Effects of soil type on the emergence, flowering, nutrient uptake and yield components of bambara groundnut (*Vigna subterranea* (L.) Verdc) landraces in Botswana

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ABSTRACT

On-station experiments were conducted at the Regional Agricultural Research Station-Impala in Francistown, Botswana, during 2003/04, 2004/05 and 2005/06 seasons to determine the effects of sandy loam and sandy clay loam soil types on the emergence, flowering, nutrient uptake and yield components of two bambara groundnut (*Vigna subterranea* (L.) Verdc) landraces. The two soil types were about 50 m apart within the same field. Within each soil type, two landraces were each planted in four 3.75m by 5 m replicate plots at 75cm inter-rows by 20cm within rows and the experimental design was a randomized complete block.
Planting bambara groundnut in sandy loam soil (SL) resulted in significantly earlier and higher percentage of seedling emergence and flowering, plant stand after emergence, total dry matter, pod number per plant, unshelled pod dry weight, grain yield, crop residue and soil nutrient uptake than in sandy clay loam soil (SCL). It is concluded that sandy loam soil is a more suitable soil for bambara groundnut production than sandy clay loam soil but might require greater management on soil nutrients as the soil is depleted of soil nutrients more than the sandy clay loam. Also, more studies are needed to establish the causal factors in the two soil types which bring about the different responses in bambara groundnut.
Key words: Bambara groundnut, soil types, emergence, flowering, nutrient uptake, yields

INTRODUCTION

Bambara groundnut (*Vigna subterranea* (L.) Verdc) also called Jugobean in Botswana is one of the tropical legumes considered to be drought tolerant (Babiker, 1989; Collinson *et al.*, 1997). It is adapted to a wide range of soils and thrives well in high temperature conditions where other pulses fail (Doku, 1969).

In Botswana, bambara groundnut is cultivated by subsistence farmers and is often found in mixed/intercropping systems throughout the country. But seed yields are quite low and yields of less than 200 kg/ha are not uncommon (Karikari *et al.*,1999, Karikari 2000) which are much lower than most of the semi-arid tropics typical yields which are often between 650 and 850 kg/ha (Stanton *et al.*, 1996). The low yields obtained in Botswana could be attributed to various factors such as use of landraces, cropping systems, harsh climatic conditions, management practices and soil types under which the crop is cultivated. Although the crop is known to be adapted to a wide range of soils, it is important to quantify the level of production of bambara groundnut in different soil types so that soils with the highest potentials can be exploited. Soil physical characteristics determine whether a soil is poorly or well drained a phenomenon that may influence crop production. Soil physical properties are important in determining nutrient-supplying ability of a soil as well as both water and air supply for plant growth. Swanevelder (1998) reported that in South Africa, the most suitable soil for bambara groundnut is light sandy loams with a pH of 5.0 to 6.5. Ramolemana (1999) found that bambara groundnut generally showed a poor response to P and N fertilization. This implies that it heavily depends on the available nutrients in the soil. Hence, it is important to quantify the extent which bambara groundnut depletes soil nutrients. Thus a study to investigate how different soil types would affect the performance of bambara groundnut in terms of seedling emergence, plant flowering, yield parameters and how the crop depletes soil nutrients would help improve the productivity of the crop. The objective of this study was to determine the effects of two soil types on the emergence, flowering, nutrient uptake and yield components of two bambara groundnut landraces.

MATERIALS AND METHODS

The study was conducted during the 2003/04, 2004/05 and 2005/06 cropping seasons at the Regional Agricultural Research Station at Impala (21^0 7' S and 27^0 33' E, 1120 m above sea level). The station is located near Francistown in the north east of Botswana. The experiment was conducted on sandy loam (SL) and sandy clay loam (SCL) soils whose physical and chemical characteristics at the beginning of the experiment are shown in Table 1. The two soil types were about 50 m apart within the same field. The two bambara groundnut landraces used in this study were mass selected among others by the Department of Agricultural Research. They were originally collected from farmers in the North East district, Botswana. They were coded N-100 (purple testa with a white eye) and MA-15A (dark cream testa with V-shaped purple colour around a white eye).

The experimental design used in each separate soil type was a randomized complete block. In each soil type four replicate plots per bambara landrace were used.. Each plot was 5 m long and 3.75 m wide. Seeds were sown in six rows at 75 cm inter-row spacing by 20 cm within row spacing giving a plant population of 6.7 plants per m^2 or 67,000 plants per hectare.

