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Original Article

Analysis of Leaf Yield Components in Fluted Pumpkin (*Telfairia occidentalis* Hook F.) Grown in Derived Savannah Agro-Ecology

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Abstract

High yield has become over the recent decades one of the major objectives of breeders and growers. Eighteen accessions of *Telfairia occidentalis* were studied in a randomized complete block design experiment replicated three times to determine the relationship among selected traits and their contribution to leaf yield. The following yield traits were studied: length of the longest vine (LLV), number of leaves plant^{-1} (LP), number of leaves per 40 cm of vine length (LVL), number of vines (NOV), length of the central leaflet (LCL), width of the central leaflet (WCL), vine diameter (VD) and leaf yield by weight. The correlation coefficient was estimated and the values partitioned to show the direct and indirect effects to yield using path coefficient analysis. LP showed the highest positive and significant correlation (r = 0.72**) with leaf yield. WCL and LP had the highest direct positive effects on leaf yield. The study revealed that increased number of wide leaves plant^{-1} with long and higher number of branches increase the leaf yield of *T. occidentalis*.

Keywords: biplot, correlation, modelling, path coefficient analysis, *Telfairia occidentalis,* yield

Introduction

Fluted pumpkin (*Telfairia occidentalis* Hook F.) is a leafy vegetable with edible seeds that are also used for propagation. *T. occidentalis* had been found useful in the area of human and animal nutrition, ethno-medicine and source of livelihood for farmers with a great potential for industrial usage. It is a dioecious plant that is distinguishable at the onset of the reproductive stage. Buyers often prefer the female plant due to its succulent and broader leaves over the male plant.

Cultivation of *T. occidentalis* for its leaf or fruit, or both, is a profitable enterprise (Odiaka *et al.*, 2008; Chukwudi and Agbo, 2014b). The desired yield determines the management practice to be employed. Frequent cutting interval (Ogar and Asiegbu, 2005) is used when leaf is the desired yield, while less cutting frequency is more adequate for higher fruit yield (Chukwudi and Agbo, 2014a). Termination of leaf harvest before or at the onset of reproductive stage in female plants gives a moderate leaf and fruit yield, whereas leaf harvest should continue in the male plants except when the plants are used as source of pollen for pollination (Chukwudi and Agbo, 2014b). The type and quantity of fertilizer applied also affect *T. occidentalis* yield (Ogar and Asiegbu, 2005). Loss of arable land to non-farming purposes and uncertainties associated with the changing climate has necessitated an increase in output per unit land area. This increase can be achieved through precision farming and crop modelling. Apart from management practices, selection of high yielding genotypes can guarantee yield increase in the plant species.

High yield has become one of the major objectives of breeders and growers over the recent decades (Wang and Li, 2008; Xing and Zhang, 2010). Yield is a complex character and is a function of several component traits and their interaction with environment (Iqbal *et al.*, 2013). Yield-related genes have pleitropic effects on plant development in addition to their effects in regulating yield (Li *et al.*, 2016). Yield potential and crop adaptation had been shown to be affected by plant architecture (Cai *et al.*, 2016). Optimal plant architecture can improve leaf area index, photosynthetic efficiency and harvest index, thus leading to increased yield. Crop selection based on plant architecture has been achieved in crops like *Zea mays* (Zhou *et al.*, 2016), *Oryza sativa* (Zhao *et al.*, 2015) and *Phaseolus vulgaris* (Silva *et al.*, 2013). Plant architecture related traits are mostly quantitative traits that are affected by environmental factors. Therefore, it is vital to measure the mutual interrelationship between various plant attributes and

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determine the component traits, on which selection procedure can be based for direct and indirect genetic improvement of *T. occidentalis* yield.

To predict crop yield, there is need to analyze data on weather, soil and crop managements. Although, one is likely to find good data collection on soil and climate factors, the available information on physiologic processes and crop phenology is insufficient (Hesketh and Dale, 1987) in *T. occidentalis*. Achieving this goal is a vital aspect in crop modelling. Modelling represents a better way of synthesizing knowledge about different components of a system, summarizing data and transferring research to users (Dourado *et al*., 1998).

