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Path Coefficient Analysis among Components of Yield in Bambara Groundnut (*Vigna subterranea* L. Verdc) Landraces under Screen House Conditions

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Abstract: A screen house experiment was conducted at the Sokoine University of Agriculture, Morogoro Tanzania, to discern the relationships among components of yield in Bambara groundnut *V. subterranea* genotypes using path coefficient analysis. The trial was conducted during January-May, 2000. Nine genotypes of Bambara groundnut landraces were laid out in a Completely Randomized Design with four replications. Results showed that leaf length was the only vegetative variable which had a significant and positive correlation (r = 0.50*) with yield. Path coefficient analysis shows that this correlation was mainly attributed to the independent (direct) contribution (0.393) of leaf length on yield though the latter was far less than its respective residual effect. Number of pods per plant were highly correlated (r = 0.83**) with seed yield and the direct effect on yield (0.998) was relatively higher than the residual. On the other hand, the number of days to flowering were negatively correlated with yield (r = -0.41*) and this correlation was predominantly attributed to its negative direct effect (-0.461). The latter was also higher than its respective residual effect. Petiole length was negatively correlated with 100 seed weight (r = -0.41*) and this was largely due to its negative direct effect (-0.310) on seed size. This direct effect was, however, far less than its residual effect. Plant height and leaf length were both positively correlated with number of pods produced. Their correlations were largely due to their direct effects on number of pods per plant although these direct effects were less than their respective residual effects. Although 100 seed weight had a non significant correlation with seed yield (r = 0.16), its independent effect (0.541) on yield was higher than the residual effect of 0.299. However, the indirect effect of seed size on yield through number of pods (-0.381) reduced the direct effect to a low and non significant correlation with yield. The present study shows that number of pods interacted negatively with 100 seed weight in influencing yield of Bambara groundnut. Taller plants, longer leaves and more podding are variables which are related to higher yields of Bambara groundnut under screen house conditions.

Key words: Bambara groundnut, independent effect, landraces, yield components, path coefficient

INTRODUCTION

Bambara groundnut *V. subterranea* is an indigenous leguminous crop in Africa. It is an important source of protein in the diet, particularly to poorer communities who can hardly afford expensive animal protein. There is currently, a growing concern that meat is a source of various non communicable ailments, such as high blood pressure, cancer and lowered immunity to infectious diseases (Sesay *et al*., 1996). Studies show that Bambara groundnut is a rich energy and protein source with 16-25.2% protein, 42.8-65% carbohydrate on a dry weight basis and that the seed protein content compares well with that of valued grain legumes (Linnemann and Azam-Ali, 1993). The crop has good agronomic values in that it is endowed with the advantages of being resistant to insect pests and diseases, has a wide range of genetic variability, drought resistant, high adaptation to marginal conditions and a good nitrogen fixer (Azam-Ali, 1992; Sesay *et al*., 1996). It is therefore a crop suited to low input farming systems that makes it popular amongst farmers with limited resources. However, the problem of securing consistent, satisfactory yields in Bambara groundnut is of practical concern in the region. Yields of

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Bambara groundnut are not only generally low, varying between 650 and 850 kg ha^{-1} (Stanton *et al*., 1966) and perhaps as low as 60-110 kg ha^{-1} (Linnemann and Azam-Ali, 1993) but also, notoriously erratic. Other workers have reported yield levels of Bambara groundnut, for instance 300 kg ha^{-1} for current landraces and 399-1310 kg ha^{-1} for promising entries (Mulila-Mitti and Kanenga, 1996). Occasionally, yields of as high as 2000 and 3900 kg ha^{-1} have been observed in experimental plots (Mulila-Mitti and Kanenga, 1996).

Linnemann and Azam-Ali (1993) had associated low yields to poor germination and late establishment while Squire *et al*. (1996) indicated that variability in growth and development of individual plants is the main cause of low yields in this crop. Yield, however, is a complex character determined by a number of components that follow a developmental sequence (Karikari and Tabone, 2003). The organs developed earlier can have a profound influence on those produced later (Grafius, 1978; Hamid and Grafius, 1978). Thus selection and improvement for yield requires manipulation of quantitative characters that may correlate and influence among themselves and yield. However, limited work is available that correlates paths of influence among developmental variables in Bambara groundnut for instance those of Karikari (1972), Linnemann (1994) and Karikari and Tabone (2003). The latter noted that yield is a complex terminal outcome of growth to which there are diverse and interrelated developmental tracks. Thus no single character that is absolutely important for yield, necessitating development of selection criteria comprising both vegetative (first order components) and reproductive (second order components) variables and hence aid breeders in improvement of yield through a component selection approach. A detailed examination of the nature of association among the components will assist in developing a more reliable criterion for selection and minimize risks of component compensation in yield improvement.

