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Genetic Correlations and Path Analysis in Bambara Groundnut (*Vigna subterranea*)

P.M. JONAH[1], O.T. ADENIJI AND D.T. WAMMANDA†
Department of Crop Science, Adamawa State University, P.M.B 25 Mubi, Nigeria
†*Department of Agricultural Production Technology, College of Agriculture, Ganye, Adamawa State, Nigeria*
[1]Corresponding author's e-mail: peterjonah2005@yahoo.com

ABSTRACT

Twelve cultivars of bambara groundnut were sown for genetic correlation studies among agronomic characters and seed yield. The associations between seed yield and other quantitative characters showed positive correlation between seed yield per hectare, pod yield per plant and seed yield per plant. There was a significant genotypic and phenotypic correlation coefficient in the association between pod length and pod width, seed length and seed width during the trial, which could be a good index for selecting high yielding cultivars, as plump pods appeared to compensate for an increase in the total yield through a relatively greater weight of seeds. The path coefficient analysis of characters showed that the seed yield per hectare indicated positive direct contribution with pod length, plant emergence at 2 WAS and stands count prior to harvest. Although these characters recorded a positive but a non-significant genotypic correlation coefficient of seed yield per hectare with other characters indicated the inefficiency of selection based on correlations alone.

Key Words: Genetic correlation; Seed yield; Path analysis; Bambara groundnut

INTRODUCTION

Bambara groundnut (*Vigna subterranea* (L.) Verdc) belongs to the family Fabaceae, and 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). Bambara groundnut with diploid chromosome (2n=22) was initially called *Glycine subterranea* (Linneaus, 1963), but was later renamed as *Voandzeia subterranea* (Du Petit-Thouars, 1806) and recently renamed *Vigna subterranea* (Verdcourt, 1981). The annual world production of Bambara groundnut is 330,000 tones; of which 45-50% is produced in West Africa, where Nigeria is the world leading producer with about 33,000-49,000 tonnes annually (PROTA 2006). Bambara groundnut is cultivated primarily for its subterranean pods (Linnemann & Azam-Ali, 1993); rich in protein, which helps to alleviate nutritional problems in human and livestock (Massawe *et al*., 2002). Immature seeds of Bambara groundnuts can be floured and use in making different kinds of food such as Kosai and Moimoi (Kadams & Sajo, 1998), whereas the haulms are used as livestock feeds. 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 on twenty seven genotypes of Bambara groundnut under optimum agronomic conditions, correlation analysis indicated that the number of stem/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'. Few attempts have been made to improve this crop through conventional breeding and selection. 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. Most cultivated varieties in sub-Sahara Africa are largely products of introduction and selection, while hybridization in this crop is limited. This study was, therefore, undertaken to evaluate the phenotypic and genotypic correlation among characters of Bambara groundnut and their direct and indirect effects on yield.

MATERIALS AND METHODS

Twelve cultivars of bambara groundnut used in this evaluation were sourced from farmers collection in the north eastern Nigeria, which were maintained in the Department

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of Crop Science as true-to-type. Five cultivars namely BG7001BS, BG7006BS, BG7007BS, BG7009BS and BG70012BS were source from farmer's collection in Gwoza, Borno State, Nigeria, while BG7002AS, BG7003AS, BG7004AS, BG7005AS, BG7008AS, BG70010AS and BG70011AS were sourced from farmer's in Mubi/Hong, Adamawa State.

Field evaluation was carried out at the teaching and research farm, Adamawa State University, Nigeria (10^{o}31N & 13^{o}71E), in July 2004 and 2005 cropping season. This period coincide with the planting season for Bambara groundnut in this location. 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 experimental site was ploughed and harrowed, two seeds of each cultivar were sown at 50 cm between plants and 64 plants were established per plot.

Weeding was done manually using 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 5^{th} and 6^{th} weeks after sowing. Data was recorded from within the two middle rows. Characters measured included: plant emergence and emergence percentage at 2 weeks after sowing. Plant height (cm) at 8 weeks after sowing was measured on ten randomly selected plants 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 ten randomly selected plants on each plot after winnowing. Weight of hundred seeds was estimated by weighing 100 clean and uniform seeds picked randomly from the bulk of seeds harvested per plot.

$$Shelling percentage = \frac{Weight of dry seed(g)}{Weight of dry pods(g)} \times 100$$

Pod width and length (cm) were measured using Venier calipers from ten randomly selected pods per plot. In the same vein both length and width of seeds were determined. The seed yield (kg/ha) was determined on plot basis and this was computed for seed yield per hectare. The mean for each trait over three replication and two years was computed for each cultivars and analyzed statistically using PROC MEANS using PROC GLM procedure of SAS (1999). Genotypic and Phenotypic correlation coefficients were computed using SAS (1998). Path coefficient analysis was calculated using the methods of Singh and Chaudhary (1985).