The knowledge of statistics had proved helpful in understanding these relationships and their implications for yield increase. Statistical tools like Principal component analysis (PCA), Regression, Correlation coefficient (r), Path coefficient analysis, Genotype-by-Environment (GGE) Biplot, and others, had been employed in studying the nature of relationship among yield component traits and yield and the contribution of each trait to the yield of many crops.

A clear understanding of the association among yield component traits and the leaf yield in fluted pumpkin will not only reduce cost and duplication of experiments, but will increase precision in research output and bumper yield. Hence, this study was undertaken to determine the relationship(s) among seven selected traits in *T. occidentalis* and their direct and indirect effects on leaf yield using path coefficient analysis.

Materials and Methods

Eighteen accessions of *T. occidentalis* were collected from two towns each, in three local government areas of Enugu State, Nigeria, where there is dense cultivation of the vegetable. The accessions were selected based on three fruit length groups namely: large (more than 50 cm), medium (34-50 cm) and small (less than 34 cm). The accessions were named according to town of collection and fruit length group namely: Ob = Obukpa, Ih =Iheaka, Or = Orba, Ib = Ibagwa-aka, Og = Ogbede, Oz = Ozalla, L= large, M = medium and S = small. Thus, the accessions comprise of Ob-L, Ob-M, Ob-S, Ih-L, Ih-M, Ih-S, Or-L, Or-M, Or-S, Ib-L, Ib-M, Ib-S, Og-L, Og-M, Og-S, Oz-L, Oz-M and Oz-S. Three fruits were collected per accession. The accessions were studied in a randomized complete block design experiment with three replications at the Research Farm, Department of Crop Science, University of Nigeria, Nsukka (07 ° 29 N, 06 ° 51 E, and 400 m.a.s.l. Enugu State Nigeria). Nsukka is characterized by lowland humid tropical conditions with bimodal annual rainfall distribution that ranges from 1,155 to 1,955 mm with a shift in the second peak of rainfall from September to October, a mean annual temperature of 29 °C to 31 °C and a relative humidity that ranges from 69% to 79% (Uguru *et al*., 2011). Ezeaku (2010) classified the soil of the study site as an ultisol.

The experimental field measuring 875 m^2 was cleared, ploughed, harrowed and marked out into three blocks. Each block contained a complete set of the accessions resulting in eighteen plots. The plot measured 4 × 3 m (12 m^2). A distance of 1 m and 0.5 m were allowed between blocks and plots, respectively. The seeds of each accession were germinated in the nursery and transplanted at a distance of 1 × 1 m. Each plot contained 12 stands of *T. occidentalis*. Well cured pig manure was applied at 20 t/ha to the plots two weeks before transplanting and supplemented with N:P:K fertilizer (15:15:15) at 750 kg/ha split at four and ten weeks after transplanting (Ogar and Asiegbu, 2005). The field was manually kept weed free and no other chemical besides the N:P:K fertilizer was applied.

The following data were collected bi-weekly on three middle plants in each plot at the vegetative stage of growth: length of the longest vine (cm), number of leaves per plant, number of leaves per 40 cm of vine length, length of the central leaflet (cm), width of the central leaflet (cm), vine diameter (cm), number of vines and marketable leaf yield by weight (kg). The marketable leaves were harvested and weighed at the early hours of the morning before noon to reduce moisture lost. A micrometer screw gauge (Outside© Micrometer, Nigeria) was used to measure the vine diameter, while flexible metric tape was used to measure the vine length, width and length of the central leaflet. The number of vines and leaves per plant were visually counted. A flexible metric tape was used to measure 40 cm from the tip of the longest vine and the number of leaves within the 40 cm length was counted to determine the number of leaves per 40 cm of vine length. The experiment was carried out during the rainy season of 2011 and repeated during the same period in 2012.

