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Vol. 10(5), pp. 334-344, 29 January, 2015
DOI: 10.5897/AJAR2013.8364
Article Number: 5FC08DB49849
ISSN 1991-637X
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http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Evaluation of agro-morphological diversity of groundnut (*Arachis hypogaea* L.) in Niger

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Received 10 December, 2013; Accepted 9 January, 2015

This work evaluated a collection of hundred groundnut (*Arachis hypogaea* L.) varieties from different origin using twenty four (24) agro-morphological traits that can help to enhance selection efficiency in crop improvement. The experiment was carried out at the experimental station of INRAN-Tarna, in the region of Maradi (Niger) during the rainy season of 2010. Analysis of variance showed a large variability among varieties for the agro-morphological traits. Principal Component Analysis (PCA), Agglomerative Hierarchical Clustering (AHC) and Fisher Discriminant Analysis (FDA) revealed that this variability is structured into four distinct groups. Groups I and II consisted of early varieties that have a high emergence rate and high pods and seed weight. These groups included mainly local varieties and those introduced in Niger through seed dissemination. Groups III and IV are composed of late varieties with large pods while group III had mostly varieties with long leaflets. Understanding the genetic control of the most discriminating among the studied traits would bring significant contribution to the genetic improvement of this important crop.

Key words: *Arachis hypogaea* L, groundnut, agro-morphological traits, genetic variability, Niger.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important grain legume that grows in wet conditions in semi-arid regions of the world (Rao, 1980). As major crop in most of the tropical and subtropical regions, groundnut ranks 12th in the world crop production. It is grown in all continents with a total area of 24.6 million hectares, and a production of 41.3 million tons in 2012 (FAO, 2013). Africa, with 11.7 million hectares of land used for groundnut production and 10.9 million tons of annual production in 2012 is second only to the American

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continent (FAO, 2013). Despite this second position in terms of groundnut production, Africa has the lowest average yield per hectare (1 ton ha^{-1}) compared to Asia (1.8 tons ha^{-1}) and America (3 tons ha^{-1}). These low yields are related not only to the rainfed production systems combined with very low input but also to the use of traditional varieties that despite their genetic diversity are low yielding.

Several studies have shown that there is a large agro-morphological diversity in groundnut. This large diversity has led to the distinction of two sub-species: *A. hypogaea* subsp. *hypogaea* and *A. hypogaea* subsp. *fastigiata*. These subspecies are distinguished primarily by their port, usually crawling in *hypogaea* and erected in *fastigiata*, the absence of flowers on the main axis in *hypogaea* and the difference in leaf color: Dark green in *hypogaea* and light green in *fastigiata* (Fonceka, 2010). Both subspecies were themselves divided into several botanical groups including several commercial types.

Groundnut plays a key role in African farming systems, including savanna zone, in rotation or in combination with staple crops. In Niger, groundnut is widely cultivated in the southern belt of the country where its production provides both food for humans and feed for livestock. In addition, it is used as fuel and also contributes to protect the environment through nitrogen fixation. It also provides an additional source of income as a cash crop (NARP, 1993). Globally in 2007, groundnut production volume representing 10% of the production of oilseeds, accounted for a turnover of about $ 17 billion (Foncéka, 2010).

Evaluation of genetic resources is a key step towards efficiency in utilization of these resources through introduction of new genes as well as for their maintenance. In addition, the evaluation and characterization of the collection on the basis of morphological and agronomic traits are the starting point of any breeding program (Fundora, 1998; Simpson et al., 1986). There are several reports on breeding for varieties adapted to abiotic and biotic stresses to alleviate the major constraints in groundnut production (Ntare and Waliyar, 2000). However, in Niger, research activities on this topic are still not well articulated (Maria, 2009) although a number of groundnut varieties were released (Ndjeunga et al., 2003). The present study aimed to (i) study the variability of a collection of groundnut varieties collected in Niger through the evaluation of morphological and agronomic traits and (ii) analyze how the diversity of these traits is structured.

MATERIALS AND METHODS

Plant materiel

This study was conducted using a collection of 100 varieties of groundnut (*A. hypogaea* L.) from various origins and cultivated in Niger (Table 1). This collection, kindly provided by Dr Adamou Moutari from Institut National de la Recherche Agronomique du Niger (INRAN) was evaluated during the rainy season of 2010.

Experimental site

The trial was carried out at the experimental station of INRAN Tarna, in the region of Maradi which is located in the Sahel sedentary agro-climatic zone (Saadou, 1990), 657 km east of Niamey (13° 27 N and 7° 06 E) and 353 m above sea level (Figure 1). The characteristics of the soil and climate are presented in Table 2. The total rainfall recorded in 2010 was 592.4 mm distributed over 47 days.

Experimental design

The experimental design was a randomized complete block design with three (3) replications each, separated by 1.5 m. In each block a variety is represented by two rows of 3 m long and separated by an alley of 0.5 m. On each row, the seed were sown in 20 holes separated from each other by 0.15 m. Sowing was done on July 18th, 2010 at the rate of three seeds per hole. Prior to sowing, the seeds were treated with fungicide (Thioral). Two weeks after emergence, the plants were thinned to one plant per hole.