RESULTS AND DISCUSSION

Correlation studies between characters have been of great value in determination of the most effective procedures for selection of superior genotypes (Adebisi *et al.*, 2004). The results indicates clearly the different patterns of association between the characters measured in the two cropping season (Tables I, II & III). In general, it was observed that estimates of genotypic correlations were in most cases higher than their corresponding phenotypic correlations. This agrees with the findings of Johnson *et al.* (1955), Paroda and Joshi (1970), Kamboj and Mani (1983). More significant genotypic association between the different pairs of character than the phenotypic correlation indicated that the characters are more related genotypically than phenotypically. Seed yield per hectare recorded positive genotypic correlation with plant emergence at 2 WAS, emergence percentage at 2 WAS, height at 8 WAS, stand count, pod yield per plant, seed yield per plant, pod width, pod length, seed width and seed length during 2004, 2005 and pooled effect across years; indicating that pod yield may be improved through the selection of any of these characters. Yield related parameters that recorded very high positive and significant genotypic correlation with seed yield per hectare (Table II & III) are pod yield per plant (r=0.87** & 0.65**); seed yield per plant (r=0.91** & 0.61**). This agrees with the findings of Kadams and Sajo (1998) in bambara groundnut and Ariyo *et al.* (1987) in okra (*Abelmoschus esculentus*).

On the other hand pod number per plant was negative and significantly correlated with 100 seed weight during the two cropping seasons. Also 100 seed weight recorded a significant positive genotypic correlation coefficient with pod width, pod length, seed length and width. Similarly, seed width and seed length recorded positive genotypic correlation coefficient with weight of 100 seeds, pod width and pod length in 2004, 2005 and the pooled effects. Pod yield per plant indicated a significant phenotypic correlation coefficient with seed yield per plant for 2004 and 2005 evaluation and the pooled effects, indicating that seed yield per plant is a strong contributor to pod yield per plant (Kadams & Sajo, 1998).

The study indicated that most characters with phenotypic correlation also had genotypic correlation in the individual years and for the pooled years. Hence they will produce repeated estimates of inter-association. Therefore any selection for genetic improvement for seed yield based on this relationship will produce reliable and enduring effects in bambara groundnut. A significant genotypic correlation coefficient between seed yield per hectare and height at 8 WAS in 2005 may be ascribed to a greater photosynthetic capacity of the plant to develop a considerable height, which will carry more leaves and flowers for greater pod yield in bambara groundnut. This observation is in confirmation with the findings of Ishaq *et al.* (2000) in sugar cane and Murtadha *et al.* (2004) in okra.

The study revealed that a significant genotypic and phenotypic correlation coefficient recorded in the association between pod length and pod width, seed length

Table I: Phenotypic (upper) and genotypic (lower) correlation coefficients for fourteen characters of Bambara groundnut evaluated in 2004

	PEwk	EP2wk	Ht8wk	SC	PN/plt	PYplt	SY/plt	100 seed	SP	PW	PL	SW	SL	SY/ha
PE2WK		0.999**	0.66**	0.82**	0.40	0.02	-0.06	-0.54	0.05	-0.29	-0.37	-0.54	-0.55	-0.59**
EP2WK	1.00**		0.66**	0.82**	0.39	0.03	-0.06	-0.54	0.04	-0.27	-0.35	-0.54	-0.53	0.59**
Ht8WK	0.91**	0.90**		0.43	0.42	-0.22	-0.30	-0.76**	0.29	-0.51	-0.47	-0.84**	-0.58**	0.08
SC	0.86**	0.86**	0.60**		0.27	0.01	-0.07	-0.52	-0.20	-0.26	-0.31	-0.48	-0.36	-0.57*
PN/Plt	0.50	0.49	0.49	0.34		0.48	0.47	-0.64**	0.36	-0.32	-0.50	-0.57*	-0.67**	0.30
PY/plt	0.07	0.08	-0.22	0.04	0.49		0.95**	0.26	-0.24	-0.41	0.31	0.31	0.18	0.31
SY/plt	0.01	-0.01	-0.41	-0.03	0.45	0.98**		0.29	-0.04	0.31	0.29	0.38	0.21	0.29
100 seed	0.62**	-0.61**	-0.81**	-0.58*	-0.65**	0.28	0.32		-0.32	0.60**	0.76**	0.96**	0.89**	0.17
SP	0.11	0.09	0.33	-0.20	0.35	-0.23	-0.07	-0.34		-0.54	-0.40	-0.30	-0.36	-0.04
PW	-0.32	-0.30	-0.61**	-0.27	0.34	0.42	0.32	0.60**	-0.57**		0.89**	0.57*	0.56*	0.30
PL	-0.42	-0.40	-0.55*	-0.34	-0.52	0.32	0.31	0.77**	-0.43	0.85**		0.68**	0.79**	0.36
SW	-0.62**	-0.60**	-0.04	0.49	-0.62**	0.30	0.37	0.98**	-0.33	-0.40	0.58*		0.82**	0.05
SL	-0.62**	-0.64**	-0.72**	-0.38	-0.70**	0.19	0.21	0.90**	-0.40	0.60**	0.85**	0.82**		-0.13
SY/ha	0.65**	0.64*	0.19	0.56*	0.38	0.38	0.36	0.17	-0.02	0.27	0.25	-0.11	-0.13	

