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Biometrical Evaluation of Morphological Traits in Family Cucurbitaceae in Lafia, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Biometrical evaluation is a valuable tool for the study of biosystematics of plant taxa. This study assessed morphological variation and phenetic relationship in the Cucurbitaceae species in Lafia, Nasarawa State, Nigeria. Plant specimens were collected by simple random sampling across the municipality and 11 species were identified in the study area. Analysis of variance and multivariate analyses were used to determine the differences and identify variation among morphological characters among the species, respectively. Genetic similarity among the taxa was generated by single linkage algorithm of Bray-Curtis similarity index. Wide variations were observed in the morphological characters; *Telfairia occidentalis* had the longest pods (46.3 cm) and the longest vines (831.4 cm), while *Cucumis sativus* had the shortest vines (162.3 cm). All the species had multi-seeded pods; *Lagenaria breviflora* had 734.7 seeds, which was significantly more than the seeds in other species, *Citrullus lanatus* had 438.3 seeds and *Momordica charantia* had the fewest seeds (12.7) per pod. *T. occidentalis* had significantly ($p \leq 0.05$) the heaviest seeds (89.8 g) of the species. Three major clusters were identified; *Lagenaria abyssinica* and *L. rufa* had similarity index of 0.9; *Cucumeropsis mannii* and *Citrullus lanatus* had index of 0.89. Principal component analysis

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established close relationship between *T. occidentalis* and *L siceraria*; then *L. breviflora, Citrullus lanatus*; *Cucumeropsis mannii*, *Cucurbita pepo*, *Cucumis sativus, Lagenaria rufa* and *Lagenaria abyssinica*, *Luffa cylindrica* and *Momordica charantia*, indicative of genetic similarity among the taxa. Closely related species are potential materials for interspecific hybridization and improvement of the family.

Keywords: Cucurbitaceae; biometric evaluation; phenetic relationship; simple random sampling.

1. INTRODUCTION

The family Cucurbitaceae with 118 genera and more than 820 plant species is a very diverse plant group; they are widely distributed in tropical and subtropical agro-ecologies of Africa and the world [1,2]. Cucurbitaceae contains important species, such as pumpkin, melon, cucumber and squash; the species are much appreciated for their nutritional, medicinal and aesthetic values; their fruits, leaves, flowers and seeds are comestible [3,4,5]. Cucurbits contain 20 to 35% protein with essential amino acids, such as arginine, aspartate and glutamic acid; 25 to 55% oil that are rich in unsaturated oleic and linoleic acid; minerals such as calcium, iron, magnesium and potassium and vitamins e.g. Vitamin A were also reported by several authors [2,6]. Most Cucurbitaceae species are consumed as vegetables in many African cuisines, they are used to purify blood, also as diuretic drugs, as remedy for constipation, asthma and arthritis, to aid digestion, boost energy, amend cholesterol level and strengthens immunity and heals wounds. Ajuru and Ajuru [7] identified the Cucurbitaceae as one of the major family of plants grown in Nigeria for their palatable fruits and vegetables. However, the family faces serious challenges in the large number of pests and pathogen attacks on the species due to the poor knowledge of the genetics and diversity of the species [8]. The pests challenges and the need to improve yield warrant breeding intervention.

Classification of the Cucurbitaceae family in Africa have been variously conducted since the 1950s by Hutchinson and Dalziel [9], Purseglove [10], Okoli [11] and more recently by Agbagwa and Ndukwu [12], yet the taxonomic categorization of this group has not been exhausted because knowledge gaps still exist. In Nigeria, many rural people mistake soft and orange skin Cucurbits as tomato because of their usage in local sauces. Furthermore, the species *Cucumeropsis mannii* (L.) Naudin has other synonyms, such as *Citrullus colocynthis* (L) Shrad. Ogbonna [13] described the species as *Colocynthis citrullus* L. The species, *C. mannii* has several common names, such as colocynth, bitter apple, bitter cucumber and 'egusi'.

Secondly, there has been intense germplasm erosion resulting from natural phenomena, such as wild fire, flooding, wind and water erosion; and human activities, such as farming, municipal development and unregulated lumbering [14]. The natural and human processes pose selection challenges on the taxa; these pressures threaten the phylogenetic composition of the species [4]. Nigeria is particularly noted for deforestation; it has lost much of its forest and many valuable genetic resources to this phenomenon [15,16]; therefore, there is urgent need for mitigation. The evaluation of plant diversity to identify groupings sharing close genetic makeup is important for conservation of genetic resources and for utilizing the diversity as breeding materials. Although, several authors, such as Rahman [17], Paris et al. [18], Abdein [19] and Roberts et al. [8] have used morphological and genetic markers to study diversity in Cucurbitaceae, yet literature on the taxa is still insufficient, especially in Nigeria.

