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Agro-Morphological Variability in Eight Bambara Groundnut (*Vigna subterranea* (L.) Verdc.) Morphotypes from Zinder (Niger)

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Abstract

Bambara groundnut (*Vigna subterranea* (L.) Verdc.) has economic importance for the producers and the traders as cash crop since it generates substantial income for households in Niger. The objective of this study was to assess eight (8) Bambara groundnut morphotype from Université André Salifou de Zinder in Niger Republic by their morphological and agronomic characters. The experiment was conducted in a randomized complete block design with three replications during the rainy season of 2020-2021. Data were collected on the Number of leaves, Plant height (cm), Growth habit (cm), Terminal leaflet length, Terminal leaflet width, Number of nodes/stem, Number of stems/plant, Number of pods/plant, Weight of 100 pods (g), Weight of 100 seeds (g), Length of seeds (mm), Width of seeds (mm), Weight of seeds/Plot (kg). There were significant differences for all characters, except Number of leaves, Terminal leaflet length, Terminal leaflet width, Length of seeds (mm) Weight of 100 pods (g), Weight of 100 seeds (g). The morphotypes UZ-VZ-04, UZ-VZ-03, UZ-VZ-06, UZ-VZ-02 and UZ-VZ-05 have demonstrated good performance for grain weight per plot and can be useful for a breeding program.

Keywords

Vigna subterranea, Accessions, Agro-Morphological Traits, Weight of 100 Seeds

1. Introduction

Bambara groundnut (*Vigna subterranea* (L.) Verdc.) originates from northeastern Nigeria and northern Cameroon [1]. It is generally cultivated in sub-Saharan and Sahelian Africa where it is the third most important food legume in terms of production and consumption after groundnut (*Arachis hypogaea* L.) and cowpea (*Vigna unguiculata* L. Walp.) [2]. Its world production is estimated at 216,575 tonnes in 2013 [3]. In Africa, this production has not varied considerably since 1993 and is around 300,000 t/year. In Niger, its average production in 2017 is estimated at 36,037 tons [3]. It is a plant adapted to various climatic and ecological conditions. The plant is mainly cultivated for its seeds rich in proteins, carbohydrates and lipids [4] [5]. It is highly rich in calories (387 kcal/100g), protein, vitamins and mineral elements [6] [7] [8] [9].

Bambara groundnut seeds contain various mineral elements including calcium, magnesium and potassium [7]. The consumption of these seeds contributes to the improvement of the quality of the diet as a protein supplement and can help maintain the body in good health because the Bambara groundnut contains antioxidants [10]. The proteins have a high lysine content and their food association with cereals constitutes a nutritional supplement, especially for rural populations with difficult access to animal proteins [5] [11]. The highly nutritious content of Bambara groundnut and its high content of essential amino acids make it an important crop to consider for food security [12]. Bambara groundnut also has therapeutic virtues well known to local populations [9]. In addition, the cultivation of Bambara groundnut contributes to the fertilization of the soil, through the symbiotic fixation of atmospheric nitrogen by bacteria of the genus Rhizobium and gives average yields ranging from 350 to 800 kg/ha in regions where the soil is poor and low rainfall [2] [9]. Some Bambara groundnut morphotypes are resistant to insect attacks, diseases and drought [13]. This gives the culture of Bambara groundnut a good capacity of adaptation to the arid regions of sub-Saharan Africa where it is mainly cultivated by women in pure culture in small areas and without adequate cultivation techniques [14] [15].

Despite all these advantages, Bambara groundnut is one of the neglected species in varietal selection programs [16]. Its cultivation is used to alleviate the suffering of the populations during the lean periods. However, the plant offers enormous potential for improvement, thanks to its genetic diversity found in thousands of accessions harvested throughout the world [5] [9] [17] [18].

