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Morphological Diversity of Corn's (*Zea mays* L.) Local Cultivar and Improved Varieties in Central and North of Benin

Hafiz A. Salami[1], Adolphe Adjanohoun[2], Wilfrid Padonou[3], Abdoul-Madjidou Yacoubou[4], Djima Aly[2], Chabi Yallou[4], Haziz Sina[1], Lamine Baba-Moussa[1*]

[1]Laboratoire de Biologie et de Typage Moléculaire en Microbiologie, Département de Biochimie et de Biologie Cellulaire, Faculté des Sciences et Techniques, Université d'Abomey-Calavi, Cotonou, Bénin
[2]Centre de Recherches Agricoles Sud, Institut National des Recherches Agricoles du Bénin (INRAB), Attogon, Benin
[3]Programme Technologie Agricole et Alimentaire (PTAA), Institut National des Recherches Agricoles du Bénin (INRAB), Porto-Novo, Benin
[4]Centre de Recherches Agricoles Nord, Institut National des Recherches Agricoles du Bénin (INRAB), N'dali, Benin
Email: [*]laminesaid@yahoo.fr

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Abstract

The better knowledge of a plant genetic biodiversity is based on a prior study of its agro-morphological characteristics. The objective of this study was to investigate the morphological diversity of maize accessions and its structure on the basis of 14 variables. For the experimentation, 43 and 98 maize accessions were planted in three replicates respectively in central and northern Benin following an incomplete randomized block. The mixed model analysis of two factors variance revealed a significant difference for all accessions considering each agro-morphological characteristic evaluated except the germination day of two areas seed accessions. The numerical classification grouped the accessions into four groups in each zone. The stepwise discriminant analysis showed that early characters related to plant height and ear insertion were the variables that discriminated accessions in both zones. Maturity and recovery ears, sensitivity to streak and the germination days are the variables that discriminate accessions of the two areas. These results provide a database for the creation of improved maize varieties that meet the needs of producers.

Keywords

Accessions, Characterization, Agro-Morphological, *Zea mays* L., Benin

[*]Corresponding author.

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1. Introduction

Maize (*Zea mays* L.), the most cultivated cereal in the world, is the staple food in Africa and in developing countries [1]. This is one of the major grains produced in the humid tropics of sub-Saharan Africa. It is a universal culture placed third after wheat and rice in world production [2]. In Benin, maize occupies almost 82% of the total area under cereals and represents about 84% of cereal production. The national maize production increased from 782,974 tons in 1999 to 1,205,200 tons in 2009, an increase of 35% in a decade [3]. As such, any action in favor of this speculation can help to lay the foundations for sustainable food security.

Benin has a diverse range of corn varieties with improved varieties developed by international research institutes, and local varieties managed by peasants and farmers themselves [4]. These traditional and local cultivars are the most cultured and most used cultivars at the expense of different types of selected varieties (hybrids, composites, etc.). Indeed, during the 2009-2010 campaign, traditional and local cultivars accounted for 63%, or 759,926 tons of the total volume produced estimated at 1,205,200 tons despite the availability of improved varieties developed by researchers [5]. Improved varieties have better agronomic performance than local and traditional varieties. However, despite their superior agronomic performance, improved maize varieties developed by research are very few adopted and therefore little cultivated by peasants because of their requirements for specific inputs and their technological and organoleptic qualities which still meet users' needs [6] [7]. This situation persists because of the extra work and expense entailed [8], and their ability to withstand biotic and abiotic stresses [9]. However, farmers' seeds are generally considered by agronomists as resources with limited potential, with a share of responsibility for the low productivity of traditional agricultural systems [10]. This is due to the widespread adoption of traditional varieties with low production potential. Indeed, in traditional agriculture, local varieties constitute the bulk of the plant material used [11]. Thus, one of the main constraints to increase maize production in Benin is that the yield is low. To contribute to the improvement in yields, it is necessary to lift this constraint by the development of improved varieties with high yield potential adapted to the needs of producers. So to solve the increasingly food demand, modern agriculture is more developed and focused not only to select performing varieties but also to the diversification of cultivars in seed system [12]. The introduction of high- yielding varieties depends mostly on access to local genetic resources. These local resources are indeed an essential component of food security as they provide the raw material used by breeders to improve the quality and productivity of corn [13].