Traits measured

All the agronomic and morphological traits studied were selected from descriptors in the peanut IBPGR / ICRISAT Manual (1992). The parameters were measured on five plants per variety and per block. Two categories of traits have been studied namely quantitative traits (Table 3) and qualitative traits (Table 4).

Data analysis

Frequency table was used for qualitative data while a comparison of means by the analysis of variance (ANOVA) was performed for quantitative data. Analysis of the variability structure was done with multivariate analysis (MANOVA). Principal component analysis (PCA) defines the main components to account for the largest fraction of the total variance. Hierarchical clustering (AHC) using the unit Euclidean distance was performed to test for linkage between varieties and the resulting clusters were characterized through Fisher discriminant analysis (FDA) on the basis of the most discriminating traits.

RESULTS

For each qualitative trait, the frequency of the different morphological types is presented in Figure 2. From all the studied traits, seed color (CGR), leaf color (CFE) and to some extent pod reticulation (RGO) were the least variable as for each of them, there was one predominant morphological type. Grain color was rose for 85% of the varieties, while 62% had light green leaves (CFE) and 67% reticulated pods (RGO). Unlike these three characters which showed a trend towards the predominance of one morphological type, there were two major morphological types for the plant port (PPL) with 47% of varieties belonging to the erected and 45% to the semi-erect type. The traits showing the highest variability

Table 1. Origins of the groundnut varieties.

N°	Varieties	Origins	N°	Varieties	Origins	N°	Varieties	Origins
1	T 4 - 83	Niger	35	T 1 -2005	Niger	69	ICGV 93305	ICRISAT
2	T 5 - 83	Niger	36	T 2 - 2006	Niger	70	ICGV 10973	ICRISAT
3	T 6 - 83	Niger	37	T 3 - 2006	Niger	71	ICGV- IS-96606	ICRISAT
4	T 18 - 83	Niger	38	T 4 - 2006	Niger	72	ICGV -IS -96806	ICRISAT
5	T 19- 83	Niger	39	T 1 - 2007	Niger	73	ICGV- SM-99506	ICRISAT
6	T 49 - 83	Niger	40	T 2 - 2007	Niger	74	ICGV-SM-99513	ICRISAT
7	T 79 - 83	Niger	41	Zanzaro Maradi	Niger	75	ICG S - 31	ICRISAT
8	T 92 - 83	Niger	42	T M - H - 94	Niger	76	TA 94092	America
9	T 95 - 83	Niger	43	KH -241 -D	Burkina Faso	77	Tx AG - 1	America
10	T 108 - 83	Niger	44	Chico	Spain	78	Tx 798739	America
11	T 133 - 83	Niger	45	UGA - 7	Nigeria	79	Tx 804472	America
12	T 134 - 83	Niger	46	RRB	Nigeria	80	Tx 855157	America
13	T 145 - 83	Niger	47	796	Russia	81	Tx 872561	America
14	T 152 - 83	Niger	48	55 - 33	ICRISAT	82	Tx 872616	America
15	T 163 - 83	Niger	49	FDRF 5 - 277	ICRISAT	83	Tx 872621	America
16	T 169 - 83	Niger	50	SRV I - 3	ICRISAT	84	Tx 883623	America
17	T 177 - 83	Niger	51	CG - 8 - 35	ICRISAT	85	Tx 903020	America
18	T 183 - 83	Niger	52	ICG 3736	ICRISAT	86	Tx 903644	America
19	T 45 - 87	Niger	53	ICG 3968	ICRISAT	87	Tx 903654	America
20	T 46 - 87	Niger	54	ICG 6121	ICRISAT	88	Tx 903714	America
21	T 42 - 88	Niger	55	ICG 6760	ICRISAT	89	Tx 903796	America
22	T 44 - 88	Niger	56	ICG 7433	ICRISAT	90	Tx 903838	America
23	T 1 - 89	Niger	57	ICG 9199	ICRISAT	91	Tx 903839	America
24	T 4 - 89	Niger	58	ICG 11183	ICRISAT	92	72 - 112	America
25	T 13 - 89	Niger	59	ICGV 86024	ICRISAT	93	73 - 30	America
26	T 14 - 89	Niger	60	ICGV 86072	ICRISAT	94	55 - 437	America
27	T 16 - 89	Niger	61	ICGV 86124	ICRISAT	95	O - 20	America
28	T 20 - 89	Niger	62	ICGV 86529	ICRISAT	96	EC - 5	America
29	T 35 - 89	Niger	63	ICGV 87003	ICRISAT	97	Nelson spanish	America
30	T39 - 89	Niger	64	ICGV 87281	ICRISAT	98	JL - 24	India
31	T 2 - 93	Niger	65	ICGV 91284	ICRISAT	99	Fleur 11	India
32	T 1 - 95	Niger	66	ICGV 91317	ICRISAT	100	Tainan 9	India
33	T 2 - 96	Niger	67	ICGV 91341	ICRISAT			

were (i) pod spout (BGO) with 3 to 4 morphological types: Moderate spout (31%), light spout (30%), without spout (25%) and to a lesser extent the prominent spout (12%); and (ii) pod throttle (EGO): thin throttle type (44%), moderate throttle (34%) and without throttle (17%).