The present investigation analyses more critically the interrelationships and influential patterns among yield and components of yield in Bambara groundnut using the path coefficient analysis tool after Wright (1921) and as revised by Dewey and Lu (1959). Results of this investigation will shed light on variables to consider in improvement of bambara groundnut for yield improvement in this location and other similar ecologies.

MATERIALS AND METHODS

An experiment was conducted in the screen house of the Department of Crop Science and Production at the Sokoine University of Agriculture (SUA), Morogoro, Tanzania during the January-May 2000 growing season. The materials used in this study were obtained from the collection of Bambara groundnut germplasm maintained by the Department of Crop Science and Production. The collected materials consisted of a mixture of landraces from different areas of Tanzania, viz. Bukoba (West Lake), Songea (South) and Mbinga (South West).

The experiment was laid out in a Completely Randomized Design (CRD) in which nine landraces (Table 1) were replicated four times in the screen house. Planting was done in 5 L size plastic pots, each containing 2 plants. The pots, each regarded as a plot, were laid on a bench in four rows at spacing of 50 cm both within and between rows. Soil was collected from the Crop Museum plots of SUA and 4 kg of soil were placed in each 5 L plastic pot. Three seeds were sown per pot and the seedlings were thinned at 3 weeks after sowing, leaving two plants per pot. Gap filling was done during the first week after emergence. Appropriate husbandry practices were done to ensure adequate moisture and protection against pests.

Data collected from each plot included number of days to first flower, average values for plant height and number of full open trifoliolate leaves, leaf length of median leaf blades and petiole length. Other variables included average weight of 100 seeds, number of pods per plant and seed yield per plant. The mean values of the variables for each plot were subjected to ANOVA and phenotypic correlations using SAS (1997) computer software. Phenotypic correlations were further partitioned into components of direct and indirect effects using path coefficient analysis after Wright (1921) and Dewey and Lu (1959). The coefficients were obtained by solving sets of simultaneous equations arranged in matrix notation which show the relationships between correlations and path coefficients as shown below:

(a) Effects of vegetative and reproductive variables on seed yield per plant and effects of first order components on weight of 100 seeds:

$$r_{16} = P_{16}+r_{12}P_{26}+r_{13}P_{36}+r_{14}P_{46}+r_{15}P_{56}$$
$$r_{26} = r_{12}P_{16}+P_{26}+r_{23}P_{36}+r_{24}P_{46}+r_{25}P_{56}$$

Table 1: List of local landraces of Bambara groundnut that were characterized and used in the analysis

Identification No.	Landrace	Source
B1	Songea njugu1	Songea
B2	Songea njugu 2	Songea
B3	Songea njugu3	Songea
B4	Mbinga songea 1	Mbinga
B5	Mbinga songea 2	Mbinga
B6	Bukoba kyonyo 1	Bukoba
B7	Bukoba kyonyo2	Bukoba
B8	M2 njugu 1	Mbinga
B9	M2 njugu 2	Mbinga

$$r_{36} = r_{13}P_{16}+r_{23}P_{26}+P_{36}+r_{34}P_{46}+r_{35}P_{56}$$
$$r_{46} = r_{14}P_{16}+r_{24}P_{26}+r_{34}P_{36}+P_{46}+r_{45}P_{56}$$
$$r_{56} = r_{15}P_{16}+r_{25}P_{26}+r_{35}P_{36}+r_{45}P_{46}+P_{56}$$
$$1 = P^2_{x6}+P^2_{26}+P^2_{36}+P^2_{46}+P^2_{56}+2P_{16}r_{12}P_{26}+2P_{16}r_{13}P_{36}+ 2P_{16}r_{14}P_{46}+2P_{16}r_{15}P_{56}+2P_{26}r_{23}P_{36}+2P_{26}r_{24}P_{46}+ 2P_{26}r_{25}P_{56}+2P_{36}r_{34}P_{46}+2P_{36}r_{35}P_{56}+2P_{46}r_{45}P_{56}$$