Thus, a prospecting mission and collection was organized in 2013 in all departments of the Centre and North of Benin. The inventory and agro-morphological characterization of these genetic resources are therefore essential to generate a solid database on the characteristics of the Central and Northern Benin maize collection, for the new varieties creation to meet the producers' expectations. This agro-morphological characterization requires the use of certain evaluation techniques using morphological markers [14]. Such studies have already been carried out on grains such as maize [13] [15], the sorghum [16], rice [17] [18], millet [19] [20], the barley [21] and wheat [22] [23]. The overall objective of this study was to evaluate the genetic variability within the maize collection at the Centre and North of Benin by using morphological descriptors.

2. Material and Methods

2.1. Collecting Zone

The different accessions were sampled during the gathering corn accessions by a team of Specialization National Center on Corn (CNS-Maïs) in 2013 in two areas that are the center (43 accessions) and northern Benin (98 accessions) [4]. In total 13 towns have been covered or 54 villages (**Figure 1**).

2.2. Study Sites

Site 1: The study was conducted on the site of the experimental agricultural research center Savè Centre (CRA-Centre) of the National Institute of Agricultural Research of Benin (INRAB) as regards accessions collected Centre of Benin. The climate that prevails is that subequatorial characterized by two rainy seasons and two dry seasons. But recently this climate has given way to a tropical Sudan type climate characterized by a one rainy season and one dry season. The average height of the rain is 1100 mm per year. The average temperature in growing season is between 27˚C and 28˚C. The soil type is tropical ferruginous [24].

Site 2: The test characterization of maize accessions collected in the north was installed in the Centre of