ANOVA exhibited highly significant differences ($p < 0.001$) for all traits except for the length of leaflets as indicated by F values (Table 5) and the extent of variation was quite large. For example, the pod weight varied from 32 g (ICGV91317) to 113.5 g (T13-89) and the number of days to flowering varied from 23 (T42-88, T134-83, T5-83, ICGV 93305 and ICGV 91341 23) to 29 days (Q2 96 ICG6760, T4-83 and ICGV IS 96806). Similarly, the 100-seed weight ranged from simple (22.3 g for ICGV IS 96806) to more than double (51 g for ICG3938). Besides, the block effect was highly significant for all traits except for the number of branches, the seed width and threshing index. For the interaction between varieties and blocks, the difference was not significant for all traits except for leaf length.

Principal component analysis (PCA) revealed that the first four axes account for 51.4% of the variation of the traits measured in the 100 varieties. To define the relationship between the agro morphological traits, the eigenvectors and the correlations between 21 traits out of 24 were analyzed along with the main components. Only characters that are highly correlated with one of the first three components were presented in Table 6. The projection of these characters on the first two principal components (Figure 3) showed that:

1. Axis 1 explains 20.6% of total variation. It combines

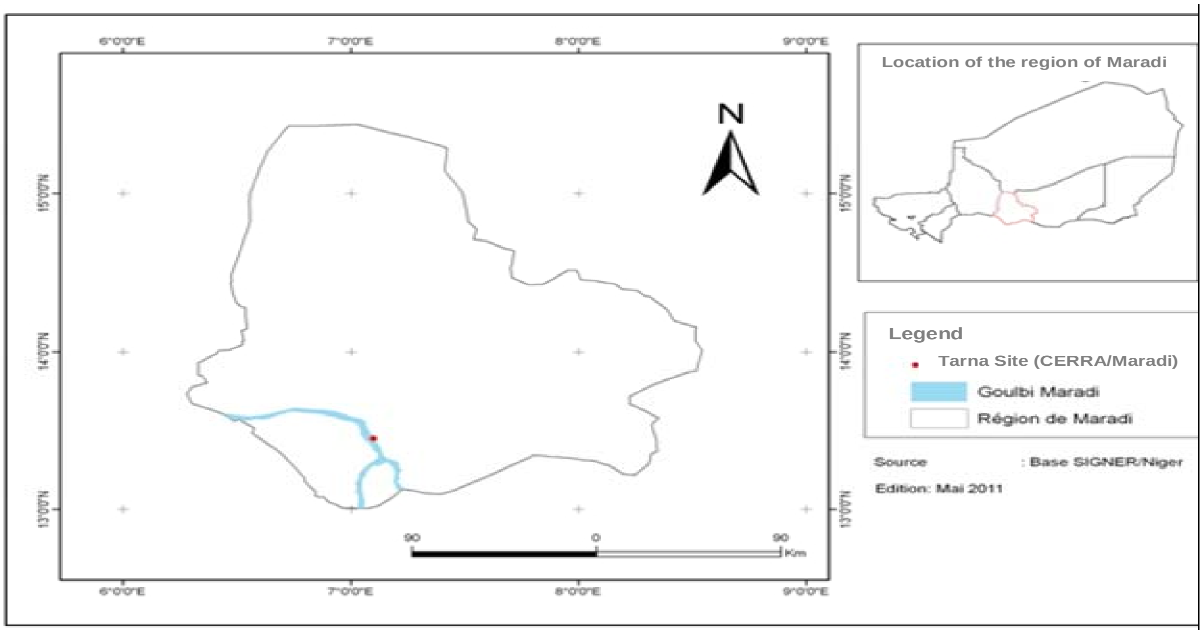

Figure 1. Experiment site location.

Table 2. Soil and weather conditions of the experiment site (INRAN Tarna).

Soil	
Type	Sandy loam
Acidity	pH = 6.49
Total Nitrogen	0.07%
Organic Carbon	0.24%
Phosphorus	16.12 ppm
CEC	1.94 meq/100g
Organic matter	0.41%
Climate	
Rainfall (mm)	400 mm≤ PI<600 mm
RH (%)	18%<HR<77%
Temperature (°**C)**	18.6°**C** <T<37.1°**C**
Average rainfall (2000-2009)	491.01 mm

high values of pod length and width of pods, seed length and days to flowering as opposed to the lowest values of main stem height, harvest index and number of plants after emergence.

2. Axis 2, with 12.6% of the variation is defined by the following characters: Seed width, 100-seed weight, pod weight and seed weight. Varieties at the positive side of axis 2 have small values and those at the negative side of this axis have high values for these traits.

These results suggest that late genotypes had larger pods, longer seeds and smaller harvest index. In addition, genotypes with low pod weight, shorter seeds and small 100-seed weight were identified from component 2.

