

# Contributions of Growth and Physiological Traits to Yield of Seven Bambara nut Landraces Grown Under the Tropical Humid Climate of Malaysia

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**Abstract** – Six introduced bambara nut landraces from Nigeria and one adapted variety from Malaysia were evaluated for their growth and yield characteristics in the tropical humid climate of Malaysia. Dry matter yield was correlated with number of leaves, plant height, leaf chlorophyll content, leaf area index, and total leaf area. While pod yield was correlated with days to 50% emergence, days to 50% flowering, number of flowers per plant, number of pods per plant and fresh pod weight per plant. Path analysis indicated that partitioning into direct and indirect effects resulted to total leaf area ( $r^2 = 0.62$ ) imparting a significant direct influence on dry matter yield. Similarly, fresh pod weight per plant ( $r^2 = 0.50$ ) has a high direct effect on pod yield. Leaf area index ( $r^2 = 0.47$ ) and total leaf area ( $r^2 = 0.65$ ) were both significantly correlated with dry matter yield while fresh pod weight per plant ( $r^2 = 0.63$ ) and number of pods per plants ( $r^2 = 0.48$ ) has a significant correlation with pod yield. Fresh pod weight per plant and total leaf area being a higher contributor to pod yield and dry matter yield of bambara nut respectively indicated their superiority to be selected for bambara nut improvement in the humid tropical climate of Malaysia.

**Keywords** – Correlation, Path Coefficient, Yield, Bambara Nut, Landraces, Humid Climate.

## I. INTRODUCTION

Bambara nut is a herbaceous plant that is indigenous to Africa (Jane *et al.*, 2012), it is regarded as the third most important legume crop after groundnut and cowpea (Alhassan *et al.*, 2012). The crop is commonly cultivated in the dry savannah belt of West Africa (Hillocks *et al.*, 2012) but now widely grown in Southern and Central Africa and is gradually becoming popular in Southeast Asian countries including Malaysia. The crop produces high yield levels with an estimated world production of 330,000 tonnes. It is used both for human and animal consumption (Bamshaiye *et al.*, 2012) as it has the latent to improve malnutrition and increase food accessibility. Its leaves are suitable for animal grazing as they are rich in nitrogen and phosphorus (Jakusko and Belel, 2009).

Many studies in bambara nut have focused on agronomic performance with little emphasis on the relationship between yield components. Also in the tropical humid climate of Malaysia, little is known about the relationship between yield and yield components of bambara nut that may help breeders in the selecting promising varieties. The path coefficient gives the relative contribution of various yields determining traits and enabling the decision between direct and indirect selection (Itai *et al.*, 2009). Ofori (1996) confirms that the primary components of seed yield in

legumes are number of pods per plant, number of seeds per pod and seed weight. The difference in pod yield and dry matter yield among landraces may require an analysis to ascertain the direct and partial contribution of some selected character to enable a better selection of varieties. The present study, therefore, seeks to investigate the contributions of some growth characters of bambara nut to yield through a correlation and path coefficient analysis studies. The concept of path coefficient analysis was originally developed by Wright (1921) but the technique was first used for plant selection by Dewey and Lu (1959). Path analysis is simply a standardized partial regression coefficient which splits the correlation coefficients into the measures of direct and indirect effects of a set of independent variables on the dependent variable. This information will help in the efficient selection of high yielding varieties of bambara nut in the study area.

## II. MATERIALS AND METHODS

The experiment was conducted between January and June 2014 at Ladang 2, It is located on 3° 02' N Latitude and 101° 43' East Longitude and altitude 31 m above sea level (Teh, 2010). The land was plowed and made into convenient ridges laid out in a randomized complete block design (RCBD) replicated three (3) times with seven landraces as treatments. The Songkla 1 seeds were indigenous to Malaysia that originated from Thailand while the introduced African landraces were all obtained from the northeastern part of Nigeria. The morphological appearance and color of the seeds of various landraces used in this experiment are as described in Table 1. The seeds are similar in size and shape except the Songkla1 variety which appeared smaller in size.

Table 1. Bambara landraces that were evaluated during the 2013/14 season at UPM Serdang, Malaysia.