PE2WK =Plant emergence at 2WAS, EP2WK = Emergence Percentage at 2WAS, Ht8WK = Height at 8WAS, 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

Table II: Phenotypic (upper) and genotypic (lower) correlation coefficient for fourteen characters of Bambara groundnut evaluated in 2005

	PE2wk	EP2wk	Ht8wk	SC	PN/plt	PY/plt	SY/plt	Seed 100	SP	PW	PL	SW	SL	SY/ha
PE2WK		0.999**	-0.07	0.99**	0.31	0.20	0.20	-0.60**	-0.58**	-0.13	-0.28	-0.48	-0.42	0.26
EP2WK	1.00**		-0.09	0.99**	0.26	0.19	0.19	-0.56*	-0.59**	-0.09	-0.25	-0.46	-0.41	0.25
Ht8WK	-0.04	-0.06		0.01	0.25	0.37	0.42	0.27	0.33	0.07	0.37	0.11	0.46	0.58**
SC	1.00**	1.00**	0.04		0.32	0.26	0.27	-0.58**	-0.55	-0.09	-0.24	-0.48	-0.40	0.35
PN/plt	0.36	0.31	0.25	0.38		0.27	0.33	-0.71**	0.35	-0.67**	-0.67**	-0.74**	0.51	0.13
PY/plt	0.20	0.19	0.40	0.28	0.26		0.92**	0.11	-0.14	0.36	0.27	-0.11	0.10	0.78**
SY/plt	0.22	0.21	0.53*	0.30	0.32	1.04**		0.06	-0.10	0.15	0.13	-0.23	-0.05	0.80**
100 Seed	-0.66**	-0.64**	0.31	-0.64**	-0.74**	0.10	0.03		0.10	0.62**	0.81**	0.85**	0.79**	0.16
SP	-0.68**	-0.71**	0.42	-0.65**	0.39	-0.17	-0.09	0.09		-0.43	-0.18	-0.03	0.04	-0.11
PW	-0.13	-0.08	0.07	0.09	-0.69**	0.38	0.20	0.64**	-0.45		0.89**	0.57*	0.56*	0.30
PL	-0.29	-0.25	0.41	-0.25	-0.70**	0.26	0.12	0.83**	-0.18	0.90**		0.68**	0.79**	0.36
SW	-0.51	-0.49	0.08	-0.50	-0.79**	-0.11	-0.29	0.88**	-0.04	0.58*	0.70**		0.82**	0.05
SL	-0.49	-0.49	0.57*	-0.48	-0.57*	0.12	-0.05	0.85**	-0.40	0.61**	0.85**	0.87**		0.22
SY/ha	0.32	0.30	0.77**	0.44	0.11	0.87**	0.91**	0.18	-0.13	0.38	0.41	0.07	0.32	

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

and seed width observed for 2004, 2005 and across years could be a good index for selecting high yielding cultivars as plump pods will compensate for increase in the total yield through a relatively greater weight of seeds.

