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Full Length Research Paper

Variations among some Nigerian *Cucurbita* landraces

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The diversity among some Nigerian accessions of *Cucurbita* species was investigated using 19 quantitative and 14 qualitative characters. The result showed that the accessions evaluated differed significantly ($p < 0.05$) in most of the quantitative characters evaluated. The clustering based on quantitative character, grouped the various accessions into two clusters. However, clustering based on the qualitative variations revealed a more realistic relationship by grouping the accessions into three distinct clusters that appeared to have some bearing with agro-ecology from which the accessions were collected. The variations in qualitative characters showed higher discrimination with some implications on the the genetic diversity and relationship among the accessions of *Cucurbita*. The Shannon diversity index (HS) was found to be 4.136 suggesting that the evaluated Nigerian *Cucurbita* accessions are truely diverse. The correlation analyses revealed that the weight of harvested fruits had significant and positive relationships with days to 50% flowering, number of male flowers, number of female flowers, number of fruits per plant, number of healthy fruits, fruit diameter, fruit length, number of seeds per fruit, 100-seed weight and seed weight. The days to 50% emergence showed negative but significant correlations with days to 50% flowering, number of female flowers, fruit length, seed length and 100-seed weight, suggesting that early crop emergence would imply prolonged vegetative growth phase and the production of higher number of female flowers that would translate to higher seed yield.

Key words: Diversity, pumpkin, *Cucurbita* spp., principal component analysis, multivariate statistics.

INTRODUCTION

The genus, *Cucurbita* is a member of the family, Cucurbitaceae which consist of about 118 genera and 825 species (Jeffery 1990). The members are warm season annuals, thriving in hot and humid weather (Omafra, 2000) and have spreading growth habit with tendril at the leaf axil. They are important fruit bearing vegetables that are widely grown in the tropics. The leaves are borne singly and may be simple or lobed. The plant has extensive, shallow root system. The flowers vary considerably in colour, size and shape. The flowers are monoecious acuminate, and pentamerous with different shades of yellow colour (Agbagwa and Ndukwu, 2004) and pollinated by various wild bees (Hurd et al., 1971). The female flower contains an ovary that is inferior (Agbagwa and Ndukwu, 2004). The pumpkin flowers are borne on the axils of the leaves, the males on long peduncles and the females on short peduncles. *Cucurbita* is considered as one of the most morphologically variable genera in the entire plant kingdom (Robinson et al., 1976). Nee (1990) reported that *Cucurbita* is one of the first plants to be domesticated and that the species are collectively referred to as pumpkin.

Natural selection has continued to play significant role on the evolution of the crop even after domestication. Artificial selection pressure has been on the fruit size, color, shape, leaf texture, maturity period, adaptation to poor soil fertility and resistance to pests and pathogens. There is tremendous genetic diversity within the family and the range of adaptation for *Cucurbita* species includes tropical and subtropical region, arid deserts and temperate locations. They are however, less frequent in temperate regions because of their sensitivity to frost (Tsuchiya and Gupta, 1991). Although cultivated Cucurbits are distributed primarily in the warmer areas of the world, they share significant numbers of morphological characteristics. They are extremely diverse in fruit

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Table 1. Accession number, names of the accession and place of collection of the *Cucurbita* accessions.

Accession No./Code	Name of the accession	Place of collection	Ecological zone
V1	Ogo-mega	Ogoja, Cross River State	Rain forest
V2	Ugwu-Lng	Ugwuoba, Enugu State	Derived savanna
V3	Uvu-Wart	Uvuru, Enugu State	Derived savanna
V4	Jos- Vari	Jos, platuea State	Guinea savanna
V5	Akw-01	Akwanga, Nassarawa State	Guinea savanna
V6	Akw-02	Akwanga, Nassarawa State	Guinea savanna
V7	Akw-03	Akwanga, Nassarawa State	Guinea savanna
V8	Awka-RV	Awka- Anambara State	Derived savanna
V9	Ugwu-Rnd	Ugwuoba, Enugu State	Derived savanna
V10	Ngwo-wart	Ngwo, Enugu State	Derived savanna