The dendrogram resulting from hierarchical clustering (CAH) with 0.8 units of truncation threshold of Euclidean distance exhibited four distinct groups (Figure 4). The number of varieties in the different groups was 22, 66, 3, and 9 for groups I, II, III, and IV, respectively (Table 7). The distribution of varieties in different groups showed that diversity was not structured based on origin.

Fisher discriminant analysis (FDA) performed using the data of the four identified groups provided distances

Table 3. Description of the studied quantitative traits.

Parameters	Abbreviations	Descriptions
No of plants	NPL	No of plants per plot 4 weeks after sowing
Days to flowering	DFL	Number of days from sowing to flowering
Main stem height	HTP	Height in cm from ground level to the terminal bud (average of 5 plants)
Haulm dry weight	PFS	Dry weight (g) of 5 plants excluding pods
No of branches/plant	NBR	Number of cotyledonary lateral branches (average of 5 plants)
Plant throttling	EPL	Length of branches (cm) 2 months after planting (average of 5 plants).
Harvest index	IR	% Ratio of seed weight to total dry biomass.
Leaflet length	LOF	Length (cm) of the apical leaflet of the third leaf of the main stem along the limbus (5 leaflets / plant and average of 5 plants).
Leaflet width	LAF	Width (mm) of the apical leaflet of the third leaf of the main stem. Measurements were taken between the tops of the leaflet. (Five leaflets per plant and average of 5 plants).
No Harvested plants	NPR	Number of plants just before harvest
Pod weight	PGO	Weight (g) of pods (average of 5 plants)
Pod length	LOG	Length (mm) of mature pod (5 pods / plant and average of 5 plants)
Pod width	LAG	Width (mm) of mature pod (5 pods / plant and average of 5 plants)
Threshing index	IB	% Ratio of seed weight to pod weight (seed weight / pod weight * 100)
Seed weight	PGR	Grain weight (g) (average of 5 plants).
100-Seed weight	PCG	100-seed weight (average of 5 plants).
Seed length	LGR	Seed length (mm)
Seed width	WGR	Mid-seed width (mm)

Table 4. Description of the studied qualitative traits.

Trait	Abbreviation	Description
Plant port	PPL	Plant port at pod development stage : 1 = erect, 3 = semi erect, 5 = crawling
Leaf color	CFE	1 yellow green, 2 = light green, 3 = green, 4 = dark green, 5 = blue green;
Pod beak	BGO	0 = without beak, 3 = thin, 5 = moderate, 7 = marked, 9 = very pronounced
Pod throttling	EGO	0 = no throttling, 3 = mild, 5 = moderate, 7 = strong, 9 = very deep
Pod reticulation	RGO	0 = without reticulation, 3 = mild, 5 = moderate, 7 = prominent, 9 = very prominent
Seed color	CGR	1 = pink, 3 = red, 5 = purple, 7=black, 9 = motley

between groups and their significance as defined by Mahalanobis (Table 8). The difference between the four groups on the basis of all the characters, except for PPL, PGO, PGR, PCG, WGR, GERD was highly significant ($p < 0.001$) (Table 9). In other words, apart from these traits, all the remaining ones have contributed to discriminate between the four groups. These results were confirmed by the Wilks' Lambda test ($P < 0.0001$).

Moreover, LOF, LAG, LOG, HTP, DFL LGR and NPL were the most discriminating traits with highly significant F and R^2 values ($p < 0.0001$) (Table 9). The eigen values of the canonical axes showed that the first two axes ($P < 0.0001$) accounted for 88.33% of the variation (Table 10).

The projection of the four groups on the canonical system of axes 1 and 2 indicated that the first axis discriminates between groups the best (Figure 5). It divides groups III and IV which were composed of varieties with long leaflets and those IV with short leaflets. Group being positioned on the positive side of axis 2, is characterized by late varieties, with low emergence rate, large pods and long seed as opposed to varieties belonging to group II which are early and have high emergence rate and relatively small pods. Varieties of group III have long leaflets unlike those of group IV. Groups I and II which were located in the center of the plan presented average values for these traits.