(b) Effects of first order components on number of pods per plant:

$$r_{17} = P_{17}+r_{12}P_{27}+r_{13}P_{37}+r_{14}P_{47}+r_{15}P_{57}$$
$$r_{27} = r_{12}P_{17}+P_{27}+r_{23}P_{37}+r_{24}P_{47}+r_{25}P_{57}$$
$$r_{37} = r_{13}P_{17}+r_{23}P_{27}+P_{37}+r_{34}P_{47}+r_{35}P_{57}$$
$$r_{47} = r_{14}P_{17}+r_{24}P_{27}+r_{34}P_{47}+P_{47}+r_{45}P_{57}$$
$$r_{57} = r_{15}P_{17}+r_{25}P_{27}+r_{35}P_{37}+r_{45}P_{57}+P_{57}$$
$$1 = P^2_{x7}+P^2_{27}+P^2_{37}+P^2_{47}+P^2_{57}+2P_{17}r_{12}P_{27}+2P_{17}r_{13}P_{37}+ 2P_{17}r_{14}P_{47}+2P_{17}r_{15}P_{57}+2P_{27}r_{23}P_{37}+2P_{27}r_{24}P_{47}+2 P_{27}r_{25}P_{57}+2P_{37}r_{34}P_{47}+2P_{37}r_{35}2P_{57}+2P_{47}r_{45}P_{57}$$

(c) Effects of second order components on seed yield per plant:

$$r_{68} = P_{68}+r_{67}P_{78}$$
$$r_{78} = r_{67}P_{78}+P_{78}$$
$$1 = P^2_{x8}+P^2_{68}+P^2_{78}+2P_{68}r_{67}P_{78}$$

In the above equations, r's are the phenotypic correlations between variables, P's are the direct effects (coefficients) of one variable upon another and r_{ij} p_{ij}'s are the indirect effects. The residual effect, Px_8, is composed of effects other than those included in the model.

RESULTS

The influence of vegetative variables on seed yield per plant: The paths of influence among vegetative variables on seed yield are shown in Fig. 1 and Table 2. Only leaf length was positively and significantly correlated with seed yield per plant and this correlation was predominantly attributed to the direct contribution of leaf length on yield.

The influence of reproductive variables on seed yield per plant: The interrelationships among reproductive variables on seed yield are indicated in Fig. 2 and Table 3. Seed size (100 seed weight) had a low correlation with seed yield; however, its direct effect was relatively high. The high direct effect was reduced to a low correlation by the negative indirect effect of 100 seed weight through number of pods. The latter was attributed to the negative correlation existing between weight of 100 seeds and number of pods while the direct effect of number of pods on yield was high and positive.

Table 2: Relations between vegetative (growth) variables with seed yield/plant

1.	Plant height with seed yield/plant, r_{16}	0.38
	Direct effect, P_{16}	0.300
	Indirect via number of leaves/plant, $r_{12}P_{26}$	0.071
	Indirect via leaf width, $r_{13}P_{36}$	0.008
	Indirect via leaf length, $r_{14}P_{46}$	0.153
	Indirect via petiole length, $r_{15}P_{56}$	-0.152
	Total	0.380
2.	Number of leaves/plant with seed yield/plant, r_{26}	0.34
	Direct effect, P_{26}	0.238
	Indirect via plant height, r_{12}/P_{16}	0.090
	Indirect via leaf width, $r_{23}P_{36}$	-0.001
	Indirect via leaf length $r_{24}P_{46}$	0.028
	Indirect via petiole length, $r_{25}P_{56}$	-0.014
	Total	0.341
3.	Leaf width with seed yield/plant, r_{36}	0.11
	Direct effect, P_{36}	0.016
	Indirect via plant height, $r_{13}P_{16}$	0.141
	Indirect via number of leaves/plant, $r_{23}P_{26}$	-0.021
	Indirect via leaf width, $r_{34}P_{46}$	0.083
	Indirect via leaf length, $r_{35}P_{56}$	-0.109
	Total	0.110
4.	Leaf length with seed yield/plant, r_{46}	0.50*
	Direct effect, P_{46}	0.393
	Indirect via plant height, $r_{14}P_{16}$	0.117
	Indirect via number of leaves/plant, $r_{24}P_{26}$	0.017
	Indirect via leaf width, $r_{34}P_{36}$	0.003
	Indirect via petiole length, $r_{45}P_{56}$	-0.030
	Total	0.500
5.	Petiole length with seed yield/plant, r_{56}	0.04
	Direct effect, P_{56}	-0.231
	Indirect via plant height, $r_{15}P_{16}$	0.198
	Indirect via number of leaves/plant, $r_{25}P_{26}$	0.014
	Indirect via leaf width, $r_{35}P_{36}$	0.008
	Indirect via leaf length, $r_{45}P_{46}$	0.051
	Total	0.040
	Residual, $P_{X6} = 0.789$	

