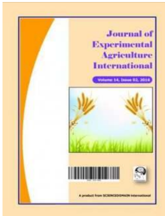

Journal of Experimental Agriculture International
15(3): 1-19, 2017; Article no.JEAI.30512
Previously known as American Journal of Experimental Agriculture
ISSN: 2231-0606

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Agro-morphological Variability of Maize Cultivars in South Benin

Florent J. B. Quenum[1*], Léonard E. Ahoton[1], Vincent Ezin[1] and Arnaud Djanta[1]

[1]*Faculty of Agronomic Sciences, University of Abomey-Calavi, Republic of Benin.*

Authors' contributions

This work was carried out in collaboration between all authors. Authors FJBQ, AD and LEA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors FJBQ, LEA, AD and VE managed the analyses of the study. Authors VE and AD managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2017/30512
Editor(s):
(1) Renata Guimarães Moreira-Whitton, Departamento de Fisiologia - Instituto de Biociências-USP, Cidade Universitária, Brazil.
Reviewers:
(1) Mohammad Tahir, Sugar Crops Research Institute, Pakistan.
(2) Harun-Ur-Rashid, Sher-e-Bangla Agricultural University, Bangladesh.
(3) J. M. Kariuki, Kenyatta University, Kenya.
Complete Peer review History: http://www.sciencedomain.org/review-history/17866

Original Research Article

Received 14th November 2016
Accepted 15th January 2017
Published 16th February 2017

ABSTRACT

In Benin, maize ranks the first among cereal production. Local maize varieties are mainly produced in the southern parts of Benin. The objective of this work was to investigate the agro-morphological diversity of 58 maize cultivars collected from 14 communes in South-Benin. The experimental design used was a block of Fisher (RCB) with 4 replications. Twenty one (21) quantitative and four (04) qualitative descriptors for maize traits were used in this study. From the results obtained, the cultivars were grouped into 3 classes by hierarchical classification both for quantitative traits and qualitative traits, thus indicating that the two categories of traits showed the same level of variability with very highly significant ($p < 0.001$) or highly significant ($p < 0.01$)differences. The cultivar collection consisted of 13 early cultivars (Group 1), 18 cultivars of intermediate cycle (Group 2) and 27 late cultivars (Group 3). In addition, the phenotypic variability of cultivars was more related to their agronomic and physiological behaviors than their geographic origin. The evaluated traits permit to identify the cultivars that can be used in the breeding programs so as to make selected cultivars available to producers. Diversity observed among the cultivars could be useful for further study of maize in Benin and conservation of genetic resources.

**Corresponding author: E-mail: quenumfl@yahoo.com;*

Keywords: Agro-morphological diversity; cultivars; Zea mays; classification; South Benin.

1. INTRODUCTION

Maize is a staple food for millions of people in developing countries. This cereal is consumed in most of West African countries. In Benin, it ranks first among cereal crops [1], with a wide range of traditional varieties and improved ones [2]. Its production increased from 829380 tons during the 2005-2006 campaign to 1345821 tons in 2013-14 [3]. Several zones of production are observed, but the principal zone has been the southern parts of the country where it has been grown extensively for many years before extending toward the northern parts of the country [4]. Therefore, the southern parts may present a diversity of traditional cultivars. Studies of diversity of cultivated crop plants demonstrated clearly that the traditional varieties, although less productive, are genetically more diverse than the improved varieties [5]. But the promotion of annual income crops and improved varieties resulted in the decline of local cultivars in the remote villages [6]. The risk of biological diversity loss is associated with climate variability, degradation of soils in relationship with high demographic growth, pest attacks and the low marketing of produces [7].

In order to avoid the decline of the biological diversity of our cultivars, this study was initiated. Therefore, the main objective of this work was to study the agro-morphological diversity of maize cultivars with a view to their storage for the various agro-morphological uses.

2. MATERIALS AND METHODS

2.1 Description of the of Study Area

The field experimentation was carried out in the experimental farm of the Faculty of Agronomic Sciences located at Sékou (06°37 min north latitude, 02°13 min East longitude and 90 m of altitude) from May to September 2015. The climate is of sub equatorial type with two rainy seasons and two dry seasons. The average annual rainfall varies between 800 mm and 1000 mm [8]. The cumulative of rainfall during the period of the experiment (May to September 2015) was 410 mm with an average temperature ranging from 22.8°C to 27.05°C (Fig. 1). The soils of the station are of degraded ferralitic soils or bar soils.

2.2 Plant Material

It consisted of seeds of maize cultivars collected from farmers in 14 communes with 2 villages per commune; and two producers per village). The communes visited were Aplahoué, Dogbo and Toviklin communes in the Department of Couffo; Athiémé and Bopa in the Department of Mono; Akpro-Missérété, Ifangni and Sèmè in the Department of Ouémé; Bonou and Adja-Ouèrè in

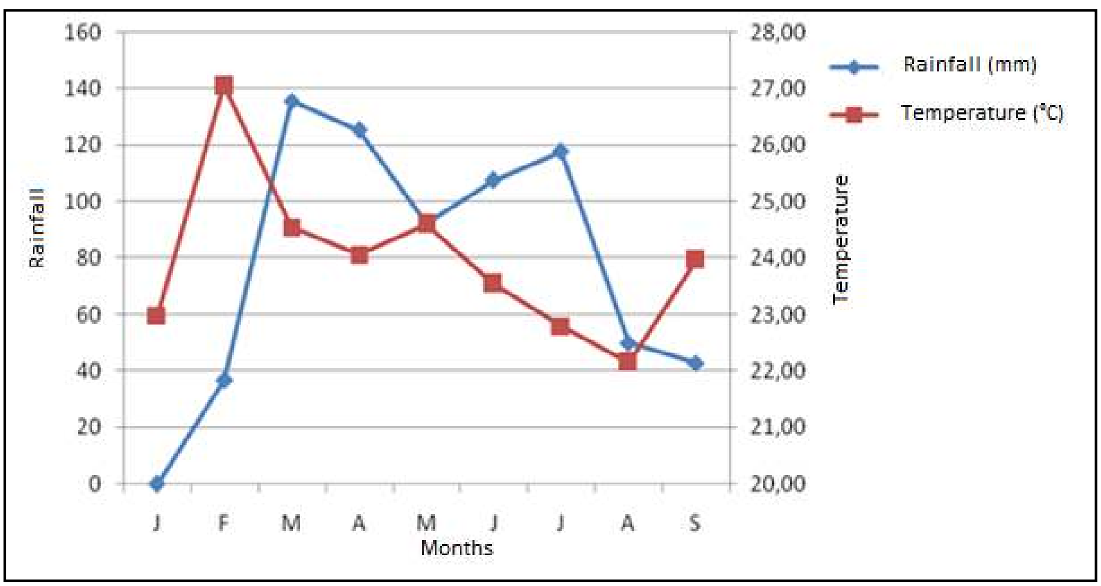

Fig. 1. Evolution of the rainfall and the temperature during the period of the experiment
Source: CRA-Niaouli 2015

the Department of Plateau; Agbangnizoun, Covè and Zangnanado in the Department of Zou and Abomey-Calavi in the Department of Atlantic (Fig. 2). A total of 58 samples have been collected, and kept at a constant temperature of 5℃ in order to maintain the viability of the seeds until the sowing.

