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Variability and Genetic Correlations for Yield and Yield Characters in some Bambara Groundnut (*Vigna subterranea*) Cultivars

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ABSTRACT

Twelve cultivars of bambara groundnut [*Vigna subterranea* (L.) Verdc.] were sown for evaluation of variability and genetic correlation among agronomic characters and seed yield in 2004 and 2005 in a randomized complete block design with three replications. Combined analysis of variance revealed highly significant effects ($p<0.05$) for genotypes (G), year (Y) and (G x Y) interaction for most characters evaluated. Estimates of genotypic and phenotypic coefficient of variation as well as broad sense heritability (H_B) were also high for characters in 2004 relative 2005. Seed length, pod length and width recorded 100% broad sense heritability estimates and high genetic advance. This indicates that these characters are under additive genetic control and selection for genetic improvement will be worthwhile and may rapidly contribute to seed yield. Significant ($P<0.05$) and positive genotypic correlation coefficients was recorded in the association between seed yield, pod yield/plant and seed yield/plant. This provides that pod yield/plant and seed yield/plant could respond to selection in bambara groundnut.

Key Words: Variability; Genetic correlations; Heritability; Genetic advance; Seed yield; Bambara groundnut cultivar

INTRODUCTION

Bambara groundnut (*Vigna subterranea* (L.) Verdc) belongs to the Fabaceae, subfamily Papilionoideae (Aremu *et al*, 2006; PROTA, 2006). It is the third most important grain legume after groundnut (*Arachis hypogea* L.) and cowpea [*Vigna unguiculata* (L). Walp] in Sub-Sahara Africa (Rachie & Silvestre, 1977). The annual world production is 330,000 tons, 45-50% of which are produced in West Africa (Nigeria, Niger, Burkina Faso, Chad, Cote d'Ivoire, Ghana & Mali) (PROTA, 2006). Bambara groundnut is cultivated primarily for its subterranean pods (Linnemann & Azam-Ali, 1993); rich in protein which helps to alleviate nutritional disorders in human and livestock (Massawe *et al*., 2002). Immature seeds of bambara groundnuts are often boiled with salt and eaten as a snack; vegetable milk and fermented products such as (*Parkia biglobosa* Jacq.) can be made from the seeds. Bambara groundnut fixes atmospheric nitrogen through symbiosis with *Rhizobium* bacteria and therefore beneficial in crop rotations and intercropping (Mukumbira, 1985; Karikari *et al*., 1999). Constraints in production of bambara groundnut in Nigeria includes poor quality seeds, low germination and poor nodulation, instability in fodder and seed yield among others.

In a study of twenty seven genotypes of bambara groundnut under optimum agronomic conditions, correlation analysis indicated that the number of stem per plant and weight of hundred seeds were positively correlated with grain yield and these characters could be of importance during selection for yield (Karikari, 1972). In another study using germplasm collection of bambara groundnut. Goli *et al*. (1997) reported that number of leaves and pods per plant, shell thickness and weight of hundred seeds correlated positively with grain yield.

Genetic studies in bambara groundnut is limited in Sub-Sahara Africa, this trend is associated with little preference for this crop among researchers in Sub-Sahara Africa, often termed 'Orphan crop'. Little attempts have been made to improve this crop through conventional breeding and selection, because it is an important staple crop. Therefore, adequate knowledge of association that exists between yield and yield related characters is essential for the identification of selection procedure, which is important for seed yield (Ouedraogo *et al*., 2008). Most cultivated varieties in sub Sahara Africa are largely products of introduction and selection, hybridization in this crop is limited. In genetic studies, characters with high genotypic coefficient of variation indicate the potential for an effective selection.

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Yield has been identified as a complex character that is associated with some yield contributing characters and is polygenic (Kadams & Sajo, 1998). Genetic variability in a base population plays an important role in any crop breeding programme. The extent of diversity in the population determines the magnitude of selection. Characters that influence yield are quantitatively inherited and are influenced by the interaction with the environment. It becomes imperative to compute variability present in the population and partition them into genotypic, phenotypic and environmental ones. Therefore, the aim was to validate the magnitude of variability within the agronomic characters and to understand selection parameters for seed yield in this environment.

