Correlation and path-coefficient analyses of yield and vegetative traits of tall coconut accessions

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ABSTRACT

As a result of the prolonged gestation period of coconut, there is need to make selection for coconut improvement with the vegetative traits at pre-flowering stage. Therefore, the objective of this study was to evaluate the contributions of vegetative traits to components of yield in coconut. Coconut palm accessions of the tall type collected from South West (SW; n = 22), South East (SE; n = 17), North Central I (NCI; n = 20) and North Central II (NCII; n = 19) were evaluated over two years. The fruit and vegetative traits were evaluated using ANOVA, correlation and the path coefficient analyses. ANOVA indicated that there was significant difference for all traits evaluated at the locations. The coefficient of variation expatiated that the level of variability was lower in the vegetative traits (6.29–12.40%) than the fruit traits (30.73–54.99%). There was high positive significant correlation between the fruit weight per hectare and the other fruit yield components evaluated; husk weight (0.74; $P < 0.01$), nut weight (0.88; $P < 0.01$), split nut weight (0.86; $P < 0.01$), water volume (0.77; $P < 0.01$), fresh meat weight (0.82; $P < 0.01$) and copra weight (0.76; $P < 0.01$). Thus, selection for high fruit weight will accelerate improvement for other components of yield. There was significant positive correlation between fruit weight and each of number of fronds (0.27; $P < 0.05$), crown diameter (0.24; $P < 0.05$) and leaf spread (0.24; $P < 0.05$) while petiole length and leaflet length had negative significant correlation with nut weight (-0.30; $P < 0.01$, -0.28; $P < 0.05$), split nut weight (-0.34; $P < 0.01$, -0.29; $P < 0.05$), fresh meat weight (-0.38; $P < 0.01$, -0.32; $P < 0.01$), copra weight (-0.34; $P < 0.01$, -0.30; $P < 0.01$) and coconut water volume (-0.26; $P < 0.05$, -0.30; $P < 0.01$) which were other components of yield in the accessions evaluated. Path analysis indicated that the vegetative traits would not be effective in selecting for yield in coconut at the pre-flowering stage.

Keywords: Accessions, selection, fruit weight, leaf spread, crown diameter, number of fronds

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INTRODUCTION

Coconut (*Cocos nucifera* L. Jacq) is one of the most important tree crops in the world. It is called the king of the tropics because of its versatile uses in the tropics. Like most palms, it is grown in the tropics at latitude 23° North and South of the equator (Chan and Elevitch, 2006). Although all the parts of the coconut are useful for domestic and industrial purposes, the principal products of the coconut palm come from the whole matured fruit. The principal commercial product derived from coconut palm is the copra. It is the source of coconut oil (Phothichitto, 2006) which is a highly saturated fatty acid oil. Copra was the major item on the international market as a source of oil for domestic and industrial uses such as soap, candle making and glycerine for cosmetics (Odewale *et al.,* 2014).

In coconut, breeding for improved cultivars is targeted at the improvement in the quality of the fruit. This is because the fruit is the main economic part of the crop and also, because of the high genetic variability that exists in the fruit which is heritable (Zizumbo-Villarreal and Piñero, 1998; Geethanjali *et al.,* 2014; Odufale *et al.,* 2021). However, it is pertinent and instructive to understand the contributions and influence of vegetative traits on fruit traits. In recent times, the liquid endosperm or coconut water as it is often called is highly sought after because of its health benefits and also being a good source of natural energy drink. It is a refreshing and nutritious beverage. It rehydrates when taken as juice and can be used for intravenous hydration of patients in remote regions (Yong *et al.,* 2009). It is widely used as a growth promoter in the plant tissue culture industry (Dahamarudin and Rivaie, 2013). The high demand for coconut water has hitherto made it a very important part of the coconut. Hence, breeding coconut varieties with high water yielding capacity would be acceptable to coconut farmers. Coconut husk is useful as raw materials in various industries such as agriculture; as a high-quality planting medium in nursery and greenhouse plant culture. Coconut briquettes made from coconut husk are a good replacement for coal in homes for cooking. Coconut coir, the soft fibre between the shell and the outer layer of the husk is used to make mats, matting, carpets, high tensile strength ropes, and brushes for homes. It is also useful as a packing material and as a thermal insulator (Satyanarayana *et al.,* 1981).