Code	Name	Color
Kur	Kurvu	Red
Tan	Tanyanyi	Red with brown stripes
Kwa	KwadaZwanlang	Cream
Bam	Bambwus	Ash with brown stripes
Ind	IndaraAyaghayagha	Black
Son	Songkla1	Maroon
Kar	Karamagdanda	Brown

Each plot size measuring 12 m<sup>2</sup> was completely covered with plastic polythene mulch to control weeds. One seed was planted at a spacing of 50 cm between ridges and 30 cm within ridges. Phosphorus (Triple Super Phosphate) and

potassium (Muriate of Potash) fertilizers were applied during land preparation /before sowing at the rates of 65kg/ha and 200kg/ha respectively (Amjad *et al.*, 2014). Mean five (5) randomly selected plants were sampled to generate data and the yield measurements were obtained from a net plot size using a 0.25 m<sup>2</sup> quadrat. Samples for yield were oven dried at 70 °C for 48 hours and later weighed using a digital balance to obtain the pod yield and biomass yield. Data obtained were analyzed using SAS version 9.4. Correlation coefficient (r) was computed (Little and Hills, 1978) among all selected traits for both dry matter yield and pod yield; and path coefficient (P) was calculated as described by Dewey and Lu (1959) by solving the following equations:

$$\begin{aligned}
 P_{16} + r_{12}P_{26} + r_{13}P_{36} + r_{14} + P_{46} + r_{15}P_{56} &= r_{16} \\
 r_{12}P_{16} + P_{26} + r_{23}P_{36} + r_{24}P_{46} + r_{25}P_{56} &= r_{26} \\
 r_{13}P_{16} + r_{23}P_{26} + P_{36} + r_{34}P_{46} + r_{35}P_{56} &= r_{36} \\
 r_{14}P_{16} + r_{24}P_{26} + r_{34}P_{36} + P_{46} + r_{45}P_{56} &= r_{46} \\
 r_{15}P_{16} + r_{25}P_{26} + r_{35}P_{36} + r_{45}P_{46} + P_{56} &= r_{56} \\
 P_2X_6 + P_216 + P_226 + P_236 + P_246 + P_256 + 2P_{16}r_{12}P_{26} + \\
 2P_{16}r_{13}P_{36} + 2P_{16}r_{14}P_{46} + 2P_{16}r_{15}P_{56} + 2P_{26}r_{23}P_{36} + 2P_{26}r_{24}P_{46} + \\
 2P_{26}r_{25}P_{56} + 2P_{36}r_{34}P_{46} + 2P_{36}r_{35}P_{56} + 2P_{46}r_{45}P_{56} &= 1
 \end{aligned}$$

Where: P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub>, P<sub>4</sub>, and P<sub>5</sub> are path coefficients that measured the direct contribution of some phenological characters to pod yield in the first instance and P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub>, P<sub>4</sub> and P<sub>5</sub> are path coefficients measured the direct contribution of some growth and physiological characters to pod yield in the second instance.

r<sub>12</sub>... r<sub>56</sub> are coefficients of correlation that measured mutual association between two characters in the first instance,

- 1 = Days to 50% emergence.
- 2 = Days to 50% flowering.
- 3= Number of flowers per plant.
- 4 = Fresh pod weight per plant.
- 5 = Number of pods per plant.

6 = Pod yield per hectare;

And r<sub>12</sub>... r<sub>56</sub> are coefficients of correlation that measured mutual association between two characters in the second instance:

- 1 = Number of leaves.
- 2 = Plant height.
- 3= Leaf chlorophyll.
- 4 = Leave area index.
- 5 = Total leaf area.
- 6 = Dry matter yield per hectare.

### III. RESULTS

The correlation coefficient and path contribution (direct and indirect) of some bambara nut characters with respect to pod yield are shown in Table 2. Days to 50% emergence is not significantly correlated with pod yield ( $r^2 = 0.010$ ). Most contributions of days to 50% emergence were from the direct effect (P<sub>16</sub>) and indirectly through Days to 50% flowering (r<sub>22</sub>P<sub>26</sub>) (Figure 1). Days to 50% flowering had only an indirect path contribution to pod yield via days to 50% emergence (r<sub>22</sub>P<sub>26</sub>) (Figure 1). Number of flower per plant is not significantly correlated ( $r^2 = 0.28$ ) with pod yield (Table 3) but has a positive direct effect on pod yield (P<sub>36</sub> = 0.345) (Table 2). Fresh pod weight per plant, however, was significantly correlated to pod yield (Table 2) and had a direct effect on pod yield (P<sub>3</sub> = 0.505) (Table 3). Fresh pod weight per plant also contributed indirectly to pod yield through; number of flower per plant (r<sub>34</sub>P<sub>46</sub>) (Table 2) and number of pod per plant (r = 0.120) (Figure 1). Number of pods per plant is significantly correlated with pod yield ( $r^2 = 0.482^*$ ). It also has a direct path contribution (P<sub>56</sub> = 0.162) to pod yield (Figure 1). Its indirect effect was equally noticed to pod yield through number of flowers per plant ( $r^2 = 0.079$ ) (Table 3) and through fresh pod weight per plant (r<sub>45</sub>P<sub>46</sub>) (Table 2).