MATERIALS AND METHODS

Twelve cultivars of bambara groundnut used in this study (Namely, BG7001BS, BG7006BS, BG7007BS, BG7009BS, BG70012BS, BG7002AS, BG7003AS, BG7004AS, BG7005AS, BG7008AS, BG70010AS & BG70011AS) were sown at the teaching and research farm, Adamawa State University, Nigeria (10^o3^1N & 13^o7^1E), in July 2004 and 2005 cropping seasons. Field experiment was laid out in a randomized complete block design with three replications, each plot was 10 m^2 and a total experimental area was 595 m^2. The physico-chemical characteristics of the experimental soil showed that it was slightly acidic. The organic carbon (0.65%) and available N (0.40%) including the available P (0.43%) values were low. The particle size analysis showed that the soil type of the experimental area was sandy-loam with a high proportion of sand (56.6%) and silt (40.5%) and less clay (3.0%). The soil had a high water holding capacity with a maximum of 39.7% (Table I). The average meteorological data on rainfall and temperature for the two years of trial were 43.18 mm and 32.63^{o}C and 38.36 mm and 32.48^{o}C for 2004 and 2005 cropping seasons, respectively.

The experimental site was ploughed and harrowed, two seeds of each cultivar were sown at 50 cm between plants, a total of 64 plants were established per plot. Weeding was done manually using hand hoe at 4 and 8 weeks after sowing. Fertilizer application of 60 kg super phosphate per hectare was applied shortly after planting as recommended by Hepper (1970), Benlate (Benomyl) was sprayed at the rate of 30 g/20 L of water, at 5th and 6th weeks after sowing. Data was collected on all the plants within the two middle rows. Measured characters were plant emergence and emergence percentage at 2 weeks after sowing (%); Plant height at 8 weeks after sowing was measured on, then randomly ten plants were selected within the two middle rows. Prior to harvest, the number of plants was estimated; The number of pods per plant was the mean number of pods of ten randomly selected plants and pod yield per plant was taken as the mean number of harvested pods of ten randomly selected plants after drying. Seed yield per plant was estimated as the average weight (g) of seeds of the 10 randomly selected plants on each plot after winnowing. Weight of 100 seeds was estimated from the bulk of seeds harvested per plot (Karikari *et al.*, 1996).

$$\text{Shelling percentage was computed} = \frac{\text{Weight of dry seeds (g)}}{\text{Weight of dry pods (g)}} \times 100$$

Pod width and length were measured using Vernier calipers from ten randomly selected pods per plot. In the same vein both length and width of seeds were determined and also the seed yield was determined on per plot basis and converted to seed yield per hectare. The mean for each trait over three replication and two years was computed for each accession and submitted for statistic using PROC MEANS using PROC GLM procedure of SAS (2004). Genotypic and Phenotypic correlation coefficients were computed as explained by SAS (1998). Broad sense heritability was computed as specified in the method of Singh and Chaudhary (1985) and Moll *et al.* (1960) as:

$$H_B = \frac{\partial_g^2}{\partial_p^2}$$

Where H_B = broad sense heritability, ∂_g^2 = Genotypic variance and ∂_p^2 = Phenotypic variance.

RESULTS AND DISCUSSION

Mean seed yield among the cultivars ranged between 1632.8 and 2820.2 kgha^{-1} (Table II), which provided basis for selection among the cultivars. The combined analysis of variance (Table III) for seed yield and other agronomic characters showed significant genotype effects for agronomic characters. Thus indicating that bambara cultivars were highly variable in performance for agronomic characters. The presence of variability in crop is important for genetic studies and consequently improvement and selection. Significant year (Y) effects ($P<0.05$) indicated the presence of variability in the environmental variables (Temperature, rainfall, humidity, sunshine) for both years of evaluation (data not shown). It was noted that unpredictable changes in weather have been described as essential in crop

Table I: The Physico-Chemical Characteristics of the Soil from the Experimental Site in 2004