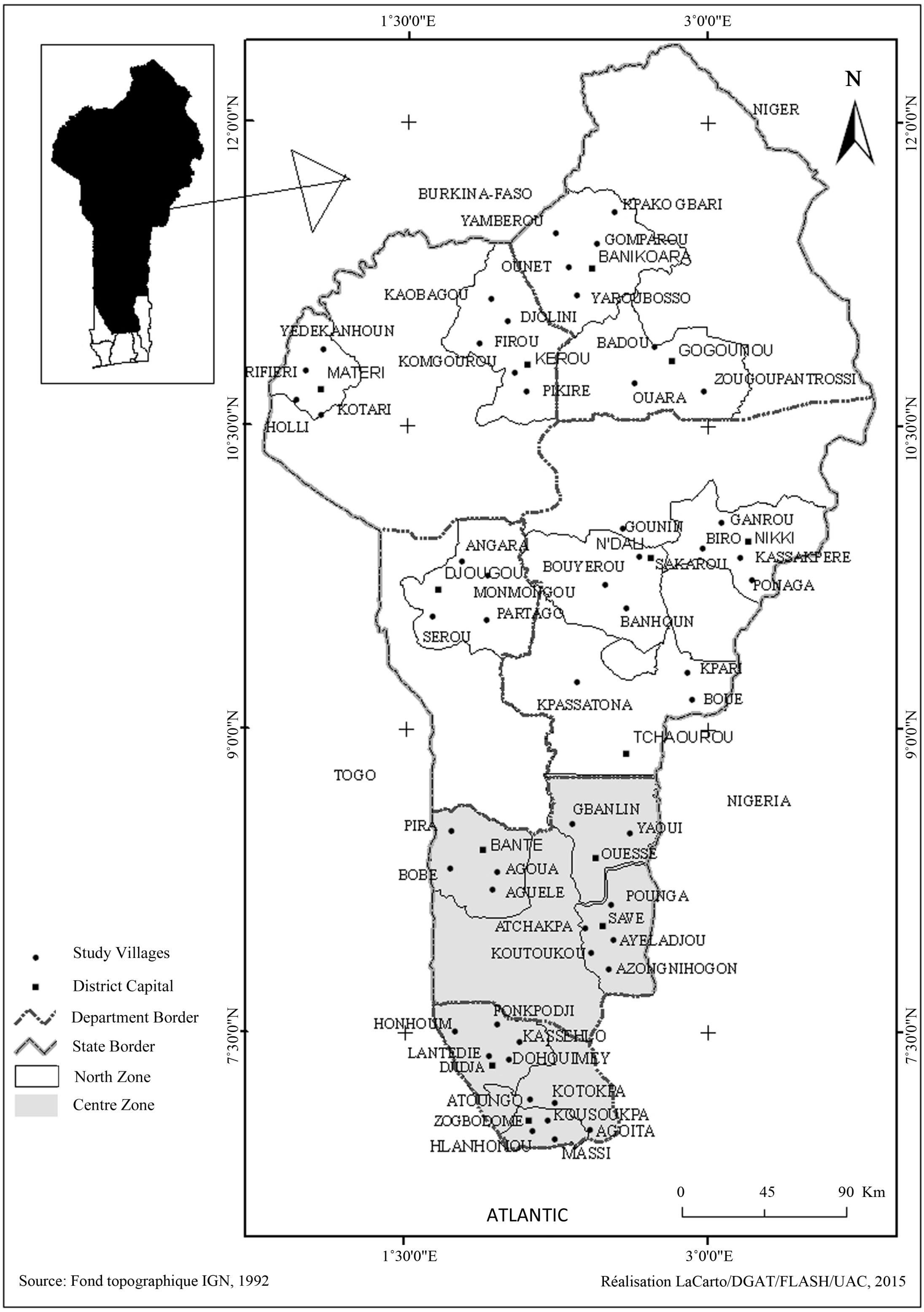

Figure 1. Map of central and northern part of Benin showing communes and villages of samples collection.

Agricultural Research North-Ina (CRA-Nord) of the National Institute of Agricultural Research of Benin (INRAB). The climate is Sudano-Guinean marked by two seasons, a dry season from November to March and a rainy season from April to October. The annual rainfall varies from 1.100 to 1400 mm. The low temperature in growing season is between 30˚C and 31˚C. Soils are tropical ferruginous type concretion formed on materials from calco-alkaline granite. These soils are fragile and susceptible to erosion [25].

2.3. Experimental Plan

The experimental device is a device incomplete randomized block design with three replications. Each collected accession was planted in four (4) lines of five (5) meters long representing a basic plot. The seeding rate is 80 cm × 40 cm with four seeds per hole, two weeks after sowing; the maize plants were separate to 2 plants per hole with a density of 62,500 plants per hectare. The useful plot was represented by the 2 central lines. Accessions collected in a given zone were sown on a test site from this zone. And 43 and 98 accessions were planted respectively in the Central and Northern test site. The dose of fertilizer applied was 200 kg NPK. Urea was made twice, first during the separate phase and the second to bolting or 45 days after sowing at 100 kg/ha each. Regular weeding was done during the vegetative phase of the culture. The duration of the experience has varied from 60 days to 120 days according to the evaluated varieties.

2.4. Data Collecting

Descriptors for Maize [26] were used for agro-morphological description of accessions. 14 agro-morphological descriptors including seven quantitative variables and seven qualitative variables were evaluated at each accession. Quantitative variables: Days to germination, Days to tasseling, Days to silking, Days to ear leaf senescence, Plant height, Ear height and Tassel length.

Qualitative variables (Foliage, Root lodging, Husk cover, Streak, Rust, Leaf blight, Sheath pubescence) were collected according to the method previously described [26].

On each elementary plot data were taken on 15 plants selected at random and marked on the two center lines.

2.5. Data Analysis

Quantitative variables were subjected to a descriptive analysis using the MINITAB software. The qualitative characteristics were made quantitative using Likert scale. The categorization of maize accessions was made through a digital based classification algorithm Ward made on adjusted means values of quantitative and qualitative agro-morphological characteristics by accessions from area from analysis of variance by R 3.0.3 software. Discrimination accessions groups obtained from the numerical classification was performed followed by a canonical discriminant analysis on groups of accessions using the most discriminant variables obtained in the previous analysis.

