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Effect of sowing year and seedbed type on yield and yield component in bambara groundnut (*Vigna subterranea* (L) Verdc) in woodland savannahs of Cote d'Ivoire

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Abstract

Bambara groundnut (*Vigna subterranea*) is one of the most promising food legumes in Africa, due to its agronomic and nutritional potential. To take advantage of these attributes, several research programmes gathering agronomic and genetic data are being implemented throughout Africa. In this context, the responses of yield and yield components to year sowing and seedbed type were tested in a three densities (13 900 plants ha−1, 62500 plants ha−1 and 250000 plants ha−1) field experiment using a bambara groundnut landrace with a semi-bunch growth habit. Three years sowing: 2005, 2006 and 2007 were coupled with two seedbed types – raised and flat. A factorial trial using a split-plot design with three replicates was set up to analyse seed yield and plant biomass, as well as nine yield components (Plant spread, Plant height, Number of leaves per plant, Number of pods per plants, Number of seeds per plant, Pods weight per plant, Pod fill ration, Seed harvest index). The seedbed type and year of experiment did not influence significantly the marketable yield and plant biomass ($p > 0.05$). This result has been attributed to the suitability of the amount and distribution of rainfall and temperature for the production of bambara groundnut at the target site. Based on the trend of yield response, cultivation of landraces of bambara groundnut characterized by a semi-bunch growth habit on flat seedbeds was suggested in woodland savannas of Côte d'Ivoire to enhance seeds yield and reduce labour.

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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 (Collinson *et al.*, 1997). 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) (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* (Sesay *et al.*, 2008). These studies aimed at testing abiotic factors (Mwale *et al.,* 2007) and some cultural practices (Karikari *et al.*, 1999) 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. Reviewing the literature on bambara groundnut also reveals that earlier studies have mainly been conducted in Eastern and Central Africa. In depth scientific investigations on the improvement of bambara groundnut productivity in West Africa are still limited to germination, phenological, pest impact and agronomic evaluation (Dje *et al.*, 2005). Since 2001, missions to collect local landraces of bambara groundnut have been undertaken throughout the main production zones in Côte d'Ivoire and Burkina Faso. Agronomic evaluation trials and genetic characterization were then undertaken with the aim of accumulating data to allow the implementation of germplasm management strategies and improved cultivation practices as well as promotion of the crop. Accessing the response of crop yield components to sowing year and to technical sowing is a prerequisite to reach such an objective, since it provides comprehensive data that are useful for management decisions (Echarte *et al.,* 2000). We herein report data on the influence of sowing year and seedbed type on yield and yield components of one of the most common bambara groundnut landraces cultivated in Côte d'Ivoire and Burkina Faso, West Africa.

Materials and methods

Study site

The farm experiments were conducted in 2005, 2006 and 2007 in the village of Manfla (6◦49 34.38 N, 5°43 47.68W) situated at 400 km north Abidjan (Côte d'Ivoire). There are two rainy seasons separated by a short dry period (July–August) and a long dry season (December–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–July each year), the mean monthly temperature was 26.5°C, and mean monthly rainfall ranged from 100.8 mm to 117.5 mm with total rainfall per experimental period of 504.2 mm to 586.3 mm. Mean relative humidity was 81%. The vegetation is a woodland savanna. The climate is described with temperature and precipitation data. The data were obtained with the SODEXAM Abidjan (Côte d'Ivoire) services. The entire area is under the influence of a humid tropical climate characterized by two seasons with a dry season from November to March and a rainy season from April to October**.** In the study area, bambara groundnut is 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; seeds are sown in July–August and harvested in November–December. All experiments were conducted during the first cropping season, and seeds were sown on the first day of the significant rainfall. This was 15 March, 17 March and 17 April, in 2005, 2006 and 2007, respectively. This irregularity prevents the control of agricultural activities by farmers. The water deficit is a handicap for agriculture in the area. The study site is 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.