Chemical Analysis	
pH in water	6.80
Organic carbon (%)	0.65
Carbon to nitrogen ratio (C:N ratio)	1.40
Available nitrogen (%)	0.40
Available phosphorus (ppm)	0.43
Available calcium (me/100g)	4.20
Available sodium (me/100g)	0.35
Available potassium (me/100g)	0.49
Particle Size Analysis	
Clay (%)	3.0
Sand (%)	56.5
Silt (%)	40.5
Soil texture	Sand-loam
Maximum water holding capacity (%)	39.7

Source: Department of Crop Science, Adamawa State University, Mubi-Nigeria

Table II: Investigated agronomic traits in Bambara groundnut cultivars

Cultivars	GC2wk	GP2wk	Ht8wk (cm)	SC	PN/plt	PYplt (g)	SY/plt (g)	100wt (g)	SP (%)	PW (cm)	PL (cm)	SW (cm)	SL (cm)	SY/ha (t)
BG7001BS	37.50d	58.60d	15.15abcd	33.67d	51.00cd	56.02cd	38.68c	84.85cd	71.58a	1.43cd	1.98d	1.03e	1.26cd	1.63f
BG7002AS	53.50ab	83.58a	14.42bcd	52.50abc	57.35bc	87.05a	53.02a	90.85c	64.03d	1.64a	2.09c	1.09c	1.26cd	2.82a
BG7003AS	47.00bc	71.15bc	15.52abc	46.17c	64.72a	58.23cd	38.70c	68.77f	71.32a	1.13g	1.53h	1.04de	1.23de	2.09bcdef
BG7004AS	36.00d	56.28d	13.73de	34.00d	34.03e	60.63c	36.98c	137.82a	67.62bc	1.65a	2.31a	1.26a	1.52a	1.66f
BG7005AS	56.17a	87.75a	15.15abcd	54.50ab	48.55d	43.73e	26.65d	55.02g	66.28cd	1.44cd	1.80e	0.99f	1.17e	2.15bcde
BG7006BS	37.50d	83.60a	14.97abcd	52.50abc	45.98d	56.65cd	35.92c	81.28d	64.66cd	1.40d	1.78e	1.08cd	1.31c	1.69ef
BG7007BS	53.17ab	83.07ab	16.17a	52.17abc	62.27ab	58.07cd	38.75c	71.90f	70.83a	1.11g	1.64g	0.97f	1.23de	1.92cdef
BG7008AS	52.83ab	82.58ab	14.08cde	51.83abc	46.67d	54.05cd	38.22c	80.90de	63.50d	1.32e	1.70fg	1.06cde	1.19de	1.77ef
BG7009BS	50.00abc	78.13abc	15.68abc	48.33abc	34.27e	53.27cd	38.32c	117.17b	70.15ab	1.46c	2.26a	1.19b	1.47ab	2.53ab
BG70010AS	48.67abc	76.03abc	15.02abcd	54.83a	49.32d	68.48b	41.65bc	85.68cd	63.42d	1.54b	2.18b	1.06cde	1.45b	2.25bcd
BG70011AS	53.83ab	84.12a	16.12ab	52.83abc	66.30a	70.17b	45.67b	69.37f	71.02a	1.31e	1.71f	0.98f	1.18e	2.31bc
BG70012BS	44.50c	69.53c	12.75e	47.17bc	47.87d	51.60d	35.40c	74.32ef	70.55ab	1.24f	1.54h	1.06cde	1.22de	1.84def
Grand Mean	47.56	76.20	14.90	48.38	50.69	59.83	39.00	84.83	67.91	1.39	1.88	1.07	1.29	2.06

PE2WK = Plant emergence at 2WAS, EP2WK = Emergence Percentage at 2WAS, Ht8WK = Height at 8WAS, SC = Stand Count Prior to harvest, PN/plant = Pod number per plant, PY/plant = Pod yield per plant, SY/plant = Seed yield per plant, 100wt = 100 seeds weight, SP= Shelling Percentage, PW = Pod width, PL = Pod length, SW = Seed width, SL = Seed Length, SY/ha = Seed yield/ha

Means in a column followed by the same letters do not differ significantly from each other at P = 0.05