DISCUSSION

The results of this study on agro-morphological traits in

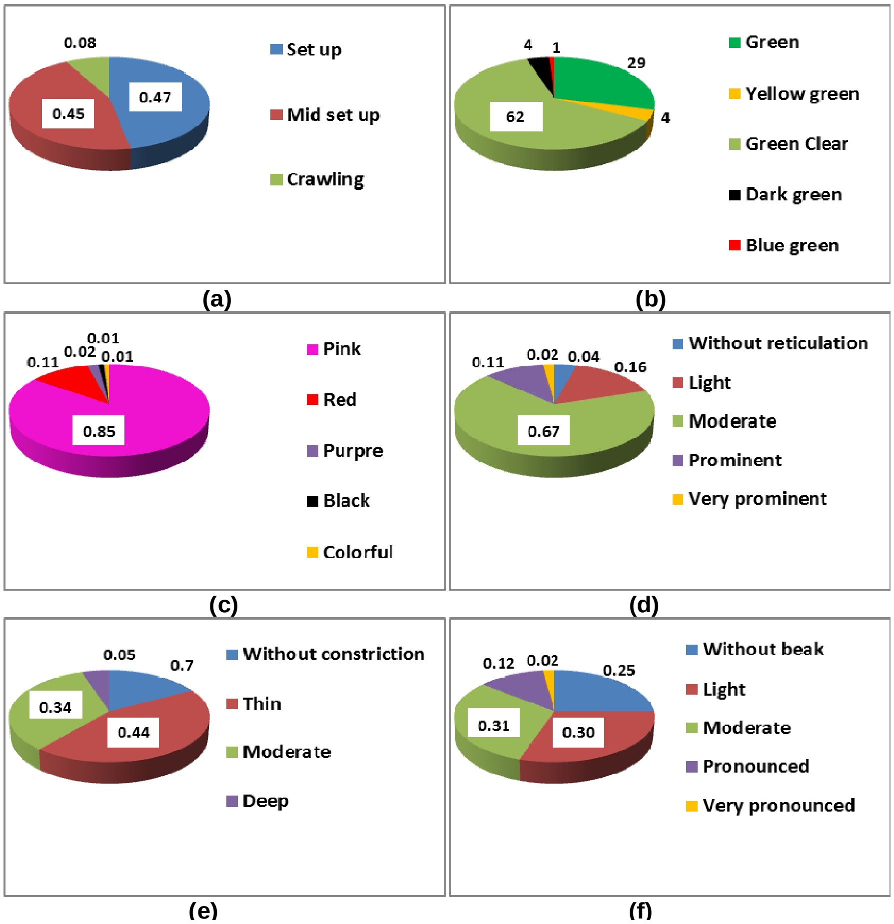

Figure 2. Morphological types for the different qualitative characters. (a) Plant port; (b) leaf color; (c) grain color; (d) pod reticulation; (e) pod throttling; (f) pod beak.

100 groundnut varieties (*A. hypogaea* L.) showed large genetic variation which might be related to the origin of the varieties. In fact, these varieties were developed in different growing areas, with a possible maintenance of some level of variability. Each variety has evolved in isolation from others, which accentuated the differences. This is favored by the mode of reproduction of the crop that is mostly autogamous with a low level of cross pollination (0.2 to 6.6%). Several authors (Clegg et al., 1992; Hamrick and Godt, 1990) reported that highly autogamous mode of reproduction promotes inter-population heterogeneity and allows good adaptation to the environment, in addition to plant-to-plant heterogeneity in the population. These results are in agreement with those of Balma (1994) who assessed the quantitative traits of 140 varieties in a groundnut collection from the center of Burkina Faso and those of Clavel (2004) on drought adaptation of groundnut in Senegal.

This varietal aspect may also explain the highly significant block effect observed for most of the studied traits except seed width, number of branches and threshing index. Because varieties are usually developed on the basis of traits that allow them to adapt to their environment, these traits are closely related to the ecological conditions in the production areas. The observed variation for the traits measured in this work is partly due to environmental factors in addition to genotypic differences, although it is often difficult to measure their relative share.

Genetic improvement is largely related to the types of correlation between traits (Bakasso, 2010). In this work, results showed that there was a significant correlation between pod length and seed length, in agreement with the findings of Godoy (1982), Soomro and Larik (1981) and Varisai and Ramachandra (1975). Moreover, the size of the pods and seeds were positively and significantly correlated, so any restriction of pod growth may result in smaller seeds. These results corroborated those reported by Zaman et al. (2011). In addition, Manggoel et al. (2012) reported that 100-seed weight is a key yield trait affecting grain yield in legumes like cowpea.

The 100 groundnut varieties tested in this study

Table 5. Analysis of variance and average performance of the varieties.

Source of variation	DDI	NPL F	DFL F	HTP F	NBR F	EPL F	LOF F	LAF F	PFS F	PGO F	LAG F	LOG F	PGR F	PCG F	LGR F	WGR F	IB F	IR F	CGO F
Blocs	2	7***	5.7***	3.1***	1.8^{ns}	67***	9.1***	2.1***	29.8***	9.5***	3.6***	7.3***	11.2***	2.1***	3.8***	1.1^{ns}	1.2^{ns}	47.7***	9.1***
varieties	99	8.3***	2.7***	2.9***	2.4***	1.4***	1.2^{ns}	14.3***	1.3***	1.8***	6.5***	8.2***	1.8***	3.5***	5.5***	2.2***	1.8***	1.5***	7.5***
Blocs * genotypes	198	0.2^{ns}	0.4^{ns}	0.6^{ns}	0.8^{ns}	0.5^{ns}	2.3***	0.6^{ns}	0.6^{ns}	1.1^{ns}	0.3^{ns}	0.3^{ns}	1.0^{ns}	0.6^{ns}	0.3^{ns}	0.5^{ns}	1.3^{ns}	0.5^{ns}	0.3^{ns}
Min		8	23	17.5	4	33.3	4	2.2	245.3	32	9..1	15.7	16.1	22.3	8.9	6.2	44.7	3.2	0
Max		36	29	43	10	64.3	8.9	3	857.9	113.5	15.2	33	74.9	51	15.7	7.9	79.3	19.3	9
Mean		20.2	25.1	30.3	5.5	49.7	5.2	2.6	402.5	66.5	11.3	23.7	43.1	33.2	11.1	7	64.6	10.7	3.4
ET		7.5	1.7	6.3	1.4	10	1.1	0.2	167.8	27.5	1.1	3.5	18.9	6.3	1.3	0.5	8.9	6.1	2