In coconut breeding, the selection and development of coconut cultivars that will have genetic gain in the yield components will be prime. Breeders need to identify causes of variability in yield in any given environment before any improvement in yield can be realized. Fluctuations in the environment influences yield primarily through the yield components. Yield contributing components are interrelated with each other showing a complex chain of relationships (Machunde, 2013). A simple measure of the correlation of characters does not quantify the relative contribution of causal factors to the ultimate yield. Since the component traits themselves are inter-dependent, this often affects their direct relationship with yield and consequently restricts the reliability of selection indices based upon correlation coefficients. Information on character association is a prerequisite for initiating a successful breeding program aiming to develop high-yielding varieties (Odewale *et al*., 2014). Path coefficient analysis quantifies the inter-relationships of different components and their indirect effects on yield. It partitions relationships between components into direct and indirect effects. This analysis is used to understand the complex relationships among traits (Streiner, 2005; Madeni *et al.,* 2017). Moreover, coconut has a prolonged gestation period. Hence, there is a need to make the selection for coconut improvement with the vegetative traits at the pre-flowering stage. Therefore, the objective of this study was to evaluate the contributions of vegetative traits to components of yield in coconut.

MATERIALS AND METHODS

The study was conducted over a period of two years (2016–2018) at the Coconut Experimental Station of the Nigerian Institute for Oil Palm Research (NIFOR) in Badagry. The field is located on latitude 6.49°N and longitude 2.96°E. Sets of 78 coconut accessions from four (4) different ecological locations in Nigeria, i.e., South West (SW), South East (SE), North Central I (NCI) and North Central II (NCII) were evaluated at over 20 years after planting after they had attained steady and regular fruiting in all the accessions. The accessions evaluated and their locations are listed in Table 1.

In each of the accessions, data were collected and recorded for the following vegetative traits in metre (m) using measuring tape: petiole length (PL; the length of the leaf petiole from point of attachment to the tree to the point of the first leaflet insertion), frond length (FL; the entire length of the whole frond), leaf spread (LS; the width of the frond at the middle where it is widest), crown diameter [CDM; this is measured using two poles positioned North South (NS) and another set positioned East West (EW) measuring the dimensions of the crown at these cardinals]. The average is given as the

CDM [(NS + EW)/2 = CDM], and the number of leaf fronds produced per annum (NF) was counted.

Fruit component analysis was carried out using five (5) matured fruits at 11–14 months after pollination from each of the accessions. From each of the selected fruits from each of the accessions, the following fruit traits were evaluated and recorded and estimated in tonne per hectare (t ha^{-1}) using an electronic scale. The weight of the whole fruit was measured to get the fruit weight (FWT). After which the mesocarp was separated from the kernel. The mesocarp (husk) was weighed as husk weight (HWT) and the kernel as nut weight (NWT). The kernel was split opened and the water was removed. The kernel without water was regarded as the split nut weight (SNT) and the coconut water was measured using a measuring cylinder and the volume of water (WV) was measured and expressed in metre cube per hectare (m^3 ha^{-1}). The white flesh of the kernel (fresh meat) was removed, and the weight was regarded as fresh meat weight (FMW). The fresh meat was oven dried at 106°C until a constant weight was achieved. The weight of oven-dried coconut meat was measured as the copra weight (CW). All measurements were later expressed as tonne per hectare (t ha^{-1}) except the coconut water which was expressed as metre cube per hectare (m^3 ha^{-1}) derived from the annual yield record of each of the accessions.

Table 1 List of selected palms from the South West, South East, North Central I and North Central II accessions obtained at the Coconut Experimental Station of the Nigerian Institute for Oil Palm Research in Badagry Lagos State

Replication	South West	South East	North Central I	North Central II
1	1135A	2B	2C	152D
2	1060A	3B	4C	155D
3	1061A	5B	5C	157D
4	1056A	7B	6C	162D
5	987A	8B	7C	177D
6	545A	43B	8C	178D
7	382A	114B	14C	180D
8	622A	117B	15C	195D
9	505A	94B	21C	203D
10	376A	148B	28C	205D
11	753A	152B	32C	221D
12	768A	196B	44C	250D
13	386A	250B	46C	254D
14	1057A	258B	57C	260D
15	305A	295B	60C	261D
16	422A	296B	97C	263D
17	385A	205B	100C	278D
18	373A		102C	154D
19	384A		105C	262D
20	280A		106C	
21	662A			
22	1146A			

