Performance of Bambara groundnut (*Vigna subterranea* [L.] Verdcourt) genotypes cropped on plinthite soil in the semi arid-zone, Burkina Faso

ABSTRACT

Bambara groundnut (*Vigna subterranea* [L.] Verdcourt) is grown mainly as a food crop in Burkina Faso. Despite its high nutritional value, it has been among the most neglected crops in the country. This study was undertaken with the objective to investigating the effects of genotypes on the physiological traits, yield and yield related traits of the crop and thereby identify the genotypes having better performance for yield and yield related traits. The field experiment was conducted at the Tenkodogo University Centre site, during the 2021 rainy season. The experiment was laid out in randomized complete block design with four replications and eight genotypes were obtained from INERA germplam bank. Data were collected on number of days to 50% field emergence, number of days from sowing to 50% flowering, number of leaves per plant, plant height, plant spread, number of pods per plant, number of one seed per pod, number of two seeds per pod, weight of seeds per plant seed length, seed width,100-seed weight and yield. The data were subjected to the analysis of variance, and means were separated through Duncan's Multiple Range Test at 95% confidence. The Pearson's correlation coefficients between pair of characters were computed using SPSS 2.0. Results showed that significant and highly significant variations were observed among genotypes for almost all studied characters, except plant spread and number of one seed per pod. Majority of the characters had positive correlations. Most of the negative correlation was observed between physiologic and agronomic traits. The result showed that genotypes KVS97-2 (33.75 days; 1578.12 $kg.ha^{-1}$); KVS360 (34.75 days; 1181 $kg.ha^{-1}$) and KVS235 (34.5 days; 1167.19 $kg.ha^{-1}$) performed better than others genotypes in yield parameters and had shorter flowering cycle.

Keywords *: Bambara groundnut, Burkina Faso, genotype, neglected crop, performance, yield,*

1. INTRODUCTION

In the low income countries, there is an urgent need for new food plants or new sources to meet the nutritional needs of growing populations. To this end, it would be very important to efficiently utilize all the cultivated crop species having promising agronomic performance in the arid and semi-arid areas. To ensure sustainability of agricultural productivity in the difficult climatic and poor soil conditions, it is essential to look for endigenous solutions. Among these, identification and evaluation of resilient crops such as Bambara groundnut (*Vigna subterranea* [L.] Verdc.) will help ensuring food security. Bambara groundnut is one of the most important but neglected and underutilized in Burkina Faso. Bambara groundnut is the third most important food legume in Sub-saharan Africa after cowpea (*Vigna unguiculata* [L.] Walp.) and groundnut (*Arachis hypogeae* L.) [1,2]. It is particularly interesting because it supports significant water deficit and has enormous agronomic potentials, and can improve soil nutrient status, especially nitrogen status, as a result of its nodulation process which traps nitrogen from atmosphere [3,4]. It can fix 100 kg N.ha^{-1} [5]. Bambara groundnut is a species that could be used to promote sustainable agriculture in a context of poor soils and insufficient rainfall. That could empower farmer's resilience to climate change. This species has an ability to resist pest and diseases and can thrive in poor soils [6]. The drought-tolerance genes traced in Bambara groundnut could be applied to others crop species that are susceptible to drought through marker-assisted selection [2]. Bambara groundnut is rich in nutrients which contribute to alleviate malnutrition within rural populations as protein supplement. It is highly calorific (387 kcal/100 g), rich in vitamins, mineral elements, essential amino acids such as lysine, methionine and proteins [7,8,9,10]. Bambara groundnut contains ~64.4% carbohydrate, 23.6% protein, 6.5% fat, and 5.5% fiber and is rich in minerals [11,12]. Besides the nutritional significance of Bambara groundnut, it also has different medicinal benefits [13,14]. Bambara groundnut is mostly grown by women and used as a cash crop. Despite all these importances, it remains a neglected crop. Research institutes and researchers have paid little attention in Burkina Faso. Consequently, there is no improved varieties and agronomical suitable practices which ultimately led to the reduced productivity of the crop in the farming environment. Thus, the promotion and intensification of Bambara groundnut are resilient choices and a strategic challenge to overcome hunger and malnutrition within the rural population in Burkina Faso. Therefore, it is essential to find out appropriate genotypes which are able to adapt to various environments that they could be include in the selection program for their agronomic performances. The objective of this study is to assess the agronomic performances and degree of adaptability of eight genotypes in the semi-arid zone of Burkina Faso.