* Significant

Table 3: Relations between reproductive variables with seed yield

1.	Weight of 100 seeds with seed yield/plant, r_{16}	0.16
	Direct effect, P_{16}	0.522
	Indirect via number of pods/plant, $r_{12}P_{26}$	-0.369
	Indirect via seed width, $r_{13}P_{36}$	0.050
	Indirect via seed length, $r_{14}P_{46}$	-0.163
	Indirect via number of days to 50% flowering, $r_{15}P_{56}$	0.120
	Total	0.160
2.	Number of pods/plant with seed yield/plant, r_{26}	0.83**
	Direct effect, P_{26}	0.998
	Indirect via weight of 100 seeds, $r_{12}P_{16}$	-0.193
	Indirect via seed width, $r_{23}P_{36}$	-0.019
	Indirect via seed length, $r_{24}P_{46}$	0.095
	Indirect via number of days to 50% flowering, $r_{25}P_{56}$	-0.051
	Total	0.830
3.	Seed width with seed yield/plant, r_{36}	0.11
	Direct effect, P_{36}	0.067
	Indirect via weight of 100 seeds, $r_{13}P_{16}$	0.386
	Indirect via number of pods/plant, $r_{23}P_{26}$	-0.289
	Indirect via seed length, $r_{34}P_{46}$	-0.183
	Indirect via number of days to 50% flowering, $r_{35}P_{56}$	0.129
	Total	0.110
4.	Seed length with seed yield/plant, r_{46}	-0.08
	Direct effect, P_{46}	-0.258
	Indirect via weight of 100 seeds, $r_{15}P_{16}$	0.329
	Indirect via number of pods/plant, $r_{24}P_{26}$	-0.369
	Indirect via seed width, $r_{34}P_{36}$	0.048
	Indirect via number of days to 50% flowering, $r_{45}P_{56}$	0.170
	Total	-0.080

Table: 3 Continued

5.	Number of days to 50% flowering with seed yield/plant, r_{56}	-0.41*
	Direct effect, P_{56}	-0.461
	Indirect via weight of 100 seeds, $r_{15}P_{16}$	-0.136
	Indirect via number of pods/plant, $r_{25}P_{26}$	0.110
	Indirect via seed width, $r_{35}P_{36}$	-0.019
	Indirect via seed length, $r_{45}P_{46}$	0.095
	Total	-0.411
	$P_{x6} = 0.000$	

* Significant; ** Highly significant

Table 4: 1st order components on weight of 100 seeds

1.	Plant height with weight of 100 seeds, r_{16}	-0.33
	Direct effect, P_{16}	-0.089
	Indirect via number of leaves/plant, $r_{12}P_{26}$	-0.023
	Indirect via leaf length, $r_{13}P_{36}$	0.004
	Indirect via petiole length, $r_{14}P_{46}$	-0.205
	Indirect via number of days to flowering, $r_{15}P_{56}$	-0.017
	Total	-0.330
2.	Number of leaves/plant with weight of 100 seeds, r_{26}	-0.09
	Direct effect, P_{26}	-0.077
	Indirect via plant height, $r_{12}P_{16}$	-0.027
	Indirect via leaf length, $r_{23}P_{36}$	0.001
	Indirect via petiole length, $r_{24}P_{46}$	-0.019
	Indirect via number of days to flowering, $r_{25}P_{56}$	0.031
	Total	-0.091
3.	Leaf length with weight of 100 seeds, r_{36}	-0.09
	Direct effect, P_{36}	0.009
	Indirect via plant height, $r_{13}P_{16}$	-0.035
	Indirect via number of leaves/plant, $r_{23}P_{26}$	-0.005
	Indirect via petiole length, $r_{34}P_{46}$	-0.040
	Indirect via number of days to flowering, $r_{35}P_{56}$	-0.019
	Total	-0.090
4.	Petiole length with weight of 100 seeds, r_{46}	-0.41*
	Direct effect, P_{46}	-0.310
	Indirect via plant height, $r_{14}P_{16}$	-0.059
	Indirect via number of leaves/plant, $r_{24}P_{26}$	-0.005
	Indirect via leaf length, $r_{34}P_{36}$	0.001
	Indirect via number of days to flowering, $r_{45}P_{56}$	-0.038
	Total	-0.411
5.	Number of days to flowering with weight of 100 seeds, r_{56}	-0.26
	Direct effect, P_{56}	-0.209
	Indirect via plant height, $r_{15}P_{16}$	-0.007
	Indirect via number of leaves/plant, $r_{25}P_{26}$	0.012
	Indirect via leaf length, $r_{35}P_{36}$	0.001
	Indirect via petiole length, $r_{45}P_{46}$	-0.056
	Total	-0.259
	Residual, $P_{x6} = 0.885$	

