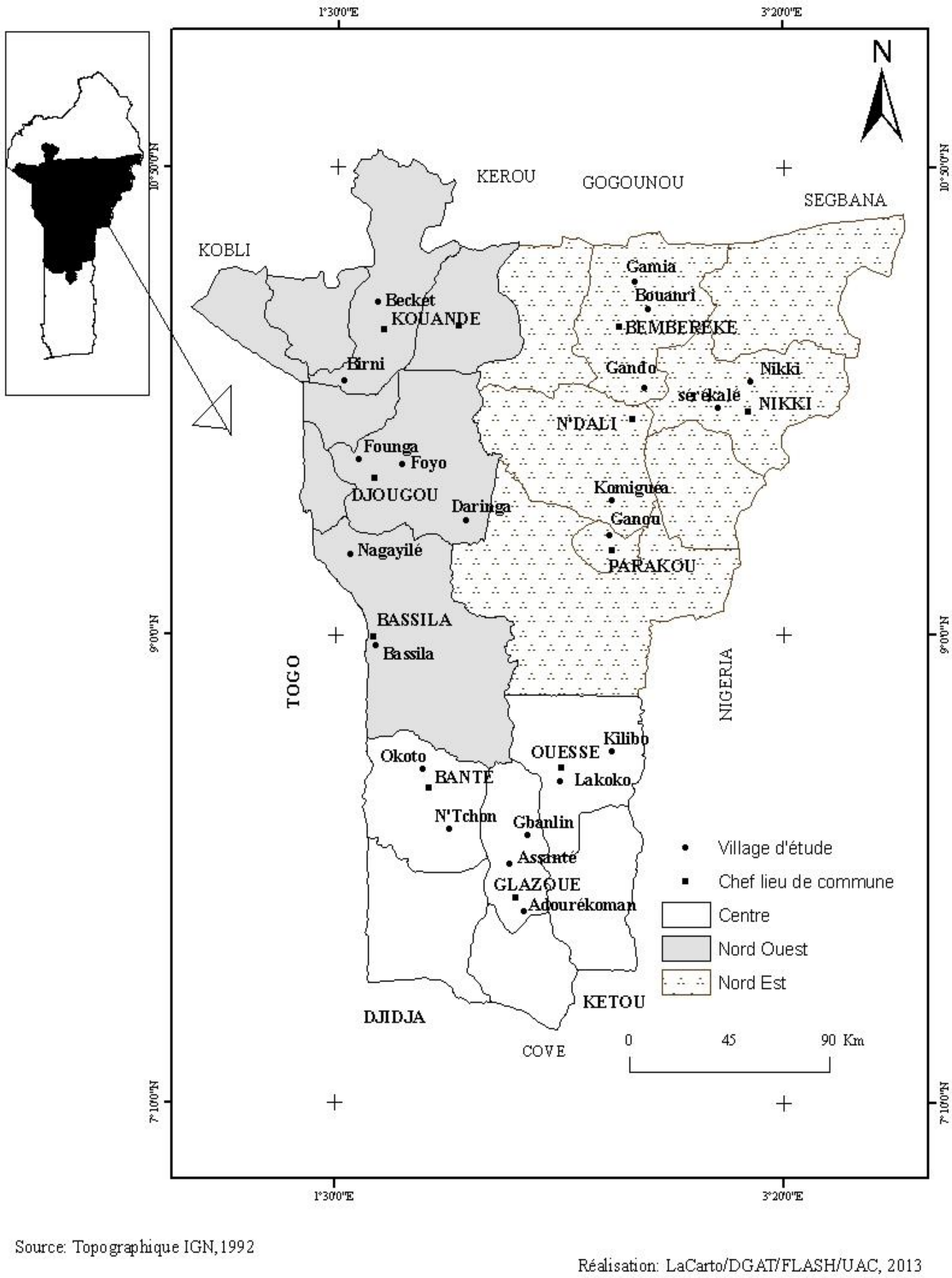

Figure 1. Geographical localization of the surveyed villages and districts of cashew in Benin.

from the following formula:

$$S = \frac{\pi \times D^2}{4} \quad (2)$$

D is the mean diameter of the crown of the tree.

Measurement of inflorescence characters

Figure 2 illustrates the different type of flowers observed on the panicle. The male flowers were characterized by 5 sepals, 5 petals and a long stamen surrounded by 5 small ones. The hermaphroditic flowers were identical to the

Table 1. Identify, site of collection and age of the 120 cashew (*Anacadium occidentale* L.) cultivars used in the study in Benin.