2.3 Methods

2.3.1 Experimental layout

The experimental design was a block of Fischer (RCB) with 4 replications. The treatments were the 58 maize cultivars collected. Each experimental unit had an area of 3.6 m^2 (3 m long x 1.2 m wide). The distance between two experimental units was 0.6 m and between two blocks the gap was 1 m. The ploughing of the experimental unit was at the depth of 25 to 30 cm which was followed by the application of basal dose of phosphorus and potash at the rate of 100 Kg/ha P_2O_5 and 30 Kg/ha KCl. Hence each experimental plot got 78 g of TSP (Triple Super Phosphate) and 18 g of KCl (Potassium Chloride). Seed was sown in the rows with 2 seeds per hole. Seed were sown in the rows with 2 seeds per hole. The distance was 0.80 m between rows and 0.40 m between holes with a density of 45,000 plants per hectare. The quantity of urea applied for during the experiment was 100 kg/ha, or 36 g of urea per experimental plot, just after the second weeding or 45 days after the seeding.

2.3.2 Measurement of traits

A total of 25 parameters of which 21 quantitative and 4 qualitative were measured, related to morphological and agronomic characteristics of different cultivars according to maize descriptor [9] (Table 1). These observations were made at different stages of plant development.

The quantitative parameters during vegetative phase include: plant height (HPla), circumference at the collar (CiCo), leaf length (LonF) and the leaf width (LarF) from the tallest maize plants i.e. the 5 self-fertilized maize plants on each plot, days to flowering [the number of days required for 50% plants to produce maize silk (DaFf) and the number of days for the appearance of panicles (DaFm)].

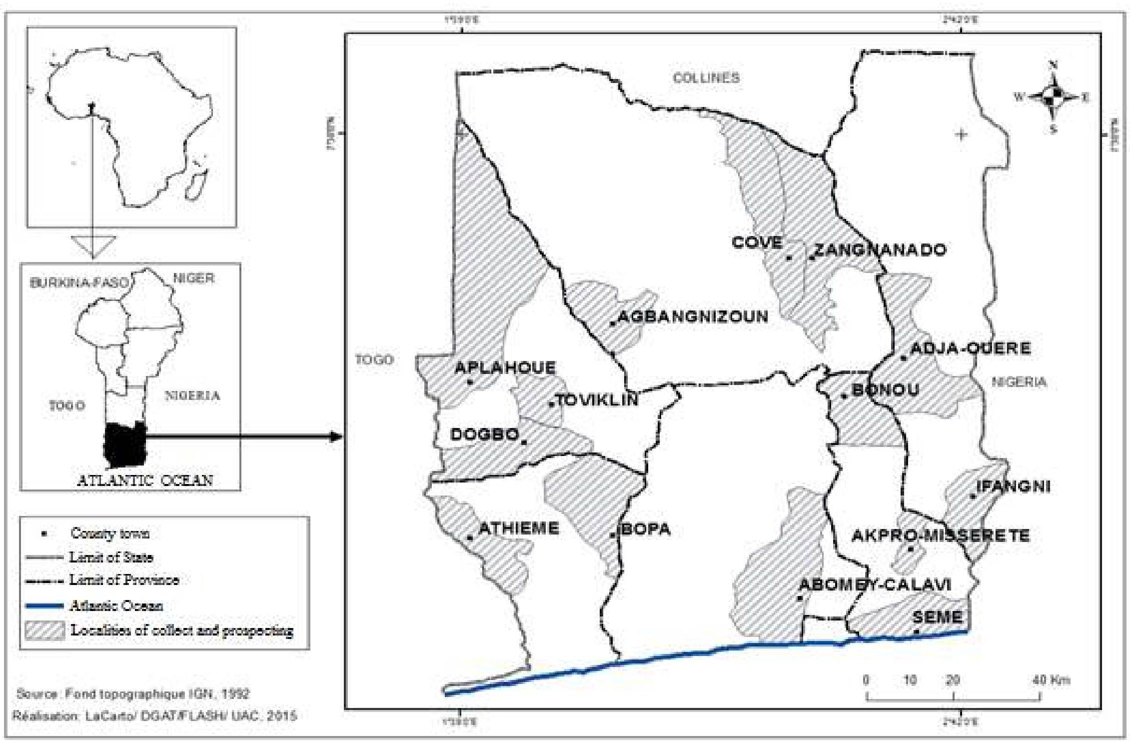

Fig. 1. Zonal map of the 58 cultivars collected for the study

The quantitative parameters during reproductive phase wererecordedfrom five (05) marked self-fertilized plants in each experimental unit. The maize ears of these plants were then protected by sachets in order to avoid cross-fertilization which is predominant (95%) in maize.These included: panicle length (LonP) and the lengthbetweenpanicle ramification (DrPa) after the stage of milky grain; the number of primary branches of the panicle (NbpP) and the number of leaves on the top of the ears (NfEP), including the leaf of the ear; the height of the ear (HEpi); the duration of the cycle (CsMa) in days.

The yield parameters weremeasured as follows: number of ears per plant (NepP); length (LoEp) and diameter of the ear (DiEp); number of grain rows per ear (NrgE) and the average number of grains per row (NmGr) These parameterswere measured on five (05) randomly selected ears among the pure ears harvested on each plot, after a preliminary drying in the sun.

The qualitative traits included: color of the silk (ColS) and color of the panicle (ColP) based on the color code of the Royal Horticultural Society, color of the grains and shape of the outer surface of the grains(FseG) with the aid of magnifying glasses.

Table 2 presents the qualitative parameters measured, the different traits associated with them and their codes.

2.3.3 Method of data analysis

Minitab 14 was used for the getting descriptive statistics and R 3.0.3 was used for other analyses. The analysis of variance (ANOVA) and principal components analysis (PCA) were only

Table 1. Quantitative descriptors used

No.	Quantitative characters	Abbreviatons
1	Circumference at the collar	CiCo
2	Leaf length	LonF
3	Leaf width	LarF
4	Length between panicle ramification	DrPa
5	Length of the panicle	LonP
6	Number of primary branches of the panicle	NbpP
7	Number of ears per plant	NepP
8	Height of the ear	HEpi
9	Plant height	HPla
10	Number of leaves on the top of the ears	NfEp
11	Male semi-flowering cycle	DaFm
12	Female semi-flowering cycle	DaFf
13	Duration of the cycle or semi-maturity cycle	CsMa
14	Length of the ear	LoEp
15	Diameter of the ear	DiEp
16	Number of grain rows per ear	NrgE
17	Average number of grains per row	NmGr
18	Grain length	LoGr
19	Grain width	LaGr
20	Grain thickness	EpGr
21	Weight of 100 grains	P100

Table 2. Qualitativetraits andassociated variables

Qualitative characters	Traits
Inflorescence	
Color of the panicle (COLP)	PoPa (purpleP), VePa(greenP), VePP (greenpurpleP)
Color of the silk (ColS)	PoSo (purpleS), VeSo(Green), VePS(greenpurpleS)
Grain	
Color of the grains (ColG)	ViGr (violet), BLGR (white), JaGr (yellow), PoGr (purple), OrGr (orange)
Shape of the outer surface of the grains (FseG)	Agr (shriveled), InGr (indented), PlGr (flat), ArGr (rounded).

computed forthe quantitative data. The qualitative data were subjected to the analyses of multiple correspondences (MCA). The hierarchical cluster analysis (HCA) was done on both quantitative and qualitative data.