characters (Agbagwa and Ndukwu, 2004). Some are large fruited, others are small fruited and every gradation between these extremes does exist. The different descriptions of the Cucurbits by different authors have given the classification of the Cucurbita species a controversial status. Many European authors have identified three primary groups namely: *Cucurbita pepo* group, which includes *C. pepo, Cucurbita moschata, Cucurbita maxima* and *Cucurbita argyrosperma* species; the *Cucurbita* veruscosa group comprising all the warty varieties of Cucurbits and *C. melo* group that are the scalloped squash (Paris et al., 2002). Linnaeus listed four species of *Cucurbita*, all of which were classified as *C. pepo* species by Duchesne (1768). This was because they were related and cross compatible. Duchesne (1786) isolated two distinct species namely; *C. maxima*, named on the basis of large fruit size, and *C. moschata* for the musky flavor. The CWF (2007) shared the views of the European authors on the description of the warty varieties, but classified them as *C. veruscosa*. Earlier work (Decker, 1988) suggested that there was a relationship between *C. pepo* and *Cucurbita texana* and that many edible forms are included in the *C. pepo* complex.

Extensive research efforts have been made on this crop by different authors both in America and Europe, but in Africa, tropical pumpkin is used as a traditional food crop and, thus has not benefited from the same level of research efforts dedicated to other crops. Information on the identification and classification of the Nigerian *Cucurbita* species are unavailable in the literature. Considering the extreme divergence of the Nigerian genotypes, this study therefore, was initiated with sole objective of establishing the level of genetic diversity of some of the Nigerian *Cucurbita* landraces. The results obtained will serve as a prelude for further research into the breeding and improvement of this important, but neglected vegetable crop.

MATERIALS AND METHODS

Ten *Cucurbita* accessions used in the study were sourced from three agro-ecological zones of Nigeria, where Pumpkins are principally grown by the traditional communities. The accession numbers and their origin are presented in Table 1. These accessions were grown at the experimental field of the Department of Crop Science, University of Nigeria, Nsukka (Lat 06° 52'N; Long 07 24' E, 447.2m a.s.l.) in a randomized complete block design (RCBD) with three replications. The land area used was 91 by 28 m. Planting distance of 2 × 2 m was used. The experimental area was divided into three blocks and each block had 10 plots of 8 × 8 m each. Each plot had four tagged sample plants of one accession. These were replicated three times thus bringing the total plant population to 120 plants. The tagged plants were in the middle of the plots to avoid border effect. Two seeds were planted per hole and later thinned to one plant per stand after emergence. 10 kg of well cured pig dung (equivalent to 174 kg/ha) was applied to each plot before planting. Weeds were controlled manually to keep weed pressure low.

Data collection

The data on 19 quantitative and 14 qualitative traits (Table 2) were collected using the standard descriptor lists developed by the International Plant Genetic Resources Institute (IPGRI) for Cucurbitacaeae (Esquinas-Alca´ zar and Gulick, 1983). The data were collected based on the expressed genetic pontentials on the individual plant basis. The quantitative charcters were taken as the mean value of four measurements made on four plants per replicate. Each qualitative character was scored by observing 12 sample plants per accession taking four plants from every block (replicate).

Data analysis

The data collected on quantitative characters were standardized using the range of each variable to eliminate scale differences (Upadhyaya et al., 2006) and were subjected to analysis of variance to estimate the differences among the genotypes. The Fisher's Least Significant Difference (F-LSD) was used to detect significant differences between treatment means. Qualitative traits that showed an array of differences were converted into binary characters (Sneath and Sokal, 1973). The score '1' was given for the presence of a specific phenotype and '0' for its absence. The transformed data for both quantitative and qualitative characters were subjected to principal component to identify the most discriminating morphological characters (Hair et al., 1992). Dendrograms and genetic similarity among the accessions were

Table 2. Descriptors used for characterizing the *Cucurbita* accessions.