No.	ID	Site of collection	Age (years)
1	C1		15
2	C2		15
3	C3		15
4	C4		15
5	C5		12
6	C6		12
7	C7		9
8	C8	Kilibo	9
9	C9		9
10	C10		12
11	C11		9
12	C12		12
13	C13		9
14	C14		12
15	C15		15
16	C16		12
17	C17		12
18	C18		9
19	C19		15
20	C20		12
21	C21		12
22	C22		12
23	C23	Adourekouma	15
24	C24		9
25	C25		9
26	C26		9
27	C27		9
28	C28		15
29	C29		15
30	C30		15
31	C31		12
32	C32		12
33	C33		12
34	C34		12
35	C35		12
36	C36		15
37	C37	N'tchon	15
38	C38		15
39	C39		9
40	C40		15
41	C41		15
42	C42		9
43	C43		9
44	C44		15
45	O1		12
46	O2	Becket	12
47	O3		12

Table 1. Contd.

48	O4		12
49	O5		12
50	06		9
51	O7		9
52	O8		9
53	O9		9
54	O10		9
55	O11	Founga	15
56	O12		15
57	O13		15
58	O14		15
59	O15		15
60	O16		9
61	O17	Founga	9
62	O18		12
63	O19		12
64	O20		12
65	O21		9
66	O22		12
67	O23		9
68	O24		12
69	O25	Basila	9
70	O26		9
71	O27		15
72	O28		9
73	O29		9
74	O30		12
75	O31		12
76	O32		12
77	O33		12
78	O34		12
79	O35		15
80	O36		15
81	O37		15
82	E1	Komiguéa	15
83	E2		15
84	E3		15
85	E4		15
86	E5		15
87	E6		9
88	E7		9
89	E8		12
90	E9		12
91	E10	Bembèrèkè	12
92	E11		12
93	E12		12
94	E13		12

Table 1. Contd.

95	E14		12
96	E15		9
97	E16		9
98	E17		9
99	E18		9
100	E19		9
101	E20		15
102	E21		15
103	E22		15
104	E23		15
105	E24		15
106	E25		12
107	E26		12
108	E27		12
109	E28		12
110	E29		12
111	E30		9
112	E31		9
113	E32	Sérekalé	9
114	E33		9
115	E34		9
116	E35		15
117	E36		15
118	E37		15
119	E38		15
120	E39		15

males but with a pistil that is slightly longer than the stamen. The abnormal flowers possessed no stamina and stigma. For data collection, three panicles were randomly selected per tree and the different types of flower observed were counted in order to obtain: the numbers of flowers (NFP), number of male flowers (NFMP), number of hermaphrodite flowers (NFHP), number of abnormal flowers (NFAP) and flowers sex ratio (SR) of each panicle following the procedure of Masawe et al. (1996).

Measurement of characters related to the apple

These parameters (Table 2) were determined following Bioversity International (IBPGR 1986) protocol. The first two parameters: apple length and apple circumference, were taken using a tape meter whereas the weight was recorded using a balance. In total, five (5) apples per tree were considered during the sample for measurements.

Measurement of characters related to the nuts and kernels

For the data collection, nuts per tree (from the apples used in previous measures) were selected and the characters documented were the length and width of the nut, and the thickness of the kernel (IPGRI 1986). The nuts and the kernels were weighed using a balance (Mettler toledo, PB 3002 Delta Range, Switzerland). Once the nuts are weighed, the hulls were separated from the kernel using pruning shears.

Qualitative data collection

Qualitative data were collected using the method of Aliyu and Awopetu (2007) and Chipojola et al. (2009). This method is based on cashew descriptors developed by Bioversity International (IBPGR, 1986). These observations were made on the fruits (apple and nut) and were related to the color and shape of the apple, the color and shape of the nuts, growth characters and plant reproduction (Table 2).

Multivariate and statistical analysis

The data on the quantitative traits of cashew accessions was subjected the multivariate analyses and principal component analysis (PCA) using SAS software. The

Table 2. List of 22 quantitative and 14 qualitative characters and their acronyms used in the study.