Statistical analysis

The two years data were pooled for the analysis. The estimate of Pearson's moment correlation coefficient was performed using Statistical Package for Social Science (SPSS 16). The correlation coefficients were partitioned into direct and indirect effects as proposed by Wright (1934) using the technique outlined by Dewey and Lu (1959). Marketable leaf yield by weight was considered as the resultant variable and the others as causal variables. Percent contribution of the direct effect of the morphological traits on yield was calculated using this equation:

%contribution of trait = ((direct effect of trait)/(correlation coefficient of trait yield)) × 100

GGE biplot (4.1 edition) software was used to test the discrimitiveness vs. representativeness of traits studied.

Results and Discussion

Correlation coefficients analysis

Number of leaves per plant (LP) showed the highest positive and significant correlation (r=0.72**, n=216, $P<0.01$) with fluted pumpkin leaf yield (Table 1). Length of the longest vine (LLV), width of the central leaflet (WCL), number of vines (NOV), length of the central leaflet (LCL) and vine diameter (VD) showed positive and significant correlation of 0.69, 0.65, 0.64, 0.60 and 0.53 respectively, with leaf yield. These results are in agreement with the reports of Fayeun *et al.* (2012) where positive and significant correlations were obtained for these traits. Number of leaves per 40 cm of vine length (LVL) showed negative and highly significant correlation of r = -0.31 with leaf yield. Obi (2011) noted that negative correlation coefficient between two traits indicated that an increase in the value of one variable trait coincides with a decrease in the other variable trait. Therefore, an increase in LVL will result in a decrease in leaf yield of fluted pumpkin. An increase in the number of leaves per 40 cm of vine length is a pointer of stunted growth in *T. occidentalis*. Odiaka (2005) measured this trait as number of nodes, while distinguishing among seven accessions of fluted pumpkin at early growth stage. However, its relationship to yield was not investigated. The detrimental effect of LVL may come from overlapping of leaves resulting in reduced photosynthetic activities.

All the yield traits studied showed positive correlation among themselves except the number of leaves per vine length of 40 cm, which exhibited negative correlation with all the other yield traits. Apart from the associations between LVL and NOV (r= -0.06) and LVL and LP (r= -0.09) that were not significant, the other traits under study showed highly significant (p=0.01) correlation among themselves. The highest positive and significant correlation of r = 0.90 was obtained between WCL and LCL, followed by r = 0.85 between LP and NOV. Fasakin and Olofintoye (2005) reported similar significant and positive results in leaf yield component traits of *Ceratotheca sesamoides*. The correlation coefficients obtained in this study suggest that increased number of wide leaves per plant with long and higher number of branches will increase the leaf yield of fluted pumpkin.

Correlation coefficient measures the mutual relationship or interdependence of two random variables or traits (Obi, 2011). It may not indicate a cause and effect relationship between the traits, but reflects the strength, as well as, the direction of the relationship that exists. Linear correlation between yield and several of its components can present a confusing picture due to inter-relationship between component traits themselves (Sunil and Mudasir, 2013).

Therefore, to comprehend the contribution of each component trait to the yield, the correlation coefficient needs to be decomposed. Path coefficient analysis provides an effective means of partitioning correlation coefficients into unidirectional path ways and alternate pathways thus permitting a critical examination of specific factors that produce a given correlation (Salahuddin *et al.*, 2010). Path coefficient analysis developed by Sewall Wright (Wright, 1934) can decompose the correlation between two variables into four components, viz. the direct effect of X on Y, the indirect effect of X (through an intervening variables) on Y, an unanalyzed component (residual) and a spurious component due to X and Y each being caused by some third variable (Wuensch, 2012).