However, in Niger, very little information is currently available on the genetic and agro-physiological diversity of this species while it should be taken into account in the design of genetic and agronomic selection programs in the country and in the western sub-region. The selection strategies that can be envisaged for the genetic improvement of this species first require a good knowledge of the genetic diversity that has accumulated within traditional varieties, under the effects of natural and human selection. More importantly, the morphotypes cultivated by farmers must be investigated and characterized to better discriminate them. In order to preserve, restore and enhance the diversity of available plant material (Bambara groundnut), it is necessary to identify its genetic potential through the analysis of its morphological and agronomic characteristics. In this general context, the main objective of this study is to characterize eight morphotypes of Bambara groundnut from Kantche department.

2. Material and Methods

The study was conducted during the 2020/2021 rainy season at Université André Salifou de Zinder, located in central Niger between 12˚48' North latitude and 12˚00' West longitude. The climate is characterized by two seasons (a dry season and rain one) with an average rainfall of 659 mm/year, divided into a rainy season from June to September. Annual temperatures range from 22.4˚C to 35.7˚C.

The plant material used in this study is composed of the seeds of eight (8) Bambara groundnut morphotypes from a selection made by [19] among the local varieties (**Figure 1**) of the department of Kantché (Zinder). The different names are attributed to these varieties according to the color of the seeds, namely the color of the integumentary coat of the seeds as well as the color and shape of the eye (**Table 1**).

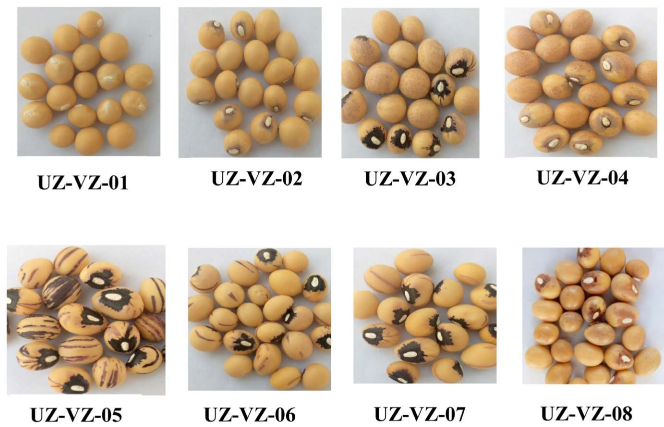

Figure 1. Seeds used in the study.

Table 1. Morphotypes of the study.

	Morphotypes	phenotypical characteristics of seeds	
		Seed color	Color and aspect of the eye
1	UZ-VZ-01	Cream without eye	
2	UZ-VZ-02	Cream	Gray eye like butterfly
3	UZ-VZ-03	Cream with purple spot	Black eye like butterfly
4	UZ-VZ-04	Cream with red spot	Gray eye like butterfly
5	UZ-VZ-05	Cream with large stripes	Black eye like butterfly
6	UZ-VZ-06	Cream with purple stripes	Black eye like butterfly
7	UZ-VZ-07	Cream with brown stripes	Black eye like butterfly
8	UZ-VZ-08	Cream with red stripes	Dark red eye like butterfly

The material was grown in randomized complete blocks with three repetitions separated from each other by 1 m. Each repetition was composed of a block of 8 elementary plots, 1.2 m and 1 m in size, separated from each other by 0.6 m, each representing a morphotype. We, therefore, had a total of 24 elementary plots. Each plot contained 5 rows of 6 plants equidistant from 0.2 m. The distance between the lines is fixed at 0.3 m. The total area of the device was 68.32 m^2 (12.2 m long and 5.6 m wide). The sowing was carried out on July 10, 2021. The seeds of 8 morphotypes were sown randomly. No fertilizer or phytosanitary treatments were used from sowing to harvest. Regular manual weeding was done during the vegetative cycle, particularly from the emergence of seedlings to fruiting. Watering came exclusively from rainfall.

Thirteen (13) agronomic and morphological characters were chosen from the list of agronomic and morphological descriptors of Bambara groundnut [20], to characterize and evaluate the different morphotypes (**Table 2**). The measurements were carried out on 5 plants marked for each morphotype as indicated in the list of agronomic and morphological descriptors of Bambara groundnut.