3. Results

3.1. Accessions of Benin Centre

3.1.1. Descriptive Statistical Analysis of Quantitative Variables

The results of the mixed model analysis of variance of two factors revealed a very highly significant ($P < 0.001$) between all accessions for each agro-morphological characteristic evaluated with the exception of the germination days. No variability associated with the blocks was noted for all evaluated characters. **Table 1** shows the statistics of the quantitative variables measured on accessions. Analysis of this table shows that the variation coefficient varies between 8.63% and 20.43%. The results showed that the plant height, ear height, tassel length exhibit high variation (>10%) while variable female flowering, male flowering, days to ear leaf senescence and germination days have a low variation (<10%).

3.1.2. Classification of Accessions and Description of Groups Obtained

The observation of the dendrogram from the origin of the height of the class shows four groups of accessions from a height of 100 (**Figure 2**). The Group G1 includes 14 accessions, the group G2, G3 and G4 respectively consist of 11, 12 and 6 accessions. In view of the results there was no clustering of accessions according to a department or a given municipality. Similarly, the groups were heterogeneous in their compositions and improved local accessions.

Table 1. The minimum, maximum, mean value and variation coefficient of quantitative variables studied of the center accessions.

Agromorphological Characters	Number of Sample	Minimum	Maximum	Mean	Standard Error	% Coefficient of Variation
Plant height (cm)	43	146	281	201.98	3.17	14.58
Ear height (cm)	43	53	139	89.75	1.97	20.43
Female flowering (day)	43	57	78	66.61	0.62	8.63
Male flowering (day)	43	54	75	63.03	0.60	8.88
Tassel length (cm)	43	31	49	38	0.44	10.92
Days to ear leaf senescence (day)	43	77	110	98.60	0.64	6.06
Days to Germination (day)	43	5	6	5.58	0.05	8.89

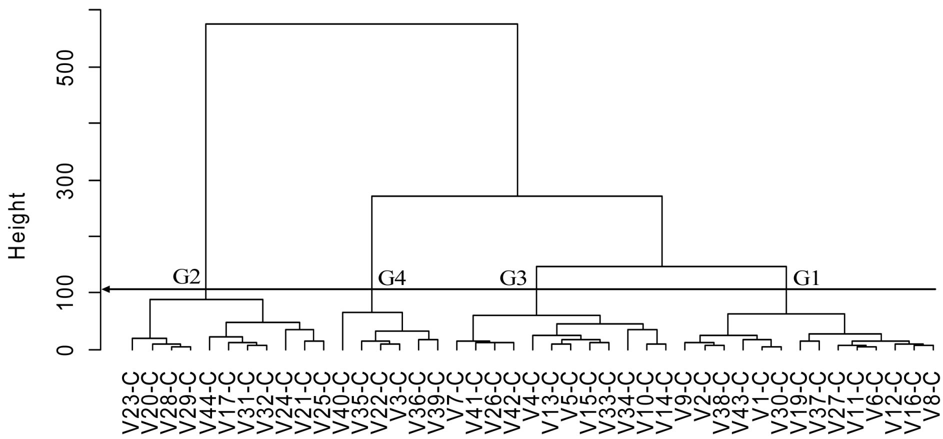

Figure 2. Dendrogram constructed from the Euclidean distances calculated on the basis of measured descriptors on maize accessions of the center Benin.