2. MATERIAL AND METHODS

2.1. Plant material and site description

The plant material of our study consisted of eight Bambara groundnut genotypes provide by the Institute of Environment and Agricultural Research (*INERA: Institut de l'Environnement et de Recherches Agricoles*). The experimental materials were KVS109A, KVS141-2, KVS360, KVS314, KVS97-2, KVS311, KVS235 and KVS075-1. This study was carried out at the experimental field of the Tenkodogo University Centre (11°48'37''N, 0°22'19''W) located in East-centre region of Burkina Faso. Climate of this region is Sudano-sahelian type characterized by annual rainfall between 600 and 900 mm. Insolation is 7 - 8 h day^{-1} with low humidity. In 2021, 52.2 mm of rainfall (May) was recorded against 249.5 mm (August); Temperature was ranged from 26°C (August) to 31°C (May) (Figure 1).

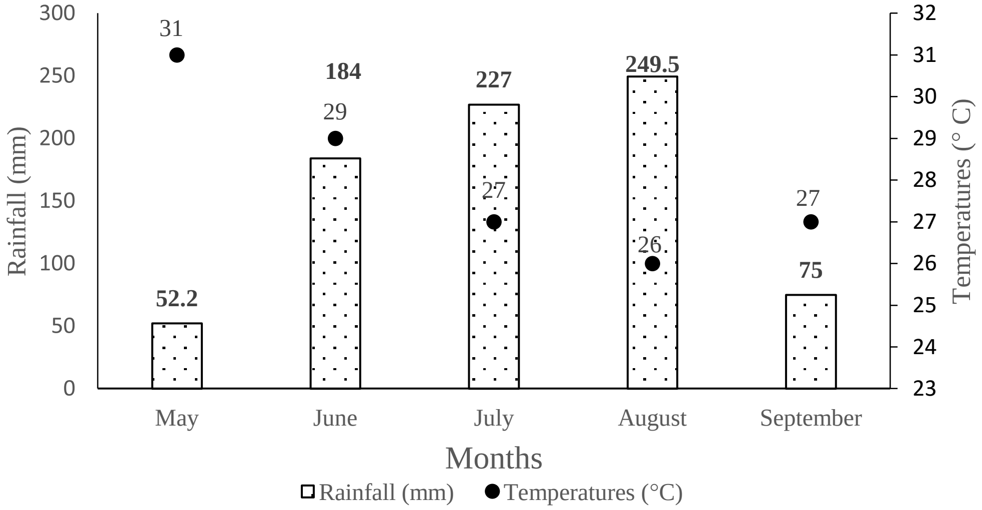

Figure 1: Average rainfall and temperature of experimental site.
(Data source: Centre-east meteorological station in 2021)

The characterization of the soil of experimental site was done according to [15]. Soil description guidelines showed that the soil has a useful depth of 0-36 cm. The 0-16 cm depth has sandy texture and the layer 16-36 cm has sandy-clay texture. Layer > 36 cm is a ferruginous shell (plinthite). The drainage is excessive to perfect and limited by the shell. This soil belongs to the ferric and manganese sesquioxides soils class and specifically to shallow leached ferruginous tropical soil according to the french classification [16]. This soil would correspond to endo petroplinthic lixisol according to the classification of [17]. The texture of soil makes it potentially suitable for Bambara groundnut cropping, because it is better drained and favors pod penetration in the soil. Well-drained, light, sandy, loamy soils with a pH of 5.0 to 6.5 are more suitable for Bambara groundnut cultivation [18].

2.2. Experimental design and field management method

Experimental device was a randomized complete blocks design with four replications separated by 1 m alley. Each replication comprised eight rows of 4 m length. Each row was randomly assigned with one genotype. The distance was 0.4 m between row and the spacing between the holes 0.2 m. A total of 21 seeds were sown on each row by genotype. Sowing was carried out on July 4, 2021 at one seed per hole, on land previously plowed flat using a tractor followed by manual shelving. Mineral fertilizer, NPK (14-23-14) was applied at a rate of 75 $kg.ha^{-1}$ at planting day. Three manual weedings were carried out on all the plots as needed. Mounding was carried out at seven weeks after sowing.