During the 2003/04, sowing was done on 10th December, 2003 and only N-100 was planted while in 2004/05 and 2005/06 both landraces, were sown on the two soil types from 14th to 15th December, 2004 and from 12th to 14th December, 2005 respectively. During the 2004/05 season, planting was delayed in the SL soil awaiting the water flooded in the SCL soil to evaporate. Thus, planting was done in the SL soil when it was dry while in SCL soil planting was done when it was wet.

During the three seasons the SCL soil used to get flooded whenever it rained and submerged the crop. When it was dry, the same soil formed hard crusts which prevented seedling emergence. In all seasons, the crop was hand weeded using hand hoe and was earthed up about two weeks after all plants had flowered.

The data collected included seedling emergence (%), plants flowering at different periods (%), total dry matter, pod number per plant, pod dry mass, shelling percentage, hundred seed mass per plant, seed yield, crop residue dry mass, plant nutrient concentration and uptake. The number of plants which had emerged at a given time was expressed as percentage of the seeds planted per plot. The number of plants flowering was recorded from the time flowers were sighted for the first time and continued on weekly basis until all plants per plot flowered and were expressed as a percentage of those plants which had emerged per plot. Dry mass of plant materials were determined by air-drying the material in the sun until no more weight loss was observed. Plant materials were sent to the Department of

Agricultural Research Soil laboratory in Sebele, Gaborone to be analyzed for N, P, K, Ca, Mg, Na, Cu, Fe, Mn and Zn concentration (% or ppm). Nutrient uptake (kg/ha or g/ha), a product of dry mass and nutrient concentration was also calculated. Grain yield and yield components were determined at maturity from plants harvested from four middle rows out of six. The number of pods per plant was recorded from a sample of ten plants randomly selected in a plot. Rainfall data during the growing seasons were also recorded.

Using Statistical Analysis System, data were subjected to analysis of variance. Each season data was treated separately as complete unit since seasons were not among the factors for the study. Also, the data for individual soil types were first analyzed separately and then combined analyses for both soil types were performed in order to enable statistical analyses to have main effects of soil type and landrace and the interactions between the soil type and the landrace. Whenever the F-values for the main effects were significant at $P \leq 0.05$, the means were separated using Duncan's Multiple Range Test. Correlations were also performed in order to find the relationship between plant flowering and percentage plant emergence at different days after planting as well as relationship between total dry matter and nutrient uptake.

Table1: Physical and chemical characteristics of the soil at the Impala Agricultural Research Field Station - Francistown prior to the planting of the first crop during the 2003/04 Cropping season

Properties	Sandy Loam	Sandy Clay Loam	Optimal levels *
Physical			
Sand (%)	72.24	50.24	-
Silt (%)	14.00	17.00	-
Clay (%)	13.76	32.76	-
Chemical			
pH ($CaCl_2$)	4.40	5.40	> 6
P (ppm)	10.50	10.0	> 10
OC (Meq/100g)	0.50	0.80	> 0.2
Ca "	3.24	8.70	> 1.0
Mg "	0.85	3.00	> 0.3
K "	0.49	0.61	> 0.1
Na "	0.41	0.19	< 1.0
CEC "	6.20	14.49	> 2.5

* Optimal levels for any crop according to Soil Analysis Laboratory, Department of Agricultural Research (DAR), Gaborone, Botswana.

Table 2: Total monthly rainfall (mm) during 2003/04; 2004/05 and 2005/06 cropping seasons at the Impala Agricultural Research Field Station, Francistown.

Month	Total monthly rainfall (mm) per growing season					
	2003/04		2004/05		2005/06	
	Rainfall	Rainy days	Rainfall	Rainy days	Rainfall	Rainy days
October	54	2	40	1	0.0	0
November	62	4	43	3	29.4	5
December	41	4	245	3	99.0	9
January	75	5	109	6	109.0	6
February	114	7	6	1	227.0	14
March	118	9	12	1	91.1	9
April	30	1	46	1	12.6	1
May	0	0	0	0	7.6	1
Total	494	33	501	16	581.8	47

RESULTS AND DISCUSSION

Rainfall data

The highest total rainfall was received during the cropping season of 2005/06 followed by 2004/05 and 2003/04. However, the cropping season of 2004/05 had the poorest rainfall distribution compared to that of 2003/04 and 2005/06 (Table 2).