Experimental design and cultural practice

A bambara groundnut landrace with a semi-bunch growth habit designated on the basis of seed colour pattern as BgR (creamy coloured seed with red spots), and widely cultivated in Côte d'Ivoire and Burkina Faso, was evaluated. Seeds were obtained from the collection of the University of Nangui Abogoua, Abidjan, Côte d'Ivoire. The experimental design was a split-plot with three replicates. Three densities were used in this study: low density with 13 900 plants ha−1, medium density with 62 500 plants ha−1 and high density with 250 000 plants ha−1. The subplots had an area of 36 m2 and received 49, 225 and 900 holes for low, medium and high density, respectively. Two planting methods regularly used by farmers from the study site to grow bambara groundnut were studied: sowing on raised beds and sowing on the flat. Indeed, to prevent weed invasion and facilitate harvest in the target zone, some farmers raise mounds when sowing bambara groundnut. In this experiment, mounds of 60 cm × 60cm and 30 cm high were raised as seedbeds. Four 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 was carried out using a carbamate-based insecticide applied when needed.

Data collection and analysis

Yields (seeds production and plant dry biomass: YLD and PDM, respectively) and nine agronomic traits selected from the bambara groundnut descriptor (IITA *et al.*, 2000) and identified as yield components elsewhere (Ouedraogo *et al,* 2008) were 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 SAS statistical package (SAS, 2004). Least significant difference multiple range-tests were used to identify differences among the means of the parameters examined, according to sowing density, seedbed type, years and interactions.

Results

Seedbed type

The trend of the results related to the effects of sowing year and seedbed type 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. Four of the tested parameters (YLD, PDM, PFR and SHI) were not significantly influenced by the seedbed type (Table 2). Highly significant ($p< 0.01$) differences were found between raised beds and flat planting for the mean values of seven traits (PS, PH, NLP, NPP, NSP, PWP and SWP). The highest values were obtained on raised beds.

The abbreviations are defined in Table 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. Means per seedbed type were calculated independently of sowing years.

Effect of climatic parameters

No significant differences were observed between years for seed yield and the plant total biomass (Table 3). For the nine other traits, significant differences were observed between years. To assess the results in relation to climatic parameters, means were calculated for each year. However, PS, PH, PWP and SWP did not vary significantly between 2005 and 2006. A partial difference was observed for four parameters (PS, PH, PWP and SWP). SHI did not vary significantly again between 2005 and 2007. Three of the tested parameters, NLP, NPP and NSP showed complete distinction. The highest values for these parameters are observed in 2006. Overall, the yield components tested did not show a clear trend for between-years variation. Indeed, a high number of traits with significantly high or low values were not obtained in any particular year.

Table 1. Method of Measurement of Yield and yield components of bambara groundnut in response to sowing year and seedbed type.

Yield and yield components	Measurement approach and sample size per plot
Yield: YLD (t ha−1)	Recordedat12±2% moisture content of seeds, on the yield of each treatment
Plant dry matter: PDM (t ha−1)	Recorded at harvest, after drying plants until constant weight, on 30 plants randomly selected in each treatment
Plant spread: PS (cm)	Recorded 10 weeks after sowing; average of 30 plants randomly selected in each replicate plot. The estimate is the widest length between two opposite points
Plant height: PH (cm)	Measured from the ground level (at the base of the plant) to the tip of the highest point, including the terminal leaflet. Recorded 10 weeks after sowing; average of 30 plants randomly selected in each replicate plot
Number of leaves per plant: NLP	Direct counting, six weeks after first flowering on 30 plants randomly selected in each treatment
Number of pods per plants: NPP	Direct counting at harvest on 30 plants randomly selected in each treatment
Number of seeds per plant: NSP	Direct counting at harvest; average of 30 plants randomly selected in each treatment
Pods weight per plant: PWP (g)	Recorded at harvest, after drying pods to constant weight, on 30 plants randomly selected in each treatment
Seeds weight per plant: SWP (g)	Recorded at harvest, after drying seeds at 12±2% moisture, on 30 plants randomly selected in each treatment
Pod fill ration: PFR	Calculated on 5 sets of 50 seeds per treatment, by subtracting the seed weight from the corresponding pod weight and dividing the result by the pod weight
Seed harvest index: SHI	Ratio between seeds yield and plants' total biomass. Recorded on 30 plants randomly selected in each treatment bean yield and harvest components

Table 2. Yield and yield components as affected by technical sowing.