Traits	Characters	Acronyms
Vegetative	Diameter of tree (cm)	DBH
	Height total of tree (cm)	H
	Crown diameter (cm)	D
	Crown surface (cm^2)	SH
Inflorescence	Number of flowers per panicle	NFP
	Number of male flowers per panicle	NFMP
	Number of hermaphrodite flowers per panicle	NFHP
	Number of abnormal flowers per panicle	NFAP
	Flowers sex ratio	SR
Apple	Apple weight (g)	PP
	Apple length (cm)	LP
	Apple circumference (cm)	CP
Nut	Nut weight (g)	PN
	Nut length (cm)	LN
	Nut lower width (cm)	LaN
	Shell weight (g)	R Co/N
	Ratio shell/nut	Pco
Kernel	Kernel weight (g)	PA
	Kernel length (cm)	LoA
	Kernel lower width (cm)	LaA
	Kernel thickness (cm)	EpA
	Out tum percent	OTP
	Ratio kernel/nut	R A/N
Qualitative	Apple color	CP
	Apple shape	FP
	Cashew apple apex	FAP
	Shape of cashew apple base	FBP
	Ridges on cashew apple	NP
	Nut shape	FN
	Nut color	CNM
	Shape of nut apex	FAN
	Shape of nut base	FAB
	Suture of nut	SIN
	Relative position of suture and apex	RSA
	Flanks of nut	FLN
	Disease incidence	DI
	Secondary flowering	SF

quantitative characters correlates with the axis of PCA were used to cluster analysis to conduct similarity estimates using Unweight Pair Group Method of Arithmetic Averages (UPGMA) in R software package. The data on the qualitative traits and the different cluster were subjected to the Factorial Correspondence Analysis (CFA) using MINITAB 15.0.

RESULTS

Quantitative variation

Table 3 gives the descriptive parameters (minimum, maximum, mean, standard deviation and coefficient of variation) of the analyzed quantitative variables. The

Figure 2. Different types of flowers detected and recorded during the study in cashew in Benin.

Table 3. Descriptive statistics of the variability of quantitative features in cashew trees of the surveyed villages and districts in Benin.

Variables	Minimum	Maximum	Mean	Standard deviation	CV
DBH (cm)	2.87	79.62	28.36	12.54	44.23
H (cm)	3.30	13.20	6.77	2.07	30.56
SH (cm^2)	3.14	1154.52	85.80	126.41	147.33
NFP	20.00	221.00	74.49	34.18	45.88
NFMP	16.00	209.00	67.50	33.14	49.09
NFHP	0	17.00	5.73	3.37	58.82
SR	0.004	0.273	0.086	0.055	63.72
PP (g)	1.00	115.00	50.24	27.316	54.36
LP (cm)	2.25	10.35	6.27	1.89	30.20
PN (g)	2.64	11.83	6.41	1.79	27.88
Pco (g)	1.38	8.33	4.48	1.30	29.14
LN (cm)	1.83	4.00	2.99	0.44	14.83
LaN (cm)	1.70	3.57	2.42	0.36	14.99
LoA (cm)	1.43	3.13	2.37	0.30	12.58
LaA (cm)	0.63	2.35	1.18	0.25	21.07
EpA (cm)	0.65	1.70	1.06	0.22	20.60
PA (g)	0.90	3.37	1.92	0.50	25.72

results showed that the coefficient of variation (CV) ranged from 12.58% (LoA) to 147.33% (SH), suggesting that important variation exists among trees for most of the studied characters. Some variables such as the SH, the SR, the DBH, the NFP and the NFMP showed the largest variations (CV > 40%) while the other variables such as LoA, LN and LaN displayed the lowest variation (CV < 15%).

The study revealed strong correlations between the variables (Table 4). For instance, regarding the inflorescence features, a significantly ($p < 0.001$) negative correlation was observed between the SR and the NFP. A highly significant correlation ($p < 0.0001$) was also found between the PP and the PN, whereas a very significant correlation ($p < 0.001$) was found between PP and the LN. Positive and highly significant correlations were also observed between the parameters of nuts (PN, LN, and LaN), kernel (LoA, LaA and PA) and the weight of the hull. The correlations between the LN and the parameters such as LaN, LoA and LaA and PA were highly significant. LoA was highly correlated with the LaA and PA.

Principal components analysis (PCA)

The principal components analysis showed that the first three axes explained 56.46% of the total variation (Table 5). First and second principal components explained with 32.17 and 13.74% respectively of the initial variation; while the third accounted for 10.65%. By considering the

Table 4. Pearson correlation coefficients between among plant descriptors of the surveyed villages and districts of cashew in Benin.