Effect of soil type and landrace on bambara groundnut emergence

During 2003/04 and 2005/06 seasons, emergence was significantly affected by soil types (Table 3). The crop planted in SL soil reached 75% emergence at 14 DAP while at this time in SCL soil, there was no emergence which had occurred during 2003/04 and only 32% emergence had occurred during 2005/06. During 2005/06, the 75% emergence occurred at 35 DAP in SCL. In both seasons, complete seedling emergence of about 88% occurred at 28 DAP in SL soil while in SCL complete emergence of 63% during 2003/04 and of 77% during 2005/06 occurred at 56 DAP and 35 DAP respectively. Thus, there was a delay in SCL soil of three weeks for seedlings to reach 75% and up to four weeks for the crop to reach complete emergence compared to that in SL soil. During 2004/05 when planting was done dry in SL and when wet in SCL, there was delay in emergence of 28 DAP in SL but when rain fell 31 DAP, the emergence at 49DAP in SL had equalld that in SCL and at 56 DAP both soil types each achieved 60% complete emergence. The delay in emergence in SL soil was due to soil moisture and not due to the soil type. However, the difference due to the soil types probably could be attributed to the fact that, whenever it rained during 2003/04 and 2005/06, the SCL soil used to get flooded and this could have interfered with the aeration which negatively affected the germination of seeds as they were found rotten. Some of the submerged seedlings also wilted and died. Also, during the dry spells which characterized the two seasons, the SCL soil used to form hard crusts which prevented seedling emergence.

During 2004/05 and 2005/06 the N-100 landrace had a higher percentage of seedling emergence than MA-15A in both soil types at 14 DAP up to 56 DAP although the difference was significant during the 2005/06 season at 28 DAP and 35 DAP (Table 3). Thus, at complete seedling emergence in both soil types, the N-100 landrace had higher plant population than MA-15A landrace. It was noted that bambara groundnut can stay in the soil for up to 56 DAP and still emerge when there is adequate moisture. Thus, it can be dry planted where ever it is possible. There were no significant interactions between soil type and landrace on percentage seedling emergence during the various cropping seasons.

Effect of soil type and landrace on flowering

At 42 DAP during 2005/06, and at 49 and 56 DAP during both 2003/04 and 2005/06, significantly higher percentages of plants growing in SL soil were flowering than those growing in SCL soil (Table 4). During 2005/06, at 42 DAP 21% of the plants had flowered in SL and none in SCL while at 49 DAP 78% plants had flowered in SL and only 22% had flowered in SCL. Also, during 2003/04 at 56 DAP, 97% plants had flowered in SL and only 10% in SCL. It was found that the delay in emergence correspondingly resulted in delayed plant flowering. This was proved true because when emergence was delayed in SL due to inadequate moisture during 2004/05, the flowering was delayed in the same soil more than in the SCL (Table 4). Generally, the N-100 landrace had in both soils types higher percentage of plants flowering than MA-15A landrace although the difference was significant at 49 DAP and 56 DAP during the 2005/06 season. There were no significant interactions between soil types and landraces on percentage flowering during the various cropping seasons. However, during 2003/04 and 2005/06, there were highly significant correlations between percent plant flowering at 42DAP to 56 DAP and percent plant emergence at different emergence periods of 14 DAP to 35 DAP. For example, the correlations between percent plant flowering at 49 DAP and percent plant emergence at the following various emergence periods were as follows: at 14DAP (r=0.99, P=0.0001); at 28DAP (r=0.92, P=0.001); at 35DAP (r=0.88, P=0.008). Similar correlation trends were observed at 42 DAP and 56 DAP flowering periods during the two seasons. This implied that, any factors that could enhance earlier emergence would result in higher percentage of plant flowering early in the season, and this could probably help the crop to escape harsh weather conditions like drought later in the season.