Data Analysis

The data generated were summarized and subjected to analysis of variance (ANOVA) using the general linear model (GLM) procedure. The least squares mean generated from Duncan's Multiple Range Test of comparing mean was used to compare the mean of the traits at the different locations because of the inequality in the number of accessions per location. The data were further subjected to a correlation analysis using SPSS statistical software after which path coefficient analysis was generated using the procedure described by Streiner (2005), Xue (2007), Williams (2015) and Madeni *et al.* (2017). In the path analysis, fruit weight was the dependent variable while the vegetative traits were the predictor variables (Figure 1). The total correlations between fruit weight and vegetative traits were partitioned into direct and indirect effects by the equations below:

$$r_{Y2} = P_{Y2} + P_{Y3}r_{23} + P_{Y4}r_{24} + P_{Y5}r_{25} + P_{Y6}r_{26}$$
$$r_{Y3} = P_{Y3} + P_{Y2}r_{32} + P_{Y4}r_{34} + P_{Y5}r_{35} + P_{Y6}r_{36}$$
$$r_{Y4} = P_{Y4} + P_{Y2}r_{42} + P_{Y3}r_{43} + P_{Y5}r_{45} + P_{Y6}r_{46}$$
$$r_{Y5} = P_{Y5} + P_{Y2}r_{52} + P_{Y3}r_{53} + P_{Y4}r_{54} + P_{Y6}r_{56}$$
$$r_{Y6} = P_{Y6} + P_{Y2}r_{62} + P_{Y3}r_{63} + P_{Y4}r_{64} + P_{Y5}r_{65}$$

where r_{Yi} represents the sum of the total direct effect and indirect effect of variable (i^{th}) on the dependent variable (Y). Coefficients given by P_{Yi} are the direct path coefficients between independent variable i^{th} and dependent variable Y. $P_{Yi}r_{ij}$ represents the indirect effects of independent variable i^{th} on dependent variable Y via j^{th} independent variable.

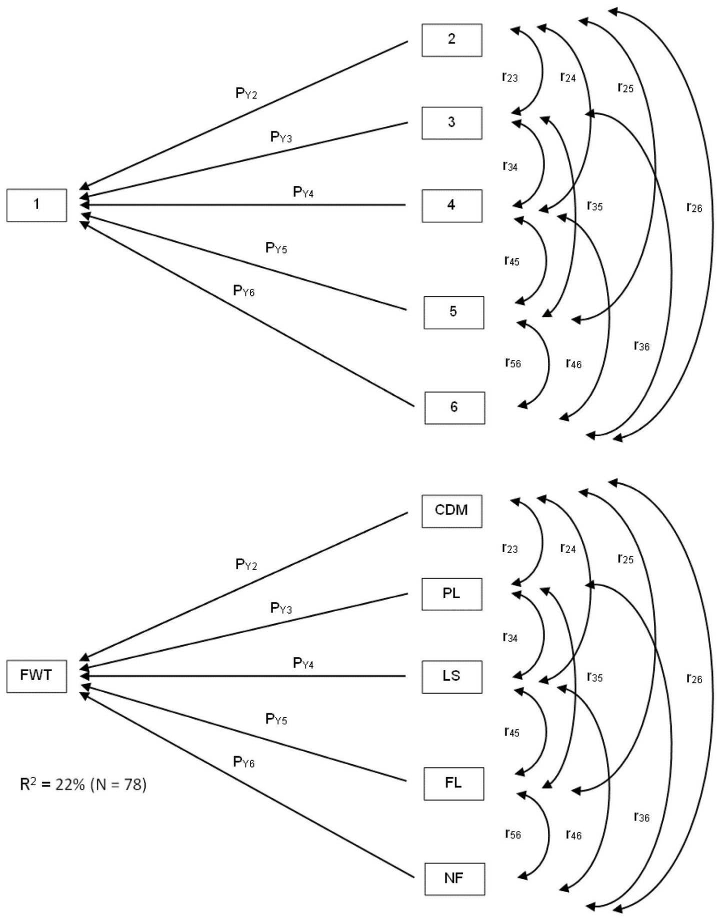

Figure 1 Path analysis diagram of the direct and indirect effect of coconut vegetative traits on fruit weight. FWT = fruit weight, CDM = crown diameter, PL = petiole length, LS = leaf spread, FL = frond length, NF = number of fronds.