* Significant

Table 5: 1st order components on number of pods/plant

1.	Plant height with number of pods, r_{17}	0.55**
	Direct effect, P_{17}	0.359
	Indirect via number of leaves/plant, $r_{12}P_{27}$	0.057
	Indirect via leaf length, $r_{13}P_{37}$	0.158
	Indirect via petiole length, $r_{14}P_{47}$	-0.030
	Indirect via number of days to flowering, $r_{15}P_{57}$	0.006
	Total	0.550
2.	Number of leaves/plant with number of pods, r_{27}	0.31
	Direct effect, P_{27}	0.189
	Indirect via plant height, $r_{12}P_{17}$	0.108
	Indirect via leaf length, $r_{23}P_{37}$	0.028
	Indirect via petiole length, $r_{24}P_{47}$	-0.003
	Indirect via number of days to flowering, $r_{25}P_{57}$	-0.012
	Total	0.31
3.	Leaf length with number of pods, r_{37}	0.56**
	Direct effect, P_{37}	0.405
	Indirect via plant height, $r_{13}P_{17}$	0.140
	Indirect via number of leaves/plant, $r_{23}P_{27}$	0.013
	Indirect via petiole length, $r_{34}P_{47}$	-0.006
	Indirect via number of days to flowering, $r_{25}P_{57}$	0.007
	Total	0.559
4.	Petiole length with number of pods/plant, r_{47}	0.27
	Direct effect, P_{47}	-0.045
	Indirect via plant height, $r_{14}P_{17}$	0.237
	Indirect via number of leaves/plant, $r_{24}P_{27}$	0.011
	Indirect via leaf length, $r_{34}P_{37}$	0.053
	Indirect via number of days to flowering, $r_{45}P_{57}$	0.015
	Total	0.271
5.	Number of days to flowering with number of pods/plant, r_{57}	0.11
	Direct effect, P_{57}	0.081
	Indirect via plant height, $r_{15}P_{17}$	0.029
	Indirect via number of leaves/plant, $r_{25}P_{27}$	-0.028
	Indirect via leaf length, $r_{35}P_{37}$	0.036
	Indirect via petiole length, $r_{45}P_{47}$	-0.008
	Total	0.110
	P_{x7}, Residual = 0.721	

** Highly significant

Table 6: 2nd Order components on seed yield/plant

1.	Weight of 100 seeds with seed yield, r68	0.16
	Direct effect, P_{68}	0.541
	Indirect via number of pods/plant, $r_{67}P_{78}$	-0.381
	Total	0.160
2.	Number of pods/plant with seed yield, r_{78}	0.83**
	Direct effect, P_{78}	1.030
	Indirect via weight of 100 seeds, $r_{67}P_{68}$	-0.200
	Total	0.830
	Residual, P_{x8}=0.299	

** Highly significant

The high and significant correlation between number of pods with seed yield was largely due to its direct effect on seed yield. Number of days to flowering was significantly and negatively correlated with seed yield and this was largely due to its negative direct effect on yield. In each correlation, weight of 100 seeds and number of pods interacted negatively on their effects on seed yield.

Two stage relations

First order components (vegetative variables) on seed size: The paths of influence of vegetative variables on seed size are shown in Fig. 3 and Table 4. Petiole length had a significant negative relationship with 100 seed weight and this was predominantly due to the negative direct effect of this variable on seed size.