Quantitative descriptors	
1) Days to 50% emergence	
2) Days to 50% flowering	
3) Fruit diameter (cm)	
4) Fruit length (cm)	
5) Girth size at 10 weeks (cm)	
6) Number of darmaged fruits	
7) Number of female flowers	
8) Number of fruits per plant	
9) Number of healthy fruits	
10) Number of male flowers	
11) Number of seeds per fruit	
12) Number of leaves at 10 weeks	
13) Seed length (cm)	
14) Seed width (cm)	
15) Seed weight per fruit (g)	
16) Vine length at 10 weeks (cm)	
17) Weight of damaged fruits (kg)	
18) Weight of harvested fruits (kg)	
19) Number of branches at 10 weeks	
Qualitative descriptors	
1) Growth habit:	1- Spreading.
2) Stem colour:	1-light green, 2-dark green.
3) Leaf pubescence:	1-glabrous, 2- very sparsely pubescent, 3- pubescent, 4-smooth
4) Leaf colour:	1- green, 2- intermediate green, 3-dark green, 4- variegated
5) Leafiness:	1-intermediate, 2-sparse (main stem easily visible), 3-abundant (very leafy)
6) Petiole colour:	1- light green, 2-dark green
7) Branching pattern:	1-central, 2-basal, 3-all over
8) Flowering period:	1-asynchronous (31-35 days), 2-intermediate (21-25 days)
9) Immature fruit colour:	1-dark green, 2- dark green with light green strips, 3-light green with white spots, 4-light green with dark green sports, 5-light yellow, 6-light yellow with green strips,
10) Mature fruit colour:	1- bright orange, 2-dark green, 3-gray, 4-gray with deep green strips, 5-yellow, 6-deep yellow, 7-varigated
11) Fruit texture:	1-very warty, 2-slightly warty, 3-very smooth
12) Fruit shape:	1-oblong, 2-cylindrical, 3-heart shape, 4-pear shape, 5- round
13) Seed shape:	flat
14) Seed colour:	1-light gray, 2-dark brown, 3-light yellow, 4-white

also generated using the Jaccard´s coefficients of similarity (Jaccard, 1908) expressed as Euclidean genetic distances. The analyses were performed using Genstat Discovery Edition 3 (Genstat, 2007) software.

The qualitative characteristics were used in the determination of the Shannon diversity index (HS) among the accessions evaluated. The HS was calculated by using the species richness (the number of species in the community) and the abundance (the total number of species in the sample) (Equation 1) (Shannon and Weiner, 1983). An ecosystem with high species diversity has large Shannon diversity index value. Conversely, an ecosystem with low species diversity has low Shannon diversity index. The evenness (measure the frequencies of occurence of each crop species in the ecosystem) was also calculated as a ratio of Shannon diversity index and the natural logarithm of the species' richness (Equation 2). The Pearson correlation coefficient was employed to estimate the relationships between the yield and yield related traits:

$$\textbf{Shannon diversity index (Hs)} = -\sum_{i=1}^{s} \mathrm{Pi}[\ln(\mathrm{Pi})]$$

where, Pi = relative abundance of species, S = the number

Table 3. Variation in quantitative characters of the 10 *Cucurbita* accessions.