Table 2 shows the discriminant analysis step by step of variables based on the groups obtained after numerical classification. Results revealed to ($p < 0.05$) five discriminating variables: male flowering, plant height, ear height, husk cover and sensitivity to streak

Figure 3 and **Table 3** respectively show the two canonical discriminant functions (CH1 and Can2) based on the most relevant variables revealed by discriminant analysis step and analysis of variance of quantitative variables studied in the Centre Benin. Analysis of the table and figure shows that the group G2 is characterized by small accessions plant height (197.50 cm) and ears height (85.79 cm) and a very late flowering male (68.17 days). The G1 group is characterized by average height of plant accessions (216.68 cm) and ears (96.43 cm) and early male flowering (61.86 days). The G3 is essentially characterized by accessions with very early flowering male (58.36 days), very small height plant (163.59 cm) and ears (69.00 cm) and are very sensitive streak. The G4 group is characterized by varieties with late male flowering (64.08 days) and tall height to plant (247.08 cm) and ears (120.67 cm).

3.2. Accessions of North Benin

3.2.1. Descriptive Statistical Analysis of Quantitative Variables

The results of the mixed model analysis of variance of two factors revealed a significant difference ($p < 0.05$) between all accessions for each agro-morphological characteristic evaluated except the tassel length and the germination days that were not varied in the accessions. A variability associated with the blocks was observed only for plant height and female flowering.

Table 4 shows the descriptive statistics for quantitative variables evaluated on accessions. The results indicate that the coefficient of variation ranging from 6.23% for smaller value to 23.82% for the larger value. Thus the

Table 2. Results of stepwise discriminant analysis on the different characteristics of corn accessions of center Benin.

Variables	R-Square	F-value	Probability
Male flowering (day)	0.58	15.97	0.000
Plant height (cm)	0.39	7.32	0.001
Ear height (cm)	0.29	4.57	0.008
Husk cover	0.22	3.15	0.037
Streak	0.23	3.42	0.028
Day to ear leaf senescence (day)	0.15	1.96	0.139
Germination (day)	0.04	0.42	0.738
Female flowering (day)	0.05	0.64	0.593
Tassel length (cm)	0.03	0.32	0.812
Foliage	0.10	1.26	0.303
Root lodging	0.03	0.36	0.782
Rust	0.08	0.92	0.443
Leaf blight	0.08	0.94	0.430
Sheath pubescence	0.09	1.04	0.386

Table 3. Comparison of center accession groups: ANOVA results.

Agromorphological Characters	G1		G2		G3		G4		Prob.
	m	cv	m	cv	m	cv	m	cv	
Days to germination (days)	5.54[a]	9.01	5.71[a]	5.86	5.36[a]	7.33	5.83[a]	4.43	0.092
Male flowering (day)	61.86[bc]	5.66	68.17[a]	8.52	58.36[c]	4.48	64.08[b]	7.90	0.000
Female flowering (day)	65.39[bc]	5.28	71.79[a]	8.37	61.77[c]	4.30	68.00[ba]	8.12	0.000
Days to ear leaf senescence	99.79[a]	3.69	99.91[a]	4.61	95.18[a]	10.01	99.50[a]	2.44	0.187
Plant height (cm)	216.68[b]	4.35	197.50[c]	4.66	163.59[d]	7.73	247.08[a]	6.85	0.000
Ear height (cm)	96.43[b]	3.52	85.79[c]	11.17	69.00[c]	15.99	120.67[a]	10.26	0.000
Tassel length (cm)	39.07[a]	12.11	37.62[a]	11.29	35.82[a]	8.17	40.25[a]	7.23	0.114

Proportions with the same letters on the same line are not significantly different. **Legend**: m = means; cv = coefficiant variation.

Table 4. Minimum, maximum, mean value and coefficient of variation for quantitative variables studied of north accessions.

Agromorphological Characters	Number of Sample	Minimum	Maximum	Mean	Standard Error	% Coefficient of Variation
Plant height (cm)	98	52.7	272.6	189.08	2.21	16.43
Ear height (cm)	98	35.7	192.1	98.29	1.67	23.82
Female flowering (day)	98	50	70	61.20	0.35	8.03
Male flowering (day)	98	46	69	57.51	0.34	8.34
Tassel length (cm)	98	27.1	87.3	42	0.34	11.37
Days to ear leaf senescence	98	80	105	93.41	0.41	6.23
Days to germination	98	3	4	3.25	0.03	13.35

variable tassel length, germination days, plant height and ear height have a high variation (>10%) while the parameters male flowering, female flowering and days to ear leaf senescence have a small variation (<10%).