Table III: Combined analysis of variance for fourteen agronomic characters in Bambara groundnut (*Vigna subterranea*) for 2004 and 2005 cropping season

Source of Variation	df	PE2wk	EP2wk	Ht8wk	SC	PN/plant	PY/plant	SY/plant	100wt	SP	PW	PL	SW	SL	SY/ha
Year	1	824.90**	1994.54**	3.30^{NS}	768.99**	1602.73**	289.46*	8.83^{NS}	148.81*	240.06**	0.002^{NS}	0.006^{NS}	0.001^{NS}	0.002^{NS}	0.005^{NS}
Replication	4	114.14	311.12	1.63	66.05	19.02	64.23	44.10	102.85	2.61	0.001	0.003	0.001	0.001	0.036
Genotype	11	249.70**	617.90**	6.02**	310.70**	664.78**	740.76**	233.60**	3044.69**	67.24**	0.184.**	0.458**	0.043**	0.087**	0.819**
Genotype x Year	11	32.72^{NS}	80.64^{NS}	4.60**	47.47^{NS}	143.40**	100.70*	23.06^{NS}	91.23**	20.45**	0.0001^{NS}	0.0021^{NS}	0.0040**	0.0061*	0.0725^{NS}
Error	44	35.81	87.26	1.61	30.69	32.13	42.00	27.01	32.07	6.20	0.0010	0.0030	0.0012	0.0029	0.1208

NS = Not significant, * = Significant at (P = 0.05), ** = Significant at (P = 0.01), df = degree of freedom, PE2WK = Plant emergence at 2WAS, EP2WK = Emergence Percentage at 2WAS, Ht8WK = Height at 8WAS, SC = Stand Count Prior to harvest, PN/plant = Pod number per plant, PY/plant = Pod yield per plant, SY/plant = Seed yield per plant, 100wt = 100 seeds weight, SP= Shelling Percentage, PW = Pod width, PL = Pod length, SW = Seed width, SL = Seed Length, SY/ha = Seed yield/ha

improvement programs (Falconer, 1989). Significant Genotype by Year interaction (P<0.05) was observed for all characters evaluated. Thus confirming inconsistencies in the performance the bambara groundnut cultivars over the years of evaluation. Several studies have highlighted the presence of genotype by environment interaction in crops; in okra (Ariyo, 1987), cassava (Otoo *et al.,* 1994) and maize (Kang & Gorman, 1989). This necessitates the selection of crops for specific environment, wherein stability over environments is poor. Therefore inconsistencies in seed yield and agronomic characters over years implied that farmers must have been discouraged by this phenomenon, which might have accounted for yield losses.

Table IV presents the mean, range, genotypic and phenotypic coefficient of variation, estimates of broad sense heritability (H_B) and genetic advance of seed yield and related characters on yearly basis. The mean performance for most characters was higher in magnitude in 2005 evaluation when compared with 2004 evaluation. The number of pods per plant, weight of 100 seeds and seed yield ha^{-1} were higher in magnitude as compared with 2005 evaluation. The relative amount of variability in a population is best expressed in term of genotypic coefficient of variation, since this variable takes into account the mean values as well as the units of measurement. The analysis of variation returned high estimates of genotypic and phenotypic coefficient for weight of hundred seed in 2004 than 2005 evaluation. The lowest genotypic coefficient of variation was recorded for seed width in both years of evaluation. A high variability observed in this study can be exploited by selection (Burton & De Vane, 1953). The relatively small difference observed between the PCV and GCV may be associated with genetic difference for these characters. Similar results have been reported for the *Abelmoschus esculentus* (Ariyo *et al.,* 1987).

Broad sense heritability (H_B) was happened high for the most characters in year 2005 relative to 2004. Pod width and length and seed width recorded 100% H_B in each year of evaluation. Allard (1960) reported that 100% heritability implies that the phenotype could provides a perfect measure of the genotype value and therefore such characters will respond to selection. Broad sense heritability estimates and genetic advance were high for most characters, exception was recorded in plant height at eight weeks after seeding and seed yield ha^{-1}, which recorded moderate heritability estimates. This implied the presence of positive gene effects, which are additive in nature and governed by few major genes. If under polygenic action, they will respond positively to selection pressure. Correlations among characters have been of great significance (Table V) in determination of the most effective procedures for selection of superior genotype in a population.

