

Interrelationships among Pod and Seed Yield Traits in Bambara Groundnut (*Vigna subterranea* L. Verdc) in the Derived Savanna Agro-Ecology of South–Eastern Nigeria under Two Planting Dates

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ABSTRACT

Two field experiments were conducted in cropping seasons at the Department of Crop Science Research Farm, University of Nigeria, Nsukka, to investigate the relationships between seed yield and its component traits using correlation and path analyses. The first experiment (early planting) was in April and the second (late planting) was in August 2007. The values of the correlations and path coefficient analyses obtained in the early planting responded differently from those of the late planting in most of the traits. This could be attributed to different in the growing conditions associated with the planting dates. The correlation coefficients of seed weight per plant with number of flowers per plant and number of pods per plant was significantly positive in both early and late planting dates. In the late planting date, traits such as number of leaves per plant, plant height, number of flowers per plant, days to 50% flowering and number of pods per plant correlated strong and positive with the seed weight per plant. The number of flowers and pods per plant had maximum positive direct contribution to seed weight per plant in early planting dates while number of pods per plant and days to 50% flowering were the main contributor to seed weight per plant in the late planting. Therefore, the results indicates that number of pods plant per plant and number of flowers per plant should be emphasis during selection in the early planting dates while number of pods plant per plant and days to 50% flowering would be emphasis in late planting dates.

Keywords: correlation, masking effect, path coefficient, planting dates

INTRODUCTION

In Africa, bambara groundnut is the third most important legume after groundnut (*Arachis hypogaea*) and cowpea (*Vigna unguiculata*) (Howell 1994) and a major source of vegetable protein. It can yield on soils of low fertility and with little rainfall. It is highly cherished by both rural and urban dwellers in Nigeria. Bambara groundnut is primarily grown for its seeds. The seeds command a high market price, with demand far outweighing supply in many areas (Coudert 1982). In recent years there has been a growing awareness of the potentials of bambara groundnut as a major source of plant protein in the local diet. However, it has not been improved through coordinated breeding programmes.

The primary components of seed yield in bambara groundnut are number of pods per plant and seed weight. Seed yield is a complex character with polygenic inheritance having positive or negative effects on the yield component traits. It is affected by genetic and environmental factors, and thus interaction between them makes it difficult to select the plant with increased yield (Azhar *et al.* 1999). It is important to examine the contribution of each of the traits in order to give more attention to those having the greatest influence on seed yield. Sarawgi *et al.* (1997) reported that the understanding of the relationship between yield and its components is of paramount importance for making the best use of these relationships in selection. Such relationships have been studied using correlation coefficients (Ali *et al.* 2002; Akbar *et al.* 2003; Ali *et al.* 2003). Correlation coefficients show relationships among independent characteristics and the degree of linear relation bet-

ween these characteristics. Further studies have used non-linear connecting paths of influence between traits through further breaking down of correlation coefficients. These influences have been termed path coefficients, attributable to direct and indirect causes (Dewey and Lu 1959; Bidgoli *et al.* 2006). It provides information on the path through which the component characters influence the expression of an economic character like seed yield and hence has extensively been used in breeding experiments in different crop species by various researchers (Punia and Gill 1994; Shalini *et al.* 2000; Ali *et al.* 2003).

Wide variations in the extent of direct and indirect effects revealed through path coefficient analyses have been reported for yield in various crops such as sorghum, *Sorghum bicolor* (Mutengwa *et al.* 1999), groundnuts, *Arachis hypogaea* (Bera and Das 2000), soybean, *Glycine max* (Singh and Yidava 2000; Iqbal 2003), linseed, *Linum usitatissimum* (Akbar *et al.* 2003), safflower, *Carthamus tinctorius* L. (Bidgoli *et al.* 2006). Many studies in bambara groundnuts have focused on the agronomic performance and general correlation with little emphasis on the relationships between yield components (Makanda *et al.* 2009). Further, no work has been reported on such relationships outside the traditional growing season in the derived savanna region of South Eastern Nigeria. There is need to understand the relationships for the potential growing environments because the crop's phenology is dependent on temperature and photoperiod. Linnemann (1995) and Karikari *et al.* (1997) showed that different growing conditions stimulated different trait responses among genotypes of bambara groundnut. The same scenario was reported for groundnut (Canavar and Kaynak 2008). This may mean dif-

Table 1 Mean rainfall (mm), temperature (°C), and the relative humidity during the experimental period.