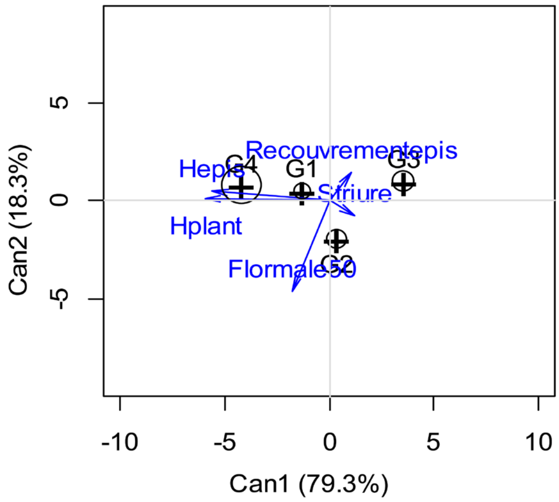

Figure 3. Graph of two canonical discriminant functions (Can1 and Can2) based on the most relevant variables revealed by discriminant analysis step by step of Center accessions. **Legend**: Hplant = Plant height, Recouvrementepis = Husk cover , Flormale50 = male flowering, Hepis = Ear height, Striure = Streak.

3.2.2. Classification of Accessions and Description of Groups Obtained

Four groups of accession were obtained for accessions of northern Benin (**Figure 4**) after the digital classification on the threshold of a height of class 200. The group G1 consists of 35 accessions and groups G2, G3 and G4 are composed respectively of 6; 31 and 26 accessions. Accessions obtained in each group are heterogeneous regarding their provenance department. There was no uniformity among accessions belonging to the same group in terms of their status (improved or local).

Table 5 shows the discriminant analysis step by step on agro-morphological characteristics of accessions. Analyses of Table revealed five agro-morphological characteristics discriminant ($p < 0.05$). This is the germination days, female flowering, days to ear leaf senescence, plant height and ear height.

Figure 5 and **Table 6** respectively show the two canonical discriminant functions (CH1 and Can2) based on the most relevant variables revealed by discriminant analysis step and analysis of variance of quantitative variables studied in the North. The analysis of the graph of the two discriminant axis of the figure and the table indicates that the accessions of group G1 are characterized by a late female flowering (64.61 days), high plant height (216.14 cm) and average ear height (109.71 cm), late maturity of corn (96.00 days). Accessions group G2 are basically tall ear height (135.74 cm) and very small plant height (143.10 cm), early female flowering (58.92 days) and late maturity of cobs (93.00 days). While for such characteristics accessions groups G3 consist to late female flowering (61.34 days), the average height of plants (190.55 cm), small ear height (90.34 cm) and late maturity of cobs (94.37 days). Accessions G4 have early silking (56.87 days), have small heights of the plants (165.40 cm), very small heights ears (82.80 cm) and early maturity of corn (88.14 days).

4. Discussion

Knowledge of the genetic diversity of plant genetic resources in plant breeding is essential [27]. For a good knowledge of this genetic diversity must be performed prior morphological study. So there are many techniques to quantify and analyze the genetic diversity at multiple levels of biological organization. Which include the evaluation techniques using morphological markers [28]. Morphological analysis (Botany) then constitutes a first genetic diversity assessment approach.