Accessions	D50%E	D50%F	NMF	NFF	NOL	GS (cm)	NOB	VL (cm)	NFP	NHF	NDF	FD (cm)	FL (cm)	WHF (kg)	NSF	100SW (g)	SL (cm)	SW (g)	WDF (kg)
Ogo-mega	3.33	30.67	38.30	7.00	138.70	0.83	16.33	596.00	5.67	1.33	4.33	64.00	43.33	2.90	214.70	53.00	1.83	1.08	2.23
Ugwu-Lng	3.00	29.00	44.70	7.67	147.00	0.90	20.00	707.00	6.00	6.00	0.00	56.93	61.33	4.79	235.00	24.07	1.55	1.00	0.00
Uvu-Wart	8.00	25.67	55.30	6.00	161.30	0.98	18.67	646.00	4.67	4.00	0.67	63.67	38.00	3.69	417.70	19.93	1.43	0.83	2.43
Jos- Vari	3.00	30.67	49.00	7.00	97.70	0.91	17.00	476.00	5.67	2.67	3.00	60.33	46.33	3.04	375.70	27.97	1.67	0.87	2.94
Akw-01	3.67	32.00	66.00	8.67	165.00	0.83	19.33	589.00	8.00	3.67	4.33	90.67	46.67	8.70	523.70	45.00	1.83	1.13	3.90
Akw-02	3.33	29.67	41.00	6.67	210.00	0.76	12.67	533.00	5.33	2.67	2.67	77.67	38.67	3.47	290.00	22.53	1.87	0.83	2.79
Akw-03	3.00	30.00	58.30	7.00	119.30	0.77	15.33	504.00	5.67	1.33	4.33	80.33	45.33	2.92	426.30	27.20	1.70	0.88	4.03
Awka-RV	3.33	24.33	38.30	7.67	137.00	0.56	16.67	463.00	6.00	0.00	6.00	71.00	33.33	2.46	304.00	10.10	1.25	0.78	2.17
Ugwu-Rnd	6.33	28.33	33.70	6.67	180.70	0.63	15.00	383.00	4.67	0.00	4.67	61.67	31.33	2.21	297.30	11.93	1.20	0.78	1.59
Ngwo-wart	8.00	26.67	42.70	7.00	187.30	0.77	19.33	615.00	6.33	0.00	6.33	62.33	30.33	2.52	269.30	15.13	1.43	0.87	1.59
F-$LSD_{0.05}$	1.24	3.26	18.45	NS	NS	0.22	NS	NS	NS	1.18	1.70	5.31	3.41	1.61	43.42	5.97	0.17	0.15	1.71

$D_{50}E$ = days to 50% emergence, $D_{50}F$ = days to 50% flowering, NMF = number of male flowers, NFF = number of female flowers, NOL = number of leaves per plant at ten weeks, GS = Girth size at ten weeks, NB = number of branches at ten weeks, VL = vine length at ten weeks, NFP = number of fruits per plant, NHF = number of healthy fruits, NDF = number of damaged fruits, FD = fruit diameter, FL = fruit length, WHF = weight of harvested fruits, NSF = number of seeds per fruit, 100SW = 100-seed weight, SL = seed length, SW = seed width and WDF = weight of damaged fruits.

of species in the sample and ln = natural logarthm:

$$\text{Evenness (J)} = HS/\ln S \qquad (2)$$

where, HS = Shannon diversity index and ln S = natural logarithm of the Species richness

RESULTS

Assessment of accessions with quantitative characters

The comparisons of means concerning quantitative characters are shown in Table 3. The result showed significant variation among the accessions in most of the traits measured. The accessions, Ogo-mega, Ugwu-Lng, Jos- Vari, Akw-02, Akw-03, and Awka-RV were the earliest in emergence at 3 days after planting. Days to emergence was delayed by 6 days in Ugwu-Rnd and, 8 days in Uvu-wart and Ngwo-wart. The accessions differed in days to 50% flowering. Awka-RV was the earliest accession to attain 50% flowering after 24 days of planting. This did not differe significantly ($p < 0.05$) from Uvu-Wart (26 days), Ngwo-wart (27 days) and Ugwu-Rnd (28 days). Flowering was delayed by eight days in Akw-01. The accessions differ significantly ($p < 0.05$) in the number of male flowers per plant. The highest number of male flowers was obtained in Akw-01 (66), Akw-03 (58), Uvu-Wart (55), while Ugwu-Rnd produced the least (34) number of male flowers. The largest stem diameter at 10 weeks was recorded for the accession Uvu-wart (0.98 cm) followed by Jos-vari (0.91 cm), Ugwu-Lng (0.90 cm), Akw-01 (0.83cm) and Ogo-mega (0.83cm), while the accession Ugwu-Rnd (0.63cm) had the smallest stem diameter.

