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Full Length Research Paper

Evaluation of agronomic performance of two landraces of Bambara groundnut (*Vigna subterranea*) in woodland savannahs of Cote d'Ivoire

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Bambara groundnut (*Vigna subterranea* L. Verdc.) is one of the most promising legume foods in Africa, due to its agronomic and nutritional potentials. To take advantage of these attributes, several research programs gathering agronomic and genetic data throughout Africa are being implemented. In this framework, we tested yield and yield components response to sowing density during 3 years (2005, 2006 and 2007) in field experiment using two landraces of Bambara groundnut. There are bunch and spreading type. Two plant population densities 62, 500 plants ha^{-1} (spacing: 40 × 40 cm) and 250, 000 plants ha^{-1} (spacing: 20 × 20 cm) were tested. Factorial trial using split-plot design with three replicates was set to analyse five yield components. Both sowing density and landrace influenced significantly ($p < 0.05$) seed yield. The highest seed yields were observed for high-density plots (means: 3.54 ± 0.21 t ha^{-1}) and for the bunch type (mean: 3.69 ± 1.63 t ha^{-1}). Based on the trend of yield response of sowing density, producing the landrace (bunch type) from the collection of the University of Abobo-Adjame at high density was suggested.

Key words: Bambara groundnut, agronomic, yield, sowing density, bunch type, spreading type, landrace.

INTRODUCTION

Most of the investments in agricultural research have been oriented towards a few crops (for example, maize, rice, wheat and cotton), so that today, only 30 plant species are used to meet 95% of world food energy needs (FAO, 1996). Indeed, the exploitation of the wealth of plant diversity (more than 7000 food species) remains far lower than the potential. Since 1990, interest in minor crop species has increased throughout the world, with the aim of identifying and developing of new crops for the export and domestic markets. Bambara groundnut (*Vigna subterranea*) is one of the African minor crops receiving growing interest from governments, plant genetic resources institutions and researchers. This is due to its numerous agronomic attributes, particularly, its yielding potential, relatively high resistance to diseases, and adaptability to poor soils and low rainfall (Elia and Mwandemele, 1986; Collinson et al., 1997; Brink, 1999; Massawe et al., 2003; Mwale et al., 2007). In addition to these agronomic advantages, the crop is rich in proteins (19 to 22% of dry matter) and carbohydrates (42 to 69% of dry matter) (Oliveira, 1976; Minka and Bruneteau, 2000). These authors also reported that Bambara groundnut seed proteins are high in essential amino acids; methionine (0.5 to 1.43 g/16 g N) and lysine (5.4 to 6.9 g/16 g N). Recently, scientists from Africa and Europe began a research programme aimed at gathering agronomic, genetic and physiological data, as well as knowledge and perceptions of peasant farmers in order to implement improved production practices for *V. subterranean* (Massawe et al., 2003; Mkandawire, 2007; Sesay et al., 2008). These studies aimed at testing abiotic factors (Elia and Mwandemele, 1986; Mwale et al., 2007) and some cultural practices (Karikari et al., 1999; Collinson et al., 2000) showed variation in the response of Bambara groundnut according to cropping system, genotypes and geographical regions. The success of such breeding programme depends largely on the identification of landraces within segregating populations that would give high yields in pure strands. The characteristic contributions to yield are governed by

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Table 1. Method of measurement of yield and yield components of Bambara groundnut in response to plant density and landraces.

Yield and yield component	Measurement approach and sample size per plot
NPP	Direct counting at harvest on 30 plants randomly selected in each treatment
NSP	Direct counting at harvest; average of 30 plants randomly selected in each treatment
PWP	Recorded at harvest, after drying pods to constant weight, on 30 plants randomly selected in each treatment
SWP	Recorded at harvest, after drying seeds at 12 ± 2% moisture, on 30 plants randomly selected in each treatment
YLD (t ha^{-1})	Yield: Recorded at 12 ± 2% moisture content of seeds, on the yield of each treatment

NPP, Number of pods per plant; NSP, number of seeds per plant; PWP, pods weight per plant; SWP, seeds weight per plant; YLD, yield (t ha^{-1}).