Analysis of the morphological diversity of maize accessions collected in central and northern Benin has revealed a large variation in quantitative variables. The parameters plant height, ear height, tassel length showed a large variation (>10%) while variable female flowering, male flowering, days to ear leaf senescence and germination days showed small variation (<10%) in both zones except in the North the germination days presented a

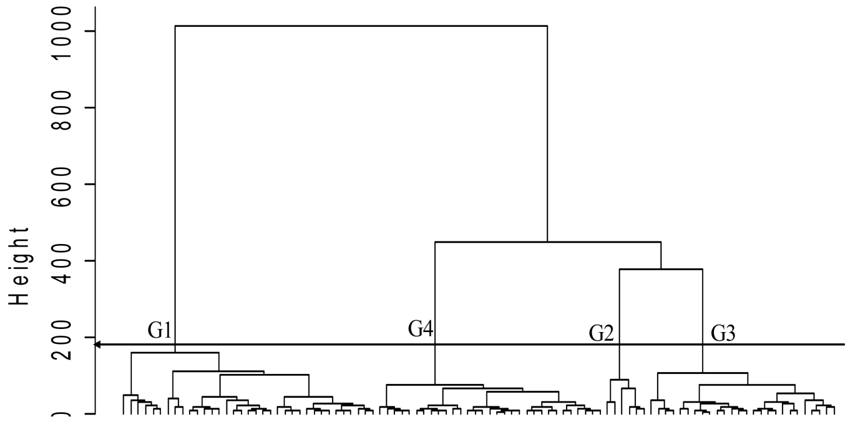

Figure 4. Dendrogram constructed from the Euclidean distances calculated on the basis of measured descriptors on maize accessions of northern Benin.

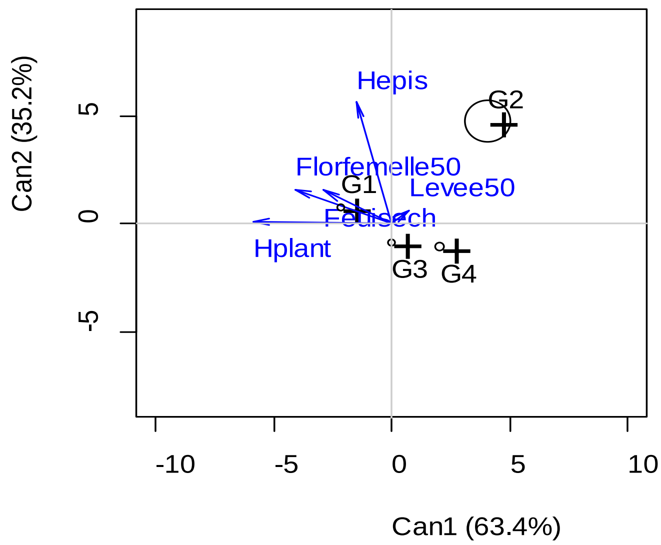

Figure 5. Graph of two canonical discriminant functions (Can1 and Can2) based on the most relevant variables revealed by discriminant analysis step by step of North accessions. Legend: Hplant = plant height; Florfemelle 50 = female flowering; Levee 50 = Germination days of grain; Feuisech = Day to ear leaf senescence; Hepis = Ear height.

large variation. This variation shows diversity among maize accessions grown in central and northern Benin. In studies conducted by N'da *et al.* [27] in Ivory Coast on the morphological characterization of maize observed a wide variation of agronomic traits such as plant height and ear height (>10%) and a low coefficient of variation (<10%) for the tassel length, male and female flowering. Unlike our results, N'da *et al.* [13] observed a small variation (<10%) of plant height of local maize accessions in Ivory Coast. This difference can be explained due to the exclusive use of local maize accessions in Ivory Coast but also the difference in the origin of these accessions and also the type of soil.

A positive correlation was found between plant height and ear height at the accessions of Benin Centre. And more plant height increases, the ear height is great. The same observation was made by Kim and Hallauer [29] who noticed a fairly strong positive correlation between plant height and ear height in maize. This result is very important in a breeding program that interest in a variety of high ears height and less vulnerable to pest.

The numerical classification revealed four groups of accessions morphological similarity perspective both at the Centre and the North of Benin. In both areas the four groups are discriminated by the earliness, characters related to plant and ear height. The work of N'da *et al.* [13] in Ivory Coast has shown that earliness, heights

Table 5. Results of the stepwise discriminant analysis on the different characteristics of corn accessions north Benin.