Although the number of fruits per plant did not differ among the accessions, Akw-01 produced the highest number of fruits (8 fruits), while Uvu-Wart, Akw-02 and Ugwu-Rnd produced the least number of fruits (5 fruits) (Table 3). The data on the number of healthy fruits revealed significant differences among the accessions, with Ugwu-Lng having the highest number of healthy fruits (6 fruits). The accessions Awka-RV, Ugwu-Rnd and Ngwo-wart did not produce any healthy fruits. Awka-RV and Ngwo-wart recorded the highest number of damaged fruits per plant (6 fruits), damaged fruits per plant (6 fruits), while no fruit damage was recorded in Ugwu-Lng. The fruit diameter varied from 56.33 cm in Ugwu-Lng to 90.67 cm in Akw-01. The longest fruit was recorded in the accession, Ugwu-Lng (61 cm), while the shortest was observed in Ugwu-Rnd (31.33 cm). Akw-01 had significantly ($p < 0.05$) higher weight of harvested fruits (8.73 kg) when compared with the rest of the accessions. The least weight of the harvested fruit (2.21 kg) was

Table 4. Eigen vectors and the total percentage variation for the first three principal components of the ten selected *Cucurbita* species.

Parameter	PC1	PC2	PC3
Days to 50% Emergence	0.170	-0.168	0.433
Days to 50% Flowering	-0.260	-0.318	-0.094
Fruit diameter	-0.168	0.387	0.092
Fruit length	-0.286	-0.197	-0.199
Girth size	-0.221	-0.370	0.004
Number of damaged fruits	0.138	0.431	0.095
Number female flowers	-0.227	0.274	0.134
Number of fruits per plant	-0.255	0.265	0.230
Number of healthy fruits	-0.263	-0.321	0.010
Number	-0.273	0.049	0.246
Number of branches	-0.160	-0.197	0.427
Number of leaves	0.089	0.021	0.199
Nunmber of seeds per fruit	-0.173	0.173	0.276
Seed length	-0.272	0.072	-0.295
Seed weight	-0.322	0.042	-0.040
Vine length	-0.205	-0.323	0.178
Weight of harvested fruits	-0.320	0.090	0.230
100Seed weight	-0.282	0.074	-0.226
Weight of damaged fruits	-0.286	-0.212	0.280
Percentage Variation	40.14	19.15	12.91

produced by the accession, Ugwu-Rnd. Akw-01 also had the highest number of seed per fruit (524 seeds), while accession, Ogo-mega had the lowest number of seeds per fruit (215 seeds). The 100 seed weight was between 10.07 g in Awka-RV and 53 g in Ogo-mega. Seed length ranged from 1.2 cm in Ugwu-Rnd to 1.87 cm in Akw-02. The mean seed weight varied from 0.78 g in Awka-RV and Ugwu-Rnd to 1.13 g in Akw-01. The accessions, Akw-01 and Akw-03 (4 kg) recorded the highest weight of damaged fruits, while the accession Ugwu-Lng had no fruit damage.

The results of the PCA of the 19 quantitative traits measured are presented in Table 4. The results showed that the first three components contributed72.2% of the variability among the 10 accessions evaluated. The PC1, PC2 and PC3 accounted for 40.14, 19.15 and 12.91% of the total variation, respectively. The first principal component axis had high loading for seed weight and weight of harvested fruits.