The data collected were first entered into a table using Excel Microsoft Office 2013 software. For each of the quantitative traits studied, the data thus collected were subjected to an Analysis of Variance (ANOVA), with Minitab software. 19. When a significant difference was observed between the varieties for a given characteristic, the ANOVA was completed by the test of grouping the means according to the method of Tukey which made it possible to identify the varieties which differ significantly from the others.

Table 2. Characters measured and periods of measurement.

Characters	Code	Periods of measurement
Number of leaves	Nle	2 Weeks after flowering
Plant height (cm)	PH	10 Weeks after sowing
Growth habit (cm)	GH	10 Weeks after sowing
Terminal leaflet length	TLL	10 Weeks after sowing (Mean of 3 leaves to 4^{th} node)
Terminal leaflet width	TLW	
Number of nodes/stem	NbrN	At harvest
Number of stems/plant	NbrSt	At harvest
Number of pods/plant	NbrP	At harvest
Weight of 100 pods (g)	W100P	2 months after the harvest
Weight of 100 seeds (g)	W100S	2 months after the harvest
Length of seeds (mm)	LSe	2 months after the harvest
Width of seeds (mm)	lSe	2 months after the harvest
Weight of seeds/Plot (kg)	WSe/Pl	2 months after the harvest

3. Results and Discussion

Morphological characters

The analysis of the number of leaves (Nle) varied from an average of 73.67 (UZ-VZ-01) to 95.00 (UZ-VZ-02) with no significant difference (**Table 3**) between the different morphotypes (P = 0.526). These results are contrary to those obtained by [2] on 15 morphotypes of Bambara groundnut in Khorgo from Cote d'Ivoire. This difference could be explained by the fact that the two trials did not have the same numbers of morphotypes (8 morphotypes and 15 morphotypes. The plant height (PH) character shows a very highly significant difference between the different morphotypes (P = 0.000). The UZ-VZ-01 and UZ-VZ-03 morphotypes have the greatest heights with respective averages of 32.47 cm and 31.560 cm and the UZ-VZ-07 morphotype has the smallest height with an average of 26.013 cm (**Table 3**). These results are similar to those obtained by [21] on varieties from Ethiopia. The difference observed between the different morphotypes for the Growth habit (GH) is highly significant (P = 0.000). The UZ-VZ-01 morphotype records the largest value with an average of 44.67 cm and the UZ-VZ-07 and UZ-VZ-08 morphotypes have the smallest value with respective averages of 31.80 cm and 31.60 cm (**Table 3**). These differences in the results may be due to the genetic variation, environment and the interaction between the two factors. These observations are similar to those of [22] when they analyzed the morphological and agronomic variability of Bambara groundnut morphotypes grown in the Sahelian zone of Niger. The length of the terminal leaflet (TLL) varies between an average of 33.96 mm (UZ-VZ-01) and 43.44 mm (UZ-VZ-02) without showing a significant difference between the different morphotypes (P = 0.513), as well as the width of the terminal leaflet (WLL) does not show a significant difference between the different morphotypes (P = 0.487) and varies between an

Table 3. Means of the morphological characters.

	Nle	PH (cm)	GH (cm)	TLL (mm)	TLW (mm)	NbrS	NbrN
UZ-VZ-01	73.6 ± 16.0	32.47a ± 4.6	44.67a ± 7.1	33.96 ± 7.2	26.22 ± 5.5	7.26ab ± 2.3	7.33a ± 1.3
UZ-VZ-02	95.0 ± 29.8	30.48ab ± 3.2	34.20bc ± 4.8	43.44 ± 13.1	33.33 ± 9.9	7.06ab ± 1.2	6.49a ± 0.9
UZ-VZ-03	85.20 ± 37.7	31.56a ± 3.4	38.60b ± 5.4	39.23 ± 16.7	30.48 ± 12.5	8.86a ± 2.2	6.44a ± 0.7
UZ-VZ-04	90.40 ± 35.2	30.14ab ± 4.6	33.47bc ± 5.0	41.40 ± 15.7	31.80 ± 11.9	8.26ab ± 1.5	6.51a ± 0.7
UZ-VZ-05	83.70 ± 21.3	31.09ab ± 1.6	35.10bc ± 5.9	38.20 ± 9.3	29.40 ± 7.0	8.50ab ± 1.8	6.26a ± 0.6
UZ-VZ-06	77.90 ± 14.7	30.54ab ± 1.7	33.00bc ± 6.3	35.62 ± 6.3	27.47 ± 4.7	7.10ab ± 1.1	6.43a ± 0.5
UZ-VZ-07	87.80 ± 25.8	26.01c ± 1.7	31.80c ± 4.1	40.13 ± 11.4	31.27 ± 8.6	6.80ab ± 1.6	6.23a ± 0.4
UZ-VZ-08	89.73 ± 22.1	27.53bc ± 3.0	31.60c ± 5.0	40.99 ± 9.7	31.91 ± 7.2	6.30b ± 2.0	6.83a ± 1.1
F	**0.526**	**0.000**	**0.000**	**0.513**	**0.487**	**0.006**	**0.041**
Significance	NS	***	***	NS	NS	**	*