Table 2. Direct and indirect contribution of some phenological characters to Pod yield.

Code	Correlation and path relationship	Values
<b>Days to 50% emergence (DT50%E)</b>		
r <sub>16</sub>	Correlation coefficient between DT50%E and Pod yield	0.102
P <sub>16</sub>	Direct effect of DT50%E to Pod yield	0.326
r <sub>12</sub> P <sub>26</sub>	Indirect effect of DT50%E to Pod yield through DT50% Flowering	0.020
r <sub>13</sub> P <sub>36</sub>	Indirect effect of DT50%E to Pod yield through NOFPP	-0.150
r <sub>14</sub> P <sub>46</sub>	Indirect effect of DT50%E to Pod yield through FPWPP	-0.051
r <sub>15</sub> P <sub>56</sub>	Indirect effect of DT50%E to Pod yield through NPP	-0.043
<b>Days to 50% flowering(DT50%F)</b>		
r <sub>26</sub>	Correlation coefficient between DT50%F and Pod yield	-0.168
P <sub>26</sub>	Direct effect of DT50%F to Pod yield	0.172
r <sub>22</sub> P <sub>26</sub>	Indirect effect of DT50%F to Pod yield through DT50% emergence	0.039
r <sub>23</sub> P <sub>36</sub>	Indirect effect of DT50%F to Pod yield through NOFPP	-0.188
r <sub>24</sub> P <sub>46</sub>	Indirect effect of DT50%F to Pod yield through FPWPP	-0.166
r <sub>25</sub> P <sub>56</sub>	Indirect effect of DT50%F to Pod yield through NPP	-0.025
<b>Number of flowers per plant (NOFPP)</b>		
r <sub>36</sub>	Correlation coefficient between NOFPP and Pod yield	0.282
P <sub>36</sub>	Direct effect of NOFPP to Pod yield	0.345
r <sub>13</sub> P <sub>16</sub>	Indirect effect of NOFPP to Pod yield through DT50%E	-0.142
r <sub>23</sub> P <sub>26</sub>	Indirect effect of NOFPP to Pod yield through DT50%F	-0.094
r <sub>34</sub> P <sub>46</sub>	Indirect effect of NOFPP to Pod yield through FPWPP	0.135
r <sub>35</sub> P <sub>56</sub>	Indirect effect of NOFPP to Pod yield through NPP	0.037
<b>Fresh pod weight per plant (FPWPP)</b>		

Code	Correlation and path relationship	Values
r <sub>46</sub>	Correlation coefficient between FPWPP and Pod yield	0.632**
P <sub>46</sub>	Direct effect of FPWPP to Pod yield	0.505
r <sub>14P46</sub>	Indirect effect of FPWPP to Pod yield through DT50%E	-0.028
r <sub>24P26</sub>	Indirect effect of FPWPP to Pod yield through DT50%F	-0.057
r <sub>34P46</sub>	Indirect effect of FPWPP to Pod yield through NOFPP	0.093
r <sub>46P56</sub>	Indirect effect of FPWPP to Pod yield through NPP	0.119
<b>Number of Pods per plant (NPP)</b>		
r <sub>56</sub>	Correlation coefficient between NPP and Pod yield	0.482*
P <sub>56</sub>	Direct effect of NPP to Pod yield	0.162
r <sub>15P56</sub>	Indirect effect of NPP to Pod yield through DT50%E	-0.101
r <sub>25P26</sub>	Indirect effect of NPP to Pod yield through DT50%F	-0.027
r <sub>35P36</sub>	Indirect effect of NPP to Pod yield through NOFPP	0.079
r <sub>45P46</sub>	Indirect effect of NPP to Pod yield through FPWPP	0.370

NB: \* = significant at  $p = 0.05$ , \*\* highly significant at  $p = 0.01$ , DT50% E = Days to 50% emergence, DT 50% F = Days to 50% flowering, NOFPP = Number of flowers per plant, FPWPP = Fresh pod weight per plant, NPP = Number of Pods per plant.

Table 3. Direct and indirect contribution to pod yield.