Month	Temp (°C) (± SEM)**		Rainfall (mm) (± SEM)**	Rainy days	Relative humidity (%) (± SEM)**	
	Min.	Max.			At 10 am	At 4 pm
Early planting						
April	22.97 ± 0.24 a	32.67 ± 0.36 a	121.66 ± 0.33 e	8	74.53 ± 0.52 c	64.53 ± 1.33 d
May	21.90 ± 0.28 b	31.13 ± 0.34 b	193.55 ± 0.27 c	11	76.32 ± 0.46 b	70.81 ± 0.76 b
June	21.83 ± 0.26 b	29.37 ± 0.25 c	327.66 ± 0.35 a	16	77.43 ± 0.34 a	72.93 ± 0.67 a
July	21.20 ± 0.17 c	28.52 ± 0.27 d	62.99 ± 0.43 f	14	78.42 ± 0.38 a	73.35 ± 0.64 a
Late planting						
August	21.16 ± 0.11 c	27.58 ± 0.29 e	323.60 ± 0.27 a	17	79.06 ± 0.43 a	74.29 ± 0.63 a
September	21.13 ± 0.16 c	28.27 ± 0.32 f	169.67 ± 0.45 d	19	78.07 ± 0.46 a	74.23 ± 0.73 a
October	20.71 ± 0.20 c	29.52 ± 0.22 c	267.20 ± 0.22 b	18	76.61 ± 0.47 b	71.77 ± 0.61 b
November	20.30 ± 0.26 b	30.40 ± 0.32 b	55.12 ± 0.21 f	4	76.33 ± 0.58 b	68.53 ± 1.08 b

** Different letters within a column indicate significant differences according to analysis of variance ($P < 0.01$).

ferent trait emphasis during selection in different planting periods, as trait response may vary due to changes in the growing conditions. The results obtained in this study would be important in the development of an excellent selection procedures for the improvement of the crop in the region. Therefore, this paper reports on the relationships between yield-determining traits of bambara groundnuts planted under two planting dates (early and late planting) in the Nsukka, derived savanna of Nigeria based on the correlations and path coefficients.

MATERIALS AND METHODS

Two field experiments were conducted in April (early planting) and August (late planting) 2007. Both experiments were carried out in the experimental field of the Department of Crop Science, University of Nigeria, Nsukka (Lat. 06° 52' N; Long. 07 24' E; Alt. 447.2 m a.s.l.). The monthly temperature, rainfall distribution, number of rainy days and the relative humidity of the location during the crop growing periods are presented in **Table 1**. The 13 bambara groundnut genotypes that were used in the present study were sourced from bambara groundnut-producing areas of Nigeria. The genotypes were classified based on the seed coat colour according to the descriptors list of *V. subterranea* edited by the International Plant Genetic Resources Institute (IPGRI *et al.* 2000). **Table 2** shows the accession numbers, names of accession and place of collection/agro-ecological zone of the genotypes evaluated. The cultivars were grown in a randomized complete block design (RCBD) with three replications. The plot size was 180 m² and the seeds were planted at a spacing of 30 × 75 cm. Four kilograms of well cured pig dung (equivalent to 222 kg/ha) was applied to each plot before planting. The plots were weeded manually to keep weed pressure low.