Path coefficient analysis

Number of vines per plant (NOV)

Table 2 showed that the direct effect of NOV on leaf yield of fluted pumpkin was positive (0.173). It contributed about 27.1% of the phenotypic correlation coefficient. The phenotypic correlation was further enhanced by NOV indirect effect through LP (0.272), WCL (0.173), LLV (0.166), LVL (0.008) and VD (0.007) which formed about 42.5%, 27.1%, 13.5%, 1.3% and 1.1% of the contribution, respectively. Number of vines per plant is useful in clustering fluted pumpkin germplasm (Odiaka, 2005) and had been associated with leaf yield increase (Fayeun *et al.*, 2012). However, NOV's influence through LCL (-0.080) on leaf yield was in the negative direction. The result showed that NOV had a positive direct effect, but contributed more via its indirect effect through LP which contributed 42.5% of its effect on leaf yield of fluted pumpkin.

Length of the longest vine (LLV)

Length of the longest vine (LLV) had a positive direct effect of 0.166 on the leaf yield of fluted pumpkin (Table 2, Fig. 1) which represented about 24% of the phenotypic correlation. The indirect effect of LLV via NOV was 0.090, LVL was 0.055, LP was 0.221, LCL was -0.098, WCL was 0.247 and VD was 0.009. Odiaka (2005) used vine length as one of the distinguishing traits in clustering fluted pumpkin accessions. Although LLV had a positive direct effect on the leaf yield of fluted pumpkin, its effect was more pronounced via the indirect effects of WCL and LP which contributed about 35.8% and 32% of the total phenotypic correlation.

Number of leaves per 40 cm of vine length (LVL)

Number of leaves per 40 cm of vine length (LVL) had a negative direct effect of -0.138 on the leaf yield of fluted pumpkin and contributed about 44.4 % of the phenotypic correlation (Table 2, Fig. 1). It also contributed negatively through its action on NOV (-0.010), LLV (-0.066), LP (-0.029), WCL (-0.107) and VD (-0.002). Odiaka (2005) measured this trait as number of nodes while distinguishing among seven accessions of fluted pumpkin. However, the direction of its contribution to yield was not established.

The negative correlation coefficients exhibited by LVL

Table 1. Correlation coefficients among eight selected traits of *T. occidentalis*

	NOV	LLV	LVL	LP	LCL	WCL	VD	YIELD
NOV	-	0.52**	-0.06	0.85**	0.51**	0.47**	0.49**	0.64**
LLV		-	-0.40**	0.69**	0.62**	0.67**	0.61**	0.69**
LVL			-	-0.09	-0.27**	-0.29**	-0.17**	-0.31**
LP				-	.059**	0.57**	0.59**	0.72**
LCL					-	0.90**	0.59**	0.60**
WCL						-	0.57**	0.65**
VD							-	0.53**
YIELD								-

VD=Vine Diameter (mm), NOV=Number of vine, LLV=Length of the Longest Vine (cm), LP= Number of Leaves per Plant, LVL= Number of leaves per vine length of 40 cm, WCL=Width of the Central Leaflet (cm), LCL= Length of the Central Leaflet (cm) and YIELD=Leaf Yield

**. Correlation was significant at the 0.01 level (2-tailed),*. Correlation was significant at the 0.05 level (2-tailed)

Table 2. Direct (Diagonal) and indirect effect of some yield component traits on leaf yield of *T. occidentalis*

	NOV	LLV	LVL	LP	LCL	WCL	VD	YIELD
NOV	0.173	0.086	0.008	0.272	-0.080	0.173	0.007	0.64
LLV	0.090	0.166	0.055	0.221	-0.098	0.247	0.009	0.69
LVL	-0.010	-0.066	-0.138	-0.029	0.043	-0.107	-0.002	-0.31
LP	0.147	0.114	0.012	0.320	-0.093	0.210	0.009	0.72
LCL	0.088	0.103	0.037	0.189	-0.157	0.332	0.009	0.60
WCL	0.082	0.111	0.040	0.182	-0.142	0.368	0.008	0.65
VD	0.085	0.101	0.023	0.189	-0.093	0.210	0.014	0.53
Residual								0.349

VD=Vine Diameter (mm), NOV=Number of vine, LLV=Length of the Longest Vine (cm), LP= Number of Leaves per Plant, LVL= Number of leaves per vine length of 40 cm, WCL=Width of the Central Leaflet (cm), LCL= Length of the Central Leaflet (cm) and YIELD= Leaf yield