polygene on which the environment has modifying effects. Furthermore, yield is a complex character determined by a number of components that follow a developmental sequence. The organs developed earlier can have a profound influence on those productions and indicated that landraces are phenotypically heterogeneous but no genetic analysis of yield components has been made. Few studies have been conducted to correlate yield with agronomic characters in Bambara groundnut. One of such study by Karikari (2000) indicated that the number of pods per plant was highly correlated with yield. Linnemann and Craufurd (1994) have shown that, an important factor affecting harvest index and crop duration is time of planting as a result of day length sensitivity for pod initiation. These traits may thus serve as criteria for indirect selection for grain yield. The objective of this study is to estimate the degree of production of two landraces of Bambara groundnut and characters influencing seed yield.

MATERIALS AND METHODS

Study site

Farm experiments were conducted in 2005, 2006 and 2007 in the village of Manfla (6° 49' 34.38" N, 5° 43' 47.68" W) at 400 km North Abidjan (Côte d'Ivoire). There are two rainy seasons separated by a short dry period (July to August) and a long dry season (December to February) at the target site. Annual rainfall varies from 800 to 1400 mm with a long-term mean of 1200 mm, and the annual mean temperature is 27°C. Over the experimental periods (March to July each year), the mean monthly temperature was 26°C, and mean monthly rainfall ranged from 100.8 to 117.5 mm with total rainfall per experimental period of 504.2 to 586.3 mm. Mean relative humidity was 81%. The vegetation was a woodland savannah. The study site was a natural fallow plot with vegetation mainly composed of *Chromoleana odorata* and *Panicum maximum*. Soils in the study area were deep, friable and sandy-silt. Analysis at a soil depth of 20 cm indicated the following characteristics: pH 6.45, 57% sand, 36% silt, 7% clay, 6% organic matter, 3.5 g/kg of total N, 24.4 g/kg of available P and 0.45 g/kg of K. In the study area, Bambara groundnut was usually produced during two cropping seasons in a year. In the first cropping season corresponding to the long rainy period, planting and harvest take place in March and July, respectively. The second cropping season corresponds to the short rainy season; here, plants were sown in July to August and harvested in November to December. All experiments were conducted during the first cropping season, and seeds were sown on the first day of significant rainfall. This was 15th March, 17th March and 17th April, in 2005, 2006 and 2007, respectively.

Experimental design and cultural practice

The plant material consisted of two landraces of Bambara groundnut. One landrace (bunch type) was obtained from the collection of the University of Abobo-Adjame (Abidjan, Cote d'Ivoire) and the second (spreading type) widely cultivated by farmers. Maturity periods of each landraces were recorded. Days to maturity varied between 90 days for the landrace from University of Abobo-Adjame and 210 days for the local landraces cultivated by farmers (the study site). The experimental design was a split-plot with three replicates. One planting method regularly used by farmers from the study site to grow Bambara groundnut was used; sowing on the flat. From preliminary observations made in the farmers' fields in the target zone, two densities were determined for the test: low density with 62, 500 plants per ha (at a spacing of 40 × 40 cm) and high density with 250, 000 plants per ha (at a spacing of 20 × 20 cm). The subplots had an area of 36 m^2 and received 225 and 900 holes for low and high density, respectively. Three seeds per hole were sown directly and thinned to the final stands at the first leaf-stage. The blocks were weeded weekly with a hoe to prevent the presence of any interaction between planting system, plant spacing and weeds. Disease and pest control were carried out using a carbamate-based insecticide applied when needed. The harvest of the pods was carried out at the end of the cycle of production of each landrace.

Data collection

All measurements were taken per unit of area (m^2). On the average, 30 m^2 were used on each subplot. Yield (seeds production) and four agronomic traits selected from the Bambara groundnut descriptor (IPGRI/IITA/BAMNET, 2000) and identified as yield components elsewhere (Ofori, 1996; Karikari and Tabona, 2004; ouédraogo et al., 2008) was measured. Further details of the selected traits and related measurement approaches are indicated in Table 1. Combined analysis of variance appropriate to a split-plot design was performed using the general linear model procedure of the Statistical Analysis System (SAS) statistical package (SAS, 1999). Least significant difference multiple range-tests were used to identify differences among the means of the parameters examined, according to the sowing density, landraces and interactions.