3. RESULTS

3.1 Quantitative Variability among Cultivars

The coefficients of variation vary from 7.98 to 34.51 (Table 3). Flowering and maturity traits such as, female semi-flowering cycle (DaFf), male semi-flowering cycle (DaFm) and semi-maturity cycle (CsMA), showed lower values of the coefficient of variation (<10%) indicating low variability for these traits.

3.2 Correlation among Variables

The positive correlations between the vegetative parameters and the reproductive parameters were observed in the study. It appeared that the height of the cultivars influenced positively the circumference at the collar, leaf length and number of leaves above the ear. In addition, the length of the panicle also influenced positively the size of the ear, the number of grain rows per ear, the average number of grains per row and the length of the grain. On the other hand, grain length showed a negative association with their thickness. Moreover, an excessive development of panicles reduced grain width (Table 4).

3.3 Principal Components Analysis

Table 5 presents the Eigenvalues and cumulative percentages of quantitative parameters on the axes. The proportions of these net values representing the variances of the components indicate that 40.66% of the information is explained by the first component. The first two components explain 62.33% of the total variability of maize cultivars. These two components are therefore enough to summarize the essential information related to agro-morphological traits of these cultivars. It is considered that the two components are the axes and 16 of the variables are represented on these axes (Table 6). The projection of the quantitative characters on the axes 1 and 2 (Fig. 3), reveals 3 distinct groups of traits according to their positioning in the plane. In a detailed way:

Axis 1: Included fifteen (15) variables of which eleven (11) were highly and positively correlated: circumference at the collar (CiCo; 78.71%), leaf length (LonF; 69.3%), length of the panicle (LonP; 85.44%), plant height at maturity (HPla; 78.95%), the number of leaves above the ear (NfEp; 81.23%), the semi-maturity cycle (CsMa; 75.04%), ear length (LoEp; 75.97%), diameter of the ear (DiEp; 72.65%), number of grain rows per ear (NrgE; 80.49%), average number of grains per row (NmGr; 80.37%) and grain length (LoGr; 81.29%). On the other hand, this axis was negatively correlated only with grain thickness (EpGr; -51.60%). It is the axis of the late cultivars, big sizes with big and long ear and less thick grain, but long. Axis 1 is therefore the axis of the height, cycle and the productivity of cultivars.

Axis 2: Consisted of seven (7) variables of which five (5) were highly correlated. It was positively correlated with the length between panicle ramification (DrPa); 68.96%), the number of primary branches per panicles (NbpP; 87.81%), the height of the ear (HEpi; 78, 36%) and negatively with the weight of 100 grains (P100; -67.40%) and the width of the grain (LaGr ; -74.53%). Axis 2 is the axis of the cultivars having a lot of spikelet, good height of ear, but small grain. It is therefore the axis of the cultivars with low productivity. The projection of the individuals in the plane formed by the system of axes 1 and 2 also shows 3 groups of individuals in close relationship with the 3 groups of traits previously identified (Fig. 4). In effect, the cultivars CO1, CO2, CO3; ZA1, Za2, ZA5, ZA7; AP3, Ap4 and TA2 showed good performance with variables which were positively correlated to axis 1. These cultivars were late, large sizes, producing large and long ear with long grain. Then, the cultivars AO1, AO2, AO4; if1, if3, fi5, MI1, MI5, Mid7 and Ag1 negatively positioned on the same axis, are early and produced thick grains. On axis 2, cultivars BO3, Bo5; Ca2, Ca4; Bp2 and If1 are positively positioned. Therefore, these cultivars produced a lot of spikelet and their ears were inserted at a good height on the stem. But negatively, cultivars Bp3, Bp4; Do2, Do5; If3; Mi4 and Za6 were connected to the same axis. Therefore, these cultivars had good productivity with big grains.

Table 3. Descriptive statistics for quantitative parameters

No.	Variables	Mean	CV (%)	Min	Max
1	CiCo	7.0418	17.46	3	12
2	LonF	68.452	21,03	6.6	105.7
3	LarF	6.8837	21.54	1.5	16.8
4	DrPa	12.092	27,52	4.5	30
5	LonP	35.158	16,15	13.1	58
6	NbpP	16.219	28.1	4	34
7	NepP	1.8879	25,82	1	3
8	HEpi	80.498	27,92	27	177
9	HPla	153.37	17.04	70	238.9
10	NfEp	5.9125	14.02	3	9
11	DaFm	51.819	8.66	42	64
12	DaFf	54.987	8.04	45	67
13	CsMa	98.427	7.98	86	126
14	LoEp	109.59	20.7	11.78	188
15	DiEp	36.32	34.51	16.41	420.3
16	NrgE	12.421	14.85	7	20
17	NmGr	24.812	22.05	7	42
18	LoGr	9.5318	10.54	6.24	12.41
19	LaGr	8.5978	10.53	5.8	18.13
20	EpGr	4.3845	13.37	3.04	8.4
21	P100	24.903	19.09	13.2	40.8

Table 4. Phenotypic correlation coefficient among each pair of quantitative traits

Traits	CiCo	LonF	LarF	DrPa	LonP	NbpP	NepP	HEpi	HPla	NfEp	DaFm	DaFf	CsMa	P100	LoEp	DiEp	NrgE	NmGr	LoGr	LaGr	EpGr
CiCo	1.000																				
LonF	**0.810***	1.000																			
LarF	**0.754***	**0.826***	1.000																		
DrPa	**0.559***	0.439	0.308	1.000																	
LonP	**0.647***	**0.612***	**0.536***	0.433	1.000																
NbpP	0.332	0.136	0.033	**0.752***	0.035	1,000															
NepP	0.235	0.107	0.078	0.314	0.034	0.437	1.000														
HEpi	**0.699***	0.483	0.314	**0.764***	0.336	**0.756**	0.413	1.000													
HPla	**0.784***	**0.583***	0.402	**0.650***	**0.578***	**0.546**	0.214	**0.878***	1.000												
NfEp	0.488	0.415	0,358	0.069	**0.691***	-0.088	-0.215	0.160	**0.538***	1.000											
DaFm	0.200	-0.021	-0.173	0.239	0.299	0.347	0.156	0,492	**0.604***	0.400	1.000										
DaFf	0.195	-0.028	-0.186	0.243	0.280	0.360	0.157	**0.504***	**0.603***	0.386	**0.996***	1.000									
CsMa	0,442	0.290	0.217	0.241	**0.657***	0.189	0.030	0.427	**0.652***	**0.649***	**0.756***	**0.745***	1,000								
P100	0.218	0.267	0.247	-0.192	0.397	-0.448	-0.271	-0.206	0.090	0.497	-0.104	-0.121	0.256	1.000							
LoEp	0,384	0.396	0.287	0.081	**0.759***	-0.163	-0.246	0.040	0.371	**0.757***	0.263	0.237	0.476	**0.534***	1.000						
DiEp	0.400	0.453	0.390	-0,030	**0.584***	-0,234	-0.217	0.037	0.349	**0.659***	0.245	0.227	0,493	0.485	**0.675***	1.000					
NrgE	**0.551***	0.480	0.412	0.168	**0.610***	0.090	-0.108	0.363	**0.618***	**0.700***	0.465	0.452	**0.616***	0.146	**0.600***	**0.652***	1.000				
NmGr	0.415	0.416	0.320	0.022	**0.760***	-0.192	-0.174	0.084	0.387	**0.737***	0.351	0.328	**0.531***	0.413	**0.932***	**0.715***	**0.685***	1.000			
LoGr	**0.585***	**0.552***	0.496	-0.017	**0.670***	-0,234	-0.087	0.165	0.437	**0.670***	0,229	0.206	**0.524***	**0.628***	**0.683***	**0.721***	**0.638***	**0.769***	1.000		
LaGr	0.083	0.136	0.169	-0.280	0.402	**-0.582***	-0.273	-0.345	-0.062	0.427	-0.072	-0.083	0.270	**0.856***	0.498	**0.501***	0.082	0.406	**0.537***	1.000	
EpGr	**-0.517***	-0.396	-0.389	-0.158	-0,406	-0.030	-0.152	-0.292	-0.361	-0.306	-0.192	-0.178	-0.280	0.141	-0.260	-0.332	-0.429	-0.461	**-0.519***	0.085	1.000