	Days to 50% Emergence	Days to 50% Flowering	Number of flowers per plant	Number of Pods per Plant	Fresh Pod Weight Per Plant
Days to 50% Emergence	<b>0.32586</b>	0.038647	-0.14152	-0.10144	-0.02799
Days to 50% Flowering	0.020417	<b>0.17215</b>	-0.09358	-0.02684	-0.05657
Number of flowers per plant	-0.14994	-0.18767	<b>0.34524</b>	0.078611	0.092559
Number of Pods per Plant	-0.05056	-0.02532	0.036981	<b>0.16241</b>	0.118819
Fresh Pod Weight Per Plant	-0.04335	-0.16582	0.135291	0.369187	<b>0.50463</b>

Table 4 shows the correlation coefficient of the various characters studied to pod yield. Days to 50% emergence is not significantly correlated to Days to 50% flowering. However, number of flowers per plant is correlated to days to 50% emergence ( $r^2 = -0.434$ ) (Table 4) and also significantly correlated to days to 50% flowering ( $r^2 = 0.544$ ). Fresh pod weight per plant is also highly correlated to number of pods per plant ( $r^2 = 0.732$ ) (Table 4). Pod yield is only significantly correlated to number of pods per plant

( $r^2 = 0.482^*$ ) and highly correlated to fresh pod weight per plant ( $r^2 = 0.631^{**}$ ). Figure 1 also depicts the direct and the indirect path contribution of the selected characters to pod yield. It is seen that fresh pod weight per plant ( $P_4 = 0.504$ ), number of flowers per plant ( $P_3 = 0.345$ ) and Days to 50% emergence ( $P_1 = 0.325$ ) are the strong characters that gave a higher direct effect to pod yield. Other characters only had an indirect influence through one another to pod yield (Figure 1).

Table 4. Correlation coefficient of phenological and yield component characters.

Variable	Days to 50% emergence	Days to 50% flowering	Number of flowers per plant	Number of pods per plant	Fresh pod weight per plant	Pod yield per hectare
Days to 50% emergence	1					
Days to 50% flowering	0.1186	1				
Number of flowers per plant	-0.4343*	-0.5436*	1			
Number of pods per plant	-0.3113	-0.1559	0.2277	1		
Fresh pod weight per plant	-0.0859	-0.3286	0.2681	0.7316**	1	
Pod yield per hectare	0.1024	-0.168	0.2824	0.4819*	0.6314**	1

NB: \* = significant at  $p = 0.05$ , \*\* = highly significant at  $p = 0.01$

Table 5 explains the correlation coefficient and its paths partitioning into direct and indirect effects on dry matter yield of bambara nut grown in the humid tropical climate of Malaysia. In the Table, number of leaves is not significantly correlated to dry matter yield ( $r_{16}$ ). It is only seen to exert

its effect indirectly via leave area index ( $r_{14P46}$ ) (Table 5), and also through total leave area ( $r^2 = 0.282$ ) (Figure 2). Similarly, plant height ( $P_2$ ) (Figure 2) is not significantly correlated ( $r^2 = 0.254$ ) (Table 5) to dry matter yield but is seen to influence dry matter yield indirectly through leave

area index ( $r_{24P_{46}}$ ) (Table 5) and a very high indirect influence of total leaf area ( $r_{15P_{56}}$ ) (Figure 2). Leave chlorophyll was equally not significantly correlated to dry matter yield ( $r^2 = 0.076$ ) but exerts some direct effect on dry matter yield (Figure 2). It, however, has some indirect effect

on number of leaves,  $r_{13P_{16}}$  ( $r^2 = 0.002$ ) (Table 5). Plant height as well as total leaf area also connects to dry matter yield the indirect path contribution to leave chlorophyll with  $r^2 = 0.040$  and  $r^2 = 0.058$  respectively (Figure 2).