Table 2. Results of the ANOVA comparing two landraces sowing at two densities.

Yield and yield component	Landrace		Density		Landrace density	
	F	P	F	P	F	P
NPP	69.93	< 0.001	15.77	0.016	4.08	0.114
NSP	91.15	< 0.001	35.54	0.004	14.95	0.020
PWP (g)	342.47	< 0.001	111.09	< 0.001	50.86	0.002
SWP (g)	411.60	< 0.001	296.17	< 0.001	112.15	< 0.001
YLD (t/ha)	402.63	< 0.001	290.23	< 0.001	110.63	< 0.001

NPP, Number of pods per plant; NSP, number of seeds per plant; PWP, pods weight per plant; SWP, seeds weight per plant; YLD, yield (t ha^1).

Table 3. Yield and yield components as affected by landraces of Bambara groundnut.

Yield and yield component	Mean (±SD) according to landrace		ANOVA result	
	Bunch type	Spreading type	F	P
NPP	450.15 ± 121.79	182.25 ± 38.52	69.93	< 0.001
NSP	493.15 ± 159.40	159.40 ± 308.43	91.15	< 0.001
PWP (g)	467.49 ± 150.65	196.00 ± 33.37	342.47	< 0.001
SWP (g)	370.07 ± 163.13	164.57 ± 39.87	411.60	< 0.001
YLD (t/ha)	3.69 ± 1.63	1.64 ± 0.39	402.63	< 0.001

Means per landraces were calculated independently of the density of sowing.

Table 4. Yield and yield components as affected by sowing density of Bambara groundnut.

Yield and yield component	Mean (±SD) according to sowing density		ANOVA result	
	Low density (62, 500)	High density (250, 000)	F	P
NPP	252.50 ± 23.33	379.81 ± 2.65	15.77	0.016
NSP	281.46 ± 9.12	444.21 ± 73.53	35.54	0.004
PWP (g)	254.43 ± 21.00	409.06 ± 27.49	111.09	< 0.001
SWP (g)	180.16 ± 8.83	354.48 ± 3.22	296.17	< 0.001
YLD (t/ha)	1.8 ± 0.13	3.54 ± 0.21	290.23	< 0.001

NPP, Number of pods per plant; NSP, number of seeds per plant; PWP, pods weight per plant; SWP, seeds weight per plant; YLD, yield (t ha^1). Means per sowing density were calculated independently of landraces.

RESULTS AND DISCUSSION

The trend of the results related to the effects of sowing density and landraces did not change through the three years of experiment. Thus, data for these two factors were pooled over years and only the means are presented. The analysis of Table 2 shows overall that the factors landraces, density of sowing and the interaction influenced the agronomic characters. Indeed, on the 15 tests carried out by taking account of the three sources of variation (landraces, density and interaction) and the five characters (NPP, number of pods per plant; NSP, number of seeds per plant; PWP, pods weight per plant; SWP, seeds weight per plant; and YLD, yield (t ha^1)), only the interaction effect on the NPP was not significant ($F = 4.08$; $P = 0.114$).

Highly significant ($p < 0.01$) differences were found between the two landraces for the mean values of all the traits analysed. The mean values observed on bunch type are higher than those of the spreading type for all the characters analysed (Table 3). The results of the statistical tests revealed a significant influence of the sowing density on all the characters studied. The highest values of the characters were obtained with the highest plant density (250, 000 plants ha^{-1}) and decreased with the densities (Table 4).

The interactions of sowing density with landraces were significant for most of the traits examined (Table 5). The highest values of four characters were obtained with the high sowing density of set up landraces. They are the weight of the pods, the number of seeds, the weight of seeds and the seed yield per unit area. The lowest values were observed at the spreading type whatever the density of sowing. No significant difference was found

Table 5. Yield and yield components as affected interaction by sowing density-landraces of Bambara groundnut.