First order components (vegetative variables) on number of pods per plant: Results of influence of first order components on number of pods are shown in Table 5 and Fig. 3. Plant height was significantly and positively correlated with number of pods and this was mainly due to its positive direct contribution on number of pods. Similarly, the significant positive correlation between leaf length with number of pods was largely due to its direct effect on number of pods.

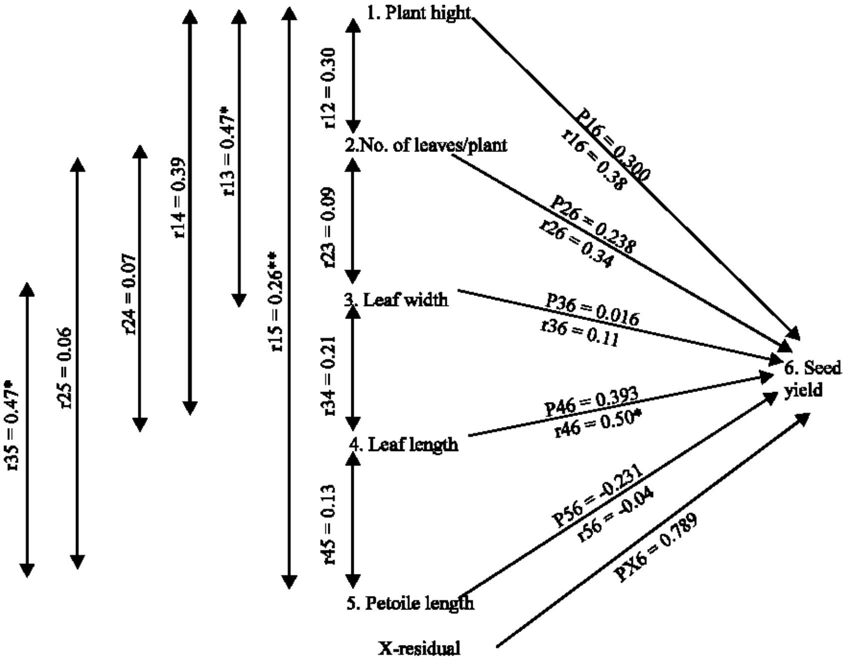

Fig. 1: Path diagram and coefficients of factors on the influence of vegetative variables on seed yield of Bambara groundnut. Pij's are the direct effects, rij's are the correlation coefficients (* Significant; ** Highly significant)

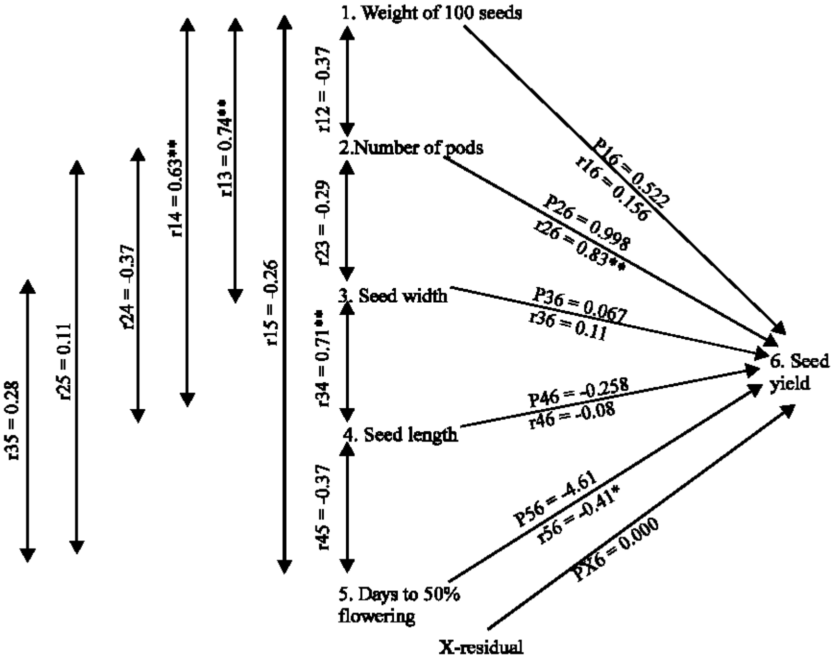

Fig. 2: Path diagram and coefficients of factors on the influence of reproductive variables on seed yield of Bambara groundnut. Pij's are the direct effects, rij's are the correlation coefficients (** Highly significant)