**significant at 5% level of probability*

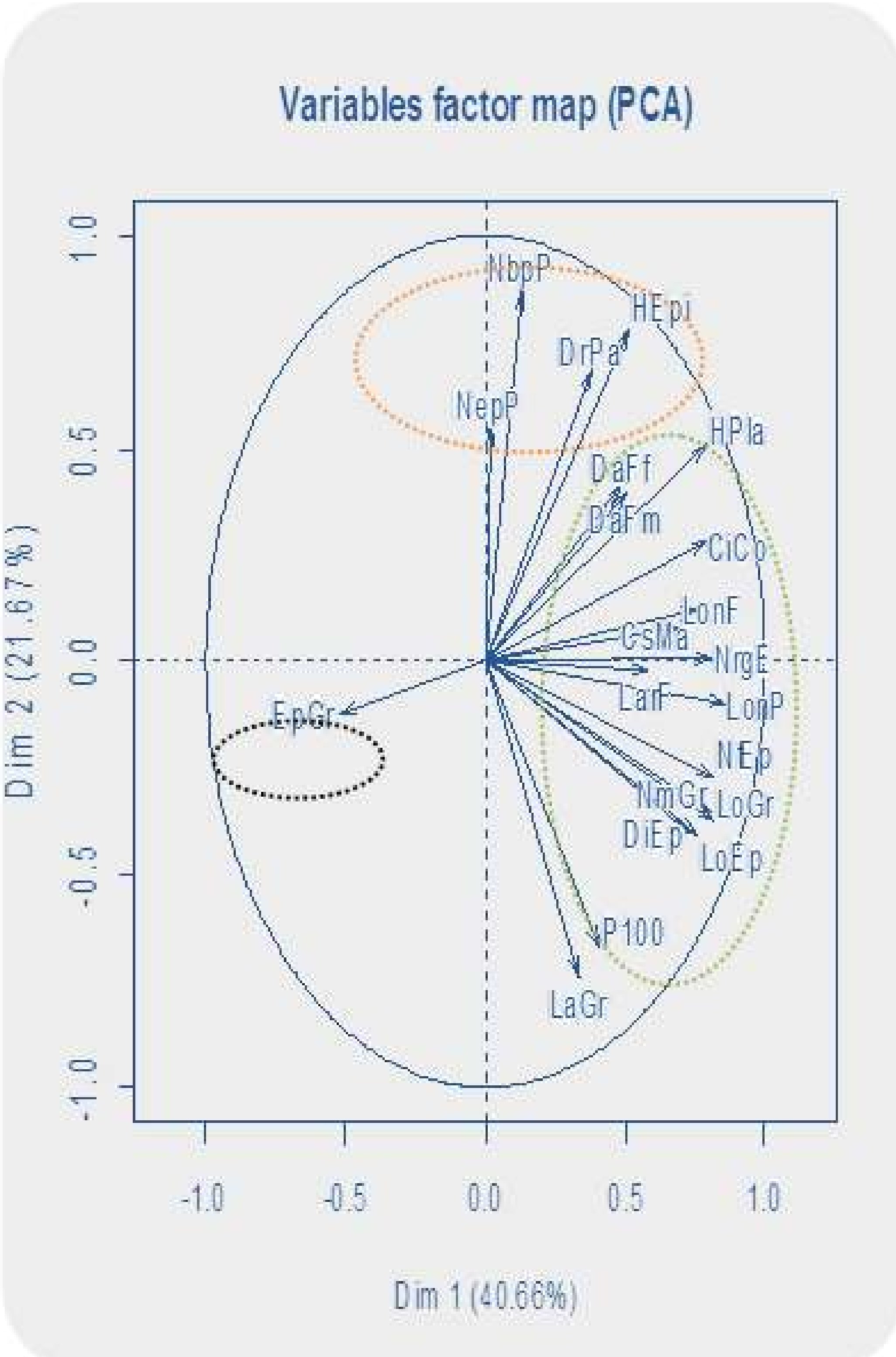

Fig. 3. PCA showing correlation of axes 1 and 2 according to the quantitative data