Table 3 : Effect of soil type and landrace on percentage emergence of bambara groundnut at different days after planting (dap) at the Impala Agricultural Research Field Station – Francistown

Soil type	Season	Bamabara groundnut seedling emergence (%) at different days after planting (DAP)											
		14 dap			28 dap			35 dap '			56 dap		
		N-100	MA-15A	Mean soils '	N-100	MA-15A	Mean soils	N-100	MA-15A	Mean soils	N-100	MA-15A	Mean soils '
	2003/04*												
SL		75a	-	-	88a	-	-	88a	-	-	88a	-	-
SCL		0b	-	-	34b	-	-	44b	-	-	63a	-	-
Landrace mean		38	-	-	61	-	-	66	-	-	76	-	-
	2004/05												
SL'		21a	13a	17b	20a	18a	19b	61a	54a	58a	65a	58a	61a
SCL		49a	45a	47a	53a	49a	51a	58a	55a	57a	61a	59a	60a
Landrace mean '		35a	29a	32	37a	33a	35	60a	55a	58	63a	59a	61
	2005/06												
SL		79a	72a	76a	90a	84b	87a	90a	84b	87a	-	-	-
SCL		33a	32a	32b	74a	69a	73b	80a	73a	77b	-	-	-
Landrace mean '		56a	52a	54	84a	77b	80	85a	79b	82	-	-	-

[a, b, c] Means of soil types across landraces or means of landraces within and across soil types followed by different letters are significantly different at P=0.05 probability level.

[d] During 2004/05 season data given was of 49 DAP and not that of 35 DAP as in 2003/04 and 2005/06 seasons

* Means for 2003/04 season are compared vertically because it was only one landrace, N-100 used. But for 2004/05 and 2005/06 seasons, means of the two landraces within each soil and across the soil types are compared horizontally while means of soil types across landraces are compared vertically. Means within each soil types are obtained from individual soil analysis of variance while means landraces across soil types and means soil types across landraces were obtained from combined analyses of variance. Note. there were no significant interaction between soil type and landrace on seedling emergence during the various seasons.

Table 4: Effect of soil type and land race on percentage flowering of bambara groundnut at different days after planting (dap) during three cropping seasons at the Impala Agricultural Research Field Station , Francistown

Soil type	Bambara groungnut plant flowering (%) in various seasons at different days after planting (dap)														
	2003/04 +		2004/05						2005/06						
	49 dap	56 dap	63 dap			42 dap			49 dap			56 dap			
	N-100	N-100	N-100	MA-5A	Mean' Soil	N-100	MA-15A	Mean	N-100	MA-15A	Mean	N-100	MA-15A	Mean
SL	64a	97a	26a	15a	20b	27a	15a	21a	85a	72b	78a	96a	90a	93a
SCL	0b	10b	71a	50b	61a	0a	0a	0b	27a	18a	22b	67a	49a	58b
Mean' landrace	32	54	49a	33a	41	14a	8a	11	56a	45b	59	82a	70b	76

Means for 2003/04 season are compared vertically across soil types because it was only one landrace used but for 2004/05 and 2005/06 seasons, means of landraces are compared horizontally within each soil type

y Means of soil types across landraces (compared vertically) or z means of landraces across soil types (compared horizontally) followed by different letters are significantly different at P>0.05 probability level. The y and z means were obtained from combined analyses of variance. There were no significant interactions between soil type and landrace on percentage flowering during the various seasons

Effect of soil type on total dry matter, nutrients concentration and content (uptake) at flowering and maturity of bambara groundnut landraces.

There were significant differences in plant total dry matter (TDM) between soil types (Tables 5 and 7). The plants grown in SL soil had 508% and 63% more TDM at flowering than those grown in SCL soil during 2003/04 and 2005/06, respectively (Table 5). At maturity, plants grown in SL soil had 105% more TDM than those in SCL during 2005/06 (Table 7). The higher TDM in those grown in SL soil could be due to the fact that the crop in SL soil had taken up more nutrients than those from SCL (Table 6b) and also more plants had emerged earlier than those in SCL, hence they had more time to accumulate more TDM. The TDM was found to be significantly correlated to the uptake of nutrients. The correlation between TDM and nutrients uptake were: for N (r=0.91, P=0.0001); P (r=0.80, P=0.0002); K (r=0.94, P=0.0001); Mg (r=0.92, P=0.0001); Fe (r=0.5, P=0.049); Mn (r=0.79, P=0.0003). The TDM of the two landraces did not differ significantly although the N-100 landrace had more than MA-15A by 21% at flowering during 2003/04 and by 9% at maturity during 2005/06. Generally, soil types did not have significant effect on the concentration of nutrients except for Na at flowering (Table 5), Mn in empty pods and N in haulms at maturity (Table 6) whereby plants in SL soil had significantly higher concentration than those in SCL. The landrace N-100 had significantly higher concentration of Ca and Mg than MA-15A at flowering. Also, within SL soil at maturity, the haulms of landrace N-100 had significantly higher concentration of CP by 14%, and of P by 40% than MA-15A but its empty pods had significantly lower concentration of CP, K and Mg than MA-15A (Table 6a). Generally, seeds from SL soil had higher concentration of nutrients than from SCL while seeds of N-100 landrace had higher concentration of nutrients than MA-15A.