Values with different letters within a column differ significantly. * = significant at 0.05 probability level; ** = significant at 0.01 probability level; *** = significant at 0.001 probability level, NS = Non Significant.

average of 26.22 mm and 33.33 mm (**Table 3**). These results are in agreement with those of [23]. On the other hand, they are contrary to those obtained by [24]. The results of the latter revealed highly significant differences for the length and width of the terminal leaflets. This testifies to the existence of a significant variability within the ecotypes of cultivated Bambara groundnut. The analysis (**Table 3**) shows that at the level of the character number of stems (NbrSt), a highly significant difference is observed between the different morphotypes (P = 0.006). The UZ-VZ-03 morphotype has the highest number of stems with an average of 8867 and the UZ-VZ-08 morphotype records the lowest number of stems with 6300. These results corroborate those obtained by [25]. For the character number of nodes (NbrN), a significant difference is observed between the different morphotypes (P = 0.041) and varies between an average of 6.233 (UZ-VZ-07) and 7.333 (**Table 3**). This could be attributed to the good potential genetics of these morphotypes. Similar results were obtained by [26] when evaluating a South African collection of Bambara groundnut.

4. Agronomical Characters

The analysis of the number of pods (NbrP) shows a highly significant difference between the different morphotypes (P = 0.005). Morphotype UZ-VZ-06 has the highest number of pods with an average of 48.00 and morphotypes UZ-VZ-08 and UZ-VZ-01 have the lowest number of pods with respective averages of 29.53 and 27.27 (**Table 4**). These results corroborate those obtained by [23]. The length of the seed (LS) varies between an average of 10.36 mm (UZ-VZ-07) and 11.93 mm (UZ-VZ-05) without significant difference between the different morphotypes (P = 0.222). As for the width of the seed (WS), a significant difference is observed between the different morphotypes (P = 0.000). Morphotype UZ-VZ-05 records the greatest width of the seed with an average of 9.23 mm and morphotypes UZ-VZ-08, UZ-VZ-02, UZ-VZ-03, UZ-VZ-07 and UZ-VZ-04 have the smallest seed widths with respective averages of 8.66 mm; 8.52 mm; 8.50 mm; 8.48 mm and 8.48 mm (**Table 4**). This last observation is similar to that of [27] while the one that alludes to the length of the seed is contrary to the results reached by these authors. This divergence can be attributed to the significant genetic variability of the morphotypes of the Zinder region for this trait. The character weight of 100 pods (W100P) varies between an average of 253.17 g (UZ-VZ-04) and 309.9 g (UZ-VZ-05) with no significant difference (**Table 4**) between the different morphotypes (P = 0.490). The weight of 100 seeds (P100S) varies between an average of 75.97 g (UZ-VZ-02) and 98.2 g (UZ-VZ-08) with no significant (**Table 4**) difference between the different morphotypes (P = 0.311). These results are consistent with those obtained by [5]. However, these observations are contrary to those obtained by [24]. This could be explained by the difference between the agro-ecological conditions of the two trials. Indeed, the trial of the latter was conducted in the Sudanian agro-ecological zone while the present study was conducted in the Sahelian agro-ecological zone. For the seed weight character

Table 4. Means of agronomic characters.