Yield and yield component	Mean (±SD) according to sowing density and landrace					
	Bunch type		Spreading type		ANOVA result	
	Low density (62, 500)	High density (250, 000)	Low density (62, 500)	High density (250, 000)	F	P
NPP	354.18 ± 2.65	546.12 ± 87.50	151.00 ± 1.41	213.50 ± 23.33	4.08	0.114
NSP	360.43 ± 73.53^{b}	625.87 ± 18.91^{c}	202.50 ± 10.60^{a}	262.55 ± 9.12^{b}	14.95	0.020
PWP (g)	337.87 ± 27.49^{b}	597.12 ± 11.13^{c}	171.00 ± 19.79^{a}	198.10 ± 14.00^{a}	50.86	0.002
SWP (g)	229.28 ± 3.22^{c}	510.87 ± 23.15^{d}	131.05 ± 8.83^{a}	198.10 ± 14.00^{b}	112.15	< 0.001
YLD (t/ha)	2.29 ± 0.02^{c}	5.10 ± 0.23^{d}	1.31 ± 0.08^{a}	1.98 ± 0.14^{b}	110.63	< 0.001

NPP, Number of pods per plant; NSP, number of seeds per plant; PWP, pods weight per plant; SWP, seeds weight per plant; YLD, yield (t ha^{1}). Mean values within rows by parameter followed by the same superscripted letter were not significantly different at P = 0.05 level, on the basis of the least significant difference test.

between the two landraces for the plant height.

The variance analyses realised to compare both landraces showed a significant difference between the landraces whatever the character. A difference between landraces of Bambara groundnut had also been observed by Djè et al. (2005) during a morphological study of diversity carried out in Côte d'Ivoire. According to these authors, the weight of 100 seeds of the bunch type is higher than that of the spreading type. The bunch type produced the highest pod and seed weight. Moreover, a proportion of mature pods for the bunch type were higher (87 to 95%) than the spreading type (60%). Our results could be explained by the fact that, for the spreading currently cultivated, pods do not arrive in maturity all whole because of their indefinite flowering. The weak rate of mature pods obtained at this landrace influence values of the characters obtained. The values of the variables observed at the bunch type are higher than those observed for the spreading type. This result shows that the productivity of the bunch type is better than that of the spreading type. So the ecological and environmental conditions which characterize the medium are very favourable to the bunch type (Mwale et al., 2007). The bunch type could be used in the area. The number of pods and seeds and the weight of seeds observed for the landraces could be due to the origin of the difference of output. When the values of these parameters are high the seed yield is high. These variables could therefore indicate as the components whose output depends mainly on the Bambara groundnut. Such a result had also been reported by Karikari (2000) and Ouédraogo et al. (2008).

Poor yield of seeds observed for the spreading type is allotted to the low values of these variables. Consequently, the increase of the output on the level of the bunch type is due to the high values of these variables. Another factor which could explain the difference in output of both landraces could be the cycle of reproduction. The bunch type with a shorter cycle of reproduction is more productive than the spreading type with long cycle of reproduction. Similar observations were obtained by Karikari and Tabona (2004). These researchers showed that the early varieties of Bambara groundnut (88 days) are more productive than the late varieties (164 days). This result could be explained by the fact that when the cycle of reproduction is long, the plants are exposed to the variations of the environmental factors (Massawe et al., 2003; Mwale et al., 2007). This variation could have a consequence on certain critical phases of the development of the plant, in particular the period of flowering and formation of the pods. Doku and Karikari (1970) showed that the spreading type has a spread out flowering. The first flowers could benefit to the rainy season, whereas those which appear later often do not profit from rain, thus causing their drying and a malformation of the pods. The consequence of these facts is a reduction of the output. Mwale et al. (2007) showed that under the adverse conditions such as the lack of water, the output of the Bambara groundnut drops considerably. On the other hand, the bunch type had a grouped flowering. According to Karikari (2000), the landraces with grouped flowering could sufficiently have time for the maturation of the pods and seeds before the appearance of the bad season. That confers an agronomic interest to some of them in the optics for an improvement of the culture in the country. This precocity makes it possible to consider more than one culture per year, which makes this landraces a material of choice in the programmes of improvement and popularization of the Bambara groundnut in Côte d'Ivoire.

Conclusion

For each production system, there is a population that optimizes the use of available resources, allowing the expression of maximum attainable marketable or biological yield in that environment. The ideal plant number per area will depend on both abiotic and biotic factors. Increasing plant density had a large direct effect on seed production of the Bambara groundnut landraces tested. The landraces collection obtained from the

University of Abobo-Adjame appeared to give the highest grain per area unit.

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