The uptake of nutrients at flowering was significantly higher in SL than in SCL during 2003/04 and 2005/06 and ranged from 75% - 472% for N, 50%-2900% for P, 67%-515% for K, 75%-444% for Ca and 52% - 567% for Mg (Table 5). At maturity, the whole plant nutrient uptake in SL was significantly higher than in SCL for only N, P and K (6b). Also, the uptake of N, P, K, Mg, Cu, Mn and Zn in seeds and P in crop residue were significantly higher in SL soil than in SCL (6b). The two landraces did not differ significantly in nutrient uptake except for N-100 landrace which took up significantly higher levels of Na at flowering (Table 5) and Zn in seeds and P in the crop residue at maturity than MA-15A (Table 6b). The higher uptake of nutrients in both SL soil and in landrace N-100 is due to the fact that the crop had more TDM than that from SCL or the landrace MA-15A respectively. There was low uptake of P of 7 kg/ha compared to that of other macronutrients like N (97 kg/ha), K (73 kg/ha), Ca (42 kg/ha) and Mg (16kg/ha) (Table 6b). Since P is important for plant growth and production, it implies that bambara groundnut had a low P requirement. This finding seem to confirm the studies of Ramolemana (1999) which concluded that bambara groundnut had low P requirement as there was lack of response to P fertilizer in the field and that this could be responsible for its ability to thrive in chemically poor soils.

Table5 Effects of soil type and landrace on plant nutrient concentration (% and ppm) and uptake (kg/ha) in bambara groundnut at flowering pegging stage grown in two seasons at the Impala Agricultural Research Field Station, Francistown

Nutrient TDM *	Nutrient concentration (%)						Total dry matter Nutrient uptake (kg/ha)					
	2003/2004		2005/2006				2003/2004 j		2005/2006			
	Soil type		Soil type		Landrace		Soil type		Soil type		landrace	
	SL	SCL	SL	SCL	N-100	MA-15A	SL	SCL	SL	SCL	N-100	MA-15A
TDM							4461a	734b	1008a	620b	890a	737a
CP	14.6a	15.7a	17.8 a	17.3a	17.4a	17.7a	-	-	-	-	-	-
N	2.3a	2.5a	2.9a	2.8a	2.8a	2.9a	103a	18b	29a	17b	25a	21a
P	0.28a	0.05a	0.18a	0.20a	0.19a	0.19a	12a	0.4b	1.8a	1.2b	1.7a	1.4a
K	1.8a	1.7a	1.95a	1.95a	1.9a	2.0a	80a	13b	20a	12b	17a	15a
Ca	1.1a	1.2a	1.40a	1.30a	1.4a	1.2b	49a	9b	14a	8b	13a	9b
Mg	0.45a	0.45a	0.37a	0.39a	0.39a	0.37b	20a	3b	3.8a	2.5b	3.5a	2.7a
Na	-	-	0.003b	0.006a	0.005a	0.004a	-	-	0.03a	0.03a	0.04a	0.02b
Nutrient	Nutrient concentration (ppm)						Nutrient uptake (g/ha)					
Cu	-	-	10.6a	17.6a	14.6a	13.6a	-	-	0.011a	0.011a	0.012a	0.009a
Fe	-	-	719a	446a	615a	549a	-	-	0.72a	0.28b	0.55a	0.45a
Mn	-	-	128a	140a	133a	135a	-	-	0.13a+	0.09b	0.12a	0.10a
Zn	-	-	28a	31a	30a	29a	-	-	0.03a	0.02a	0.03a	0.02a

* Means of nutrients/TDM are compared horizontally between two soil types or two landraces and when they are followed by different letters, they are significantly different at P = 0.05 probability level.

j = Only one bambara groundnut landrace N-100 was planted during 2003/2004 season

Note: This is a combined analyses of variance of the two soil types

+ The interaction between soil type and landrace on Mn uptake was significant at P=0.01 during 2005/2006 season