The objective of this study was to evaluate the variation in some biometric traits in the Cucurbitaceae family germplasm collection in Lafia, Nigeria.

2. MATERIALS AND METHODS

2.1 Study Area

Eleven species in family Cucurbitaceae were collected in Lafia (8°29'N, 8°31'E); located in the north central and within the Guinea Savannah ecology of Nigeria. It has tropical climate with rainfall of 1311.75 cm per annum and mean annual temperature of about 28°C; the rainy season starts from March to October and the dry season (sometimes with little rain) starts from November to February, humidity is of about 80% in the rainy season [20]. The vegetation of the area is a derived forest type with economic trees clusters cultivated among grasses and shrubs. The common economic trees are citrus (lemon,

grapes and oranges), cashew, mango, *Moringa* spp, guava and other tree crops which have replaced most of the natural tree vegetation [21]. The landscape is undulating with plain lands and hills measuring up to 300 ft above the sea level.

2.2 Specimen Collections

The plant specimens were collected by simple random sampling; made by traversing the town, in fields and along the banks of water-bodies. Morphological characterization was identified according to the standard descriptor of Agro-Botanical Institute (ABI), Tapiószele, Hungary. Multiple measurements of three to five random samples were taken of each trait.

2.3 Data Analysis

Data collected on morphological traits were subjected to analysis of variance to estimate the differences among the species and significant means were separated with Duncan New Multiple Range Test (DNMRT).

Data collected were also subjected to principal component analysis to identify the most discriminating morphological characters. Dendrograms and genetic similarity among the taxa were generated by the single linkage algorithm of Bray-Curtis similarity index. The multivariate analyses were computed with Past 3 package [22].

3. RESULTS AND DISCUSSION

3.1 Morphological Traits in Cucurbitaceae in Lafia, Nasarawa State, Nigeria

Eleven species were collected in the course of survey in Lafia, Nasarawa State, Nigeria. The species were *Cucumeropsis mannii* (L) Naudin., *Citrullus lanatus* (Thunb) Matsum and Nakai, *Cucumis sativus* L, *Cucurbita pepo* L, *Lagenaria abyssinica* (Hook. f) Jeffrey, *L. breviflora* (Benth) Roberty, *L. rufa* (Gilg) Jeffrey, *L. siceraria* (Molina) Standl, *Luffa cylindrica* (L.) M. Roem, *Momordica charantia* (L.) Karela and *Telfaria occidentalis* Hooke. The districts in Lafia where the species were found are presented in Table 1. Roberts et al. [8] found 14 species in eastern Nigeria, including *Cucurbita moschata*, *Luffa aegyptiaca*, *Coccinia barteri*, *Melothria scabra*, *Trichosanthes cucumerina* and *Zehneria scabra*. *L. aegyptica* is synonymous with *L. cylindrica* in this study [23].

The morphological and yield traits of the species collected in the Cucurbitaceae family in Lafia, Nasarawa State, Nigeria are presented in Table 2. The vine length ranged from 162.3 cm in *Cucumis sativus* to 831.4 cm in *Telfairia occidentalis*. *Telfairia occidentalis* had significantly ($p \leq 0.05$) the longest vines (831.4 cm), followed by *Lagenaria siceraria* (705 cm). Length of leaf blades ranged from 2 cm in *Momordica charantia* to 14 cm in *Telfaria occidentalis*. *M. charantia* had the smallest leaf blades (0.68 cm), while, *T. occidentalis* had the largest leaf blades (8.5 cm). The length of pods ranged from 5.4 cm in *Momordica charantia* to 46.3 cm in *Telfairia occidentalis*.

Characteristic of Cucurbitaceae, all the species in the study were multi-seeded; *Lagenaria breviflora* had 734.7 seeds per pod, *Citrullus lanatus* had an average of 438.3 seeds per pod, *L. siceraria* had 328.3 seeds per pod, while *M. charantia* had the least number of seeds per pod (12.7). *M. charantia* had the lightest seeds weight per pod (2.58 g), followed by *Cucumis sativus* (3.92 g), *Telfairia occidentalis* had largest and heaviest seeds per pod (89.7 g). The weight of 30 seeds ranged from 0.5 g in *Cucumis sativus* to 37 g in *Telfaria occidentalis*. The seed weight per pod of *T. occidentalis* (89.8 g) was significantly ($p \leq 0.05$) the heaviest of the species in Lafia, Nigeria.