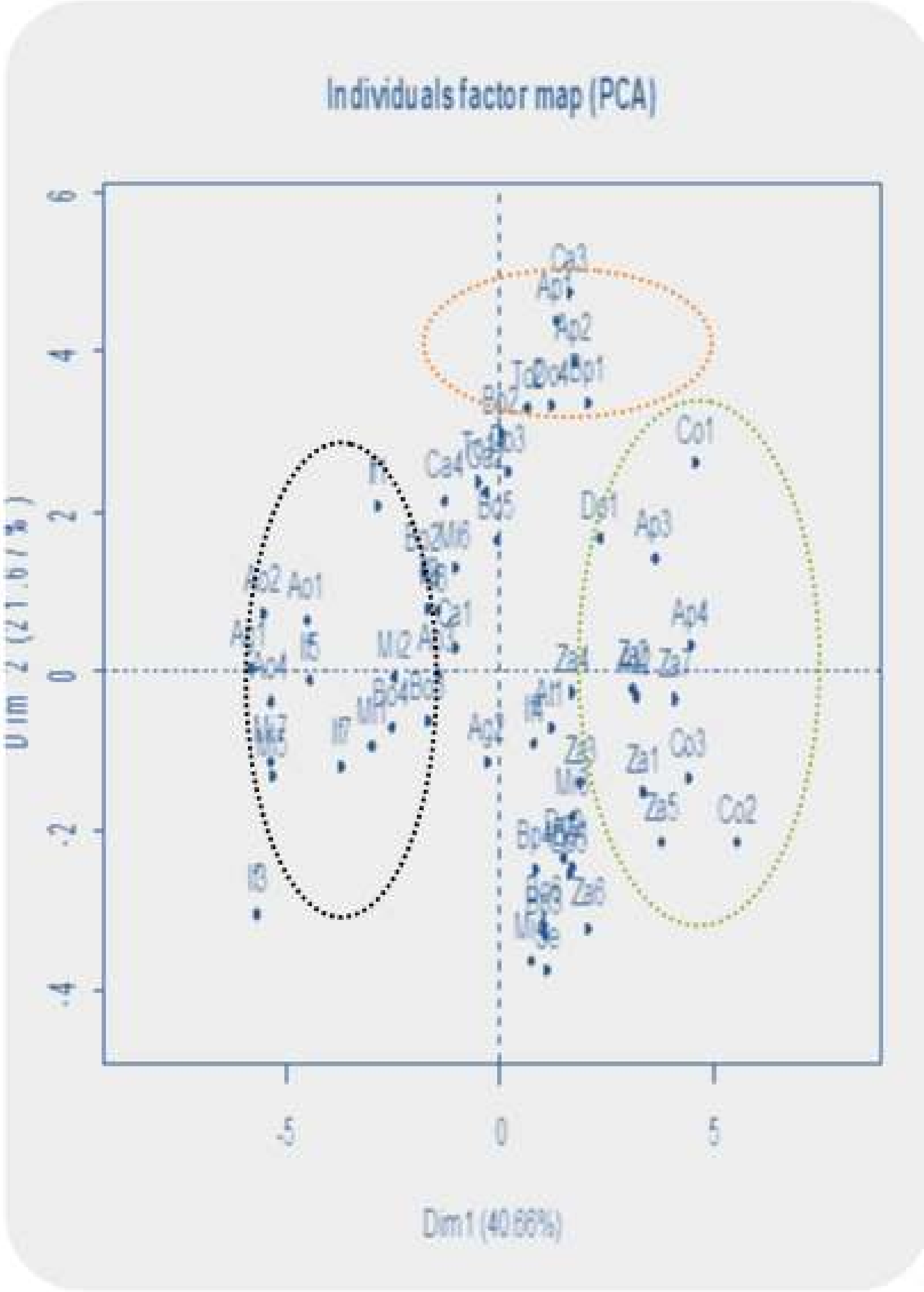

Fig. 4. Distribution of cultivars in the plane formed by the axes 1 and 2 of PCA performed for quantitative data

Table 1. Eigenvalues, proportions of variability and cumulative of variance according to axis

Component	Eigen values	Percentage of variance	Cumulative percentage of variance
1	8.537	40.656	40.656
2	4.551	21.671	62.328
3	2.551	12.152	74.480

Table 6. Contribution of quantitative variables for the formation of the first two axes

No.	Variables	Axis 1	Axis 2
1	CiCo	**0.787**	0.280
2	LonF	**0.693**	0.079
3	LarF	**0.577**	-0.019
4	DrPa	0.380	**0.689**
5	LonP	**0.854**	-0096
6	NbpP	0.134	**0.878**
7	NepP	0.017	**0.555**
8	HEpi	0.516	**0.783**
9	HPla	**0.789**	0.506
10	NfEp	**0.812**	-0.269
11	DaFm	**0.504**	0.395
12	DaFf	0.487	0.412
13	CsMa	**0.750**	0.119
14	P100	0.408	**-0.674**
15	LoEp	**0.759**	-0.406
16	DiEp	**0.726**	-0.404
17	NrGr	**0.804**	0.005
18	NmGr	**0.803**	-0.353
19	LoGr	**0.812**	-0.372
20	LaGr	0.336	-0.745
21	EpGr	**-0.516**	0.120

3.4 Hierarchical Cluster Analysis (HCA) with Quantitative Traits

Hierarchical classification was carried out on the basis of 21 quantitative parameters in order to better appreciate the agro-morphological diversity of maize cultivars. The number of classes to retain is not easy to determine, the package FactoMineR in the framework of its HCPC function, suggests the use of the partition with the highest relative loss of inertia. The function best cutree allows calculating this criterion from any dendrogram. Therefore, the number of homogeneous groups is given in the Table 7.

The latter presents three (03) groups for a percentage of homogeneity intra-group of 85.20. There are therefore three distinct groups of cultivars statistically homogeneous on the dendrogram (Fig. 6).

3.5 Analysis of the Variance

The results from the HCA were tested by the variance analysis of the quantitative characters. Two models of test of significance were used. The significance of variables, of which residues were not normal and /or homogeneous after transformation of variables, was tested by Kruskal-Wallis (Table 8). Then, the model of ANOVA was used to test for the variables verifying the conditions of normality and homogeneity (Table 9). It therefore appears that the Classes constituted, present a very highly significant difference in relation to the different traits.

3.6 Composition of the Groups

The characteristics (Table 10 and Fig. 5) of each group are as follows:

Group 1 (G1): Consists of 13 cultivars having for variable characteristic of this class EpGr. These cultivars thus produced grains with a good thickness.

Group 2 (G2): Composed of 18 cultivars with intermediate cycle and the smallest difference between the dates of male and female flowering, of which 16.66% were originating from Zagnanado. This class is characterized by the variables NfEp, P100, LoEp, DiEp, NrgE, NmGr, LoGr and LaGr. It then gathered together cultivars resistant to drought and having a good productivity in ears and in grains.

Group 3 (G3): It is the largest class, with 27 late cultivars of which 14.81% were collected from Zangnanado, and Aplahoué. This group is defined by the variables HPla, CiCo, LonF, LarF, DrPa, LonP, NbpP, NepP, HEpi, DaFm, and CsMa. These are late cultivars with good vegetative traits, reproduction and productivity in ears.

Fig. 5. Photograph showing different cultivars. A, B: Late cultivars with big and long ears; C, D: Early cultivars with thick grains; E: Cultivars with big grains

Table 7. Choice of the number of groups based on function best cutree

Best.cutree		**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
(result_ cn, loss=true)	[1] **3**	0.852	0.891	0.896	0.928	0.935	0.945	0.949	0.948

Table 8. Significance of quantitative traits with Kruskal-Wallis test

Variables	**DF**	**Kruskal-Wallis chi-squared**	**P-value**
HPla	57	468.2906	<2.2 e-16***
CiCo	57	321.9353	< 2.2 e-16 ***
LonF	57	416.1914	< 2.2 e-16 ***
LarF	57	243.5823	< 2.2 e-16 ***
Ppd	57	126.8956	3,099 e-07***
LonP	57	330.0256	< 2.2 e-16 ***
NbpP	57	189.9004	3,405 e-16 ***
HEpi	57	154.1645	6,971 e-11***
LoEp	57	341.0007	< 2.2 e-16 ***
DiEp	57	570.3863	< 2.2 e-16 ***
NrgE	57	321.4131	< 2.2 e-16 ***
LoGr	57	545.0346	< 2.2 e-16 ***
LaGr	57	421.7231	< 2.2 e-16 ***
EpGr	57	306.2949	< 2.2 e-16 ***
DaFm	57	194.5243	< 2.2 e-16 ***
CsMa	57	170.4032	3.104 e-13***
P100	57	89.8439	0.003592**