Data on days to emergence, days to 50% flowering, number of flowers per plant, number of leaves per plant, plant height, number of pods per plant and seed weight per plant (g) were measured. The correlation coefficients (r) were computed among all the measured traits using SPSS for Windows Version 16 (SPSS, Inc., Chicago, IL). Path coefficient analyses were calculated using the Analysis for Moment Structures for Windows Version 16 (AMOS Development Corp., Spring House, USA) software program to partition the correlations obtained into components due to direct and indirect effects in the two planting period.

RESULTS

Correlation coefficient

The results of the correlation coefficient among the six traits studied during early and late planting are shown in **Table 3**. The correlation coefficient values obtained in the early planting differed from that of the late planting in most of the traits. Seed weight per plant showed a significant and highly significant positive correlations with number of flowers per plant ($r = 0.620^*$) and number of pods per plant ($r = 0.697^{**}$) in the early planting dates, respectively. Moreover, results indicated that in the late planting, seed weight per plant had positive and highly significant correlations with number of flowers per plant and number of pods

Table 2 Accessional numbers and place of collection of the accessions.

Accession number	Place of collection	Ecological zone
Bg-01	Quaanpan, LGA	Southern Guinea Savanna
Bg-02	Mikang, LGA	Southern Guinea Savanna
Bg-03	Langtan South, LGA	Southern Guinea Savanna
Bg-04	Langtan North, LGA	Southern Guinea Savanna
Bg-05	Pankshin, LGA	Southern Guinea Savanna
Bg-06	Shendam, LGA	Southern Guinea Savanna
Bg-07	Langtan South, LGA	Southern Guinea Savanna
Bg-08	Mikang, LGA	Southern Guinea Savanna
Bg-09	Shendam, LGA	Southern Guinea Savanna
Bg-10	Quaanpan, LGA	Southern Guinea Savanna
Bg-11	Pankshin, LGA	Southern Guinea Savanna
Bg-12	Langtan North, LGA	Southern Guinea Savanna
Bg-13	Langtan South, LGA	Southern Guinea Savanna

LGA: Local Government Area

per plant ($r = 0.745^{**}$ and $r = 0.837^{**}$, respectively). Significant and positive correlations were found between seed weight per plant and number of leaves per plant ($r = 0.682^*$), plant height ($r = 0.760^*$) and days to 50% flowering ($r = 0.673^*$) in the late planting date. However, correlations between seed weight per plant and days to emergence ($r = -0.207$), number of leaves per plant ($r = -0.473$), plant height ($r = -0.099$) and days to 50% flowering ($r = -0.272$) were weak and negative during the early planting. The relationships between seed weight per plant and days to emergence were non significant, having negative ($r = -0.207$) and positive ($r = 0.378$) values in the early and late planting dates, respectively. Significant and positive correlation was observed between number of pods per plant and number of leaves per plant ($r = 0.663^*$), plant height ($r = 0.660^*$) and number of flowers per plant ($r = 0.808^*$) in the late planting date. However, during the early planting, number of pods per plant was non significant and negatively correlated with all the traits evaluated with the exception of number of flowers per plant. Number of flowers per plant showed strong positive association with plant height ($r = 0.675^*$) in the late planting. Days to 50% emergence was positive and weakly correlated with number of leaves per plant, number of flowers per plant and days to 50% flowering during the early planting date. However, the above traits correlated weak but positive with days to 50% emergence during the late planting date.

Path coefficient analysis

The estimates of the direct, indirect and total indirect effects of the six yield traits of bambara groundnut on seed weight per plant in two planting dates are presented in **Table 4**. The path coefficients obtained from early planting were found to be different from the late planting. In the early planting, plant height and number of flowers per plant had high and positive direct effects (0.57 and 0.47, respectively) on the seed weight per plant. The direct effects of days to 50% flowering and number of leaves per plant on seed weight per plant showed high but negative values (-0.78 and -0.47, respectively). Days to emergence had low negative direct

Table 3 Correlation coefficients among traits calculated from 13 cultivars of bambara groundnut grown in the derived savanna ecological conditions of April (early) and August (late) 2007 planting dates.