Min, minimum; Max, maximum; ET, standard deviation; cv, coefficient of variation; F, F- test (Fischer), ***, highly significant (5%), ns : non-significant; Legend: NPL, Number of seedlings at emergence, DFL, Days to flowering; NBR, Number of branches; HTP, Height of main stem; LOF, Length of the leaflet; LAF, width of the leaflet; PFS, haulms dry weight; PGO, pods weight; LOG, pod length; LAG, pod width; PGR, seed weight; PCG, 100-seed weight; LGR, seed length; WGR, seed width; IB, threshing index; IR, harvest index; PPL, plant port; CFE, leaf color; RGO, pod reticulation; CGR, seed color; EPL, plant throttling.

Table 6. Eigen values and proportion of information on the four axes of PCA.

Axes	Eigen values	Proportions	Cumulative %	HTP	LOG	LAG	LGR	IR	NPL	WGR	PCG	PGO	PGR	DFL
1	4.328	20.6	20.6	-0.323	0.341	0.329	-0.324	-0.324	-0.314	0.016	0.081	-0.155	-0.226	0.287
2	2.648	12.6	33.2	-0.021	-0.25	-0.174	-0.359	-0.227	-0.07	-0.417	-0.501	-0.3	-0.301	0.123
3	2.223	10.6	43.8	-0.231	-0.11	-0.105	-0.06	0.288	-0.29	-0.221	-0.11	0.45	0.44	0.326
4	1.585	0.075	51.4											

NPL, Number of seedlings at emergence; DFL, Days to flowering NBR, Number of branches; HTP, Height of main stem; PGO, pods weight; LOG, pod length; LAG, pod width; PGR, seed weight; PCG, 100-seed weight; LGR; seed length; WGR seed width; IR, harvest index;

were clustered into four different groups. Varieties of groups I and II, with medium performance, like 55-437, T169-83, T 177-83, JL 24, ICGV 87003, ICGV 87281, RRB, O-20,

Tx 872,561 are the most disseminated in Niger. For a better exploitation of the species in Niger, varieties of these groups, especially those of group II, which are from erect or semi-erect type, early and have high emergence rate, high seed and pod weight, would be more appropriate for the country. Varieties of Group III as well as those from group IV, which were found to be late with large pods, should be grown in areas where the rainy season is longer. Their low performance in this work may be related to environmental conditions, particularly the duration of the rainy season which was quite short. However, these varieties can be used for haulm production as feed for livestock.

The structure was proved to be not origin based as each group is a mixture of varieties from several origins. All the traits measured have contributed to discriminate between the groups except those primarily related to grain yield and plant port. In a study of peanut collection of 86 accessions from Cuba, Fundora et al. (2004) showed that the traits pod length, number of seeds per pod, pod/seed weight and pod width were predominant among the 14 traits measured. This implies that these varieties were developed for high grain yield in relation to plant port type. Indeed, in this study, the analysis of qualitative traits showed that all varieties were divided mainly

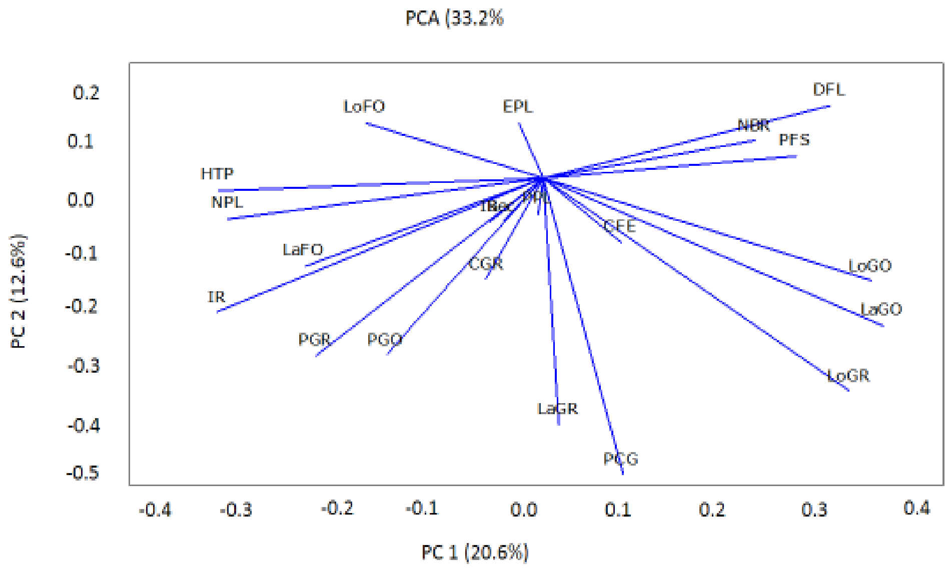

Figure 3. Graphical representation of the first two axes.