In this study, we found that estimates of genotypic correlation coefficients were higher in magnitude than their corresponding phenotypic correlation coefficients. This may be ascribed to the masking of the environment influence in

Table IV: Investigated parameters in first year (Y_1) and second year (Y_2)

Characters		Mean	Range	Genotypic Coefficient Variation	Phenotypic Coefficient Variation	Heritability (%)	GA (%)
Plant Emergence	Y_1	45.36	30.0-52.7	13.74	21.99	59.2	13.8
	Y_2	52.42	41.3-59.7	12.54	14.35	74.5	26.4
Emergence %	Y_1	70.71	46.9-82.3	13.86	21.85	40.8	13.9
	Y_2	81.69	72.4-88.6	12.54	14.87	71.2	24.4
Height at 8WAS	Y_1	14.69	12.3-16.8	8.90	11.89	34.9	6.8
	Y_2	15.10	12.3-16.9	8.14	10.04	54.2	10.1
Stand count	Y_1	45.00	22.7-53.7	18.69	24.54	58.6	19.0
	Y_2	51.75	41.3-58.7	11.80	13.72	74.3	24.3
Pods/plant	Y_1	45.99	40.0-64.8	20.43	24.72	78.8	19.1
	Y_2	55.39	36.0-78.4	21.53	24.81	75.1	16.4
Pod yield/plant	Y_1	61.84	41.3-88.5	27.05	20.58	69.8	16.2
	Y_2	51.82	45.5-85.6	20.85	17.52	69.1	16.3
Seed yield/plant	Y_1	38.65	22.9-53.1	16.47	19.36	72.8	15.1
	Y_2	39.34	30.4-52.9	19.42	29.38	70.1	22.5
100 seed wt	Y_1	83.46	55.6-107	24.91	35.57	92.1	12.4
	Y_2	86.19	54.5-139.5	24.01	25.73	94.8	13.4
Shelling %	Y_1	66.10	59.9-70.6	4.98	6.38	61.2	5.0
	Y_2	69.72	63.3-74.6	5.88	6.38	69.8	4.2
Pod width	Y_1	1.38	1.11-1.64	12.55	42.55	100	18.5
	Y_2	1.39	1.11-1.66	10.53	12.58	100	14.9
Pod length	Y_1	1.87	1.52-2.30	15.12	15.21	100	19.5
	Y_2	1.88	1.54-2.31	25.56	25.59	100	16.2
Seed width	Y_1	1.06	0.93-1.26	2.68	2.85	85.2	6.6
	Y_2	1.08	0.98-1.26	2.61	2.82	87.9	5.9
Seed length	Y_1	1.29	1.13-1.58	10.96	10.97	100	14.8
	Y_2	1.32	1.17-1.50	10.96	10.96	96	17.8
Seed yield/ha	Y_1	2040.6	1.40-2.96	19.60	38.75	54.8	19.7
	Y_2	2165.8	1.75-2.45	19.72	27.87	52.4	19.9

GA=Genetic advance, Y_1= Year one, Y_2= Year two, C.V. = Coefficient of variation