	PD	1	2	3	4	5	6	7
1. Days to emergence	Early	1.000						
	Late	1.000						
2. Number of leaves per plant	Early	-0.050	1.000					
	Late	0.368	1.000					
3. Plant height	Early	0.017	0.346	1.000				
	Late	0.042	0.575*	1.000				
4. Number of flowers per plant	Early	-0.147	0.059	0.540	1.000			
	Late	0.396	0.515	0.675*	1.000			
5. Days to 50% flowering	Early	-0.005	0.270	0.937**	0.355	1.000		
	Late	0.059	0.477	0.513	0.341	1.000		
6. Number of pods per plant	Early	-0.480	-0.078	-0.094	0.503	-0.243	1.000	
	Late	0.329	0.663*	0.660*	0.808**	0.436	1.000	
7. Seed weight per plant	Early	-0.207	-0.473	-0.099	.620*	-0.272	.697**	1.000
	Late	0.378	0.682*	0.760**	0.745**	0.673*	0.837**	1.000

* and ** = significant at $P < 0.05$ and 0.01 , respectively.

Table 4 Path-coefficient values estimated for seed weight per plant and other yield traits during the early and late planting dates.

	Direct effect	Indirect effects to SWP via					Total indirect effects	Total correlation to SWP	
		DTE	NLP	PH	NFP	D50%F			NPP
Early planting									
DTE	-0.05		0.0235	0.0114	-0.071	0.0078	-0.13	-0.157	-0.207
NLP	-0.47	0.0025		0.1995	0.0282	-0.2106	-0.022	-0.005	-0.472
PH	0.57	-0.001	-0.165		0.2538	-0.7332	-0.024	-0.668	-0.099
NFP	0.47	0.0075	-0.028	0.3078		-0.273	0.135	0.142	0.619*
D50%F	-0.78	0.0005	-0.127	0.5358	0.1645		-0.065	0.509	-0.271
NPP	0.27	0.024	0.0376	-0.051	0.235	0.1872		0.409	0.703**
Late planting									
DTE	0.15		0.0666	0.0096	0.0240	0.0174	0.1089	0.227	0.377
NLP	0.18	0.0555		0.1368	0.0312	0.1392	0.1278	0.435	0.671*
PH	0.24	0.006	0.1026		0.0408	0.1479	0.2178	0.509	0.755**
NFP	0.06	0.06	0.0936	0.1632		0.0986	0.2673	0.623	0.743**
D50%F	0.29	0.009	0.0864	0.1224	0.0204		0.1452	0.374	0.673*
NPP	0.33	0.0495	0.1188	0.1584	0.0486	0.1276		0.453	0.833**

DTE: days to emergence, NLP: number of leaves per plant, PH: plant height, NFP: number of flowers per plant, D50%F: days to 50% flowering, NPP: number of pods per plant and SWP: seed weight per plant

* and ** = significant at $P < 0.05$ and 0.01 , respectively.

effect (-0.05) on seed weight per plant. Days to 50% flowering and number of flowers per plant recorded the high and positive indirect effect (0.536 and 0.3078, respectively) on seed weight per plant via the plant height. On the other hand, the highest negative indirect effect was found via days to 50% flowering (-0.733). Days to 50% flowering had the highest (0.509) positive total indirect effect and was followed by the number of pods per plant (0.453) and number flowers per plant (0.1416). The total indirect effects of seed weight per plant on plant height, days to emergence and number of leaves per plant were negative (-0.668, -0.157 and -0.005, respectively). The path diagram showing cause and effect relationships of seed weight per plant and its components is presented in **Fig. 1**. The double-headed lines indicate correlation between the two variables and the single-headed lines represent the direct influence as measured by the path coefficient. The residual estimates was 0.37.