3.2 Variation in the Cucurbitaceae Species in Lafia, Nigeria

The Bray-Curtis single linkage cluster measuring the similarity among the species is presented in Fig. 1. The similarity indices ranged from 0.75 to 0.99, *Lagenaria abyssinica* (G5) and *L. rufa* (G7) had similarity index of 0.9; *Cucumeropsis mannii* (G1) and *Citrullus lanatus* (G2) had index of approximately 0.87; G1 and G2 had similarity index of 0.87 with *Cucurbita pepo* (G4). *Lagenarias siceraria* (G8) and *Telfaria occidentalis* (G11) were clustered together and separated from the other species. *Momordica charantia* (G10) was morphologically distinct; it was isolated into a separate cluster, from the other species.

In the production of interspecific hybrids, crossing is achievable by genetic closeness; closely related species cross more easily than distantly related ones. One of the basic assumptions in numerical taxonomy is that similarity in biometrical evaluation is a measure of their genetic similarity [24], by this assumption,

interspecific and possibly intergeneric hybridization can be achieved in taxa in the same clusters in this study. Rakha et al. [25] reported successful crossed between *Cucurbita moschata, C. ficifolia* and *C. martinezii* (as male parents) with *C. pepo*. Yu et al. [26] also crossed cucumber (*Cucumis sativus*) with its wild relative (*C. hystrix*) to improve shade tolerance in cultivated cucumber. Oloyede-Kamiyo and Akoroda [27] crossed different sexes of *Cucumis sativus* (pickling, poinsett and burpless tasty) to generated interspecific hybrids. Intergeneric hybridization was achieved in Brassicaceae species with some success [28], nevertheless, chromosome doubling was needed in advance, to enhance crossability.

The scatter plot of the principal component analysis (Fig. 2) presents *T. occidentalis* (G11) and *Lagenaria siceraria* (G8) in the first quadrant, *Lagenaria breviflora* (G6) and *Citrullus lanatus* (G2) in the second quadrant; *Cucumeropsis mannii* (G1), *Cucurbita pepo* (G4), *Cucumis sativus* (G3) and *Lagenaria rufa* (G7) in the third quadrant and *Lagenaria abyssinica* (G5), *Luffa cylindrica* (G9) and *Momordica charantia* (G10) in the forth quadrant. The occurrence of taxa in the same quadrant is indicative of the phenetic relationship between them. This is evident from Rahman et al. [29] who used morphometric analysis to identified phenetic similarities in eleven *Senna* species in Bangladesh. Wide variation in morphometric characters among species in this study showed high discrimination; with some implications on the genetic diversity and relationship among the species; indicative that closely related species can be crossed.

Table 3 presents the principal components (PC) matrix for morphological traits in the family Cucurbitaceae in Lafia, Nigeria. Eight of the principal component (PC) had Eigen-values greater than 1. Sixty-four per cent of the variation in the morphological traits was explained by the first principal component (PC1); and 34% was explained by the second principal component (PC2), the dissimilarity in PC1 and PC2 were created by the variation in vine length and number of seeds per pod. The variation in PC3 was loaded on weight of seeds per pod and weight of 30 seeds.

There were positive correlations between most morphological traits of the Cucurbitaceae species in Lafia, Nigeria (Table 4). For example, the weight of 30 seeds had highly significant and strong correlation with seed weight per pod ($p = 0.813$, $r = 0.001$), but medium correlation with pod diameter ($p = 0.662$, $r = 0.001$).

Table 1. Plant species used in the study and districts (locations) specimen were collected