Table V: Calculated Correlations Coefficients

	PE2wk	EP2wk	Ht8wk	SC	PN/plt	PY/plt	SY/plt	100wt	SP	PW	PL	SW	SL	SY/ha
PE2wk		1.00**	0.45	0.94**	0.38	0.10	0.07	-0.58*	-0.35	-0.23	-0.34	-0.52	-0.49	0.49
EP2wk	1.00**		0.43	0.93**	0.35	0.10	0.07	-0.56*	-0.37	-0.20	-0.31	-0.52	-0.48	0.48
Ht8wk	0.53*	0.51		0.32	0.47	0.08	0.12	-0.27	0.28	-0.30	-0.05	-0.41	-0.11	0.33
SC	0.96**	0.96**	0.37		0.36	0.15	0.10	-0.57*	-0.44	-0.20	-0.31	-0.49	-0.37	0.49
PN/plt	0.40	0.37	0.57*	0.39		0.37	0.40	-0.72**	0.28	-0.57*	-0.63**	-0.80**	-0.69**	0.23
PY/plt	0.10	0.10	0.06	0.17	0.38		0.95**	0.18	-0.27	0.40	0.32	0.07	0.13	0.59*
SY/plt	0.08	0.08	0.16	0.12	0.40	0.95**		0.18	-0.11	0.24	0.23	0.05	0.07	0.57*
100wt	-0.59**	-0.57*	-0.34	-0.59**	-0.73**	0.18	0.19		-0.07	0.62**	0.80**	0.94**	0.87**	0.09
SP	-0.41	-0.43	0.27	0.50	0.24	-0.32	-0.13	0.07		-0.56	-0.31	-0.17	0.15	-0.13
PW	-0.24	-0.21	-0.36	-0.21	-0.59**	0.41	0.25	0.62**	-0.59**		0.87**	0.62**	0.60**	0.27
PL	-.035	-0.32	-0.05	-0.32	-0.65**	0.38	0.24	0.80**	-0.32	0.87**		0.72**	0.84**	0.29
SW	-0.59*	-0.52	-0.46	-0.51	-0.86**	0.07	0.04	0.96**	-0.17	0.63*	0.74**		0.84**	0.20
SL	0.49	-0.048	-0.13	-0.37	-0.74**	0.13	0.06	0.89**	-0.15	0.61**	0.85**	0.86**		0.04
SY/ha	0.49	0.48	0.37	0.49	0.24	0.65**	0.61**	0.09	0.16	0.28	0.29	0.20	0.06	

PE2WK = Plant Emergence at 2 weeks after seeding, EP2WK = Emergence Percentage at 2weeks after seeding, Ht8WK = Height at 8weeks after seeding, SC = Stand Count Prior to harvest, PN/plt = Pod number per plant, PY/plt = Pod yield per plant, SY/plt = Seed yield per plant, 100wt = 100 seeds weight, SP = Shelling Percentage, PW = Pod width, PL= Pod length, SW= Seed width, SL = Seed Length, SY/ha = Seed yield/ha

the expression of characters evaluated, thereby reducing the phenotypic expression (Paroda & Joshi, 1970). Seed yield ha^{-1} recorded positive genotypic and phenotypic correlation coefficients with pod and seed yield on individual plant basis. But the weight of hundred seeds recorded a significant negative genotypic correlation coefficient with stand count at harvest, height at 8 weeks and pod number/plant.

CONCLUSION

Considerable amount of variation exists among bambara groundnut cultivars for yield and yield components. High heritability and genetic advance recorded for length and width of pods, seed length and width clearly indicates that genetic improvement and selection procedure will be worthwhile. However moderate heritability for seed yield/ha suggests that considerable limitations for improvement in yield will be encountered.

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REFERENCES

Allard, R.W., 1960. *Principle of Plant Breeding*, pp: 93–96. John Wiley and sons, Inc., New York Chichester Brisbane Toronto Singapore

Aremu, M.O., O. Olaofe and E.T. Akintayo, 2006. Chemical composition and physiochemical characteristics of two varieties of bambara groundnut (*Vigna subterranea*) flours. *J. Appl. Sci.,* 6: 1900–1903

Ariyo, O.J. M.E. Aken'ova and G.A. Fatokun, 1987. Plant character correlations and path analysis of pod yield in Okra (*Abelmoschus esculentus). Euphytica*, 36: 677–686

Falconer, D.S., 1989. *Introduction to Quantitative Genetics*, 3rd edition. London Scientific and Technical Essex, England

Burton, G.W. and E.H. De Vane, 1953. Estimating heritability in tall fescus from replicated clonal material. *Agric. J.,* 45: 478–481

Goli, A.E., F. Begemann and N.Q. Ng, 1997. Characterisation and evaluation of IITA'S Bambara groundnut (*Vigna subterranean* (L.) Verdc). *In*: Heller, J., F. Begemann and J. Mushonga (eds.), *Promoting the Conservation and Use of Underutilized and Neglected Crops*, Vol. 9, pp: 101–118. International plant genetic resources Institute Rome, Italy