This axis is regarded as productivity and yield axis since it is loaded highly for the yield component traits. The second principal component axis weighed the highest in the days to 50% flowering, fruit diameter, girth size, number of damaged fruits, number of healthy fruits and vine length, while days to 50% emergence and number of branches were loaded highly in the third principal component axis. The intra-population variability evaluated by hierarchial cluster analysis (dendrogram) conducted on the quantitative traits, grouped the accessions into two clusters (Figure 1). Cluster I comprised the accessions V3 (Uvu-wart), V8 (Awka-RV), V9 (Ugwu-Rnd) and V10 (Ngwo-wart), while cluster II consist of V1 (Ogo-mega), V2 (Ugwu-Lng), V4 (Jos-vari), V6 (Akw-02) and V7 (Akw-03) accessions. The accession, V5 (Akw-01) was an outlier and, therefore did not belong to any of the clusters. The two clusters have the coefficient of similarity of about 0.863 and appear to maintain some level of distance from each other (Figures 1 and 2). The cluster means (Table 5) shows that cluster I comprise of early emerging accessions with high production of male and female flowers, long vine length, less number of damaged fruits and high potentials for the production of heavier fruits and seeds. The accessions in cluster II are essentially late emerging and early flowering characterized with prolific leaf production and are susceptible to fruit damage. Although, accession Akw-01 did not belong to any of the clusters, it flowered early and has the largest fruits size. It also performed best in most of the agronomic and yield traits evaluated.

Assessment of accessions with qualitative charcters

All the *Cucurbita* accessions evaluated had spreading growth habit. Three branching types observed are the basal, overall and central. *C. pepo* had only the overall branching pattern; *C. maxima* had overall and central, while *C. moschata* had both overall and basal branching patterns. With respect to the floral characteristics, pumpkins are monoecious with both male and female flowers borne on the same plant. *C. moschata*, *C. maxima* and *C. pepo* showed great diversity in fruit shape, size, colour and skin texture. The observed fruit shapes are the round, heart-shaped, oblong and cylindrical. The cylindrical shaped fruits were the most frequent, followed by the oblong, round and heart-shaped in that order. Fruit colour ranged from bright orange through yellow, green, gray, green with white spots to variegated. Green fruit colour was the most frequent, followed by the yellow fruit. Fruit skin texture varied from very warty to smooth skin. The very smooth skin was the most frequent followed by the slightly warty skin. The fruit of pumpkin is a berry with pronounced fleshy yellow pulp. Inferior ovary and parietal placentation were observed in

C. pepo and *C. Maxima*, while *C. moschata* showed axile placentation. Their seeds showed differences in size and colour but had the same shape. The seed colour ranged from brown through light brown to white. The seeds of *C. pepo* are white while the seeds of *C. moschata* are brown and light brown. The seeds of *C. maxima* are light brown. The major qualitative characters describing the first three principal components and their respective scores are presented in Table 6. The plant growth habit and seed shape were constant for all the accessions and were not included in the PCA. The first