S/N	Plants Species	Genus	Common Name	Location
1.	*Cucumeropsis mannii* (L) Naudin.	*Cucumeropsis*	colocynth, bitter apple, 'egusi'	G, BS
2.	*Citrullus lanatus* (Thunb) Matsum and Nakai	*Citrullus*	Watermelon	LN, MA, G, AM
3.	*Cucumis sativus* L	*Cucumis*	cucumber	G
4.	*Cucurbita pepo* L	*Cucurbita*	winter squash, pumpkin	LN, LE, A
5.	*Lagenaria abyssinica* (Hook. f) Jeffrey	*Lagenaria*	No common name	G, BS, A
6.	*Lagenaria breviflora* (Benth) Roberty	*Lagenaria*	No common name	LN, MA, G
7.	*Lagenaria rufa* (Gilg) Jeffrey	*Lagenaria*	No common name	BS
8.	*Lagenaria siceraria* (Molina) Standl	*Lagenaria*	Bottle gourd	MA, G, AO
9.	*Luffa cylindrica* (L.) M. Roem	*Luffa*	sponge gourd	LN, LE, MA, W, BS, BK
10.	*Momordica charantia* (L.) Karela	*Momordica*	bitter gourd	LE, MA, BS
11.	*Telfaria occidentalis* Hooke.	*Telfaria*	fluted pumpkin, fluted gourd	LN, LE, MA, W, AO, A, AM

Key: LN = Lafia North; LE = Lafia East; MA = Mararaba Akunza, G = Gandu, W = Wankwa, BS = Bukan sidi, AO= Akuruba Osanyan, BK= Buka Kuto, A= Agodu, AM= Angwan Mada

Table 2. Variation in morphological and yield traits of some species in the family Cucurbitaceae in Lafia, Nasarawa State, Nigeria

Plants Species	Length of vine (cm)	length of leaves (cm)	Width of leaves (cm)	Weight of oven-dried leaves (g)	Length of pod (cm)	Diameter of pod (cm)	Number of seeds per pod	Seed weight per pod (g)	Weight of 30 seeds (g)
1. *Cucumeropsis mannii* (L) Naudin.	241.1^{e}	12.1^{ab}	1.44^{ef}	0.512^{b}	11.3^{c}	11.9^{bc}	316.7^{c}	43.17^{c}	3.04^{bc}
2. *Citrullus lanatus* (Thunb) Matsum and Nakai	248.1^{e}	10.9^{ab}	6.66^{bc}	0.584^{b}	23.7^{b}	15.7^{b}	438.3^{bc}	21.60^{d}	1.60^{d}
3. *Cucumis sativus* L	162.3^{f}	7.62^{c}	5.92^{c}	0.475^{b}	24.9^{b}	6.7^{c}	238.0^{cd}	3.92^{f}	0.53^{f}
4. *Cucurbita pepo* L	337.2^{d}	13.6^{a}	4.9^{d}	1.830^{a}	16.1^{bc}	14.9^{b}	274.0^{cd}	23.28^{d}	2.52^{cd}
5. *Lagenaria abyssinica* (Hook. f) Jeffrey	324.9^{d}	11.7^{ab}	5.24^{cd}	0.409^{b}	14.1^{c}	4.7^{c}	140.3^{d}	12.63e	2.68^{bc}
6. *Lagenaria breviflora* (Benth) Roberty	245.1^{e}	8.0^{bc}	6.7^{bc}	0.502^{b}	11.4^{c}	9.2^{bc}	734.7^{a}	26.27^{d}	1.35^{d}
7. *Lagenaria rufa* (Gilg) Jeffrey	246.3^{e}	8.4^{bc}	5.74^{cd}	0.521^{b}	6.5^{d}	5.6^{c}	148.0^{d}	10.23^{e}	1.84^{d}
8. *Lagenarias siceraria* (Molina) Standl	705.7^{ab}	13.2^{a}	7.6^{bc}	1.192^{a}	22.6^{b}	6.6^{c}	328.3^{c}	55.62^{bc}	4.44^{bc}
9. *Luffa cylindrica* (L.) M. Roem	525.6^{c}	10.86^{ab}	2.36^{e}	1.377^{a}	14.0^{c}	7.0^{c}	128.3^{e}	9.42^{e}	2.33^{cd}
10. *Momordica charantia* (L.) Karela	347.2^{d}	2.02^{d}	0.68^{f}	0.047^{b}	5.4^{d}	2.5^{d}	12.7^{f}	2.58^{f}	3.87^{bc}
11. *Telfaria occidentalis* Hooke	831.4^{a}	14.0^{a}	8.5^{ab}	1.314^{a}	46.3^{a}	21.5^{a}	110.3^{e}	89.76^{a}	37.11^{a}

Key: Means with the same letters in the same column are not significantly different at 5 % probability (DNMRT)

Similarly, highly significant and strong correlation between seed weight per pod and length of pod (p =0.741, r = 0.001) and diameter of pod (p = 0.707, r = 0.001). The length of pod had significant and medium correlation with width of leaves (p = 0.67, r = 0.05). Traits with high positive and strong or medium correlation show that as one trait increases, the other increases correspondingly, this indicates that both traits can be improved simultaneously; consequently, weight of seeds, pod diameter and pod length are agronomic traits that can be improved at the same time in a breeding programme in the Cucurbitaceae species.