2.3. Data collection and analyses

Data were recorded during plants growth and development stage and after harvest. Data collection was carried out base on the Bambara groundnut descriptor established by the International Institute of Plant Genetic Resources [19]. A total of 13 characters were recorded in this study (Table I). For each genotype, the characters were observed and measured in each replication for statistical analysis. Data were subjected to the analysis of variance (ANOVA) using Genstat 12ed software to reveal differences between genotypes for each trait, and means were separated through Duncan's test at P = .05. The genetic parameters studied were estimated from the mean squares derived from the ANOVA with all the quantitative traits. The Pearson's correlation coefficients between characters were performed using SPSS 20 software.

Table I: Quantitative traits studied

Characters	Code	Unit
Number of days to 50% field emergence	EMG50	Day
Number of days from sowing to 50% flowering	FLO50	Day
Number of leaves per plant	NL/P	Number
Plant height	PlH	cm
Plant spread	PlS	cm
Number of pods per plant	NP/P	Number
Number of one seed per pod	N1S	Number
Number of two seeds per pod	N2S	Number
Weight of seeds per plant	WS/P	g
Seed length	SLen	mm
Seed width	SWid	mm
100-seed weight	W100S	g
Yield	YLD	$Kg.ha^{-1}$

3. RESULTS AND DISCUSSION

3.1. Variation of studied characters

The results of analysis of variance using the mean square values are shown in table II. Significant and highly significant variations were observed for almost all studied characters, except plant spread (PlS) and number of one seed per pod (N1S). The significant variation for the most characters studied implies there is agromorphological diversity between the genotypes considered. Previously research works done in Niger by [20] and in Burkina Faso showed significant variability within Bambara groundnut varieties [21,22].

Variability is considered as basis of breeding, and genetic variability could be exploited for selection and release best performing varieties. Mean squares are an estimate of the variance within population. Mean square values of genotypes are higher than those of residual for all the studied characters. These results indicates that the influence of the environment does not have significant effect on the expression of the characters [23]. Furthermore, the employment of various genotypes and environments can be able to led the variable response and a number of factors have been identified as having a negative influence among vegetative traits, yield, and its attributed components [24].

Table II : Mean squares and variability of variance for physiologic and agronomic contributing 13 traits in Bambara groundnut

Source	Block	Genotype	Error	F. pr.	Significance
df	3	18	54	-	-
EMG50	0.28	2.63	0.9	0.026	*
FLO50	9.78	15.28	0.75	< 0,001	**
NL/P	495.93	1152.82	80.39	< 0.001	**
PlH	8.85	6.88	2.52	0.035	*
PlS	19.92	70	33.79	0.093	NS
NP/P	135.78	89.71	17.04	0.001	**
N1S	156.24	37.87	17.17	0.076	NS
N2S	0.64	2.98	0.8	0,009	*
WS/P	37.33	47.11	3.74	< 0.001	**
SLen	1.56	0.69	0.27	0.046	*
SWid	1.18	0.54	0.21	0,046	*
W100S	17.28	177.71	24.31	< 0,001	**
YLD	86512	496092	132318	0.009	*

***EMG50**: Number of days to 50% field emergence ; **FLO50** : Number of days from sowing to 50% flowering ; **NL/P** : Number of leaves per plant ; **PlH** : Plant height ; **PlS** : Plant spread ;**NP/P** : Number of pods per plant ; **N1S** : Number of one seed per pod ; **N2S** : Number of two seeds per pod ; **WS/P** : Weight of seeds per plant ; **SLen** : Seed length ; **SWid** : Seed width ; **W100S** : 100-seed weight ; **YLD** : Yield ; **NS** : Not significant ; * : Significant difference at 5% ; ** : Hight significant difference at 5%*