Correlation study including path coefficient analysis is a powerful tool for finding out reliable traits associations for aiding and development of superior genotypes (Ado *et al.*, 1988). The path coefficient analysis of characters evaluated in this study (Table IV) showed that the seed/ha recorded a positive direct contribution of pod length, plant emergence at 2 WAS and stand count prior to harvest. Although these characters recorded a positive but not significant genotypic correlation coefficient with seed yield per ha, indicating the inefficiency of selection based on correlation alone. This agrees with the observation of Murtadha *et al.* (2004). Pod length had the largest direct effect on seed yield per ha. This was largely due to the high positive indirect contributions of all the other traits to seed yield per ha with exception of height at 8 WAS. This indicated that pod length is the most reliable component for selecting yielding bambara cultivars. Pod yield per plant and seed yield per plant had positive genotypic correlation with seed yield (Table III), but recorded low direct effects on seed yield per hectare. Apart from their low direct effects contributions, the effects of the traits were positive but very low values.

CONCLUSION

This study shows that the significant genotypic and phenotypic correlation in the association between pod length and pod width, seed length and seed width could serve as a good index for selection in bambara groundnut genotypes. Furthermore the Path coefficient analysis revealed that traits such as pod length, plant emergence and stand count prior to harvest indicated the largest positive direct contributions to seed yield. Although these characters recorded a non-significant correlation coefficient with seed yield, revealing the inefficiency of selection based on correlation alone.

Table III: Phenotypic (upper) and Genotypic (lower) correlation coefficient of yield, yield components and other agronomic characters of the twelve (12) Bambara groundnut (*Vigna subterranea*) cultivars evaluated in 2004 and 2005

	PE2wk	EP2wk	Ht8wk	SC	PN/plt	PY/plt	SY/plt	100 wt	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 2WAS, EP2WK = Emergence Percentage at 2WAS, Ht8WK = Height at 8WAS, 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

Table IV: Direct (diagonal) and indirect effects of characters on seed yield/ha in Bambara groundnut combined over two years (2004 & 2005)

Characters	PE2wks	EP2wks	Ht8wks	SC	PN/plt	PY/plt	SY/plt	100 wt	SP	PW	PL	SW	SL	Correlation of character with SY/ha
PE2wks	**0.80**	0.40	-0.02	0.45	-0.06	0.02	0.02	-0.87	-0.07	-0.51	0.37	0.09	-0.13	0.49
EP2wks	0.80	**0.40**	-0.02	0.68	-0.06	0.02	0.02	-0.53	-0.25	-0.48	0.51	-0.37	-0.32	0.48
Ht8wks	0.42	0.21	**-0.04**	0.25	-0.09	0.01	0.04	-0.10	0.05	-0.10	-0.04	0.06	-0.30	0.37
SC	0.51	0.38	-0.02	**0.71**	-0.06	0.10	0.03	-0.87	0.11	-0.48	0.26	-0.08	-0.10	0.49
PN/plt	0.32	0.13	-0.02	0.20	**-0.16**	0.08	0.09	-0.20	0.04	-0.16	0.30	0.13	-0.51	0.24
PY/plt	0.08	0.04	-0.02	0.38	-0.06	**0.24**	0.10	-0.05	-0.12	-0.19	0.28	0.01	-0.04	0.65**
SY/plt	0.06	0.03	-0.01	0.10	-0.06	0.11	**0.22**	-0.08	0.10	-0.09	0.24	0.01	-0.02	0.61**
100wt	-0.27	0.10	-0.28	0.42	-0.12	0.04	0.06	**-0.28**	0.01	-0.17	0.68	0.14	-0.24	0.09
SP	-0.33	-0.17	-0.01	0.43	-0.04	0.15	0.09	-0.02	**0.18**	-0.16	0.27	0.03	-0.42	-0.16
PW	-0.19	-0.08	-0.01	0.15	-0.09	0.17	0.08	-0.17	0.11	**-0.27**	0.65	0.09	-0.16	0.28
PL	0.31	0.13	-0.09	0.21	-0.81	0.12	0.05	-0.22	0.06	-0.23	**0.85**	0.14	-0.23	0.29
SW	0.27	-0.21	-0.02	0.36	-0.15	0.02	0.01	-0.27	0.03	-0.17	0.41	**0.15**	-0.23	0.20
SL	0.31	-0.02	-0.17	0.16	-0.40	0.03	0.01	-0.25	-0.03	-0.16	0.72	0.13	**-0.27**	0.06

PE2WK = Plant emergence at 2WAS, GP2WK = Emergence Percentage at 2WAS, Ht8WK = Height at 8WAS, SC = Stand Count Prior to harvest, PN/plt = Pod number per plant, PY/plt = Pod yield per plant, SY/plt = Seed yield per plant, 100 wt = 100 seeds weight, SP = Shelling Percentage, PW = Pod width, PL = Pod length, SW = Seed width, SL = Seed Length, SY/ha = Seed yield/ha

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