	DBH	H	SH	NFP	NFMP	NFHP	SR	PP	LP	PN	Pco	LN	LaN	LoA	LaA	EpA
H	0.500***															
SH	0.377***	0.228*														
NFP	-0.057 *NS*	0.034 *NS*	-0.089 *NS*													
NFMP	-0.041 *NS*	0.018 *NS*	-0.091 *NS*	0.994***												
NFHP	-0.097 *NS*	0.158 *NS*	0.030 NS	0.213*	0.107 *NS*											
Ratio	-0.075 *NS*	0.121 *NS*	0.098 *NS*	-0.360***	-0.450***	0.761***										
PP	-0.099 *NS*	-0.021 *NS*	0.011 *NS*	0.010 *NS*	-0.005 *NS*	0.110 *NS*	0.051 *NS*									
LP	-0.102 *NS*	0.048 *NS*	-0.094 *NS*	0.012 *NS*	-0.001 *NS*	0.098 *NS*	0.014 *NS*	0.826***								
PN	-0.101 *NS*	-0.087 *NS*	0.060 *NS*	0.051 *NS*	0.046 *NS*	0.025 *NS*	0.045 *NS*	0.344***	0.125 *NS*							
Pco	-0.107 *NS*	-0.068 *NS*	0.073 *NS*	0.033 *NS*	0.025 *NS*	0.045 *NS*	0.071 *NS*	0.346***	0.139 *NS*	0.973***						
LN	-0.052 *NS*	-0.158 *NS*	0.043 *NS*	0.077 *NS*	0.079 *NS*	0.023 *NS*	0.030 *NS*	0.284**	0.088 *NS*	0.774***	0.771***					
LaN	-0.057 *NS*	-0.098 *NS*	0.054 *NS*	0.104 *NS*	0.105 *NS*	-0.005 *NS*	-0.014 *NS*	0.339***	0.174 *NS*	0.793***	0.804***	0.751***				
LoA	-0.003 *NS*	-0.095 *NS*	0.014 *NS*	0.162 *NS*	0.163 *NS*	0.022 *NS*	-0.054 *NS*	0.244***	0.145 *NS*	0.580***	0.544***	0.712***	0.518***			
LaA	-0.027 *NS*	-0.136 *NS*	-0.063 *NS*	0.049 *NS*	0.056 *NS*	-0.060 *NS*	-0.070 *NS*	0.264**	0.216*	0.455***	0.409***	0.497***	0.510***	0.627***		
EpA	-0.088 *NS*	0.098 *NS*	0.115 *NS*	0.056 *NS*	0.066 *NS*	-0.101 *NS*	-0.112 *NS*	0.115 *NS*	0.055 *NS*	0.411***	0.391***	0.186*	0.307**	0.235*	0.270**	
PA	-0.147 *NS*	-0.094 *NS*	0.018 *NS*	0.132 *NS*	0.137 *NS*	-0.044 *NS*	-0.089 *NS*	0.340***	0.183 *NS*	0.773***	0.722***	0.650***	0.702***	0.736***	0.604***	0.396***

NS = non-significant (P > 0.05); * = significant (P < 0.05); ** = very significant (P < 0.001); *** = highly significant (P<0.0001) computed using standard linear Pearson correlation.

Table 5. Eigenvalues of the five first principal components (PCs).

PC axis	Eigen values	Proportions	Cumulated proportions
1	5.47	0.32	0.32
2	2.32	0.14	0.46
3	1.81	0.11	0.56
4	1.76	0.10	0.67
5	1.53	0.09	0.76

Table 6. Variables associated with the first three principal components.

Characters	PC1	PC2	PC3
Vegetative			
DBH	-0.13836 NS	0.06725 NS	-0.37666*
H	-0.13792 NS	0.11556 NS	-0.02586 NS
SH	0.02198 NS	0.22370 NS	-0.29409*
Floral			
NFP	0.15974 NS	-0.84304*	0.36909 NS
NFMP	0.15916 NS	-0.88875*	0.29474 NS
NFHP	0.01413 NS	0.27843 NS	0.70692*
RS	-0.04326 NS	0.75037 *	0.40398 NS
Apple			
PP	0.47511 NS	0.19239 NS	0.51496*
LP	0.29159 NS	0.14089 NS	0.58523*
Nut			
PN	0.90645*	0.11757 NS	-0.10434 NS
Pco	0.88643*	0.14964 NS	-0.08646 NS
LN	0.84579*	0.06254 NS	-0.09585 NS
LaN	0.85684*	0.04253 NS	-0.07429 NS
Kernel			
LoA	0.77207*	-0.07590 NS	-0.05957 NS
LaA	0.67022*	-0.02383 NS	-0.06264 NS
EpA	0.43534 NS	-0.05128 NS	-0.20582 NS
PA	0.87982*	-0.04452 NS	-0.07885 NS

NS = non-significant (P > 0.05); * = significant (P < 0.05) computed using standard linear Pearson correlation.

planes, axis 1 by 2 explains 45.81% of the total variation whereas the second axis 1 by 3 explains 42.82% of the variation.