Effect of soil type on yield and yield components of bambara groundnut landraces

Soil types had significant effect on yield components except for 100 seed weight and shelling percentage (Table 7). The crop grown in SL soil performed better and gave significantly more of the following components than that grown in SCL soil as follows: grain yield by 1058% in 2003/04 and by 361% in 2005/06; unshelled pod dry weight by 956% in 2003/04 and by 359% in 2005/06; pod number per plant by 273%, seed weight per plant by 350% and crop residue by 55% during the 2005/06 season. Also, the crop from SL soil had non- significantly more 100 seed weight and shelling percentage than that from SCL soil. During the 2004/05 season, the landrace N-100 had significantly more unshelled pod dry weight, 100 seed weight, seed weight per plant, shelling percentage and grain yield than MA-15A landrace. The better performance of bambara groundnut in SL soil than in SCL and of landrace N-100 than MA-15A could be due to the fact that the crop in SL and the N-100 landrace had accumulated more dry matter than their counterparts (Table 5 and 7) which was probably partitioned to the yield components. There were highly significant correlations between final total dry matter and the following parameters as follows: grain yield (r = 0.94, P = 0.0001), pod number/plant (r=0.88, P=0.0001), unshelled pod dry weight (r=0.96, P=0.0001), seed yield/plant (r=0.94, P=0.0001) as well as between grain yield and the following: pod number per plant (r = 0.93, P = 0.0001), unshelled pod dry weight (r = 0.98, P =0.0001) and seed yield per plant (r =0.99, P= 0.0001). The correlation of seed yield and pod number per plant corresponds well with the findings of Ofori–I (1996) who reported that pod number per plant gave the best indication of seed yield status of bambara groundnut. Also, the better performance of bambara groundnuts in sandy loam soil corresponds well with the findings of Swanevelder (1998) who reported that the crop prefers well-drained sandy loam as it can utilize lighter rain showers to greater advantage than clay soil and the soil cannot damage the seed.

Table 6: Effects of soil type and landrace on (a) nutrient concentration (% and ppm) and (b) nutrient content or uptake in bambara groundnut at maturity grown at Impala Agricultural Research Station, Francistown – during 2005/06 season.

(a) concentration	Seeds				Empty pods				Haulms			
Nutrient*	Soil type		Landrace		Soil type		Landrace		Soil type		Landrace	
	SL	SCL	N-100	MA-15A	SL	SCL	N-100	MA-15A	SL	SCL	N-100	MA-15A
CP %	23.8a	19.3a	22.4a	20.7a	5.1a +	6.9a	5.9 a	6.2a	11.43b++	16.28a	13.7a	14.0a
N "	3.8 a	3.1a	3.6 a	3.3a	1.8 a	1.1a	0.9a	2.0a	1.83b ++	2.6a	2.2a	2.3a
P "	0.29a	0.28a	0.31a	0.26a	0.08a	0.11a	0.09a	0.10a	0.14a ++	0.17a	0.18a	0.13b
K "	1.9a+	1.8a	1.89a	1.81a	2.5a	2.9a	2.31a	2.24a	1.74a	1.42a	1.5a	1.7a
Ca "	0.11a	0.05a	0.11a	0.05a	0.41a	0.35a	0.42a	0.34a	1.72a	1.51a	1.6a	1.7a
Mg "	0.17a+	0.16a	0.17a	0.16a	0.22a	0.19a	0.20a	0.21a	0.50a	0.57a	0.5a	0.5a
Na "	0.016a	0.004a	0.016a	0.004a	0.05a	0.08a	0.07a	0.07a	0.013a	0.019a	0.02a	0.01a
Cu ppm	7.1a	5.9a	6.6a	6.4a	4.6a	5.9a	5.0 a	5.5a	10.0a	8.0a	9.3a	8.8a
Fe "	39.4 a	41.1a	42.6a	37.9a	243a	231a	240a	235a	675.4a	665.6a	653a	688a
Mn "	13.1 a	10.4a	13.0a	10.5a	28.3a	8.4b	21.6a	25.0a	121.6a	109.8a	104a	128a
Zn "	22.5a	25.9a	27.1a	21.3 a	14.4a	24.6a	17.9a	21.1a	27.4a	15.4a	21.4a	21.4a
(b) content	Seeds				Residue (empty pods & haulms)				Whole plant			
N kg ha	69.0a	12.8b	39.4a	42.4a	55.3a	57.3a	59.2a	53.4a	124.3a	70.3b	98.5a	96.0 a
P "	5.2 a	1.1b	3.4a	2.9a	4.4a	3.5a	4.7a	3.3b	9.8a	4.8b++	8.1a	6.4a
K "	33.5a	8.0b	19.8a	21.7a	69.4a	38.6b	51.5a	56.5a	103.0a	42.0b	71.4a	73.6a
Ca "	0.8a	0.5a	0.6 a	0.7a	50.9a	33.2a	44.5a	39.6a	50.1a	33.3a	43.4a	40.0a
Mg "	3.0 a	0.7 b	1.8 a	1.9a	14.8a	12.6a	14.3a	13.0a	18.4a	13.4a	16.6a	15.1a
Na "	0.04a	0.10a	0.02a	0.12a	0.75a	0.51a	0.65a	0.61a	0.80a	0.62a	0.68a	0.74a
Cu g ha	13.1a	2.7b	8.2 a	7.6 a	24.6a	22.3a	25.5a	21.4a	38.0a	25.0a	33.9a	29.1a
Fe "	71.6a	41.3a	44.0a	69.0a	1981a	1608a	1781a	1808a	2268a /	1649a	2040a	1877a
Mn "	24.3a	4.2b	11.7a	16.8a	314a+	244a	265a	293a	338a+	249a	276.9a	309.9a
Zn "	40.7a	11.3b	29.8a	22.2b	53.8a	58.6a	60.3a	52.1a	94.4a	69.6a	89.8a	74.3a