Second order components on seed yield per plant: Effects of second order components (weight of 100 seeds and number of pods) on seed yield are shown in Fig. 3 and Table 6. The high positive independent effect of seed size on yield was reduced to a low correlation by the negative indirect effect of seed size on yield through number of pods per plant. The latter was in turn attributed to the negative correlation between seed size and number of

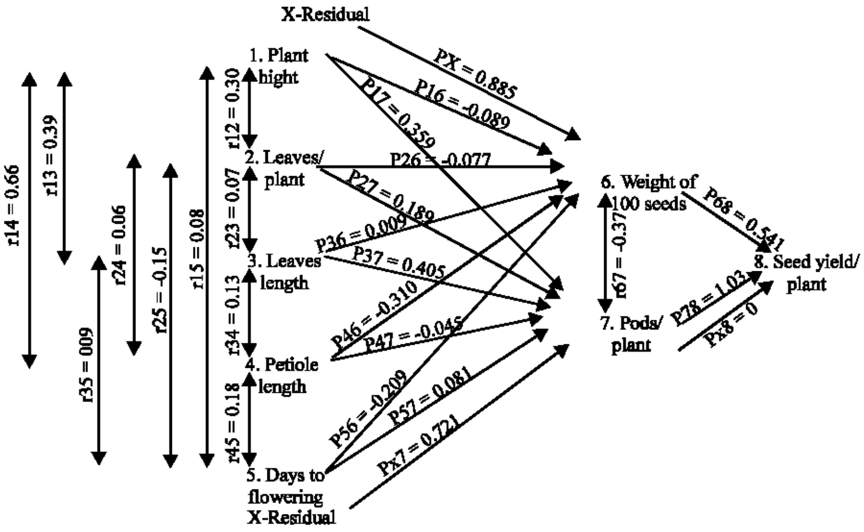

Fig. 3: Path diagram and coefficients of factors on the influence of first order on second order components and the latter on yield of Bambara groundnut. Pij's are the direct effects, rij's are the correlation coefficients

pods per plant while the direct effect of number of pods per plant was high and positive. Number of pods produced was significantly and positively correlated with seed yield and this was mainly due to the high direct effect of pods per plant on seed yield.

DISCUSSION

The positive relationship and contribution of leaf length on pod formation and yield suggests that plant architecture for Bambara groundnut crop that favors longer leaves results to more pods and higher seed yield. Karikari and Tabone (2003) advocated that canopy spread was among variables that could be used for indirect selection for drought tolerance. Leaf and petiole lengths determine spread of the canopy above the ground and hence provide the necessary ground cover against moisture loss from the soil. Increased photosynthetic area from the increased leaf size as a result of increased leaf area index may have contributed to increased agronomic performance. Pod formation in Bambara groundnut is an important yield attribute as the current investigation indicates strong contribution of this variable on seed yield. Other investigations (Karikari, 1972; Wigglesworth, 1996; Karikari and Tabone, 2003) have also indicated the importance of higher poding in yields of Bambara groundnut although the variable indicated low heritability suggesting that selection for high pod number may be difficult.

Component compensation was noted in the relationships among seed size, pod number and yield of Bambara groundnut. Thus the non-significant relationship between seed size on yield was due to the sacrificial and unfavorable influence through pod number. Results suggest that if pod variation was to be held constant, increased seed size would increase yield. However, the consistent negative relationship between pod number and seed size compensated and sacrificed the relationship between seed size and yield. While Karikari and Tabone (2003) also reported high independent contribution of seed size on yield of Bambara groundnut, they found positive and significant correlation between seed size and yield. Differential environments and genotypes used might have contributed to the different responses. Various factors have been advocated in contributing to negative relationships among plant components including competition for ambient resources such as nutrients, moisture, light; genetic factors such as linkage and pleiotropy. Wigglesworth (1996) noted the importances of reducing inter and intraplant competition by raising the crop under stress free conditions so as to minimize yield sacrifice through component compensation.

Genetic improvement for more pods should be accompanied by optimum husbandry practices that minimize adverse relationships among components of yield in order to realize the benefits of genetic manipulation. Crossing, selfing and selection among segregates may break unfavorable linkages resulting to progenies combining genes of higher number of pods and larger seeds. The significant positive relationships among the seed size variables viz. weight of 100 seeds, seed width and seed length suggest that these variables are influenced by similar physiological and genetic patterns and that simultaneous selection for them can be done in a breeding programme.