**** p< 0.001; ** p < 0.01*

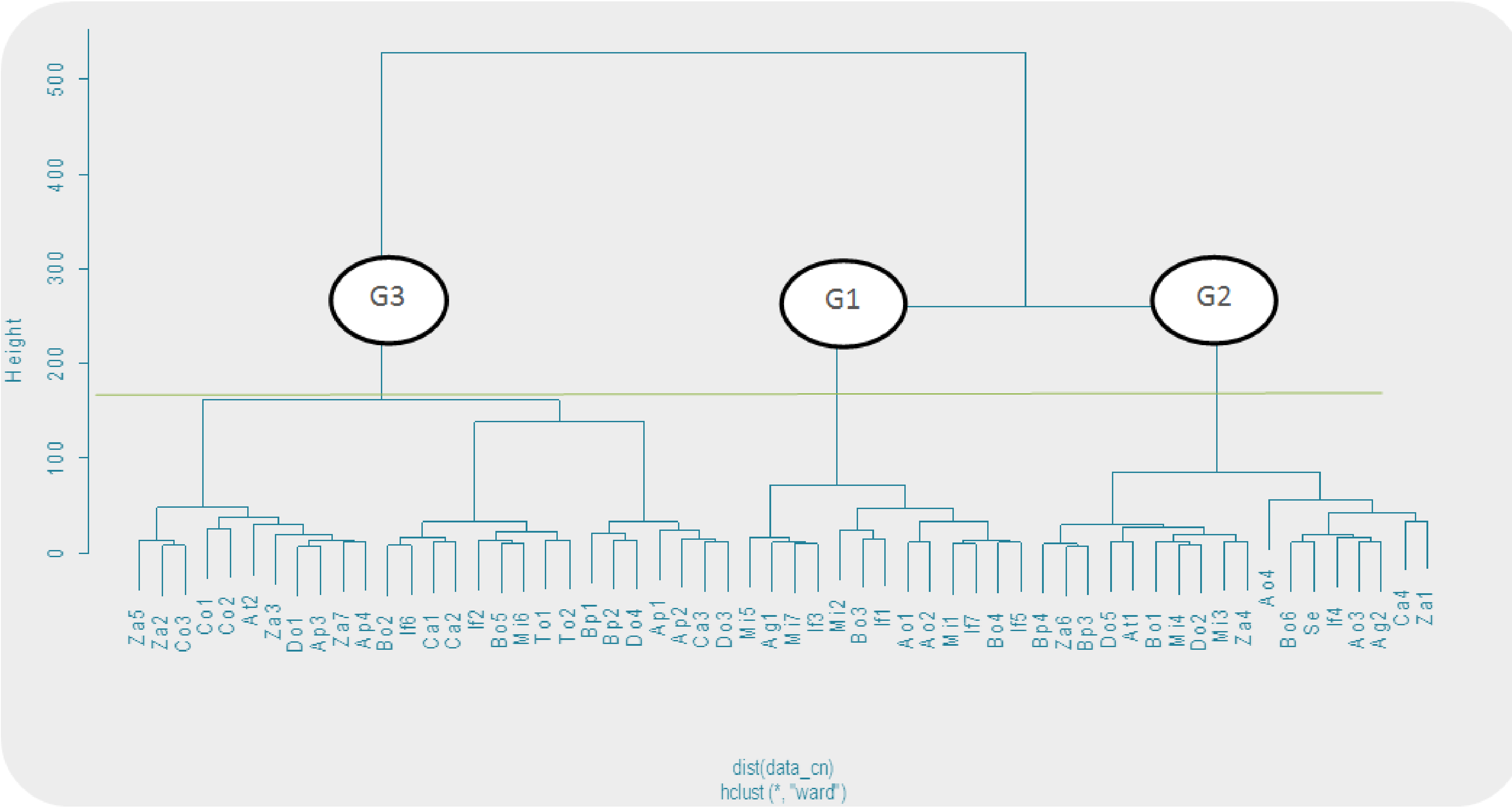

Fig. 6. Dendrogram showing cluster of 58 cultivars from Southern Benin, based on quantitative characters

Table 9. Significance of quantitative traitswith ANOVA

The variables	DF	SS	MS	F	P
NepP	57	270,43	4,744	2.979 e+27	<2e-16 ***
NfEp	57	250.1	4,388	9.412	< 2e-16 ***
NmGr	57	11830	207.54	11.890	< 2e-16 ***
DaFm	57	3797	66,62	16.068	< 2e-16 ***

*** *p< 0.001; ** p < 0.01*

Table 10. Discriminant variables of each group of the dendrogram based on quantitative traits

The variables	Group 1		Group 2		Group 3	
	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation
HPla	130.076	9.329	148.159	6.069	168.057	11.180
CiCo	6.357	0.429	6.785	0.703	7.542	0.401
LonF	62.475	9.698	66.012	11.435	73.967	4.915
LarF	6.525	0.624	6.695	1.214	7.182	0.331
Ppd	11.070	1.115	11.176	1.316	13.195	1.216
LonP	31.349	2.230	35.631	2.406	35.685	2.705
NbpP	15.202	1.650	14.528	1.889	17.837	1.823
NepP	1.924	0.277	1.639	0.479	2.037	0.517
HEpi	66.431	7.204	69.977	8.038	94.288	9.956
NfFp	5.390	0.212	6.156	0.342	6.002	0.445
DaFm	47.423	3.530	52.667	4.025	53.370	2.927
DaFf	50.808	3.547	55.611	4.067	56.583	2.871
CsMa	90.423	1.974	100.167	6.842	101.120	5.696
P100	23.358	2.548	26.487	2.977	24.595	2.921
LoEp	95.986	6.165	117.487	6.099	110.869	12.441
DiEp	31.987	1.447	38.521	3.009	36.938	5.266
NrgE	11.311	0.702	12.780	0.819	12.715	0.792
NmGr	21.111	1.427	26.780	1.443	25.281	3.275
LoGr	8.809	0.455	9.810	0.597	9.695	0.631
LaGr	8.428	0.377	8.911	0.526	8.471	0.539
EpGr	4.567	0.339	4.388	0.266	4.294	0.278

3.7 Multiple Correspondence Analysis (MCA) of Cultivars

The variability of cultivars for the qualitative traits was determined by a multiple correspondence analysis. The frequency of occurrence of different modalities was variable for the four traits (Table 11). The color of the panicle (ColP) and the color of the silk (ColS) had three variables with the same frequencies. As a matter of fact, for all the cultivars, 46.552% of panicles and silk showed green color; 39.655% were purple and 13.793% were green-purple. For the shape of the outer surface of the grains, 4 variables were observed: rounded grains (43.103%), indented (24.138%); flat (18.965%) and shriveled (13.793%). Regarding the color of the grains, we noted the predominance of white grain cultivars (56.896%), purple grain cultivar and the violet grain cultivars.

The analysis of the matrix of net values indicates that the first two components explain 58.41% of the total variance of the cultivars compared to qualitative traits observed. These two axes are therefore enough to ensure a good quality of interpertation (Table 12).