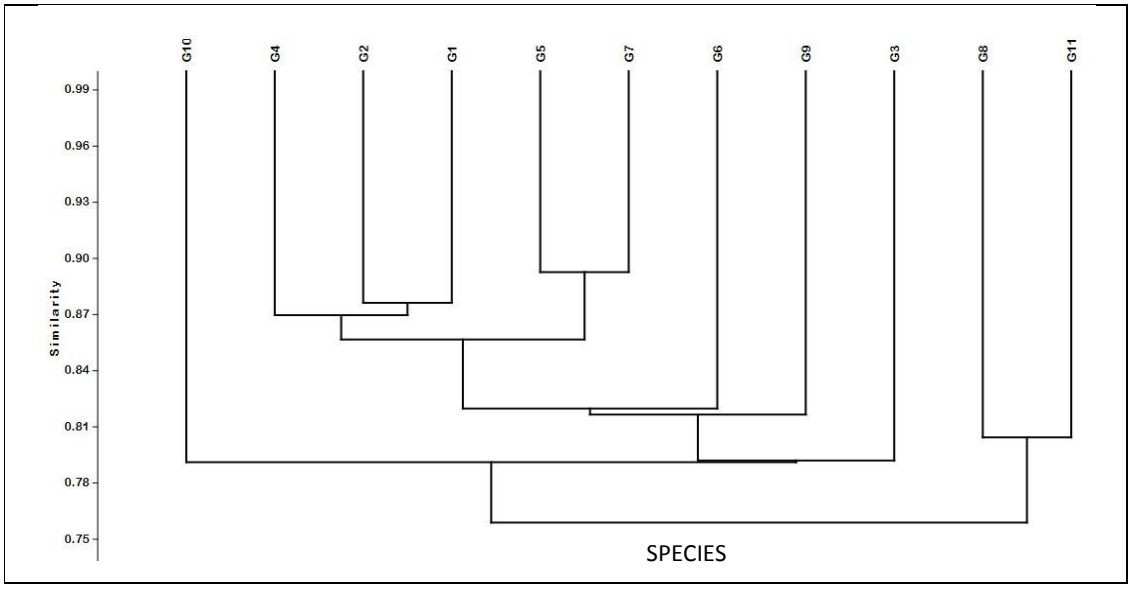

Fig. 1. Bray-Curtis similarity indices of species in the family Cucurbitaceae in Lafia, Nigeria
Key: Cucumeropsis mannii (G1); Citrullus lanatus (G2); Cucumis sativus (G3); Cucurbita pepo (G4); Lagenaria abyssinica (G5); Lagenaria breviflora (G6); Lagenaria rufa (G7); Lagenarias siceraria (G8); Luffa cylindrica (G9); Momordica charantia (G10); Telfaria occidentalis (G11).