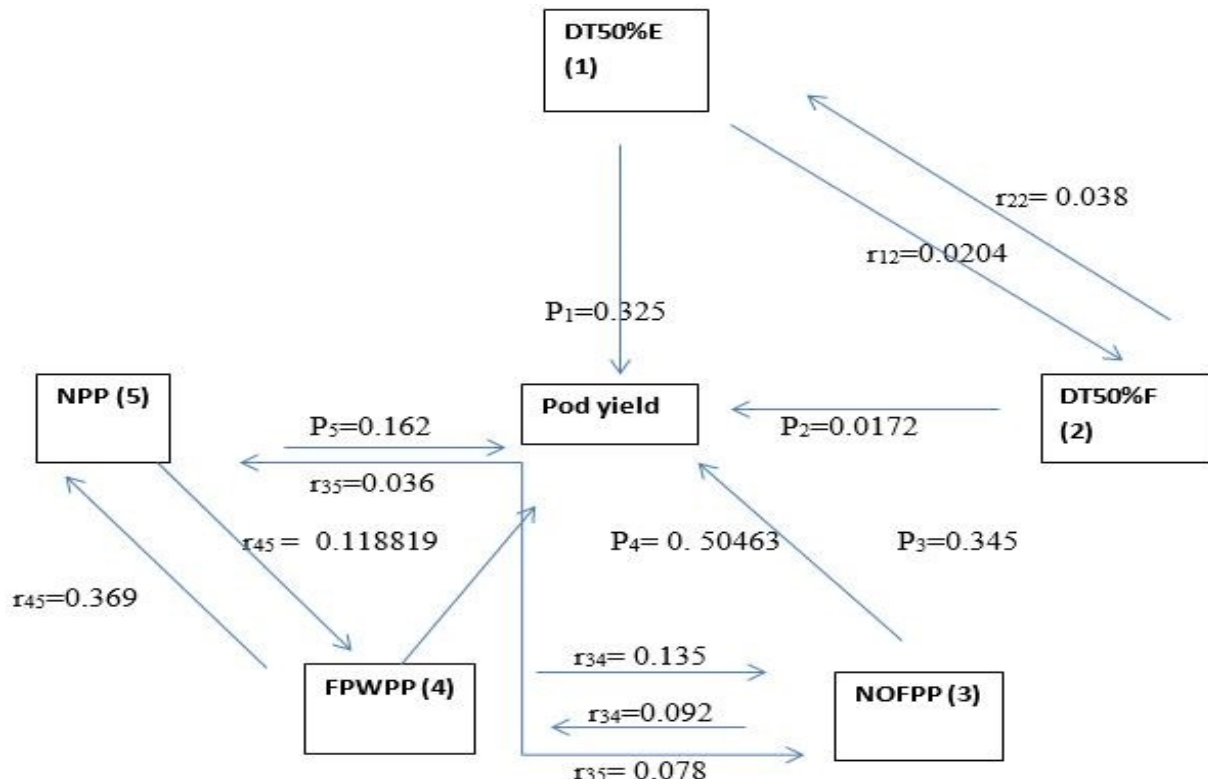


Fig. 1. A path diagram and coefficient of factors affecting total pod yield of Bambara groundnut (*Vigna subterranea L. verdc*)

NB: DT50%E (1) = Days to 50% emergence, DT50%F (2) = Days to 50% flowering, NOFPP (3) = Number of flowers per plant, FPWPP (4) = Fresh pod weight per plant, NPP (5) = Number of pods per plant,  $r$  = indirect effect,  $P$  = Direct effect.

Table 5. Direct and indirect contribution of some growth and physiological characters to Dry matter yield.

Code	Correlation and path relationship	Values
<b>Number of leaves(NOL)</b>		
$r_{16}$	Correlation coefficient between NOL and Dry matter yield (Dmy)	0.242
$P_{16}$	Direct effect of NOL and Dry matter yield	-0.005
$r_{12P_{26}}$	Indirect effect of NOL and Dry matter yield through plant height	-0.122
$r_{13P_{36}}$	Indirect effect of NOL and Dry matter yield through SPAD	-0.008
$r_{14P_{46}}$	Indirect effect of NOL and Dry matter yield through LAI	0.095
$r_{15P_{56}}$	Indirect effect of NOL and Dry matter yield through TLA	0.282
<b>Plant height</b>		
$r_{26}$	Correlation coefficient between plant height and DMY	0.254
$P_{26}$	Direct effect of plant height and DMY	-0.204
$r_{22P_{26}}$	Indirect effect of plant height and DMY through NOL	-0.003
$r_{23P_{36}}$	Indirect effect of plant height and DMY through SPAD	-0.006
$r_{24P_{46}}$	Indirect effect of plant height and DMY through LAI	0.143
$r_{25P_{56}}$	Indirect effect of plant height and DMY through TLA	0.324
<b>Leaf chlorophyll (SPAD)</b>		
$r_{36}$	Correlation coefficient between SPAD and DMY	0.076
$P_{36}$	Direct effect of SPAD and DMY	0.029
$r_{13P_{16}}$	Indirect effect of SPAD and DMY through NOL	0.002
$r_{23P_{26}}$	Indirect effect of SPAD and DMY through plant height	0.040
$r_{34P_{46}}$	Indirect effect of SPAD and DMY through LAI	-0.053
$r_{35P_{56}}$	Indirect effect of SPAD and DMY through TLA	0.058
<b>Leave Area Index(LAI)</b>		
$r_{46}$	Correlation coefficient between LAI and DMY	0.469*
$P_{46}$	Direct effect of LAI and DMY	0.300