The panicles, purple and green silk; white, yellow, orange and purple grain cultivars and indented and shriveled grain cultivars, contributed to the formation of the first axis. Then, the panicles and green-purple silk; rounded and flat grain cultivars and violet grain cultivars were well represented on the second axis. With regard to the cultivars, the majority was characterized by the variables in the first component. Among these cultivars white grain cultivars were predominant (Fig. 7). The yellow grain cultivars are dominant in relation to the orange and purple grain cultivars. The indented and shrunken grain cultivars were observed in all the colorations. On the other hand, the cultivars Za2, Co1, Co2, Bp2, Do1, Ap2, Ap3, and Ap4 produced dominant purple, rounded or flat grains (Table 13).

The projection of individuals and variables in the system of axes 1 and 2 shows that the cultivars Do1 and Ap1 produced violet and purple grains, respectively (Fig. 8). We can also distinguish cultivars MI3, If4, Ag2, Za5, Co3 and Ap4 with orange grains. The maize cultivars with yellow grainswere Bo4, Bo5, Ca1, Ca2, Mi1, Mi2, Mi4, Mi6, If3, If5, If7, Bp1, Bp2, Do3, Do4, At2 and To1. The other cultivars were white grains (Fig. 8).

Table 11. Frequency of qualitative traits observed in the cultivars

	The variables	Workforce	Total Strength	Frequency (%)
	VeSo	27	58	46.552
ColS	PoSo	23	58	39.655
	VePS	8	58	13.793
	VePa	27	58	46.552
ColP	PoPa	23	58	39.655
	VePP	8	58	13.793
	BlGr	33	58	56.896
	JaGr	17	58	29.310
ColG	OrGr	6	58	10.345
	ViGr	1	58	1.724
	PoGr	1	58	1.724
	ArGr	25	58	43.103
FSEG	InGr	14	58	24.138
	PlGr	8	58	13.793
	Agr	11	58	18.965

Table 12. Net values and proportions of information on the axes

Components	Net values	Variance (%)	Cumulative variance (%)
1	8.321076E-01	31.20	31.20
2	7.256203E-01	27.21	58.41
3	3.333333E-01	12.50	70.91

Fig. 7. Photograph showing the diversity of qualitative traits of maize cultivars

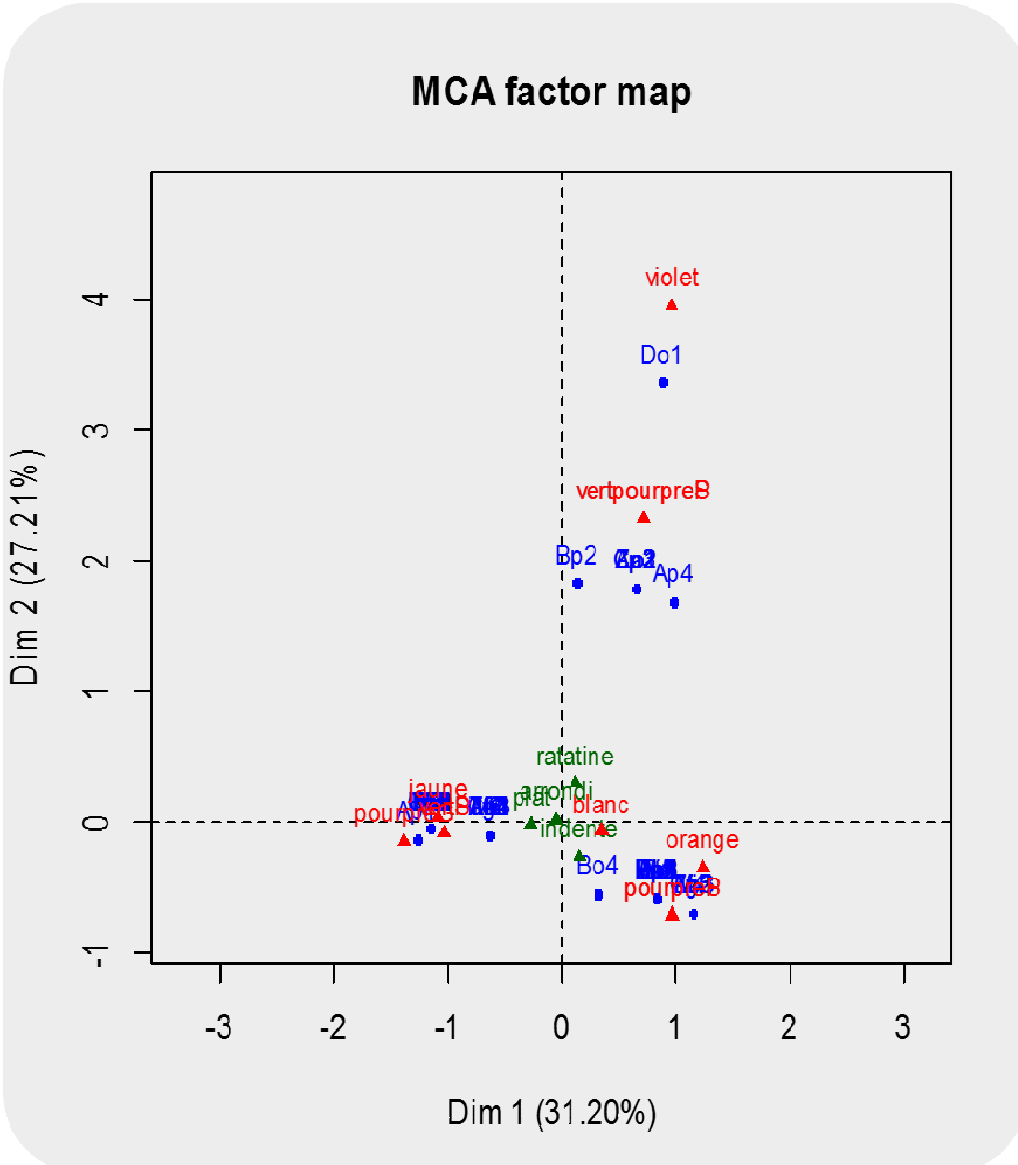

Fig. 8. MCA projection of individuals and qualitative traits in the plane

Table 13. Contribution of qualitative variables and cultivars in the formation of the axes

Axis 1	Axis 2
Variables	
PoSo (14.77), VeSo(19.33), Popa (14.77), VePa (19.33) BlGr(2.77), JaGr(13.88), OrGr(6.31), PoGr (1.32) InGr (1.48), AGR (4.70)	VePS (34.18), VePP(34.18) ViGr(12.34), ArGr (0.76) PlGr (0.09)
Individuals	
Ao1, AO2, AO3, AO4, Bo1, Bo2, Bo3, Bo4, Bo5, Bo6, CA1, CA2, CA3, CA4, MI1, MI2, MI3, MI4, MI5, MI6, MI7, SE, FI1, if2, if3, If4 , if5 FI6, fi7, Ag1, Ag2, ZA1, ZA3, ZA4 , Za5, ZA6, ZA7, CO3, BP1, BP3, BP4, DO2, DO4, DO5, AP1, AT1, AT2, TB1 and TB2.	Za2, CO1, CO2, BP2, DO1, AP2, Ap3 and AP4.