In the late planting, the result of the path analysis showed that number of pods per plant had the largest direct effect (0.33) on seed weight per plant followed by days to 50% flowering (0.29) and plant height (0.24). However, number of flowers per plant showed negligible positive direct effect on seed weight per plant (0.06). Number of flowers per plant and plant height recorded maximum positive indirect effect on seed weight per plant (0.267 and 0.218, respectively) via number of pods per plant. This was followed by the indirect effects of number of flowers per plant and number of pods per plant (0.163 and 0.158, respectively) via plant height. Plant height (0.006) and days to 50% flowering (0.009) via days to emergence had positive and negligible indirect effect on seed weight per plant. The total indirect effects of number of flowers per plant (0.623), plant height (0.509), number of pods per plant (0.45) and number

of leaves per plant (0.435) on seed weight per plant were high and positive. **Fig. 2** shows a path diagram showing cause and effect relationships of seed weight and its components. The residual estimate was 0.32.

DISCUSSION

Seed yield being polygenic trait is greatly influence by its component characters. Therefore, direct crop selection on the basis of yield is often misleading. Studies on the character association is of great important for the improvement of bambara groundnut. The estimates of coefficients of correlation and path coefficients analyses are important for better understanding of the relationship between yield components and their relative contributions to yield. Path coefficient analysis separates the direct effects from the indirect effects via other related traits by partitioning the correlation coefficients (Dixit and Dubey 1984; Bidgoli *et al.* 2006). It gives the relative contribution of various yield-determining traits, enabling breeders to decide between direct and indirect selection (Ofori 1996; Talebi *et al.* 2007). The direct and indirect relationship of seed yield per plant with competent traits and estimates of correlation among path analysis helps in indirect selection for genetic improvement in yield.

In the present study, different genotypes of bambara groundnut were studied under two different planting dates. The result revealed that the correlation coefficients for the early planting differed from those of the late planting in most of the traits which indicates differences in the environmental condition of the two planting dates. This result is in line with Ofori (1996), Ouedraogo *et al.* (2008) and Makanda *et al.* (2009). The observed positive and significant association of seed weight per plant with number of flowers

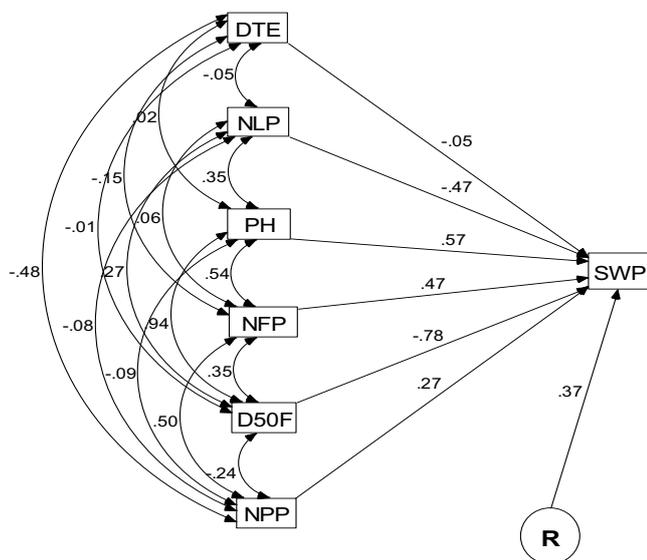


Fig. 1 Path diagram showing causal relationship between six yield traits (predictor variables) and the seed weight per plant (response variable) during the early planting. The residual variable (R) is the undetermined portion. DTE = days to emergence, NLP = number of leaves per plant, PH = plant height, NFP = number of flowers per plant, D50%F = days to 50% flowering, NPP = number of pods per plant and SWP = seed weight per plant.