	Mean (± SD) according to technical sowing		ANOVA results	
Yield components	Raised beds	Flat	*F*	*P*
YLD (t ha−1)	2,50±1,70	2,12±1,48	0,51	0,501
PDM (t ha−1)	2,03±1,88	1,68±1,40	0,40	0,530
PS (cm))	55,11±11,59	53,20±11,90	21,63	<0,001
PH (cm)	29,30±4,17	27,82±2,97	46,72	<0,001
NLP	124,55±50,29	113,78±52,20	37,87	<0,001
NPP	42,95±27,95	38,73±22,63	12,10	0,005
NSP	43,49±28,32	39,01±22,78	13,53	0,003
PWP (g)	41,77±27,38	34,11±18,79	41,50	<0,001
SWP (g)	30,32±19,50	24,58±13,30	45,88	<0,001
PFR	73,00±9,00	72,00±4,00	1,10	0,295
SHI	0,58±0,16	0,57±0,12	1,79	0,181

Table 3. Yield and yield components as affected by year sowing.

Yield components	Mean (± SD) according to year sowing			ANOVA results	
	2005	2006	2007	*F*	*P*
YLD (t ha−1)	2,62±1,91	1,96±1,15	2,36±1,65	0,51	0,608
PDM (ha−1)	1,90±2,06	2,38±1,76	1,30±0,80	1,31	0,282
PS (cm))	56,00±12,36^{b}	55,22±12,19^{b}	51,25±10,20^{a}	57,7	<0,001
PH (cm)	29,48±4,27^{b}	29,65±3,56^{b}	26,55±2,02^{a}	85,75	<0,001
NLP	98,80±34,20^{a}	137,48±64,65^{c}	121,21±43,27^{b}	164,32	<0,001
NPP	40,31±19,89^{b}	52,08±33,20^{c}	30,12±14,67^{a}	109,57	<0,001
NSP	40,53±20,00^{b}	52,87±33,80^{c}	30,35±14,23^{a}	114,36	<0,001
PWP (g)	44,75±24,18^{b}	42,62±27,31^{b}	26,45±12,98^{a}	94,44	<0,001
SWP (g)	32,21±15,23^{b}	31,09±19,11^{b}	19,07±9,65^{a}	98,58	<0,001
PFR	72,00±10,00^{a}	73,00±5,00^{b}	72,00±5,00^{a}	3,39	0,034
SHI	0,63±0,15^{b}	0,46±0,11^{a}	0,63±0,09^{b}	205,94	<0,001

The abbreviations are defined in Table 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. Means per sowing years were calculated independently of seedbed type.

Interactions effect of climatic parameters and seedbed type

Statistical analysis of the interaction between the seedbed type and the sowing year highlighted a significant variation for seed yield and plant biomass, as well as for most of the yield components tested (Tables 4). Seedbed type × year interaction was not significant for seed yield and the plant total biomass, due to the fact that the two factors did not influence significantly seed production (t ha^{-1}) and plant biomass (tha^{-1}). This interaction significantly influenced (P <0.05) six of the 11 characters analyzed. Conversely, five characters (YLD, PDM, NPP, NSP and PFR) have not been influenced by the interaction. The highest values of PS, SWP and SHI were observed in 2005 on raised beds. However, for the other nine characters, a significant difference was observed. Among these characteristics, three showed complete distinction and six partial differences. The highest values of PH and NLP were observed with seedling 2006. No overall trend was observed for yield components passing from one year to another.

Table 4. Yield and yield components as affected by year sowing combined with technical sowing.