The present investigation suggests that late flowering has a detrimental effect on seed yield of Bambara groundnut in the environment of investigation. In areas with marginal rains, earlier flowering confers an advantage of forming more pods and seeds and consequently higher yields. Early pod induction may cause plants to use assimilates for reproductive growth at the expense of continued vegetative growth. Flowering earliness in Bambara groundnut confers drought tolerance through drought escape according to reports of Karikari (1972) and Karikari and Tabone (2003).

Plant stature determines the number of nodes and sites where pod-bearing branches are formed. This study suggests that taller plants produce more pods emanating from more branching that in turn results to increased yield (Table 5 and 6). Breeders in these areas therefore, should develop earlier genotypes with architecture of Bambara groundnut varieties that are tall with more pods and longer foliage. However, the programmes should aim at developing genotypes producing amounts of pods that do not largely sacrifice seed size for optimum production of yield. Research is needed to investigate husbandry practices that minimize component compensation effects for realizing higher yields of Bambara groundnut. Studies should also be done under field conditions so as to investigate the consistency of such findings.

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REFERENCES

Azam-Ali, S.N., 1992. Evaluating the potential of Bambara groundnut (*Vigna subterranea* L. Verdc.) as a food crop for Semi-Arid Africa. Proc. 3rd SADC Regional Conference on Land and Water Management, Harare, October 1992, pp: 203-217.

Dewey, D.R. and K.H. Lu, 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. Agron. J., 51: 515-518.

Grafius, J.E., 1978. Multiple characters and correlated response. Crop Sci., 18: 931-934.

Hamid, Z.A. and J.E. Grafius, 1978. Development allometry and its implication to grain yield in barley. Crop Sci., 18: 83-86.

Karikari, S.K., 1972. Correlation studies between yield and some agronomic characters in Bambara groundnut (*Voandzeia subterranea* Thouars). Ghana J. Agric. Sci., 5: 79-83.

Karikari, S.K. and T.T. Tabone, 2003. Constutive traits and selective indices of bambara groundnut (*Vigna subterranean* (L.) Verdc. L.) landraces for drought tolerance under Botswana conditions. http://www.waternetonline.ihe.nl/docs/Papers2003/Warfsa-WaterNet%. Downloaded 10/10/2006.

Linnemann, A.R. and S.N. Azam-Ali, 1993. Bambara Groundnut (*Vigna subterranea* (L) Verdc) In: Underutilized Crops Series. II Vegetables and Pulses. Chapman and Hall, London.

Linnemann, A.R., 1994. Phenological development in Bambara groundnut (*Vigna subterranean*) at alternate exposure to 12 and 14 h photoperiods. J. Agric. Sci., 123: 333-340.

Mulila-Mitti J.M. and K. Kanenga, 1996. Towards improved bambara groundnut production in Zambia. In: Proceddings of the International Bambara Groundnut Symposium. University of Nottingham UK 23-25 July, 1996, pp: 193-200.

SAS, 1997. SAS Statistics Users Guide, Statistical Analysis System, 5th Edn., SAS Institute Inc. Carry, USA, pp: 1028.

Sesay, A., S.T. Collinson and S.N. Azam-Ali, 1996. Where are we now with bambara groundnut? In: Proceedings of the International Bambara Groundnut Symposium. University of Nottingham UK 23-25 July, 1996, pp: 215-228.

Squire, G.R., H. Connoly, J. Crawford, S.T. Collinson and A. Seay, 1996. Linking vegetative and reproductive trait variability in landraces of Bambara groundnut. In: Azam-Ali, S.N. (Ed.), Proceedings of the International Bambara groundnut symposium, University of Nottingham, U.K., pp: 201-213.

Stanton, W.R., J. Doughty, R. Orraca-Tetteh and W. Steele, 1966. *Voandzeia subterranea* Thouars. In: Food and Agric. Organization Rome, pp: 128-133.

Wigglesworth, 1996. The potential for genetic improvement of Bambara groundnut *Vigna subterranea* (L) Verdc.) in Botswana. In: Proceedings of the International Bambara Groundnut Symposium. University of Nottingham UK 23-25 July, 1996, pp: 181-191.

Wright, S., 1921. Correlation and causation. J. Agric. Res., 20: 557-585.