	NbrP	LS (mm)	WS (mm)	W100P (g)	W100S (g)	WS/Pl (g)
UZ-VZ-01	27.27b ± 11.4	10.46 ± 0.4	8.7ab ± 0.3	256.83 ± 15.4	84.27 ± 4.13	440a ± 0.0397
UZ-VZ-02	36.87ab ± 13.6	11.04 ± 2.2	8.52b ± 0.4	258.8 ± 26.4	75.97 ± 5.61	655a ± 0.0361
UZ-VZ-03	36.80ab ± 16.3	11.20 ± 2.8	8.51b ± 0.6	256.8 ± 35.1	80.87 ± 15.1	665a ± 0.0826
UZ-VZ-04	39.87ab ± 10.2	10.62 ± 0.3	8.48b ± 0.4	253.17 ± 3.47	79.53 ± 5.20	668.3a ± 0.0729
UZ-VZ-05	41.80ab ± 11.3	11.93 ± 0.4	9.23a ± 0.2	309.9 ± 22.1	92.8 ± 14.5	630a ± 0.0354
UZ-VZ-06	48.00a ± 12.5	10.90 ± 0.3	8.7ab ± 0.2	259.25 ± 0.212	87.10 ± 4.38	657a ± 0.159
UZ-VZ-07	40.93ab ± 16.5	10.36 ± 0.4	8.48b ± 0.2	277.8 ± 48.6	79.75 ± 7.99	505a ± 0.0495
UZ-VZ-08	29.53b ± 12.8	11.07 ± 0.3	8.66b ± 0.2	268.7 ± 47.4	98.2 ± 15.3	592.5a ± 0.1237
F	**0.005**	**0.222**	**0.000**	**0.490**	**0.311**	**0.037**
Significance	**	NS	***	NS	NS	*

Values with different letters within a column differ significantly. * = significant at 0.05 probability level; ** = significant at 0.01 probability level; *** = significant at 0.001 probability level, NS = Non Significant.

per plot (WS/P), a significant difference is observed between the different morphotypes (P = 0.037). The morphotypes UZ-VZ-04, UZ-VZ-03, UZ-VZ-06, UZ-VZ-02 and UZ-VZ-05 give the highest seed weights per plot with respective averages of 668.3; 665; 657; 655 and 630 g/plot and the UZ-VZ-01 morphotype records the lowest seed weight per plot with an average of 440 g/plot. Similar results were obtained by [24].

5. Conclusion

This characterization showed significant differences between the eight morphotypes, especially for vegetative growth and yield parameters. Among the thirteen (13) parameters studied, seven (7) can be used to distinguish the different morphotypes; these seven are the height of the plant, the spread of the plant, the number of stems, the number of nodes, number of pods, seed width, seed weight per plot. For the other parameters, no significant difference was observed between the different morphotypes. Morphotypes UZ-VZ-04, UZ-VZ-03, UZ-VZ-06, UZ-VZ-02 and UZ-VZ-05 have demonstrated good performance for grain weight per plot and can be useful for a breeding program. Thus, their improvement and a better match of these morphotypes with the seasons could help improve yields and provide a solution to recurrent food crises in rural areas. It will be interesting to conduct the study of the nutritional quality of the seeds to make a better selection of the collection.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

Contribution of Authors

Saley Adamou Salamatou conducted the field study, did the statistical analysis of the data; Agbo So Timothée Kouassi did data analysis and interpretation, wrote the manuscript of the article; Rabiou Abdou designed research methodology; Oumarou Zongo corrected the manuscript; Bakasso Yacoubou, approved the manuscript.

References

[1] Begemann, F. (1988) Ecogeographic Differentiation of Bambara Groundnut (*Vigna subterranea*) in the Collection of the International Institute of Tropical Agriculture (IITA). Wissenschaftlicher Fachverlag Dr Fleck, Niederkleen, 153.