Code	Correlation and path relationship	Values
r <sub>14</sub> P <sub>46</sub>	Indirect effect of LAI and DMY through NOL	-0.002
r <sub>24</sub> P <sub>26</sub>	Indirect effect of LAI and DMY through plant height	-0.097
r <sub>34</sub> P <sub>46</sub>	Indirect effect of LAI and DMY through SPAD	-0.005
r <sub>46</sub> P <sub>56</sub>	Indirect effect of LAI and DMY through TLA	0.274
<b>Total Leave Area (TLA)</b>		
r <sub>56</sub>	Correlation coefficient between TLA and DMY	0.647**
P <sub>56</sub>	Direct effect of TLA and DMY	0.621
r <sub>15</sub> P <sub>56</sub>	Indirect effect of TLA and DMY through NOL	-0.002
r <sub>25</sub> P <sub>26</sub>	Indirect effect of TLA and DMY through Plant height	-0.107
r <sub>35</sub> P <sub>36</sub>	Indirect effect of TLA and DMY through SPAD	0.003
r <sub>45</sub> P <sub>46</sub>	Indirect effect of TLA and DMY through LAI	0.132

NB: \*\*= highly significant at p=0.01, \*= significant at p=0.05, DMY= Dry matter yield, NOL =Number of leaves, SPAD =Leaf chlorophyll, LAI =Leave Area Index, TLA =Total Leave Area.

Table 6. Direct and indirect contribution to Dry matter yield.

	Number of leaves	Plant Height	Leave chlorophyll	Leave area index	Total leaf area
Number of leaves	<b>-0.00537</b>	-0.0032	0.001527	-0.00171	-0.00244
Plant Height	-0.12182	<b>-0.20412</b>	0.040171	-0.09716	-0.10649
Leave chlorophyll	-0.00809	-0.0056	<b>0.02846</b>	-0.00499	0.002664
Leave Area Index	0.095186	0.142614	-0.05255	<b>0.29961</b>	0.132008
Total Leaf Area	0.281864	0.323824	0.058098	0.273485	<b>0.62071</b>

Leave area index is significantly correlated ( $r^2 = 0.469^*$ ) to dry matter yield and path partitioning shows a direct contribution of leave area index ( $P_4 = 0.299$ ) (Table 5) to dry matter yield. It also had an indirect contribution to dry matter yield through total leave area ( $r_{46}P_{56}$ ) (Table 5) with  $r^2 = 0.273$ . Total leave area is further highly correlated to dry matter yield and the path partitioning further revealed its high direct effect on dry matter yield at  $P_5 = 0.620$  (Figure 2). It, however, recorded an indirect path contribution via leave chlorophyll content ( $r_{35}P_{36}$ ) (Table 5)

and leave area index ( $r_{45}P_{46}$ ) (Figure 2) with  $r^2 = 0.003$  and 0.132 respectively.

Table 6 further gave the direct and indirect contribution of selected characters to dry matter yield of bambara nut. Number of leaves and plant height witnessed a negative direct effect. Leave chlorophyll content, leave area index and total leave area had a positive direct contribution to bambara dry matter yield. Other indirect contributions are as shown in Table 6.

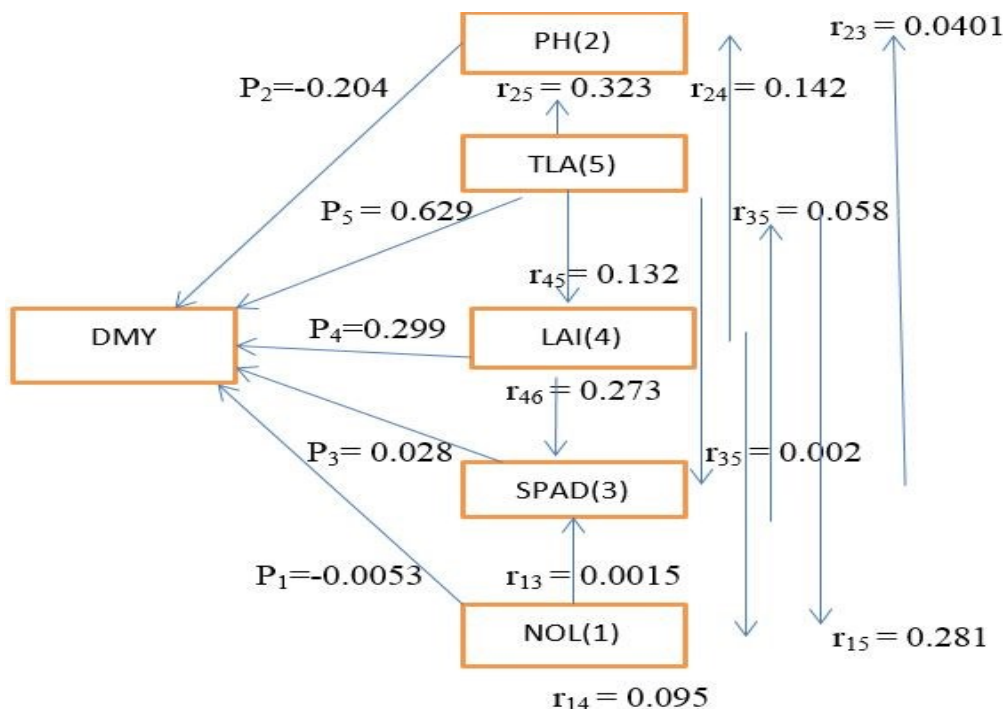


Fig. 2. A path diagram and coefficient of factors affecting total dry matter yield of bambara nut (*Vigna subterranea L. Verdc*).