RESULTS AND DISCUSSION

Analysis of Variance

The result of ANOVA (analysis of variance) indicated that there was a highly significant difference for all the traits evaluated at the different locations ($P < 0.01$) except for CDM which was significant at $P < 0.05$ (Table 2). There was high variability among the traits evaluated with the ANOVA model suitably explaining more than 50% variability in most of the traits (x: x ≥ R^2 ≥ 50%) except for the number of fronds, crown diameter and husk weight which were lesser (x: x ≥ 40% ≤ R^2 ≤ 50%). The CV expatiated that the level of variability was lower in the vegetative traits (NF = 9.22%, PL = 11.75%, FL = 6.29%, LS = 12.40%, and CDM = 9.63%) than the fruit traits (FWT = 32.52%, HWT= 41.98%, NTW = 34.35%, SNT = 33.12%, WV = 54.99%, SWT = 30.73%, FMW = 35.80%, and CW = 35.64%). It can be implied that the low variability in the vegetative traits relative to the fruit traits was a result of the high impact of environmental factors on vegetative traits than the fruit traits. This is in support of the findings of Geethanjali *et al.* (2014).

Table 2 Mean squares derived from analysis of variance (ANOVA) for vegetative and fruit traits of 78 coconut accessions selected from four locations: South West, South East, North Central I and North Central II accessions obtained at the Coconut Experimental Station of the Nigerian Institute for Oil Palm Research in Badagry Lagos State

Source	df	NF	PL	FL	LS	CDM	FWT	HWT	NWT	SNT	WV	SWT	FMW	CW
Location	3	38.32**	0.32**	1.04**	7.42**	1.39*	525.18**	79.19**	109.66**	56.49**	11.91**	4.28**	31.41**	8.33**
Replication	21	10.27^{ns}	0.87^{ns}	0.16*	0.04^{ns}	0.43^{ns}	21.47^{ns}	9.22^{ns}	7.46^{ns}	4.06^{ns}	0.83^{ns}	0.38^{ns}	2.08^{ns}	0.72^{ns}
Error	53	7.63	0.02	0.08	0.04	0.38	27.90	9.20	7.15	4.00	0.98	0.37	2.11	0.73
R^2		0.44	0.60	0.61	0.92	0.41	0.59	0.48	0.56	0.55	0.50	0.53	0.55	0.51
CV (%)		9.22	11.75	6.29	12.40	9.63	32.52	41.98	34.35	33.12	54.99	30.73	35.80	35.64

Note: ns = not significant, * significant at $P < 0.05$, ** significant at $P < 0.01$. NF = number of fronds, PL = petiole length, FL = frond length, LS = leaf spread, CDM = crown diameter, FWT = fruit weight, HWT = husk weight, NWT = nut weight, SNT = split nut weight, WV = water volume, SWT = shell weight, FMW = fresh meat weight, CW = copra weight, CV = coefficient of variation.

Least Squares Mean of Traits at the Different Locations

Among the evaluated accessions, the SW accessions were prolific and high yielding with annual fruit weight production of 22.60 t ha^{-1} and nested by NCII accessions (17.74 t ha^{-1}) while the SE and NCI accessions had 12.79 and 11.10 t ha^{-1}, respectively (Table 3). The component of the yield of the SW accessions outperformed all the other accessions in all components of yield except the husk yield in which the NCII accessions were better. The yields of accessions involved in this study outperform the national average yield in Indonesia and the yield of the SW accessions is comparable to the yield of elite tall coconut varieties in Indonesia (Alouw and Wulandari, 2020).