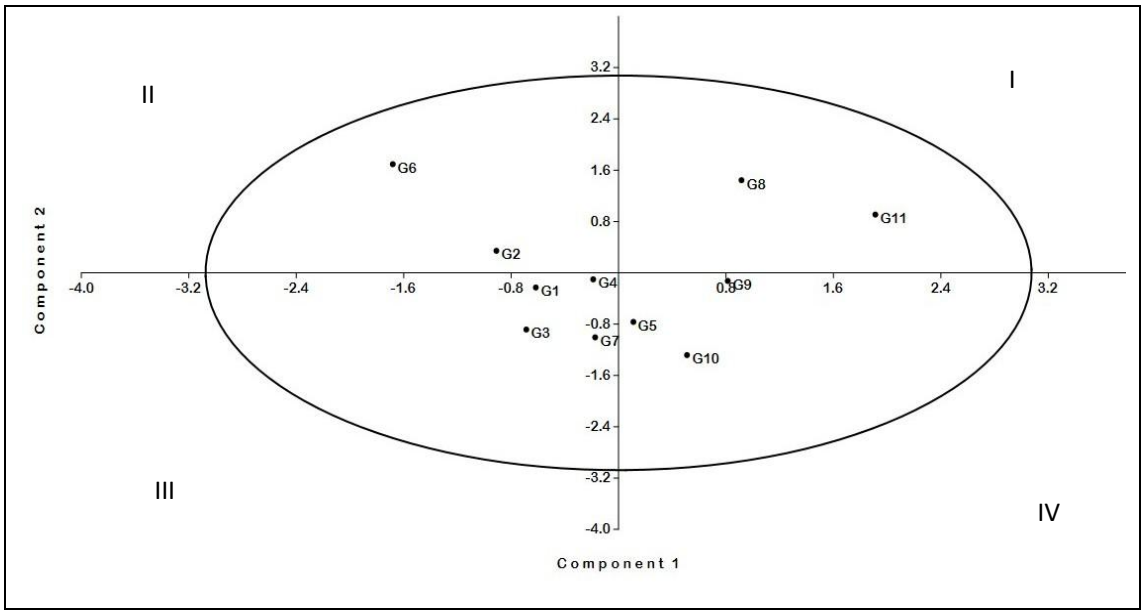

Fig. 2. Scatter plot of the Principal component analysis showing 95% ellipsis

Table 3. Principal component matrix for morphological traits in Cucurbitaceae in Lafia, Nigeria

	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8
Length of vine (cm)	0.792	0.599	-0.117	0.0104	-0.002	0.012	-0.005	0.003
length of leaves (cm)	0.004	0.010	0.068	-0.003	0.505	0.344	0.592	-0.515
Width of leaves (cm)	0.001	0.009	0.036	0.146	0.064	-0.183	0.663	0.707
Weight of dried leaves (g)	0.001	0.001	-0.001	0.010	0.050	0.090	0.031	0.004
Length of pod (cm)	0.024	0.029	0.346	0.807	0.286	-0.309	-0.194	-0.108
Diameter of pod (cm)	0.0039	0.015	0.225	0.193	0.067	0.834	-0.242	0.384
Number of seeds per pod	-0.607	0.793	-0.043	0.013	-0.015	0.002	0.000	-0.009
Seed weight per pod (g)	0.057	0.100	0.834	-0.484	0.137	-0.171	-0.064	0.060
Weight of 30 seeds (g)	0.031	0.019	0.334	0.234	-0.795	0.139	0.330	-0.267
Eigen value	55788.1	29870.8	293.634	57.843	17.533	10.4883	3.20597	1.2308
Variance %	64.838	34.716	0.3412	0.0672	0.0204	0.0122	0.0037	0.0014

Table 4. Correlation matrix between morphological traits of Cucurbitaceae in Lafia, Nigeria

	VL (cm)	LL (cm)	LW (cm)	WL (g)	PL (cm)	PD (cm)	SP	SW (g)
LL (cm)	0.475							
LW (cm)	0.354*	0.467**						
WL (g)	0.572*	0.729*	0.291					
PL (cm)	0.632*	0.541	0.671*	0.430				
PD (cm)	0.359*	0.634*	0.450	0.528	0.732			
SP	-0.297*	0.127	0.365	-0.036	-0.053*	0.204*		
SW (g)	0.755	0.643	0.509	0.435*	0.741**	0.707**	0.087**	
S30 (g)	0.746	0.365	0.415	0.328	0.803	0.662**	-0.286	0.813**

Key: VL = Length of vine; LL = length of leaves; LW = Width of leaves; WL = Weight of dried leaves; PL = Length of pod; PD = Diameter of pod; SP = Number of seeds per pod; SW = Seed weight per pod; S30 = Weight of 30 seeds

4. CONCLUSION

Variability among Cucurbitaceae is valuable for the study of biosystematics of the taxonomic group. Among the species in this study, *Telfairia occidentalis* had the longest vines, longest and widest leaves, longest pods, largest seeds and the most seeds per pod. The eleven species were distributed into eight genera, *Citrullus lanatus*, *Cucumeropsis mannii*, *Cucumis sativus*, *Cucurbita pepo* and *T occidentalis* were common in most districts of Lafia, while *Lagenaria siceraria* and *Momordica charantia* were found cultivated and in the wild. The variations in fruits, seeds and other attributes in the Cucurbitaceae family are documented by Ittah and Ajibodu, [30].

Analyses with scatter plot and principal component analysis established close relationship between *T. occidentalis* and *L siceraria*; then *L. breviflora* and *C. lanatus*; *C. mannii*, *Cucurbita pepo*, *Cucumis sativus* and *Lagenaria rufa* and *Lagenaria abyssinica*, *Luffa cylindrica* and *M. charantia*, indicative of genetic similarity among the taxa. Closely related species are potential materials for interspecific hybridization and improvement of the family. When more than one method of analysis give identical result, one can increase the confidence on the reliability of the inference.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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