NB: PH (2) = Plant height, TLA (5) = Total leave area, LAI (4) = Leave area index, SPAD (3) = Leave chlorophyll, NOL (1) = Number of leaves, DMY = Dry matter yield, r = indirect effect, P = Direct effect.

Table 7 shows the correlation coefficient of the selected characters for path analysis of dry matter yield of Bambara groundnut. Plant height is highly correlated ( $r^2 = 0.597^{**}$ ) to number of leaves. Leave area index is also significantly correlated ( $r^2 = 0.476^*$ ) with plant height. Total leaf area

shows a significant correlation with numbers of leave ( $r^2 = 0.454^*$ ), plant height ( $r^2 = 0.522^*$ ) and leave area index ( $r^2 = 0.441^*$ ). Dry matter yield shows a significant correlation to leave area index ( $r^2 = 0.469^*$ ) and a highly significant correlation to total leaf area ( $r^2 = 0.646^{**}$ ).

Table 7. Correlation coefficient of growth and physiological characters.

Variable	Number of leaves	Plant height	Leave chlorophyll	Leave area index	Total leaf area	Dry matter Yield/ha
Number of leaves	1.0000					
Plant height	0.5968**	1.0000				
Leave chlorophyll	-0.2844	-0.1968	1.0000			
Leave area index	0.3177	0.4760*	-0.1754	1.0000		
Total leaf area	0.4541*	0.5217*	0.0936	0.4406*	1.0000	
Dry matter Yield/ha	0.2418	0.2535	0.0757	0.4692*	0.6464**	1.0000

#### IV. DISCUSSION

Pod production is a very important stage in determining the yield of bambara nut (Wigglesworth, 1996; Karikari and Tabone, 2003). Days to 50% emergence, numbers of flowers per plant and fresh pod weight per plant appeared to be the most important components of pod yield in bambara nut. This goes contrary to the findings of (Ofori, 1996) who reported number of pods per plant, among others, to be an important yield component in legume pod yield. The direct contribution of number of flowers per plant and fresh pod weight to pod yield can equally be attributed to earliness in crop establishment in all the landraces as a most desirable trait for improved pod yield. Early crop establishment allows better vegetative growth as well as enhances early flower production. This coupled with good photosynthetic activity may translate to better pod yield. Itai *et al.* (2009) reported that selection for good plant establishment as a most desirable trait for improved pod yield. Thus, the direct contribution of days to 50% emergence to pod yield suggest better selection criteria for improved pod yield in bambara nut. As the number of flowers increases for all landraces so also the number of pods as well as fresh pod weight per plant increases which equally suggest a linear relationship between flower production and pod development. This probably may be due to the positive relation between the bambara crop and favorable environmental condition during growing season; hence the more the crop stayed green, the better the photosynthetic advantage in terms of grain filling. Anwar *et al.* (2009) earlier reported a positive correlation between days to maturity and grain yield under favorable environmental condition. The weak positive correlation between days to 50% emergence, days to 50% flowering and number of flowers as well as number of pods per plant to pod yield, probably reflects differences in performance of landraces to the environment. Bashir *et al.* (2001) reported a negative correlation between grain yield and days to maturity in forage legumes. Also (Zafarnaderi *et al.*, 2013) reported a negative relationship between days to

flowering and grain yield per plant in their studies in advanced wheat lines.

Plants growth characters such as plant height and number of leaves are basic morphological traits associated with dry matter. The negative direct effect of both number of leaves and plant height to dry matter yield of bambara nut seems to compromise the indirect contribution of both to dry matter yield through leave area index and total leaf area. Muhamman *et al.*, (2010) reported leaf area per plant was negative and negligible showing that the taller the plant, more branches were formed and lower leaves were shaded by the upper leaves. Ultimately, affecting the photosynthetic efficiency of the shaded lower leaves; leading to senescence and death. Number of leaves and plant height were positively correlated to dry matter yield in bambara nut. This result goes contrary to the findings of Muhamman *et al.*, (2010) that in sesame the higher the plant the more the branches and consequently more pods were produced which resulted in higher seed yield. It is the opinion of Maunde *et al.*, (2015) that the negative relationship among plant components could result from competition for ambient resources such as nutrients, moisture, light, genetic factors such as linkages and pleiotropy. Leave chlorophyll, however, turned a negative indirect contribution through leave area index. This may be connected to the evergreen response of the vegetation to the favorable environment during its growth cycle and this may have subsequently contributed to a better energy conversion into the dry matter during energy synthesis (Photosynthesis). Interestingly, the significant correlation of leave area index and total leaf area to dry matter as well as their positive direct contribution makes them important as a factor in this study for selecting a trait for bambara nut dry matter yield.