Table 3 Least squares mean for vegetative and fruit traits of 78 coconut accessions selected from South West, South East, North Central I and North Central II accessions obtained at the Coconut Experimental Station of the Nigerian Institute for Oil Palm Research in Badagry Lagos State

Traits	South West	South East	North Central I	North Central II	SEM
NF	31.50^{a}	29.96^{ab}	28.65^{b}	28.50^{b}	0.35
PL (m)	0.94^{b}	0.98^{b}	1.17^{a}	1.19^{a}	0.02
FL (m)	4.22^{b}	4.32^{b}	4.62^{a}	4.71^{a}	0.04
LS (m)	1.84^{a}	0.58^{b}	1.89^{a}	1.96^{a}	0.07
CDM (m)	6.59^{a}	6.04^{b}	6.32^{ab}	6.65^{a}	0.08
FWT (t ha^{-1})	22.60^{a}	12.79^{c}	11.10^{c}	17.74^{b}	0.78
HWT (t ha^{-1})	7.89^{a}	6.01^{b}	5.86^{b}	10.27^{a}	0.40
NWT (t ha^{-1})	10.81^{a}	6.74^{bc}	5.25^{c}	7.38^{b}	0.38
SNT (t ha^{-1})	8.18^{a}	5.68^{b}	4.12^{c}	5.62^{b}	0.28
WV (m^{3} ha^{-1})	2.82^{a}	1.15^{b}	1.15^{b}	1.67^{b}	0.13
SWT (t ha^{-1})	2.55^{a}	1.85^{b}	1.42^{c}	1.96^{b}	0.08
FMW (t ha^{-1})	5.66^{a}	3.82^{b}	2.66^{c}	3.58^{bc}	0.20
CW (t ha^{-1})	3.21^{a}	2.29^{b}	1.65^{c}	2.24^{b}	0.11

Note: ^{a,b,c}Least squares means with different superscript letters in a row indicate statistically significant difference at P < 0.05. NF = number of fronds, PL = petiole length, FL = frond length, LS = leaf spread, CDM = crown diameter, FWT = fruit weight, HWT = husk weight, NWT = nut weight, SNT = split nut weight, WV = water volume, SWT= shell weight, FMW = fresh meat weight, CW = copra weight, SEM = standard error of means.

Correlation Analysis

In this study, fruit weight influences all other yield components greatly. It had a significantly high positive correlation with all evaluated yield components. Fruit weight had the highest correlation coefficient with nut weight (0.88; P < 0.01) and split nut weight (0.86; P < 0.01) which are the major component of yield in coconut. The correlation coefficient with the other fruit yield components per hectare are husk weight (0.74; P < 0.01), water volume (0.77; P < 0.01), fresh meat weight (0.82; P < 0.01) and copra weight (0.76; P < 0.01; Table 4).

Table 4 Phenotypic correlation of fruit yield components of 78 coconut accessions from South West, South East, North Central I and North Central II accessions obtained at the Coconut Experimental Station of the Nigerian Institute for Oil Palm Research in Badagry Lagos State

Traits	HWT	NWT	SNT	WV	FMW	CW
FWT	0.74**	0.88**	0.86**	0.77**	0.82**	0.76**
HWT		0.40**	0.40**	0.24*	0.30**	0.30**
NWT			0.98**	0.91**	0.97**	0.92**
SNT				0.84**	0.99**	0.95**
WV					0.87**	0.77**
FMW						0.95**

Note: * Significant at P < 0.05, ** significant at P < 0.01. FWT = fruit weight, HWT = husk weight, NWT = nut weight, SNT = split nut weight, WV = water volume, FMW = fresh meat weight and CW = copra weight.

Among the fruit yield components evaluated, the NWT had the highest correlation coefficient with other fruit yield components. It had coefficient of 0.98 (P < 0.01), 0.91 (P < 0.01), 0.97 (P < 0.01) and 0.92 (P < 0.01) with SNT, WV, FMW and CW, respectively. The correlation coefficient of SNT with other fruit yield components are WV (0.84; P < 0.01), FMW (0.99; P < 0.01) and CW (0.95; P < 0.01). The CW was highly correlated with FMW and WV with r = 0.95 (P < 0.01) and 0.77 (P < 0.01), respectively (Table 4). Palm accessions with high fruit weight per hectare will have increased fresh meat weight, copra weight, husk weight, and high water volume per hectare. Selection for high fruit weight will bring about selection for other components of yield. It would rapidly enhance selection gain per cycle in the coconut improvement programme for more traits at a time. These findings corroborated the findings of Zizumbo-Villarreal and Piñero (1998) and Ranasinghe and Premasiri (2015) who suggested that coconut cultivars with fewer fruit numbers per palm per annum but with high fruit weight could in the long run yield higher coconut fresh meat weight and copra weight per palm per annum than cultivars with smaller fruit weight but more number of fruits.