The contribution of each quantitative variable to the formation of the PCs revealed that the nuts and kernel parameters were positively correlated to the first axis, except for the EpA (Table 6). Second axis explains the variations in the most of inflorescence parameters while third axis explains the variations related to the apple parameters showing LP and PP and the inflorescence parameter NFHP positively correlated to the axis. Finally, the data showed the dendrometric variables differently correlated with the three axes. For instance, DBH and SH were negatively correlated with third axis while the H was negatively correlated with the first axis and third axis.

Cashew tree classification and groups' description

To better appreciate the agro-morphological variability in cashew trees, a hierarchical clustering (HCA) was performed on the basis of evaluated quantitative traits. In this analysis, 13 of the variables that contribute to the total variability explained by the axis of the ACP were selected. These variables were NFP, NFMP, NFHP, SR, PP, LP, PN, LN, PCo, LaN, PA, LoA and LaA.

The HCA analysis based on the Euclidean distance computed using the UPGMA method clustered the trees into four homogenous groups (Figure 3). The cluster 1 was composed of 44 trees organized into two sub-groups while the cluster 2 was formed by three sub-groups, contained 42 trees. Finally, cluster 3 and 4 were respectively formed of 9 and 25 trees.

The results of the HCA were subjected to analysis of variance (Table 7). The analysis displayed 13 variables, from which, 4 showed a highly significant variation between inferred groups ($p < 0.0001$): NFP, NFMP, PP and LP, 3 showed very significant variation ($p < 0.001$): SR, LA and PA, 5 showed significant variation ($p < 0.05$): NFHP, PN, PCo and LaA and no significant variation has been detected for one variables ($p > 0.05$): LN.

Cluster 1, composed of 44 trees, was characterized by trees that flowered weakly (low NFP, reduced NFMP and NFHP) but gave very large and long apples and nuts. The second cluster, with its 42 individuals, was mostly characterized by trees that flowered moderately (an average

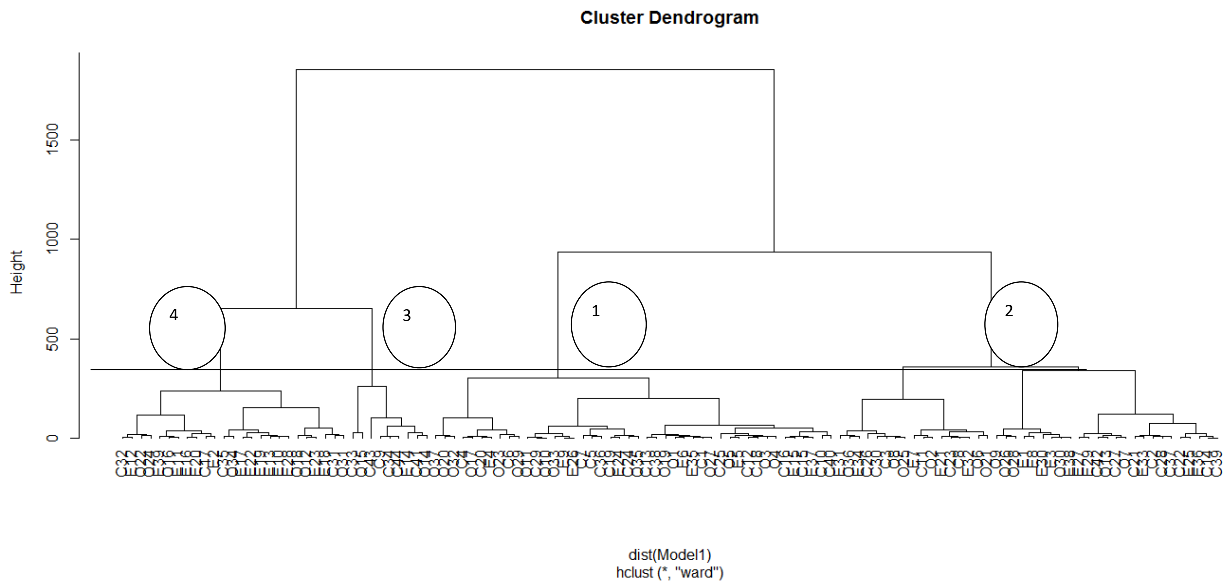

Figure 3. Euclidean distances-based dendrogram constructed using quantitative descriptors of the surveyed villages and districts of cashew in Benin.