Variables	R-Square	F-value	Probabilité
Days to germination (day)	0.11	3.58	0.017
Female flowering (day)	0.14	4.73	0.004
Days to ear leaf senescence	0.12	3.98	0.010
Plant height (cm)	0.68	63.13	0.000
Ear height (cm)	0.66	59.41	0.000
Male flowering (day)	0.02	0.68	0.564
Tassel length (cm)	0.01	0.32	0.813
Foliage	0.01	0.42	0.739
Root lodging	0.00	0.13	0.943
Streak	0.03	1.19	0.316
Rust	0.012	0.37	0.778
Husk cover	0.01	0.28	0.836
Leaf blight	0.01	0.40	0.755
Sheath pubescence	0.01	0.38	0.771

Table 6. Comparison of north accession groups: ANOVA.

Agromorphological Characters	G1		G2		G3		G4		Prob.
	m	cv	m	cv	m	cv	m	cv	
Days to germination (day)	3.23[a]	9.46	3.42[a]	14.39	3.23[a]	8.80	3.27[a]	12.41	0.614
Male flowering (day)	60.69[a]	5.31	55.75[bc]	6.05	57.69[b]	6.49	54.17[c]	9.29	0.000
Female flowering (day)	64.61[a]	4.94	58.92[bc]	5.19	61.34[b]	6.00	56.87[c]	7.13	0.000
Days to ear leaf senescence	96.00[a]	5.82	93.00[a]	4.21	94.37[a]	3.34	88.14[b]	7.34	0.000
Plant height (cm)	216.14[a]	7.12	143.10[d]	19.39	190.55[b]	3.39	165.40[c]	6.17	0.000
Ear height (cm)	109.71[b]	11.53	135.74[a]	12.91	90.34[c]	8.15	82.80[c]	12.39	0.000
Tassel length	43.99[a]	9.84	42.83[a]	6.21	41.68[ba]	5.34	39.54[b]	6.19	0.000

Proportions with the same letters on the same line are not significantly different. **Legend**: m = means; cv = coefficiant variation.

characters, and cob parameters contribute to discriminate corn accessions. Similarly, these characters have been used to describe the variability of maize varieties grown Cuzalapa populations in Mexico by Louette and Smale [30]. According N'da *et al*. [27] peasant phenotypic selection based on visible characters (phenology, vegetative, ear) could explain the contribution of these variables to the structuring of variability. The importance of semi-flowering period in the differentiation of accessions is due to the fact that all the descriptors involved in the distinction are related to this descriptor. Moreover, the husk cover and sensitivity to streak discriminate Centre accessions unlike North accessions that are discriminated by the germinal parameters and maturity cobs. This difference can be explained by the difference in climate prevailing between the two different areas. The groups obtained at the Centre and North of Benin are heterogeneous in terms of status and origin of accessions. Thus in each cluster it has been observed a mixture of local and improved accessions. Similarly, there was not a grouping accession from the same locality. This could be explained by the exchange of varieties that occur among peasants from different localities. Indeed, several authors have shown that peasant seed management practices, including exchange of varieties among farmers are the cause of a significant diversity between populations of crop plants [11] [31].

5. Conclusion

Preliminary results on the morphological diversity of corn grown in the Centre and North of Benin showed that the studied accessions presented a variation for all characters used. Thus, a significant difference was found among all accessions for each agro-morphological characteristics evaluated with the exception of the germination days for accessions of the Centre; the tassel length and germination days for accessions of Northern Benin. Significant differences were recorded between the minimum and maximum values of the variables under study. This diversity has been structured into four groups for Centre and North Benin accessions. The characters which are the most distinctive among accessions of the Centre are those related to the precocity, the height of plant and ear, husk cover and sensitivity to streak. For the North accessions, the most discriminating agro-morphological characteristics are based on the germinal parameter, precocity, maturity of cobs and variables related to the plant and ear height. Each group has got in its interesting characters in maize breeding in Benin. The morpho-genetic variability among accessions is then given a real base for future breeding work. For a complete characterization of these accessions it will be important to perform a molecular characterization.

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