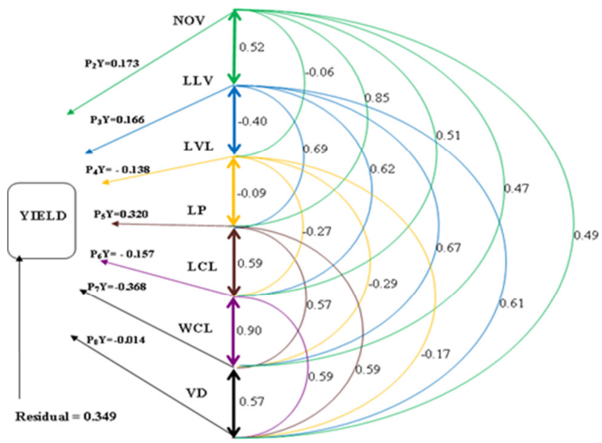

Fig. 1. Diagrammatic representation of direct and indirect influence of yield component traits on leaf yield of fluted pumpkin. PY=path through, VD=Vine Diameter (mm), NOV=Number of vine, LLV=Length of the Longest Vine (cm), LP= Number of Leaves per Plant, LVL= Number of leaves per vine length of 40 cm, WCL=Width of the Central Leaflet (cm), LCL= Length of the Central Leaflet (cm) and YIELD= Leaf yield

with other parameters measured including yield suggest that this trait did not improve yield. LVL would increase with decrease in the internode distance and vice versa. The correlation coefficient, path analysis coefficient and GGE biplot point to the low desirability of this trait in yield improvement. The large angle maintained by LVL from the GGE biplot origin against the small angles observed in other traits confirms its difference from other traits studied.

Number of leaves per plant (LP)

The direct effect of LP was 0.320 and in the positive direction with about 44.5% contribution to the phenotypic correlation of the leaf yield of fluted pumpkin (Table 2, Fig. 1). The indirect effect of LP through NOV was 0.147, LLV was 0.114, WCL was 0.210 and LCL was -0.093. Fayeun *et al.* (2012) observed a high phenotypic coefficient of variation for this trait and suggested its inclusion in fluted pumpkin leaf improvement programme. Though, LP influenced the leaf yield of fluted pumpkin significantly, its indirect effects via WCL (29.2%) and NOV (20.5%) were remarkable.

Length of the central leaflet (LCL)

Length of the central leaflet (LCL) had a negative direct effect of -0.157 on the leaf yield of fluted pumpkin representing about 26.2% negative contribution to the phenotypic correlation (Table 2, Fig. 1). Its effect was however, counter balanced by its indirect effect via NOV (0.088), LLV (0.103), LVL (0.037), LP (0.189), WCL (0.332) and VD (0.008). The major influence of LCL to the leaf yield of fluted pumpkin was via WCL and LP which contributed about 55.3% and 31.5%, respectively.

Width of the central leaflet (WCL)

Width of the central leaflet (WCL) had the highest positive direct effect of 0.368 on the leaf yield of fluted pumpkin which contributed about 56.7% to the phenotypic correlation coefficient (Table 2, Fig. 1). The indirect effect of WCL on leaf yield of fluted pumpkin was positive via NOV (0.082), LLV (0.111), LVL (0.040), LP (0.182) and VD (0.008) and negative via LCL (-0.093). This result revealed that broadness of the leaf (WCL) had the highest direct effect on the leaf yield which is in agreement with the finding of Aremu and Adewale (2012) who recommended breeding for increased number and wideness of foliage of fluted pumpkin.

Vine diameter (VD)

Vine diameter (VD) had the lowest positive direct effect of 0.014 on the leaf yield of fluted pumpkin which represented about 2.7% contribution to the phenotypic correlation (Table 2, Fig. 1). The bulk of its effect was via its indirect effect through the path of WCL and LP that contributed 39.6% and 35.6% to the phenotypic correlation, respectively.