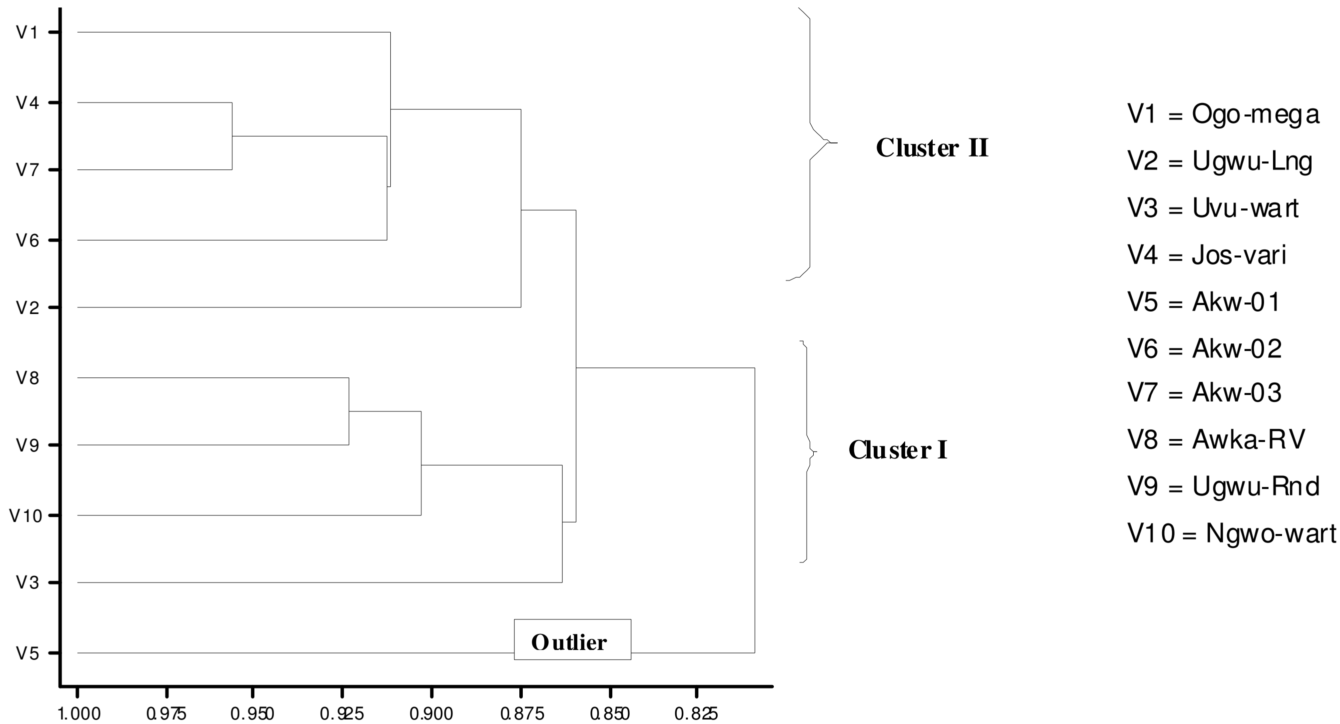

Figure 1. Dendrogram of 10 *Cucurbita* accessions based on quantitative characters.