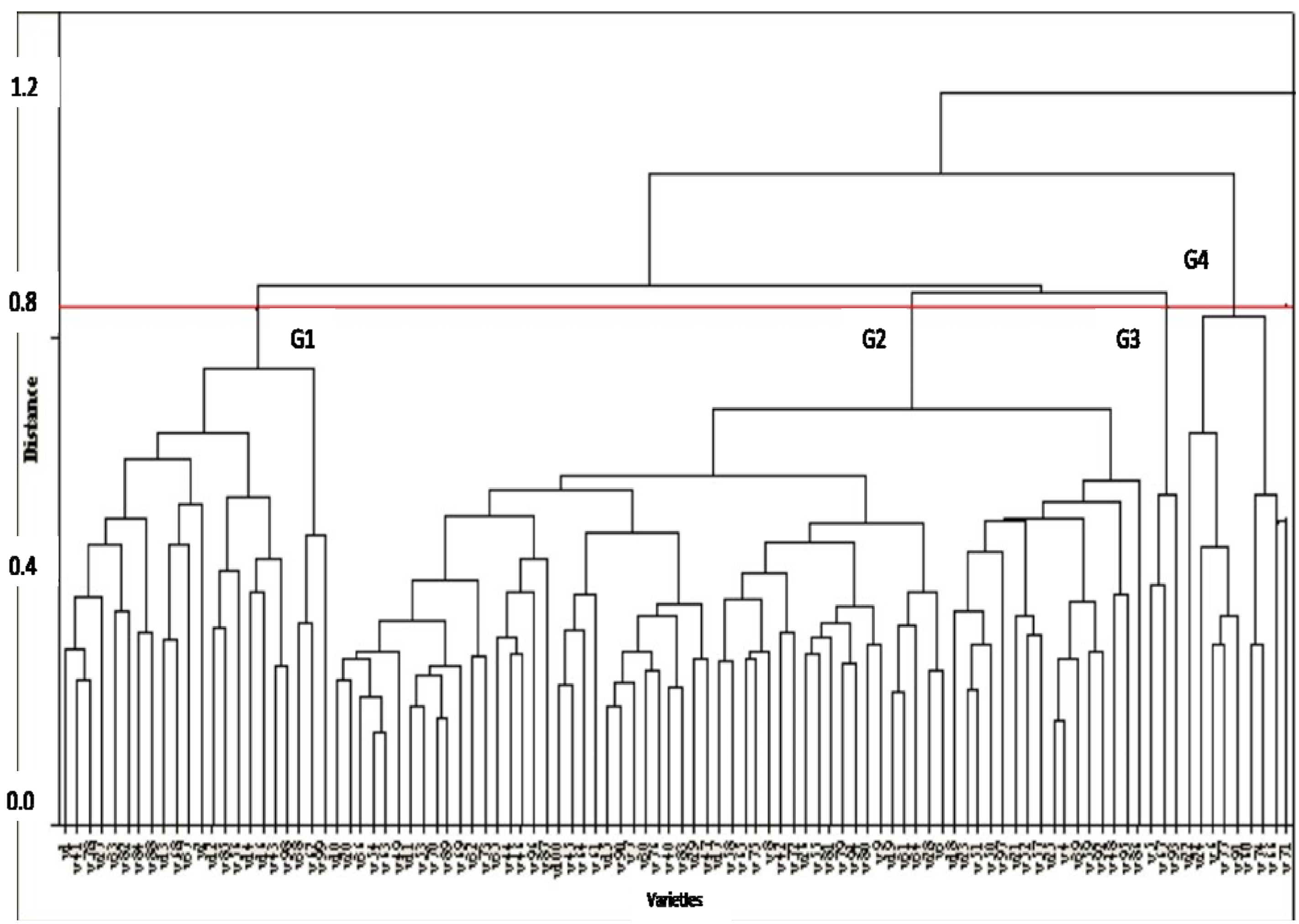

Figure 4. Dendrogram obtained by hierarchical clustering of groundnut varieties (*Arachis hypogaea* L.).

Table 7. Groups composition from hierarchical clustering analysis.

N Group	Number	Composition
I	22	V54. V57. V25. V74. V36. V50. V39. V90. V40. V22. V6. V13. V45. V11. V71. V52. V69. V65. V98. V66. V41. V73.
II	66	V92. V83. V14. V84. V3. V2. V97. V81. V5. V91. V48. V87. V84. V94. V47. V26. V32. V59. V88. V10. V38. V53. V20. V30. V18. V35. V100. V51. V79. V1. V63. V64. V99. V97. V28. V46. V82. V23. V17. V43. V60. V34. V19. V15. V21. V76. V9. V12. V31. V95. V78. V29. V4. V77. V93. V82. V96. V27. V85. V8. V75. V89. V61. V56. V49. V24.
III	3	V80. V44. V67.
IV	9	V33. V55. V70. V58. V37. V89. V72. V62. V16.

Table 8. Discrimination test using Mahalanobis distance.