+ indicates that within the same soil type the MA-15A landrace had significantly more of the nutrient than the N-100 while
++ indicate that within the same soil type the N-100 landrace had significantly more of the nutrient than the MA-15A

* Means of nutrients are compared horizontally between soil types or landraces and those followed by different letter are significantly different at P<0.05 prob. level

/ Interaction between soil type and landrace on Mn uptake was significant at P<0.05. Note: this is a combined analyses of variance

CONCLUSIONS AND RECOMMENDATIONS

Planting bambara groundnut in sandy loam soil (SL) resulted in earlier and higher percentage of seedling emergence and flowering, higher plant stand after complete emergence, more total dry matter, more pod number per plant, more unshelled pod dry weight, more grain yield, more crop residue and more soil nutrient uptake than that grown in sandy clay loam soil (SCL). The uptake of macro-nutrients showed that, P had the lowest uptake. In order to maximize grain yield the sandy loam soil should be used in bambara groundnut production. Also, because the crop grown in SL depletes soil nutrients more than in SCL, greater soil nutrient management should be practiced in SL soil. Further research is needed to establish the reasons why the two soil types caused different responses to bambara groundnut landraces.

ACKNOWLEDGEMENTS

The author thanks the Department of Agricultural Research for funding this work and F.M. Phindela and B.N. Baipoledi for their technical assistance.

Table 7: Effects of soil type and landrace on mean yield and yield components of bambara groundnut grown in different seasons at Impala Agricultural Research Field Station, Francistown

Yield components +	2003/04 Season *		2004/05 Season *		2005/06 Season			
	Sandy Loam	Sandy clay loam	Sandy clay loam N100	Sandy clay loam MA-15A	Sandy loam	Sandy clay loam	N-100	MA-15A
Total dry matter (kg/ha)	-	-	-	-	5410a	2644b	4194a	3861a
Pod number / plant	-	-	-	-	56a++	15b	31b	41a
Unshelled pod dry wt (kg/ha)	4625a	438b	308a	139b	2839a	619b	1767a	1691a
100 seed wt (g)	-	-	38a	30b	68a	63a	62a	71a
Seed wt / plant (g)	-	-	3.2a	1.1b	27a	6.b	17a	16a
Shelling %	78a	71a	68a	55b	64a	52a	60a	57a
Grain yield (kg/ha)	3625a	313b	234a	76b	1820a	395b	1133a	1082a
Crop Residue dry wt (kg/ha)	-	-	-	-	3591a	2249b	3063a	2779a

* During 2003/04 season only one bambara groundnut landrace the N-100 was used while during the 2004/05 season, data were obtained from one soil type the sandy clay loam.
+ Means of each yield component are compared horizontally between the two soil types or the two bambara groundnut landraces.
Means compared between two soil types or two bambara groundnut landraces followed by the same letter do not differ significantly ($P=0.05$) (DMRT)
++ Interaction between soil type and landrace on pod number per plant was significant at $P<0.05$. Also within sandy loam soil, MA-15A had significantly more pod number/plant than N-100. Means of 2003/04 and 2005/06 seasons are obtained from the combined analyses of variance

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