Table 7. Quantitative description of the different groups of trees characterized.

Variables	Clusters				F	CV
	1	2	3	4		
NFP	61.77^{c}	54.62^{c}	162.56^{a}	98.56^{b}	134.59***	21.95
NFMP	54.27^{c}	49.07^{c}	152.11^{a}	91.28^{b}	128.96***	23.88
NFHP	6.36^{b}	4.57^{b}	7.67^{a}	5.88^{b}	3.37*	57.14
SR	0.104^{a}	0.089^{b}	0.049^{c}	0.062^{b}	5.25**	60.55
PP	74.82^{a}	22.77^{c}	48.72^{b}	41.89^{b}	41.51***	38.23
LP	7.76^{a}	5^{c}	6.31^{b}	5.76^{bc}	26.24***	23.60
PN	6.91^{a}	5.88^{a}	6.85^{a}	6.26^{a}	2.74*	27.29
PCo	4.88^{a}	4.10^{a}	4,85^{a}	4,28^{a}	3.14*	28.38
LN	3.09^{a}	2.84 ^{a}	3.02 ^{a}	3.03 ^{a}	2.54^{NS}	14.55
LaN	2.52^{a}	2.31^{b}	2.61^{a}	2,37^{b}	3.72*	14.50
LA	2.43^{a}	2.21^{b}	2.40^{a}	2.51^{a}	7.25**	11.69
LaA	1.23^{a}	1.08^{a}	1.23^{a}	1.23^{a}	3.75*	20.38
PA	2.07^{a}	1.72^{a}	2.11^{a}	2.00^{a}	4.26**	24.73

NS = non-significant ($P > 0.05$); * = significant ($P < 0.05$); ** = very significant ($P < 0.001$); *** = highly significant ($P < 0.0001$) computed using standard linear Pearson correlation.

55 flowers per panicle) with small apples and small nuts. The cluster 3, composed of nine individuals, contained trees that flowered abundantly (an average of 163 flowers per panicle) and produced large apples and large nuts. Finally, cluster 4 with 25 trees was formed by plants that flowered moderately but produced apples and nuts of medium size.

Qualitative variation

Figure 4 showed the results of the Factorial Correspondence Analysis (FCA) performed on the data related to the inferred classes and qualitative descriptors of trees. The first two components expressed 81.44% of baseline information. Axis 1, linked to the morphological groups 1, 2 and 4, was characterized by several qualitative descriptors such as the FN, the TI, the FP, the yellow color of the apple, the FAB and SIN. Axis 2, correlated to the group 3 was explained by the qualitative descriptors such as the red color of the apple, the FP, the NP, the FBP, the FN, the RSA and FLN. In summary, trees of group 1 had oblong nuts with rounded apex and apples with rounded base and oblique apex. Concerning group