3.2. Correlations between studied characters

Pearson coefficients from correlation matrix showed numerous positive associations between the characters (Table III). Number of days to 50% field emergence showed a positive correlation with number of days to 50% flowering (r = 0.738). In addition, number of one seed per pod is positively and strongly correlated with number of pods (r = 0.917, *P* = .01), weight of seed (r = 0.907, *P* = .01). Number of pods also showed positive correlation with 100-seed weight (r = 0.871, *P* = .01), seed weight (r = 0.825, *P* = .01), weight of seed per (r = 0.930, *P* = .01) and yield (r = 0.830, P = .05). Important correlation was observed between 100-seed weight and seed width (r = 0.866, *P* = .01), weight of seed per plant (r = 0.857, *P* = .01) and yield (r = 0.825, *P* =.05). Knowledge of the relationships between traits is an important and useful approach for identification of potential interesting agronomic traits to be taken into consideration according to breeding objectives in genetic improvement programs. In agreement with our results, [25] showed that dry pod weight, 100-seed weight, number of pods and fresh pod weight could be used as selection criteria to improve the seed yield of Bambara groundnut. The positive correlations observed between two characters imply that the characters evolve in the same direction. Even though positive correlations have been observed, there are certain negative correlations. Most of the negative correlations were observed between physiological and agronomical traits. Number of day to 50% flowering was negatively correlated with agronomic traits such as number of one seed per pod and seed width (r = - 0.828 and - 0.789 respectively, *P* = .05) and often showed a strong correlation at *P* = .01 with number of pods per plant (r = - 0.954), 100-seed weight (r = - 0.939), weight of seed per plant (r = - 0.949) and the yield (r = - 0.890). Plant spread shown negative but non-significant correlations, with all the agronomic traits. Negative correlations were observed between yield and number of days to 50% flowering (r = - 0.890, *P* = .01), plant height (r = - 0.736, *P* = .05) and plant spread (r = - 0.648) indicate that direct selections toward these three traits could not be interesting for the improvement of Bambara groundnut yield.

Table III. Pearson's correlation coefficient for 14 characters in Bambara groundnut genotypes

Characters	EMG50	FLO50	NL/P	PIH	PIS	N1S	N2S	NP/P	W100S	SLen	SWid	WS/P
FLO50	**0.738***											
NL/P	-0.526	-0.519										
PIH	0.100	0.572	-0.094									
PIS	0.602	0.685	0.094	0.580								
N1S	-0.432	**-0.828***	0.644	**-0.729***	-0.480							
N2S	-0.556	**-0.922****	0.431	-0.596	-0.545	**0.752***						
NP/P	**-0.734***	**-0.954****	0.641	-0.638	-0.644	**0.917****	**0.858****					
W100S	**-0.840****	**-0.939****	0.562	-0.328	-0.567	0.673	**0.811***	**0.871****				
SLen	-0.692	-0.330	0.128	0.420	-0.284	-0.150	0.130	0.164	0.569			
SWid	**-0.913****	**-0.789***	0.694	-0.250	-0.540	0.643	0.538	**0.825***	**0.866****	0.573		
WS/P	-0.604	**-0.949****	0.648	-0.531	-0.523	**0.907****	**0.875****	**0.930****	**0.857****	0.193	**0.735***	
YLD	-0.504	**-0.890****	0.268	**-0.736***	-0.648	**0.748***	**0.847****	**0.830***	**0.825***	0.163	0.590	**0.787***

significative correlation at 0.05 level ; ** significative correlation at 0.01 level ;** ***EMG50 *: Number of days to 50% field emergence ;* ***FLO50*** *: Number of days from sowing to 50% flowering ;* ***NL/P*** *: Number of leaves per plant ;* ***PIH*** *: Plant height ;* ***PIS*** *: Plant spread ;* ***NP/P*** *: Number of pods per plant ;* ***N1S*** *: Number of one seed per pod ;* ***N2S*** *: Number of two seeds per pod ;* ***WS/P*** *: Weight of seeds per plant ;* ***SLen*** *: Seed length ;* ***SWid*** *: Seed width ;* ***W100S*** *: 100-seed weight ;* ***YLD*** *: Yield*