The residual value of 0.349 indicated that the component traits selected in this study accounted for 65.1% of the traits that affect leaf yield of fluted pumpkin. Path coefficients have been used to develop selection criteria for complex traits in several crop species (Wright, 1934; Dewey and Lu, 1959; Iqbal *et al.*, 2013; Nwofia *et al.*, 2013; Sunil and Mudasir, 2013).

Discrimitiveness vs. Representativeness of studied traits

In Fig. 2, the biplot explained 82.1% of the total variation which was accounted for by PC 1 (70.6%) and PC2 (11.5%). Width of the central leaflet was the most representative of the yield traits studied, since it had the smallest angle with the average environment axis (AEA), that is, the line that passes through the average trait and the biplot origin (Yan and Tinker, 2006), while LVL was the

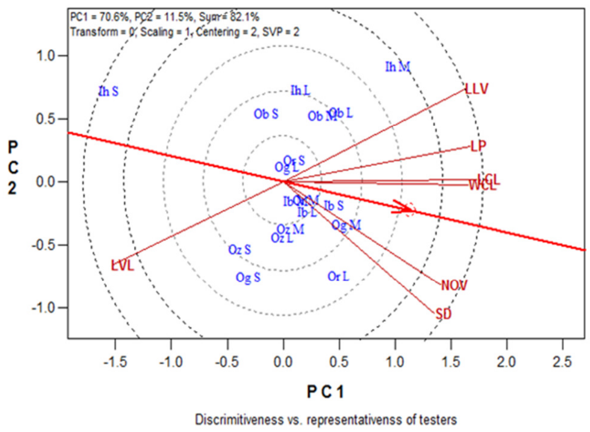

Fig. 2. The discrimination and representativeness view of the GGE biplot to show the discriminating ability and representativeness the test yield traits. NOV=Number of vine, LLV=Length of the Longest Vine (cm), LP= Number of Leaves per Plant, LVL= Number of leaves per vine length of 40 cm, WCL=Width of the Central Leaflet (cm), SD=VD=Vine Diameter (mm), LCL= Length of the Central Leaflet (cm) and YIELD= Leaf yield. Ob-L, Ob-M, Ob-S, Ih-L, Ih-M, Ih-S, Or-L, Or-M, Or-S, Ib-L, Ib-M, Ib-S, Og-L, Og-M, Og-S, Oz-L, Oz-M, and Oz-S = fluted pumpkin accessions

least representative in the yield traits studied due to its large angle with the AEA. Yan (2011) based this interpretation on the cosine-correlation equality of the GGE biplot.

All the yield traits studied were fairly discriminating as shown in their long vectors positioned away from the biplot origin. This discriminating ability of NOV, LLV, LVL, LP, LCL, WCL and VD aligned with the report of Odiaka (2005) where PCA, metroglyph and semi-graphical methods were used to analyze their morphological variations in fluted pumpkin.

Yan and Tinker (2006) reported that a test trait with short vector is less discriminating meaning that all genotypes tend to perform similarly and little or no information about their differences can be revealed with such a trait, *vis-à-vis*, a trait with long vector. They stated that an ideal trait should be both discriminating and representative. Yan (2011) recommended that a trait that is discriminating but not representative should not be selected. Number of leaves per 40 cm of vine length (LVL) fit into this category of discriminating but non-representing; therefore, it should not be selected in leaf yield improvement program of fluted pumpkin.

The small angle between WCL and LCL indicated a close association between them in the biplot implying that the two traits provide similar information. One of the traits should be selected for leaf yield improvement without consequences. The path coefficient analysis result indicated that WCL should be selected due to its positive direct effect on leaf yield and its other influence on the other yield traits studied.

Conclusions

The relationships that exist among the yield traits studied and the leaf yield of *T. occidentalis* emphasized that leaf yield can be improved through establishment of plants with more broad leaves on high number of long branches. Hence, selection of *T. occidentalis* crop for higher leaf yield should incorporate width of the central leaflet, number of leaves per plant, number of vines per plant and length of the longest vine in its improvement.

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