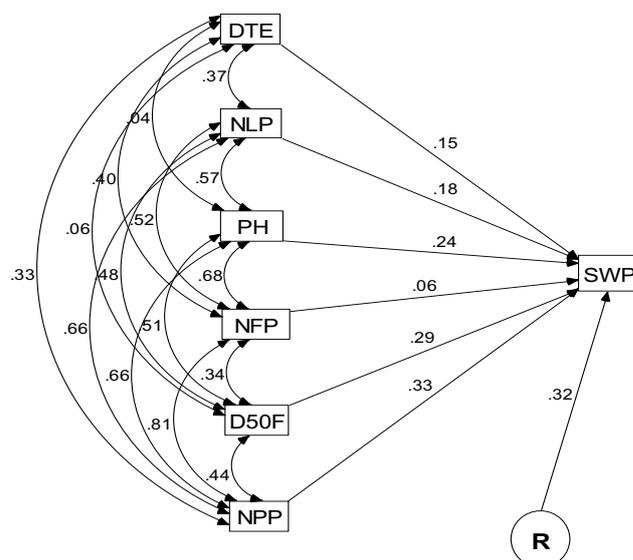


Fig. 2 Path diagram showing causal relationship between six yield traits (predictor variables) and the seed weight per plant (response variable) during the late planting. The residual variable (R) is the undetermined portion. DTE = days to emergence, NLP = number of leaves per plant, PH = plant height, NFP = number of flowers per plant, D50%F = days to 50% flowering, NPP = number of pods per plant and SWP = seed weight per plant.

and pods per plant in both planting dates revealed that increase in the two traits would contribute more to seed weight per plant. The number of flowers per plant and number of pods per plant are therefore, considered the most important seed yield component traits. The present results are confirmed by earlier research findings on crops like rapeseed (*Brassica campestris/Brassica napus*) (Thompson 1983; Shabana *et al.* 1990); Faba bean (*Vicia faba* L.) (Talal and Ghalib 2006); Soybean (*Glycine max* (L.) Merrill) (Singh and Yidava 2000; Iqbal *et al.* 2003) and chickpea (*Cicer arietinum* L.) (Wadud and Yaqoob 1989; Talebi *et al.* 2007). Ofori (1996) and Iqbal *et al.* (2003) reported that the number of flowers per plant and number of pods per plant are an important yield component in legumes. Therefore, emphasis should be given to the above two traits for increased seed yield of bambara groundnut in both planting dates.

Seed weight per plant was significant and positively correlated with number of leaves per plant, plant height and days to 50% flowering in late planting date which illustrated that higher mean values for these traits would increase the seed weight per plant. The positive correlation of seed weight per plant with days to 50% flowering indicates that genotypes which take more time on vegetative stage would have more seed weight per plant. Similar results were reported in soybean (Jagtap and Choudhary 1993; Malik *et al.* 2006), mungbean (*Vigna radiata*) (Reddy *et al.* 1991) and bambara groundnut (Misangu *et al.* 2007). However, correlations between seed weight per plant and number of leaves per plant, plant height and days to 50% flowering were non-significant and negative during the early planting indicating weak inverse relationships between the seed weight per plant and the above traits. Significant and positive correlation obtained between number of pods per plant and number of leaves per plant, plant height and number of flowers per plant in the late planting suggest increase in the number of pods per plant would result from increase in the above traits. A positive correlation between number of pods per plant and plant height was earlier reported in faba bean (*Vicia faba* L.) (Hakan *et al.* 2003; Talal and Ghalib 2006), rice bean (*Vigna mungo* L.) (Ghafoor *et al.* 1988) and bambara groundnut (Misangu *et al.* 2007).

The relationships between the number of pods per plant and days to emergence were non significant in both early

and late planting dates. The above traits correlated negatively and positively with the number of pods per plant during early and late planting dates, respectively. Negative correlation shows that the changes of two variables are in the opposite direction (*i.e.* high values of one variable are associated with low values of the other) while positive correlation connotes changes of two variables are in the same direction (*i.e.* high values of one variable are associated with high values of the other). The positive and significant association obtained between the number of flowers per plant and plant height in the late planting date suggests that increase in the plant height would result in higher number of flowers produced. Therefore, plant height could be said to be largely controlled by genes that govern the number of flowers per plant.