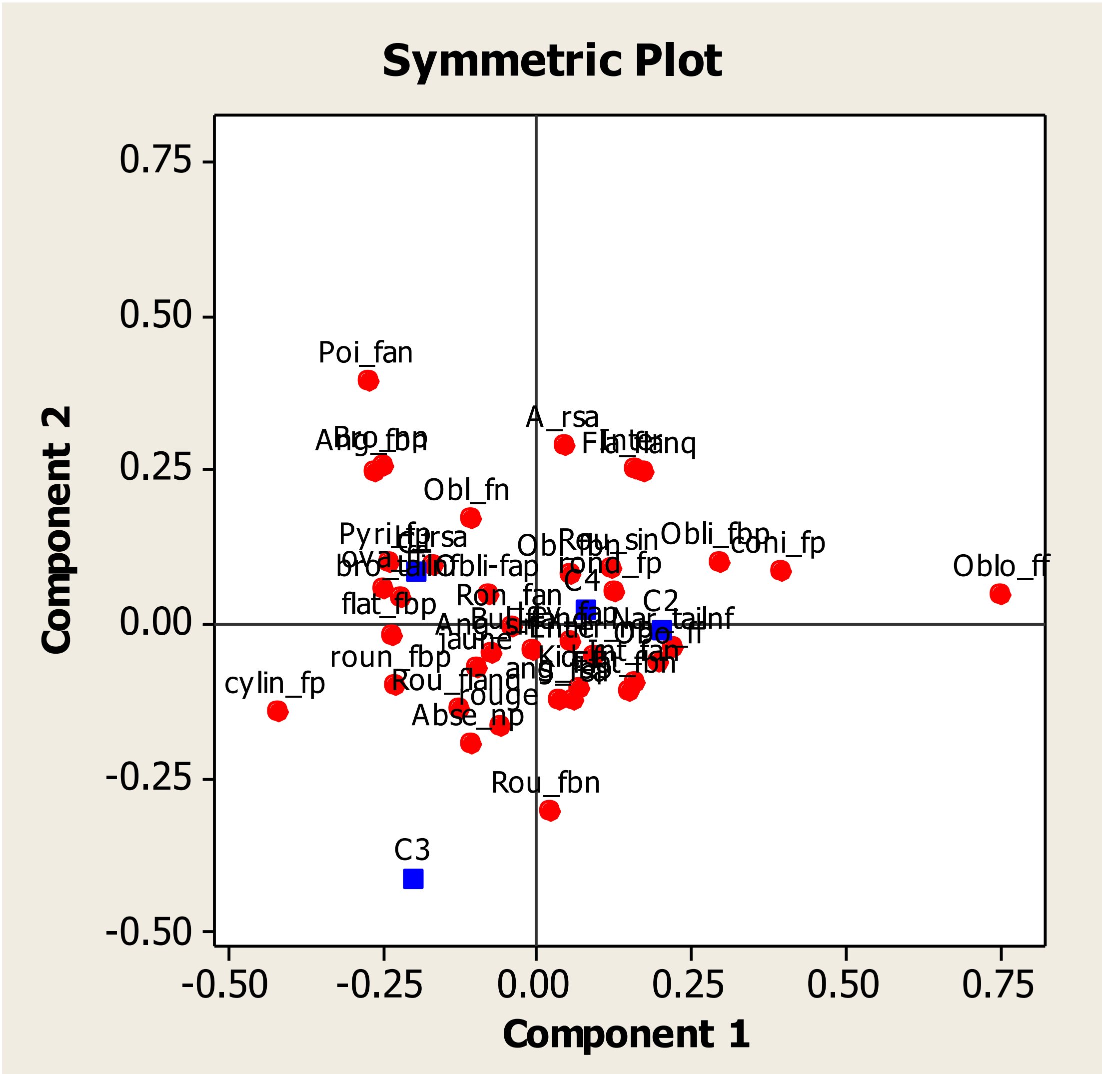

Figure 4. Factorial Correspondence Analysis showing the correlations of axes 1 and 2 based on qualitative and different morphological groups of the villages and districts of cashew in Benin.

4, trees had conical or rounded apples, apples with oblique base and nuts with rounded suture. Group 2 was characterized by trees with kidney-like nuts displaying rounded base and small inflorescences. The trees of group 3 had cylindrical apple with rounded base and without rib. Finally, both red and yellow apples were observed in this group.

DISCUSSION

Knowledge of genetic diversity is an important step in the process of plant breeding and conservation of plant genetic resources (Adoukonou-Sagbadja et al., 2007). Diverse works conducted around the world such as those of Chipojola et al. (2009) and Castro et al. (2011) on cashew in Malawi and Brazil, respectively, revealed the important genetic diversity in cashew germplasm. The present study confirmed these results by revealing a significantly large agro-morphological diversity within cashew trees cultivated in Benin. This wide variation is particularly observed in agronomic characteristics such as LP, the PN, and SR on the inflorescence, suggesting a good prospect for selection and improvement of the plant in Benin.

The classification of cashew trees in different groups is important as it can help breeders in making selection of appropriate genotypes for heterotic crosses (Adoukonou-Sagbadja et al., 2007). The analysis of variance of the inferred four classes confirmed the significant differences between them (Table 7) and also revealed that the classes have different agronomic performances. These groups can thus be used as heterotic groups for cashew breeding in Benin. Similar approaches have been suggested for cashew breeding by several authors in many countries such as Brazil (Castro et al., 2011), Malawi

(Chipojola et al., 2009) and Nigeria (Aliyu, 2012).