The number of fronds produced by coconut accessions was essential for increased yield as evident in the positive correlation coefficient between the number of fronds produced per accession and the various yield components (NWT, SNT, FMW, CW, and WV). However, the number of fronds per accession had no significant correlation with the other vegetative traits evaluated except the petiole length (-0.30; P < 0.01). However, the PL had significant positive correlation coefficient with frond length (0.68; P < 0.01), leaflet length (LL: 0.34; P < 0.01), leaf spread (0.38; P < 0.01) and crown diameter (0.28; P < 0.05). Similarly, the frond length had positive significant correlation with some evaluated vegetative traits, i.e., number of leaflet (NL: 0.39; P < 0.01), LL (0.71; P < 0.01), LS (0.32; P < 0.01) and CDM (0.37; P < 0.01). The CDM had a significant coefficient of correlation with LS (0.40; P < 0.01) in addition to PL and FL which had already been stated (Table 5).

The FWT had a positive significant correlation with the number of fronds, leaf spread, and crown diameter of the coconut palm. However, among the evaluated vegetative traits, the NF was significantly positively correlated with all the fruit traits or fruit yield components except the HWT where the correlation coefficient was not significant. The correlation coefficient of the NF and the fruit yield components are: FWT (0.27; P < 0.05), NWT (0.32; P < 0.01), SNT (0.34; P < 0.01), WV (0.26; P < 0.05), FMW (0.34; P < 0.01) and CW (0.34; P < 0.01). The petiole length and leaflet length were negatively influenced the fruit yield components. The PL had negative significant correlation coefficient with NWT (-0.30; P < 0.01), SNT (-0.34; P < 0.01), WV (-0.26; P < 0.05), FMW (-0.38; P < 0.01) and CW (-0.34; P < 0.01) while the LL had significant negative coefficient of correlation with NWT (-0.28; P < 0.05), SNT (-0.29; P < 0.05), WV (-0.30; P < 0.01), FMW (-0.32; P < 0.01), CW (-0.30; P < 0.01) and FWT (-0.18; P < 0.08) which is not significant. The number of leaflet and crown diameter were significantly correlated to only one fruit yield component each HWT (0.32; P < 0.01) and FWT (0.24; P < 0.05), respectively. LS had positive significant correlation with FWT (0.24; P < 0.05; Table 6)

Table 5 Phenotypic correlation of vegetative traits of 78 coconut accessions from South West, South East, North Central I and North Central II accessions obtained at the Coconut Experimental Station of the Nigerian Institute for Oil Palm Research in Badagry Lagos State

Traits	PL	FL	NL	LL	LS	CDM
NF	-0.30**	-0.22	0.002	-0.14	-0.10	0.05
PL		0.68**	0.20	0.34**	0.38**	0.28*
FL			0.39**	0.71**	0.32**	0.37**
NL				0.15	0.12	0.17
LL					0.13	0.15
LS						0.40**

Note: * Significant at P < 0.05, ** significant at P < 0.01. NF = number of fronds, PL = petiole length, FL = frond length, NL = number of leaflets, LL = leaflet length, LS = leaf spread, CDM = crown diameter

Table 6 Phenotypic correlation of vegetative and fruit yield component traits of 78 coconut accessions South West, South East, North Central I and North Central II accessions obtained at the Coconut Experimental Station of the Nigerian Institute for Oil Palm Research in Badagry Lagos State

Traits	NF	PL	FL	NL	LL	LS	CDM
HWT	0.04	0.15	0.21	0.32**	0.12	0.32**	0.18
FWT	0.27*	-0.17	-0.09	0.09	-0.18	0.24*	0.24*
NWT	0.32**	-0.30**	-0.19	-0.02	-0.28*	0.04	0.14
SNT	0.34**	-0.34**	-0.22	-0.02	-0.29*	-0.03	0.13
WV	0.26*	-0.26*	-0.21	-0.12	-0.30**	0.15	0.13
FMW	0.34**	-0.38**	-0.26*	-0.06	-0.32**	-0.06	0.09
CW	0.34**	-0.34**	-0.24*	0.01	-0.30**	-0.05	0.13

Note: * Significant at P < 0.05, ** significant at P < 0.01. NF = number of fronds, PL = petiole length, FL = frond length, NL = number of leaflets, LL = leaflet length, LS = leaf spread, CDM = crown diameter, FWT = fruit weight, HWT = husk weight, NWT = nut weight, SNT = split nut weight, WV = water volume, FMW = fresh meat weight, CW = copra weight.