Hepper, F.N., 1970. Bambara groundnut (*Vigna subterrenea*)*. Field Crop Abst.,* 23: 1–6

Kadams, A.M. and A.A. Sajo, 1998. Variability and correlation studies in yield and yield components in bambara groundnut (*Vigna subterrenea* L. Verdc). *J. Appl. Sci. Manag.*, 2: 66–70

Kang, M.S. and D.P. Gorman, 1989. Genotype x Environment interaction in maize. *Agron. J.,* 81: 662–664

Karikari, S.K., B. Sebolai and D.C. Munthali, 1996. Field studies of Bambara groundnut in Botswana. *In*: Azam-Ali, S.N., A. Sesay and S.T. Collinson, (eds.), *Proc. International Bambara Groundnut Symposium*, pp: 72–84. Held at the University of Nottingham, UK, 23-25 July, 1998

Karikari, S.K., O. Chaba and B. Molosiwa, 1999. Effects of intercropping bambara groundnut on Pearl millet, Sorghum and Maize in Botswana. *African Crop Sci. J*., 7: 143–152

Karikari, S.K., 1972. Correlation studies between yields and some agronomic characters in bambara groundnuts (*Vigna subterrenea* (L.) Verdc.). *Ghana J. Agric. Sci.,* 5: 79–83

Linnemann, A.R. and S.A. Azam-Ali, 1993. Underutilized Crops, Pulses and Vegetables. *In*: Williams, J.T. (ed.), *Bambara Groundnut (Vigna subterranea)*, pp: 13–57. Chapman and Hall, London

Massawe, F.J., M. Dickinson, J.A. Roberts and S.N. Azam-Ali, 2002. *Genetic Diversity in Bambara Groundnut (Vigna Subterranea (L.) Verdc) Land Races Revealed by AFLP Markers.* Published on NRC Research press website at htpp:/genome.nrc.ca, Canada, Last access 14th July, 2004

Moll, R.H., F.H. Robinson and C.C. Cockerham, 1960. Genetic variability in advanced generation of a cross of two open pollinated variety of corn. *Agron. J.,* 52: 171–173

Mukumbira, L.M., 1985. Effects of rate nitrogen fertilizer and previous grain legume crop on maize yields. *Zimbabwe Agric. J.,* 82: 177–179

Otoo, J.A., A.G.O. Dixon, R. Asiedu, J.E. Okeke, G.N. Maroye, K Tougnon, O.O. Okoli, J.P. Tetteh and S.K. Hahn, 1994. Genotype x Environment interaction studies with Cassava. Symposium in tropical root crop in a Developing Economy. *ISHS Acta Hort.,* 380

Ouedraogo, M., J.T. Ouedraogo, J.B. Tignere, D. Balma, C.B. Dabire and G. Konate, 2008. Characterization and evaluation of accessions of Bambara groundnut (*Vigna subterranea* (L.) Verdcourt) from Burkina Faso. *Sci. Nat.*, 5: 191–197

Paroda, R.S. and A.B. Joshi, 1970. Correlation, path coefficient and implication of discriminate function for selection in wheat (*Triticum aestivum). Heredity*, 25: 383–392

PROTA (Plant Resources of Tropical Africa), 2006. *In*: Brink, M. and G. Belay (eds.), *Cereals and Pulses*, pp: 213–217. PROTA Foundation, The Netherlands

Rachie, K.O. and P. Silvestre, 1977. *In*: Leakey, C.L.A. and J.B. Wills (eds.), *Food Crop of Low Land Tropics*, pp: 41–44. Oxford University Press, Oxford

SAS, 1998. *Statistical Analysis System, User's Guide.* 1998 edition, SAS Institute, Inc Cary, North Carolina

SAS Institute, 2004. *SAS Users Guide: Statistics*, Version 5 edition. SAS Inst. Gary, North Carolina

Singh, R.K. and B.D. Chaudhary, 1985. *Biometrical Methods in Quantitative Genetic Analysis*, pp: 253–260. Kalyani Publishers New Delhi, India

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