Group	Grp I	Grp II	Grp III	Grp IV
I	0	-	-	-
II	5.0***	0	-	-
III	12.5***	14.6***	0	-
IV	8.2***	12.6***	14.9***	0

Table 9. Univariate and multivariate analysis of variance.

Variables	R^2	F(3)*	Prob
NPL	0.8	11.36	< 0.0001
DFL	0.58	15.27	< 0.0001
NBR	0.56	7.2	0.001
HTP	0.6	8.1	< 0.0001
LOF	0.97	90.15	< 0.0001
LAF	0.54	5.18	< 0.0001
EPL	0.57	2.72	0.048
CFE	0.72	6.13	0.001
PPL	0.7	0.8	0.496
PFS	0.49	5.16	0.002
PGO	0.49	1.8	0.151
LOG	0.8	22.29	< 0.0001
LAG	0.76	19.46	< 0.0001
PGR	0.5	2.39	0.073
PCG	0.64	2.51	0.063
LGR	0.74	9.34	< 0.0001
WGR	0.53	1.88	0.137
IB	0.47	4.08	0.009
IR	0.55	5.02	0.003
RGO	0.53	3.19	0.027
CGR	0.4	4.39	0.006
Wilks' Lambda test		0.021 (ddl= 96)	<0.0001

(3)*, ddl = 3; NPL, Number of seedlings at emergence; DFL, Days to flowering NBR, Number of branches; HTP, Height of main stem; LOF, Length of the leaflet; LAF, width of the leaflet; PFS, haulms dry weight ; PGO, pods weight; LOG, pod length; LAG, pod width; PGR, seed weight; PCG, 100-seed weight; LGR; seed length; WGR seed width; IB, threshing index; IR, harvest index; PPL, plant port; CFE, leaf color; RGO, pod reticulation; CGR, seed color; EPL, plant throttling.

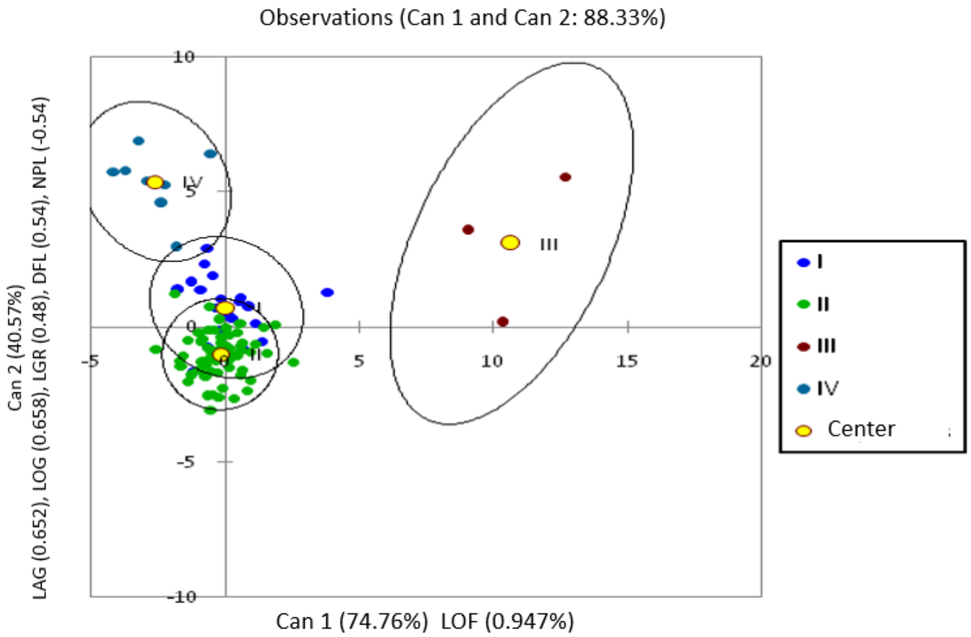

Figure 5. Projection of the four groups on the plane defined by the two first axes of canonical discrimination.

Table 10. Proportions of information from canonical axes (Correlations and significance of canonical axes).

Axes	Proportions	Cumulative proportions	Prob
1	0.48	0.48	<0.0001
2	0.40	0.88	<0.0001
3	0.12	1.00	0.710

Into erected and semi-erected types.

Conclusion

The results of this study have revealed a large genetic diversity in the groundnut collection of Niger. It also helped to understand that even if the varieties are geographically distant, some of them have agro-morphological and genetic traits that are close to each other. However, cultivated varieties, even if they are not genetically variable have strong potential for ecotypic differentiation related to abiotic and biotic stresses they were exposed to. The genetic variation observed in this work demonstrates the possibility of genetic improvement of groundnut to meet the agronomic and morphological requirements for increased productivity and adaptation to local conditions. The four groups defined by the CAH based on agro-morphological traits may represent the required variability for a basic collection. In order to establish an efficient improvement program, it is indispensable to understand the nature of the genetic control of these different traits, especially the most discriminating.

Conflict of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGMENT

The authors are grateful to the Tropical Legumes II project for financial support and INRAN for providing facility to carry out this study.

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