From this study, we observed that the grouping of cashew cultivars followed their geographic origin and agro-morphological characteristics. Thus, in a given area, cultivars often have the same characteristics on some specific traits. This can be explained by the selection criteria used by producers but also by the accession adaptation to similar eco-geographical conditions (Aliyu and Awopetu, 2007). But no group was composed of single plants from a same growing region. Finally, some inferred groups contained individuals from the three study areas, indicating a genetic similarity background between these individuals. This observation can be explained by seed exchanges between producers conducting to a wide dispersion of same cultivars through different cashew producing regions in Benin. Same observations were also made by Aliyu (2012) in Nigeria confirming the dynamic germplasm exchanges between farmers and their perpetual needs to improve the productivity of their cashew plantations. The concordance between the cashews groups' characteristics in this study with those observed in other countries such as Nigeria (Aliyu, 2012) suggests the possible single origin of the plant and thus confirms the exogenous source of cashew in Benin (Chabi Sika et al., 2013).

The principal component analysis (PCA) showed that the parameters related to nuts, apple and inflorescence are highly correlated with the axes. These results are consistent with those reported by Chipojola et al. (2009) which showed strong correlations between nut, apple and inflorescence parameters. It appeared from these results that the characters related to the apple, the inflorescence, the nuts and the kernel play a very important role in the classification of cashew trees.

It is important to note that the correspondence between local names based on peasant descriptions allowed grouping the cashew varieties into 9 morphotypes within which 4 were defined on the basis of nut characteristics and 5 were defined on the basis of apple characteristics (Chabi Sika et al., 2013). For example, in the folk description, there was the group of large nuts and apple and the group of small nuts and apple that were corresponded to clusters I and II respectively inferred in the present study.

We also observed a correspondence between the peasant classification and morphological classification even though farmers had not knowledge about any inflorescence. Similar results were already obtained in fonio (Adoukonou-Sagbadja et al., 2007) and sorghum (Missihoun et al., 2012), confirming the importance of local knowledge and folk taxonomy in a preliminary survey of crop diversity. According to the Caribbean Technological Consultancy Services Network (1993), the cashew plant has large variations in their capacity for growth, quality and quantity of nuts and apple produced. The cross pollination, a particular characteristic of cashew tree, contributes greatly to this variability.

Finally, in contrast to the quantitative traits, a relatively low level of variability between trees was observed in qualitative characters. This low variability, especially regarding the apple colors and the kernel shape could be explained by the producers' preferences. Similarly, in their study Chabi Sika et al. (2013) they observed that producers preferred specific nut color and shape more than others. Therefore it appears, in the cashew varietal classification, qualitative traits are less important than quantitative variables. The same results were obtained for studies of cashew tree in other places around the world, like Malawi (Chipojola et al., 2009), Brasil (Castro et al., 2011) and Nigeria (Aliyu et al., 2007) but not only on cashews also in other species such as *Sesamum radiatum* (Adéoti et al., 2012) in Benin. Note that qualitative traits, though displaying less diversity, shall be analyzed by curators and breeders in genetic diversity studies, as they are essential in peasant fields where the phenotypic selection criteria has great influence.

CONCLUSION

Morphological characterization of Beninese cashew trees from 36 descriptors showed variability within the population. Most of the variations are related to the inflorescence, the apple, the nuts and kernel. The trees belonging to the cluster 1 are the best for the farmer. This study provides useful information that can be used in breeding program to make a better use of cashew trees.

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ABBREVIATIONS: PCA, Principal component analysis; **HCA,** hierarchical clustering analysis; **IBPGR,** International Board for Plant Genetic Resources; **FCA,** factorial correspondence analysis; **UPGMA,** unweighted pair-group method with arithmetic averages; **DBH,** diameter of tree; **H,** height total of tree; **D,** crown diameter; **SH,** crown surface; **NFP,** number of flowers per panicle; **NFMP,** number of male flowers per panicle; **NFHP,** number of hermaphrodite flowers per panicle; **NFAP,** number of abnormal flowers per panicle; **SR,** flowers sex ratio; **PP,** apple weight; **LP,** apple length; **CP,** apple circumference; **PN,** nut weight; **LN,** nut length; **LaN,** nut lower width; **R Co/N,** ratio shell/nut; **PA,** kernel weight; **LoA,** kernel length; **LaA,** kernel lower width; **EpA,** kernel thickness; **OTP,** out tum percent; **R A/N,** ratio kernel/nut; **CP,** apple color; **FP,** apple shape; **FAP,**

cashew apple apex; **FBP,** shape of cashew apple base; **NP,** ridges on cashew apple; **FN,** nut shape; **CNM,** nut color; **FAN,** shape of nut apex; **FAB,** shape of nut base; **SIN,** suture of nut; **RSA,** relative position of suture and apex; **FLN,** flanks of nut; **DI,** disease incidence; **SF,** Secondary flowering.

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