Variables	Mean (± SD) according to year sowing combined with technical sowing						Statistiques	
	2005		2006		2007			
	Raised beds	Flat	Raised beds	Flat	Raised beds	Flat	*F*	*P*
YLD (ha−1)	2,84±2,04	2,39±1,95	2,05±1,18	1,88±1,24	2,62±1,96	2,10±1,42	0,29	0,91
PDM (ha−1)	2,12±2,48	1,68±1,76	2,63±2,05	2,13±1,57	1,36±0,85	1,24±0,81	0,58	0,71
PS (cm))	58,15±11,11^{d}	53,86±13,12^{c}	55,21±12,15^{c}	55,23±12,28^{c}	51,97±10,72^{b}	50,52±9,64^{a}	9,49	<0,001
PH (cm)	31,25±4,55^{e}	27,71±3,11^{c}	29,70±5,30^{d}	29,60±2,64^{d}	26,96±1,96^{b}	26,14±2,60^{a}	23,29	<0,001
NLP	112,90±38,26^{b}	84,6±21,90^{a}	137,7±62,94^{d}	137,2±66,57^{d}	122,93±43,50^{c}	119,50±43,15^{c}	25,58	<0,001
NPP	41,15±22,92	39,48±16,38	55,49±36,07	48,67±29,82	32,20±15,90	28,04±13,08	1,50	0,222
NSP	41,58±23,06	39,49±16,40	56,38±37,00	49,37±30,01	32,52±150,80	28,18±13,03	1,36	0,257
PWP (g)	50,85±28,65^{d}	38,65±16,69^{b}	46,51±30,94^{c}	38,73±22,59^{b}	27,95±13,60^{a}	24,95±12,21^{a}	4,99	0,007
SWP (g)	36,75±20,45^{c}	27,66±11,66^{b}	34,04±21,49^{c}	28,13±15,94^{b}	20,18±10,36^{a}	17,96±8,78^{a}	5,48	0,043
PFR	73,00±13,00	71,00±3,00	74,00±4,00	73,00±6,00	72,00±5,00	72,00±4,00	0,81	0,450
SHI	0,65±0,16^{c}	0,61±0,13^{b}	0,45±0,12^{a}	0,47±0,10^{a}	0,65±0,09^{c}	0,62±0,09^{b}	15,52	<0,001

The abbreviations are defined in Table 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. Means per sowing years and seedbed type were calculated together

Discussion

Optimization of plant spatial arrangement and seedbed type is essential for maximizing yield of any crop. Research on manipulations of sowing year and seedbed type to fit production factors and objectives are therefore of practical interest for agronomists and breeders. Variation in yield and yield components in relation to factorial change in planting density and technique in a semi-bunch type bambara groundnut revealed relevant trends. Seed yield (ha−1), biomass production and two yield components (PFR and SHI) were not significantly influenced by the seedbed type. This result could be related to the composition of the soil at the study site. Indeed, with 57% sand, soils are usually so friable that physical management for superficial crusting control is not required (Bresson, 1995). The results were in accordance with those from a study conducted by Mkandawire and Sibuga (2002) on the same species. The authors reported that when the amount of precipitation is sufficient, in the long rainy season, planting bambara groundnut on the flat resulted in significantly high grain yield compared to planting in furrows or on ridges. Planting in furrows or on ridges enhanced grain yield only during the short rainy season where rainfalls were low. The results related to the effect of seedbed type were also similar to those reported in common bean (Valenciano *et al.*, 2006) and pea (Neumann *et al.*, 2007). Indeed, Valenciano *et al.* (2006), showed that sowing common bean on raised beds favoured fast emergence, without yield enhancement. Plant production components (seed and biomass production per unit area) were statistically similar over the three years. Such results were expected since the rainfall during the growing seasons did not vary markedly throughout the three years (504–586 mm). Yield stability is characteristic of bambara groundnut, mainly due to its adaptability to poor soils, high temperatures and low rainfall (Brink, 1999; Mkandawire and Sibuga, 2006; Mwale *et al.*, 2007). The amount and distribution of seasonal precipitation during the three experimental years appeared to be suitable for the water needs of the genotype used in this study. Using laboratory, greenhouse and field studies, it has been established that the water and temperature requirements of bambara groundnut are around 600 mm and 25°C, respectively (Mpotokwane *et al.*, 2008).

Conclusion

For each production system, there are a sowing year and seedbed type that optimized 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. For this plant materiel, sowing year and seedbed type had no effect on seed production and biomass. Planting on the raised beds appeared to give the highest yield of seed regardless of biomass.

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