[2] Touré, Y., Koné, M., Silué, S. and Yatty, J. (2013) Prospection, collecte et caractérisation agromorphologique des morphotypes de Voandzou de la zone savanicole en Côte d'Ivoire. *European Scientific Journal*, **9**, 1857-7881.

[3] MAE (Ministère de l'Agriculture et de l'Elevage) (2018) Rapport définitifs de l'enquête sur les productions agricoles 2017-2018. 54 p.

[4] Brough, S.H. and Azam-Ali, S.N. (1992) The Effect of Soil Moisture on the Proximate Composition of Bambara Groundnut [*Vigna subterranea* (L.) Verdc.]. *Journal of Science Food and Agriculture*, **60**, 197-203. https://doi.org/10.1002/jsfa.2740600207

[5] Ndiang, Z., Bell, J.M., Missoup, A.D., Fokam, P.E. and Amougou, A. (2012) Etude de la variabilité morphologique de Bambara groundnut (*Vigna subterranea*) au Cameroun. *Journal of Applied Biosciences*, **60**, 4410-4420.

[6] Minka, S.R. and Bruneteau, M. (2000) Partial Chemical Composition of Bambara Pea (*Vigna subterranea* (L.) Verdc). *Food Chemistry*, **68**, 273-276. https://doi.org/10.1016/S0308-8146(99)00186-7

[7] Amarteifio, J.O., Tibe, O. and Njogu, R.M. (2006) The Mineral Composition of Bambara Groundnut (*Vigna subterranea* (L.) Verdc) Grown in Southern Africa. *African Journal of Biotechnology*, **5**, 2408-2411.

[8] Onwubiko, N.I.C., Odum, O.B., Utazi, C.O. and Poly-Mbah, P.C. (2011) Studies on the Adaptation of Bambara Groundnut [*Vigna subterranea* (L.) Verdc] in Owerri Southeastern Nigeria. *New York Scientific Journal*, **4**, 60-67. https://doi.org/10.3923/aj.2011.60.65

[9] Sévérin, B.B. and Yao, D. (2011) Variabilité morphologique et agronomique des variétés traditionnelles de Bambara groundnut (*Vigna subterranea* (L.) Verdc.) de Côte d'Ivoire. *Journal of Applied Biosciences*, **41**, 2820-2835.

[10] Mbaiogaou, A., Héma, A., Ouédraogo, M., *et al.* (2013) Etude comparative des teneurs en polyphénols et en antioxydants totaux d'extraits de grains de 44 variétés de Bambara groundnut (*Vigna subterranea* (L.) Verdc.). *International Journal Biological and Chemical Sciences*, **7**, 861-871. https://doi.org/10.4314/ijbcs.v7i2.41

[11] Massawe, F.J., Mwale, S.S., Azam-Ali, S.N. and Roberts, J.A. (2005) Breeding in Bambara Groundnut (*Vigna subterranea* (L.) Verdc.): Strategic Considerations. *African*

Journal of Biotechnology, **4**, 463-471.

[12] Yao, D.N., Kouassi, K.N., Erba, D., *et al.* (2015) Nutritive Evaluation of the Bambara Groundnut Ci12 Landrace [*Vigna subterranea* (L.) Verdc. (Fabaceae)] Produced in Côte d'Ivoire. *International Journal of Molecular Sciences*, **16**, 21428-21441. https://doi.org/10.3390/ijms160921428

[13] Gueye, M., James, E.K., Kierans, M. and Sprent, J.L. (1998) The Development and Structure of Root Nodules on Bambara Groundnut [Voandzeia (Vigna)subterranea]. *World Journal of Microbiology and Biotechnology*, **14**, 177-184. https://doi.org/10.1023/A:1008869710607

[14] Mungate, D. (1997) Bambara Groundnut [*Vigna subterranea* (L.) Verdc.]. *Proceedings of the Workshop on Conservation and Improvement of Bambara Groundnut* (*Vigna subterranea* (L.) Verdc.), Harare, 14-16 November 1995, 166 p.