The efficiency of the crop in this regard to apportioning assimilates into the dry matter and vegetative part is genetic (Jayasekara *et al*., 1996; Ranasinghe and Premasiri, 2015). According to Ranasinghe and Premasiri (2015), the competition for assimilates between fruit and vegetative part of the crop is high and accessions with increased ability to divert a chunk of assimilates produced per palm to the fruit will have increased fruit set and yield.

The leaf spread of the coconut frond was the essential part of the tree for photosynthesis and the production of assimilates for the crop's use. Accessions with wide leaf spread had higher portion of leaf exposed for photosynthesis. This, no doubt is reflected in the significant positive correlation between the leaf spread and both HWT and FRT. However, crown diameter, which was an indication of how the frond is positioned and extended on the palm had a positive significant correlation with FWT but not significant with HWT and other fruit yield components evaluated. This could be as a result of differences in the diameter of the different shapes of crown diameters present in the accessions as a result of differences in the angle of inclination of the palm frond to the trunk. According to Odewale *et al.*

(2012), the shape of the crown diameter affected yield in coconut. Bigger-sized frond accessions had longer petiole length, frond length and leaflet length which had positive correlation coefficient with one another but had negative influences on the fruit yield components (Ahanon *et al.,* 2016). The bigger-sized fronds compete more with the fruit for assimilates than smaller sized frond sized palm accessions. This could be a result of the high demand for assimilation for respiration and growth of the vegetative organs to the detriment of the vegetative organs (Lambert *et al.,* 2014; Ranasinghe and Premasiri, 2015). This indicated that palm accessions with long frond length, petiole length and leaflet length should be selected when making selections for improvements in coconut development projects.

Path Coefficient Analysis

Path analysis indicated that petiole length and frond length had negative direct effect on fruit weight (-0.24) and (-0.04), respectively, but the other vegetative traits had positive but low direct effects; number of fronds (0.21), leaf spread (0.29) and crown diameter (0.20; Table 7). The direct and indirect coefficients of the vegetative traits were very low and insignificant to be reckoned with for consideration. The poor direct and indirect effect the vegetative traits had on yield can be traced to both the petiole length and the frond length. Thus, they can be flagged as negative markers for coconut development. This is in line with the findings of Odufale *et al.* (2021) who stated that petiole length and frond length should be selected against in the coconut development programme for tall coconut.

Table 7 Path coefficient (phenotypic) of vegetative traits showing direct (along diagonal) and indirect effects (above and below diagonals) on fruit weight of the coconut accessions from South West, South East, North Central I and North Central II accessions obtained at the Coconut Experimental Station of the Nigerian Institute for Oil Palm Research in Badagry Lagos State

Traits	NF	PL	FL	LS	CDM	r with FWT
NF	0.21	0.07	0.01	-0.03	0.01	0.27*
PL	-0.06	-0.24	-0.03	0.11	0.06	-0.17
FL	-0.05	-0.16	-0.04	0.09	0.07	-0.09
LS	-0.02	-0.09	-0.01	0.29	0.08	0.24*
CDM	0.01	-0.07	-0.02	0.11	0.20	0.24*

Note: * Significant at $P < 0.05$. NF = number of fronds, PL = petiole length, FL = frond length, LS = leaf spread, CDM = crown diameter, r with FWT = correlation coefficient of traits with fruit weight.

CONCLUSION

It can be concluded from this study that coconut palms with high fruit weight should be selected over smaller fruit palms as this will result in high husk weight, nut weight, split nut weight and fresh meat weight per hectare. It can thus be inferred that the vegetative traits would not be effective in selecting for yield in coconut at the pre-flowering stage. Thus, selection should be based on the pedigree of the parent. The path analysis model used in this study was not reliable in predicting sustainable path for coconut selection or improvement at the pre-flowering stage where only the vegetative parts are functional.

REFERENCES

Ahanon, M.J., V.O. Adetimirin, J.O. Odewale, G. Odiowaya, L.O. Enaberue, C. Agho, B.E. Awanlemhen and O.O. Odufale. 2016. Relationship among vegetative traits in coconut hybrid population, pp. 212–216. *In*: Proceedings of the Africa Regional Forum on Sustainable Development, 7–19 May 2016, Cairo, Egypt.