#### V. CONCLUSION

Significant and positive correlation between some characters such as total leaf area and leave area index to dry matter yield whereas number of pods per plant, fresh pod weight per plant were positively correlated with pod

yield. When this correlation coefficient was partitioned into direct and indirect effects, total leaf area had the highest contribution to dry matter yield then followed by leaf area index. Similarly, when correlation coefficient for pod yield was partitioned into direct and indirect effect, fresh pod weight per plant gave the highest contribution, then followed by days to 50% emergence and number of flowers per plant which both are at par. This, therefore, indicates that for bambara nut improvement, total leaf area, and leaf area index should be selected for dry matter yield, whereas fresh pod weight per plant, days to 50% emergence and number of flowers per plant be selected for higher pod yield.

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### Appendices

Appendix 1. Morphological and Physiological characters of seven bambara nut Landraces grown in humid climates of Malaysia

Source	Df	PH (cm)	NOL	TLA(cm <sup>2</sup> pl <sup>-1</sup> )	LAI	SPAD	DMY(kg ha <sup>-1</sup> )
Replications	2	29.47ns	2627.86ns	3167.18ns	2.56**	17.06ns	466013.24ns
Varieties	6	8.14*	17315.44*	1160.78ns	0.08ns	16.73ns	274248.73ns
Error	12	4.28	7754.96	1081.22	0.04	30.80	131978.06
<b>Varieties</b>							
Bambwus		27.47b	311.80abc	159.88	1.94	46.23	1924.20
KwadaZwalang		29.73ab	318.60abc	163.71	1.75	43.13	1843.10
Kurvu		28.80ab	282.00bc	212.11	2.01	45.20	2342.50
Tanyanyi		29.20ab	453.20a	165.61	2.19	40.30	1735.90
IndaraAyaghayagha		31.33a	364.40ab	174.76	2.05	47.00	1840.50
Songkla l		26.27b	207.00c	154.88	1.71	46.20	1505.90
Karamagdanda		29.67ab	294.60bc	158.34	1.93	46.00	1419.60
LSD (0.05)		3.68	156.66	ns	ns	ns	ns

**NB:** Means within columns with similar letters are not significantly different (p=0.05), DF = degrees of freedom, PH = plant height, TLA = Total leaf area, LAI = Leaf Area index, SPAD = Leaf chlorophyll, DMY = Dry matter yield.

Appendix 2: Some phonological and pod characters of seven bambara nut landraces grown in humid climates of Malaysia

Source	Df	Days to 50% emergence	Days to 50% flowering	NOFPP	FPWPP (g m <sup>2</sup> )	NPP	PY (kg ha <sup>-1</sup> )
Replications	2	0.33ns	27.19**	17.40ns	10921.05**	125.52ns	197752.29**
Varieties	6	4.19**	41.60**	35.95ns	2239.57**	136.79*	64637.65*
Error	12	0.66	0.91	21.25	410.00	37.42	18816.07
<b>Varieties</b>							
Bambwus		8.00b	46.66c	16.53ab	132.00a	18.75a	1173.90ab
KwadaZwalang		7.00bc	47.00c	15.46ab	49.58c	5.25b	964.70bc
Kurvu		7.00bc	50.00b	14.53ab	96.75ab	19.75a	1349.00a
Tanyanyi		7.00bc	47.33c	18.40a	73.67bc	5.75b	977.80bc
IndaraAyaghayagha		6.00c	45.66c	18.46a	98.58ab	19.75a	1098.00bc
Songkla1		7.00bc	56.66a	9.20b	63.58bc	9.67ab	925.50c
Karamagdanda		10.00a	49.33b	11.53ab	74.42bc	7.67b	1095.40bc
LSD (0.05)		1.45	1.69	8.20	36.03	10.88	244.03

NB: Means within columns with similar letters are not significantly different (P=0.05), DF = degrees of freedom, NOFPP = Number of flowers per plant, FPWPP = Fresh pod weight per plant, NPP = Number of pods per plant, PY = Pod yield.

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