4. DISCUSSION

The descriptive analyses have shown large discrepancies between the minimum and maximum values for all the morphological traits. This indicates a great variability amongst cultivars. Similarly, the projection of the cultivars in the plane formed byaxis1 and 2 of the PCA and the MCA shows a random distribution of cultivars. This dispersal of cultivars in the planes of PCA and MCA, indicates a significant agro-morphological variability amongst cultivars. PCA showed a wide dispersion among cultivars. Similarly, cultivars were diverse in quantitative than in qualitative characters. Several works have also revealed a great diversity amongmaizecultivars in relation to quantitative traits [10,11]. This great diversity would result in management practices of maize seeds. In fact, the management practices of farmer seeds, particularly the exchange of varieties between farmers are at the origin of a significant diversity among populations of cultivated plants [12]. Also, the planting of several varieties seems to be responsible for this varietal diversity observed, taking into account the mode of reproduction preferentially outbreeder maize.

The percentages of variances expressed by the 3 main axes in principal component analysis for quantitative variables (40.66 to 12.15%) and for qualitative variables (31.2% to 12.5%) indicate that agro-morphological traits aredominant for the descriptors considered. A good representativeness of the different axes expresses the existence of good genotypic and phenotypicorganization between cultivars [13], confirming our results.

Among the 21 quantitative morphological characters 16 were highly correlated ($r > 0.6$) with the axes of principal components (Table 6), indicating that the more remarkable phenotypic traits in the field would have influenced the selection made by the farmers. In fact, the most interesting cultivars would be those with good yield parameters. Thus, the quantitative parameters, although strongly influenced by environmental conditions, must be considered in the studies of genetic diversity because they are essential in the peasant environment and significantly influenced the criteria of phenotypic selection.

The analyses of the variance of all parameters having served in the constitution of the classes forming the dendrograms showed a significant difference. These descriptors are therefore relevant for the explanation of the variability. Similar results were obtained by several authors including [14] who found that the earliness, the heights of the plant and of the insertion of the ear as well as the traits associated with the ears were used to describe the variability of maize varieties grown at Cuzalapa in Mexico. The characters are divided in classes not according to their origin, but according to their performance in relation to the traits studied, except for a few cultivars. On the other hand, the study of [15] demonstrated the existence of a genetic variability amongst cultivars through three groups of cultivars identified according to their geographical origin in Burkina Faso. The local cultivars are virtually different between them for the majority of the traits studied.

The grouping of cultivars in 3 homogeneous classes at the height 200 by the hierarchical cluster analysis (HCA) was observed for the maize collection from south Benin. But [16,17] have found 4 classes at the height 100 for the collections from the center and north of the same country. The southern parts of the country are the principal zone where maize has been grown extensively for many years before extending toward the northern parts of the country [4].

Thus, on the basis of quantitative characters, class 1 was dominated by 30.77% of the individuals in the commune of Apro-Missérété, class 2 by 16.66% of the individuals in the commune of Zangnanado and class 3 also by 14.81% of the individuals in the commune of Zangnanado. But the individuals in the Covè commune were only characteristics of discriminant variables of class 3. The distribution of maizevarieties with the same characteristics in several localities, is an advantage in terms of conservation of plant genetic resources, because of the presence in several communes of the same type of cultivar constitutes an *in situ conservation* of this cultivar. It is the case of the *Yêtin* cultivar, subject to confirmation by a molecular characterization, originating from both Covê and Zagnanado. Thus, in case of its disappearance of its cultivation in one commune, it would still be possible to find it in the other commune. Although the spatial distribution of cultivars is favored by seed exchanges between farmers, some cultivars still remain connected to their locality of origin. This is important since with the adverse effects of climate change, the knowledge of the level and structure of the genetic diversity of a species is an important asset to define strategies for its conservation [18, 19]. This permit to choose the genetic entities to conserve and the ecogeographicalunits and social organizations (villages,groups of villages, ethnicity, etc.) on which the initiatives of conservation must rely upon.

The cultivars having good vegetative and productive traits revealed by the analyses are those of classes 2 and 3 of hierarchical classification based on the quantitative traits. In addition, white and yellow maize cultivars widely consumed and appreciated by the users can be found among the cultivars of these 2 classes.

The analysis of the rainfall curve shows that the cumulative rainfall received during the period of the experiment was 410 mm, which is much lower than the rainfall necessary for the early varieties. The cultivars were collected from various agro-ecological zones. A lack of rain during 30 consecutive days has been observed during the field experiment. But this did not have a significant impact on the yield parameters because the water deficit would have been met by the night dew observed during the period of the experiment. Indeed, the work of [20] in Burkina Faso has shown that the grain yield was not affected by the rainfall during the first two months of the development cycle of maize. Also the low daily temperatures do maintain the high relative humidity, therefore limiting plant evapotranspiration.

5. CONCLUSION

The study of agro-morphological diversity of maize cultivars collected in southern parts of Benin has revealed important morphological diversity for all traits considered. This agro-morphological variability observed among the Communes and within the Communes, is an asset to facilitate work on varietal selection. It is also apparent that the phenotypic variability of cultivars is more related to their physiological and agronomic behavior than their origin. The analysis of diversity structured three groups by hierarchical classification. Each group is therefore a source of interesting traits for the improvement of maize in the region of the study. The collection consist of 13 early cultivars (Group 1), 18 intermediate cycle cultivars (Group 2) and 27 late cultivars (Group 3). The individuals of the group 3 had an average height, with ears inserted at an average height and an average number of ears per plant. This group shows the best vegetative characteristics and productivity in fresh maize. It can serve as a source of brood stock for a breeding program that aims at the improvement of these traits. These results are stepping stone in the process of varietal improvements by selection strategies. The use of the ecotypes in the short term can be done through varietal suggestions at the level of traditional agriculture. Finally, the strategies for long-term conservation of these cultivars must aim at distributing the collections to the users (farmers, plant breeders and other researchers).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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ANNEXE

Table of some climatic data

Communes	Codes	From 2005 to 2015		Observations
		Annual average rainfall (mm)	**Monthly average temperature (°C)**	
Adja-Ouèrè	Ao	1025-1275	24-32	Palm tree, cocoa poduction zone
Agbangnizoun	Ag	721-1355	23-30	Cotton and other crops
Aplahoué	Ap	800-1120	26.5-31	Cotton and other crops
Athiémé	At	795-1044	22-32	Small valley
Bonou	Bo	883-1560	24.5-33	Valley, Palm tree production zone and other crops
Bopa	Bp	701-1400	23-32	Palm tree production zone
Abomey-Calavi	Ca	1000-1200	25-30	Ferralitic soil,
Covè	Co	755-1477	24-34	Many rivers, rice production zone
Dogbo	Do	600-1305	23-30	Palm tree, rice production zone
Ifangni	If	972-1308	24-30	Cocoa production
Akpro-Missérété	Mi	748-1520	24-32	Various soil types
Sèmè-podji	Se	900-1200	24-32	Sand soil about 1Km from the sea
Toviklin	To	900-1100	26-31	Pigeonpea and other crops
Zangnanando	Za	715-1375	23-34	Many rivers, rice production zone

Sources: ASECNA, 2016; PDC, 2012-2016

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/17866