Alouw, J.C. and S. Wulandari. 2020. Present status and outlook of coconut development in Indonesia. IOP Conf. Ser: Earth Environ. Sci. 418: 012035.

Chan, E. and C.R. Elevitch. 2006. *Cocos nucifera* (coconut), ver. 2.1. *In*: C.R. Elevitch, (Ed), Species Profiles for Pacific Island Agroforestry. Permanent Agriculture Resources, Hawaii, USA.

Dahamarudin, L. and A.A. Rivaie. 2013. Germination capacity, growth and yield of three upland rice varieties increased following seed invigoration treatments. Int. Res. J. Agric. Sci. Soil Sci. 3(2): 43–50.

Geethanjali, S., D. Rajkumar and N. Shoba. 2014. Correlation and path coefficient analysis in coconut (*Cocos nucifera* L.). Electron. J. Plant Breed. 5(4): 702–707.

Jayasekara, C., N.P.A.D. Nainanayake and K.S. Jayasekara. 1996. Photosynthetic characteristics and productivity of the coconut palm. Cocos 11: 7–20.

Lambert, R.J., B.D. Mansfield and R.H. Mumm 2014. Effect of leaf area on maize productivity. Maydica 59(1): 58–64.

Machunde, Z.A. 2013. Variation and Interrelationships among Yield and Yield Components in Lowland Rice Genotypes (*Oryza sativa* L.) in Mwanza Region. MS Thesis, Sokoine University of Agriculture, Morogoro, Tanzania.

Madeni, J.P.N., D.G. Msuya, S.O.W.M. Reuben and P.A.L. Masawe. 2017. A correlation and path-coefficient analyses of yield and selected yield components of cashew hybrids in Tanzania. Res. J. Agric. For. Sci. 5(4): 16–22.

Odewale, J.O., C.D. Ataga, C. Agho, M.J. Ahanon, G. Odiowaya and M.N. Okoye. 2014. Character interrelationships and path analysis for copra yield in coconut (*Cocos nucifera* L.), pp. 602–609. *In*: Proceedings of the 38th Annual Conference of the Genetic Society of Nigeria. Edo State, Nigeria.

Odewale, J.O., G. Odiowaya, A. Collins, L. Enaberue and M.N. Okoye. 2012. Relationship between canopy sizes and shapes and the productivity and yield of coconut (*Cocos nucifera* L.) varieties in Nigeria. Greener J. Agric. Sci. 2(8): 378–380.

Odufale, O.O., A. Oluwaranti, G. Odiowaya, M.J. Ahanon, C. Agho, M.N. Okoye, C.J. Ozurumba and A.O. Yusuf. 2021. Characterization of coconut accessions from selected germplasm using morphological traits. Niger. Agric. J. 52(1): 17–24.

Phothichitto, K. 2006. Isolation and Characterization of Mannanase Producing Microorganism. MS Thesis, Kasetsart University, Bangkok, Thailand.

Ranasinghe, C.S. and R.D.N. Premasiri. 2015. Dry matter requirement for growth and respiration of coconut. Cocos 21: 21–31.

Satyanarayana, K.G., A.G. Kulkarni and P.K. Rohatgi. 1981. Structure and properties of coir fibres. Proc. Indian Acad. Sci. (Engg. Sci.). 4(4): 419–436.

Streiner, D.L. 2005. Finding our way: an introduction to path analysis. Can. J. Psychiatry. 50(2): 115–122.

Williams, R. 2015. Intro to Path Analysis. University of Notre Dame, Indiana, USA.

Xue, Q.L. 2007. Introduction to Path Analysis. Statistics for Psychosocial Research II: Structural Models. Johns Hopkins Bloomberg School of Public Health, Maryland, USA.

Yong, J.W.H., L. Ge, Y.F. Ng and S.N. Tan. 2009. The chemical composition and biological properties of coconut (*Cocos nucifera* L.) water. Molecules 14: 5144–5164.

Zizumbo-Villarreal, D. and D. Piñero. 1998. Pattern of morphological variation and diversity of *Cocos nucifera* (Arecaceae) in Mexico. Am. J. Bot. 85(6): 855–865.