[15] Ntundu, W.H., Bach, I.C., Christiansen, J.L. and Andersen, S.B. (2004) Analysis of Genetic Diversity in Bambara Groundnut (*Vigna subterranea* (L.) Verdc.) Landraces Using (AFLP) Markers. *African Journal of Biotechnology*, **3**, 220-225.

[16] Ngwako, S., Balole, T.V., Mogotsi, K.K., Kwerepe, B.C. and Sesay, A. (2011) Growers, Consumers and Trader's Perceptions of Bambara Groundnut (*Vigna subterranea* (L.) Verdc.) in Botswana. *International Journal of Tropical Agriculture and Food System*, **5**, 267-273.

[17] Zerihun, T. (2009) Role of Orphan Crops in Enhancing and Diversifying Food Production in Africa. *African Technology Development Forum Journal*, **6**, 83.

[18] Djè, Y., Bonny, B.S. and Zoro, B.I.A. (2005) Observations préliminaires de la variabilité entre quelques morphotypes de Bambara groundnut (*Vigna subterranea* (L.) Verdc., Fabaceae) de Côte d'Ivoire. *Biotechnologie*, *Agronomie*, *Société et Environnement*, **9**, 249-258.

[19] Sani, I.A. (2021) Production, enjeux socioeconomiques et environnementaux de la culture du voandzou (*Vigna subterranea* (L.) Verdc.) dans le departement de kantche, Mémoire de master. Université de Dosso, Niger.

[20] IPGRI, IITA, BAMNET (2000) Descripteurs du pois bambara (*Vigna subterranea*. Institut international des ressources phytogénétiques, Rome, Institut International d'Agriculture Tropicale, Ibadan, Réseau International de pois bambara, Allemagne, 59 p.

[21] Paulos, M., Loha, G. and Kassa, M. (2022) Characterization and Evaluation of Bambara Groundnut (*Vigna subterranea* (L.) Verdc.) for Yield and Related Traits in Asosa Zone, Northwestern Ethiopia. *Applied and Environmental Soil Science*. https://doi.org/10.1155/2022/8533233

[22] Harouna, A.I., Alhassane, A., Daouda, O.S. and Boureima, K.S. (2018) Variabilité Morphologique et Agronomique des Morphotypes de Bambara groundnut (*Vigna subterranea* L.) Cultivés Dans La Zone Sahélienne Du Niger. *European Scientific Journal*, **14**, 377-393. https://doi.org/10.19044/esj.2018.v14n36p377

[23] Unigwe, A.E., Gerrano, A.S., Adebola, P., Pillay, M. and Monrovia, L. (2016) Morphological Variation in Selected Accessions of Bambara Groundnut (*Vigna subterranea* L. Verdc) in South Africa. *Journal of Agricultural Science*, **8**, 69-80. https://doi.org/10.5539/jas.v8n11p69

[24] Diagara, S.M., Issa, A.H., Mamoudou, B.M. and Kiari, B.K.K. (2022) Caractérisation agro-morphologique de 30 accessions de voandzou [*Vigna subterranea* (L.) Verdc] cultivées dans la zone soudanienne du Niger. *International Journal of Innovation and Applied Studies*, **36**, 553-563.

[25] Esan, V.I., Oke, G.O. and Ogunbode, T.O. (2022) Characterization of Genetic Variation of Bambara Groundnut [*Vigna subterranea* (L.) Verdc.] under Different Environmental Conditions for Yields and Yield Component Performances. https://doi.org/10.21203/rs.3.rs-1454574/v1

[26] Siwale, J., Labuschagne, M., Gerrano, A.S. and Mbuma, N.W. (2022) Phenotypic Diversity and Characterization of the Southern African Bambara Groundnut Germplasm Collection for Grain Yield and Yield Components. *Agronomy*, **12**, 1811. https://doi.org/10.3390/agronomy12081811

[27] Kambou, D.J., Nandkangre, H., Ouoba, A., *et al*. (2020) Agro-Morphological Characterization of Bambara Nut Accessions [*Vigna subterranea* (L.) Verdcourt] from Burkina Faso. *Journal of Applied Biosciences*, **153**, 15727-15744. https://doi.org/10.35759/JABs.153.1