The weak negative correlation observed between the days to emergence and number of leaves per plant, number of flowers per plant and days to 50% flowering in the early planting means that decrease in days to emergence would lead to increase in the above traits. However, the positive correlation observed between the days to emergence and number of leaves per plant, number of flowers per plant and days to 50% flowering during the late planting suggest that increase in the days to emergence would give rise to increase in the above traits. A positive but non significant phenotypic ($r = 0.044$) and genetic ($r = 0.197$) correlation have been reported between days to emergence and days to 50% flowering in bambara groundnut (Nawab *et al.* 2008).

The results of the path coefficients in the early planting differed from those of the late planting which could be due to the different environmental conditions (*i.e.*, variation in temperature and precipitation, **Table 1**) associated with the two planting dates. The result suggested that the yield component relationships in bambara groundnut appear, to be characterized by a strong environmental control. This result is in line those reported for rapeseed by Ozer *et al.* (1999).

The data revealed that in the early planting, plant height had the maximum positive direct effect on seed weight per plant (0.57) but was masked by negative indirect effects of days to 50% flowering (-0.7332), number of leaves per plant (-0.165), number of pods per plant (-0.024) and date to 50% emergence (-0.001), giving a net negative non significant correlation coefficient between seed weight per plant and plant height. The high values of direct effect of

number of flowers per plant approached the value of correlation coefficient of this trait with seed weight per plant which indicated that number of flowers per plant had the maximum direct contribution toward the seed yield resulting to the observed significant correlation with seed weight per plant. The number of pods per plant also had a high positive direct effect on the seed weight per plant. Therefore, the number of flowers and pods per plant are considered the main contributor towards seed yield. Makanda *et al.* (2009) also reported high positive direct contribution of number of pods per plant to seed yield in bambara groundnut. Direct selection of the above traits should be adopted for the seed yield improvement in bambara groundnut in the early planting. The data further revealed that days to 50% flowering had the highest negative direct effects. This was followed by the number of leaves per plant and days to emergence. Although the negative direct effect of days to 50% flowering on seed weight per plant was highest, non significant correlation was obtained due to the masking effect of the positive indirect effect of plant height and number of flowers per plant. These findings agree with those obtained by Reddy *et al.* (1991) and Vandana and Dubey (1993) in mungbean and faba bean, respectively.

In the late planting, the path analysis showed that number of pods per plant had the highest positive direct effect and had also contributed maximum towards the significant positive correlation of the seed weight per plant, making it an important yield trait for selection during the improvement of the crop in the late planting. This trait was followed by days to 50% flowering, plant height, number of leaves per plant, days to emergence and number of flowers per plant in that order. Makanda *et al.* (2009), Tomar *et al.* (1973) and Rahman and Sarwar (1982) reported similar results in bambara groundnut, mungbean and lentil genotypes, respectively. The indirect effects of number of flowers per plant via number of pods per plant also provided the maximum contribution towards the significant correlation observed with the seed weight per plant. This was followed by the plant height via number of pods per plant and number of flowers per plant via plant height in that order. The observed result revealed that seed weight per plant was more dependent on the indirect effects of above yield components compared to their direct effects, suggesting that indirect selection through the mentioned yield components are the most effective.

In conclusion, the study indicated that number of pods per plant was the most important seed yield component in bambara groundnut because of its strong positive correlation and positive high direct effects to seed weight per plant in the two planting dates. This was followed by the number of flowers per plant and days to 50% flowering which also displayed strong positive correlation and positive direct effects on seed weight per plant in the early and late planting dates, respectively. This implies that in selection for high yielding genotypes, number of flowers per plant and days to 50% flowering should also be emphasis during selection in the early and late planting dates, respectively. The indirect influences via number of pods per plant were also important for the significant correlation of seed weight per plant with number of flowers per plant and plant height in the late planting. The indirect effects were generally low indicating that positive correlations between number of pods per plant and seed weight per plant were largely due to the direct effects. These findings suggested that selection for high number of pods per plant should be emphasized across the two planting dates.

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