3.3. Performance analysis for assessed genotypes

There were significant differences among the genotypes with regard to physiological traits, yield and yield components (Table IV). Certain genotypes showed interesting performance for the assessed characters. The flowering cycles of the genotypes ranged from 33.75 to 38.50 days. High-yield genotypes (>1000 kg.ha^{-1}) flowered between 33.75 and 34.75 days. However, [26] recorded 41 to 56 days with Bambara groundnut accessions from Ivory Coast. The genotype KVS075-1 had a short flowering cycle (34.5 days) and the best yield (1650 kg.ha^{-1}). The yields were higher than those obtained (830 kg.ha^{-1}) by [21] with the similar flowering cycle. Researches undertook by [27] on 20 Bambara groundnut varieties from Zimbabwe showed that all the varieties have a very long time to flower (> 60 days) with pod yield comprised between 1 100 and 2 300 kg.ha^{-1}. The genotype KVS109A, KVS314, KVS311 and KVS141-2 took more time to flower (> 37 days) with a very low seed weight per plant, 100-seed weight and low yields. After flowering comes reproductive stage and occurring of pods in the soil. So, early flowering genotypes could have pods that appear much earlier than other genotypes, and have more time for pod filling compared to late flowering genotypes. This would explain why these genotypes have interesting yield and yield components traits. To this end, improving productivity of Bambara groundnut in Burkina Faso should take into account genotypes that combine high seed weight per plant (WS/P), High number of pods per plant (NP/P), high yield (YLD) and early flowering cycle (FLO50). This must be judiciously combined with appropriate cultural options depending on the production context in order to maximize the yield potential of cultivars with high productive value. The genotypes KVS141-2, KVS235, KVS360, and KVS97-2 had high number of leaves (respectively 79.25, 69.40, 65.50, 67.10). However, the genotypes KVS97-2 (33.75 days; 1578.12 kg.ha^{-1}); KVS360 (34.75 days; 1181 kg.ha^{-1}) and KVS235 (34.5 days; 1167.19 kg.ha^{-1}) performed than the others in yield parameters and the shorter flowering cycle. Late genotypes gave the lowest yields. These results are different from those obtained by [28] with Bambara groundnut from Ivory Coast. This could be explained by the fact the rains are abundant in this country. The number of pod per plant (NP/P) was between 13 (KVS314) and 25.50 (KVS360, KVS235 and KVS97-2). This result is different from that obtained by [1] range from 18.24 to 46.52 pods per plant, [29] and [22]. These genotypes recorded high weight seed per plant (WS/P).

Table I : Effects of genotypes on the physiological traits, yield and yield related components of Bambara groundnut from Burkina Faso

Génotypes	NL/P	FLO50	NP/P	W100S	WS/P	YLD
KVS109A	36.6 a	38.50 b	16.25 ab	45.00 a	8.79 a	881.25 a
KVS141-2	79.25 b	37.50 b	19.00 ab	47.50 a	13.14 abc	848.44 a
KVS360	65.50 b	34.75 a	23.50 b	56.25 b	17.66 c	1181.25 ab
KVS314	41.50 a	38.25 b	13.00 a	48.25 a	9.49 a	692.19 a
KVS235	69.40 b	34.5 a	25.50 b	56.50 b	15.82 bc	1167.19 ab
KVS97-2	67.10 b	33.75 a	25.50 b	62.25 b	17.26 c	1578.12 b
KVS311	35.30 a	37.50 b	16.75 ab	43.5 a	12.06 ab	878.12 a
KVS075-1	47.45 a	34.5 a	23.25 b	55.5 b	15.88 bc	1650 b
Mean	55.2625	36.15	20.3438	51.8438	13.7625	1109.57

NL/P *: Number of leaves per plant ;* ***FLO50*** *: Number of days from sowing to 50% flowering ;* ***NP/P*** *: Number of pods per plant ;* ***W100S*** *: 100-seed weight ;* ***WS/P*** *: Weight of seeds per plant ;* ***YLD*** *: Yield*

4. CONCLUSION

From the results obtained in this study, it could be concluded that the average yield obtained with all the eight Bambara groundnut genotypes from INERA germplasm were 1109.57 kg.ha-1. This shows a good performance compared to the national average which is estimated at less than 500 kg.ha-1. The agronomical performances of the Bambara groundnut genotypes from INERA germplasm showed that KVS 075-1, KVS97-2, KVS360 and KVS235 performed well both in physiological and in yield parameters. This testifies to a good adaptation of these genotypes to the semi-arid zone with annual rainfall ranging between 600 to 900 mm. Using performant genotypes in the area with well-distributed rainfall and good soil fertility could contribute to improve Bambara groundnut production.

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COMPETING INTERESTS

No competing interests exist.

AUTHORS' CONTRIBUTIONS

The concept, design, and methods of the paper were constructed by Hervé NANDKANGRE, Koulibi Fidèle ZONGO and Diane Judicaëlle KAMBOU. Data collection was carried out by Boukare NIKIEMA, Hervé NANDKANGRE, Koulibi Fidèle ZONGO. Statistical analysis software and interpretation were undertaken by Hervé NANDKANGRE, Koulibi Fidèle ZONGO and Diane Judicaëlle KAMBOU. Writing original draft preparation of the manuscript was carried out by Hervé NANDKANGRE. Review and editing by Aimé Sévérin KIMA, Hamed Mahamadi OUEDRAOGO, OUOBA Adjima, Moussa N'Golo KONATE, Koulibi Fidèle ZONGO and Diane Judicaëlle KAMBOU. Supervision by Mahama OUEDRAOGO. All authors have read and agreed to the published version of the manuscript.

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