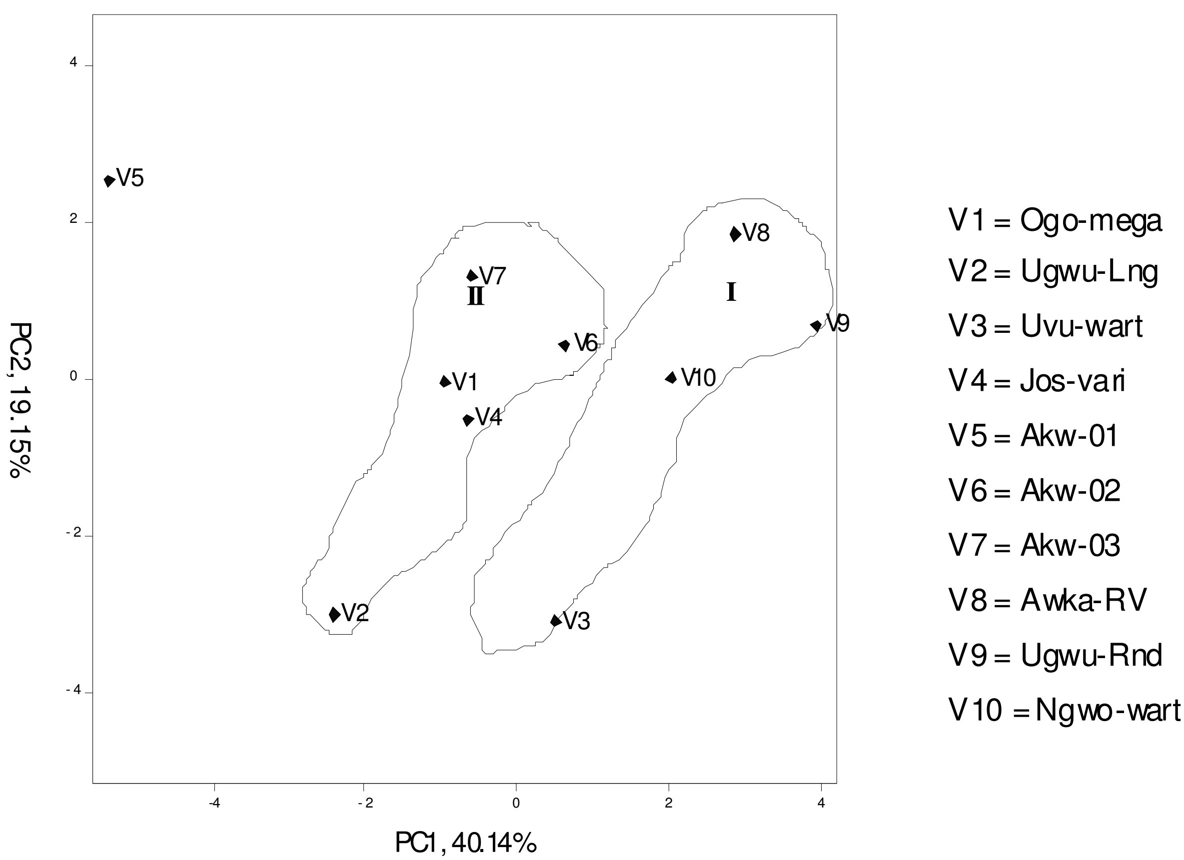

Figure 2. First and second principal component scores (PC1 and PC2) for the identification of *Cucurbita* accession performance on the 19 quantitative traits.

Table 5. Clusters means for 19 quantitative traits of 10 *Cucurbita* accessions.

	Cluster means		
Quantitative traits	**I**	**II**	**(V5) Akw-01**
Days to 50% Emergence	3.13	6.42	3.67
Days to 50% Flowering	30	26.25	32
Fruit diameter (cm)	67.85	64.67	90.67
Fruit length (cm)	47	33.25	46.67
Girth size (cm)	0.83	0.74	0.83
Number of damaged fruits	2.87	4.42	4.33
Number female flowers	7.07	6.84	8.67
Number of fruits per plant	5.67	5.42	8
Number of healthy fruits	2.8	2.72	8.7
Number male flowers	46.26	42.5	66
Number of branches	16.27	17.42	19.33
Number of leaves	142.54	166.58	165
Nunmber of seeds per fruit	308.34	322.08	523.7
Seed length (cm)	1.72	1.33	1.83
Seed weight (g)	0.93	0.82	1.13
Vine length (cm)	563.2	526.75	589
Weight of harvested fruits (kg)	3.42	1	3.67
100-seed weight (g)	30.95	14.27	45
Weight of damged fruits (Kg)	1.945	2.63	3.9

Table 6. Clusters means for 14 qualitative traits of 10 *Cucurbita* accessions.

Parameter	PC1	PC2	PC3
Branching pattern	0.18756	0.18920	-0.44616
Flowering period	-0.44237	0.01363	-0.13249
Fruit texture	0.41424	0.01327	0.05598
Fruit shape	-0.29284	-0.37798	0.10323
Immature fruit colour	0.35186	-0.24944	-0.07725
Leaf colour	0.00139	-0.49193	-0.13800
Leaf pubiscense	-0.37809	-0.19150	-0.11130
Leafiness	-0.07732	-0.17794	0.61495
Mature fruit colour	0.41521	-0.14198	-0.08470
Petiole colour	0.09823	-0.38347	-0.15057
Seed colour	0.23862	-0.21081	0.47175
Stem colour	-0.00734	-0.48659	-0.31881
Percentage variation	37.51	24.48	12.95

three principal components accounted for 74.94% of the total variation with respect to the 12 qualitative characters describing the accessions. The first principal component accounted for 37.51% of the total variance, and had high positive contributing factor loadings from fruit texture, immature fruit colour and mature fruit colour. The second principal component had high positive contributing factor loadings from branching pattern and contributed 24.48% of the total variation. The third principal component accounted for 12.95% of the total variation, with high factor loadings for leafiness and seed colour. The graphic representation of the scores of the principal components is shown in Figure 3. The accessions were clearly separated into three groups. All accessions collected from Southern Guinea Savanna except Ogo-mega (from Rain Forest) and Ugwu-Lng (from Derived Savanna) were located on the right hand side of the PCA graph, while the remaining accessions from the Derived Savanna were on the left hand side. The resultant UPGMA cluster analysis (Figure 4) showed the existence of three major clusters at 0.31 similarity coefficient. The accessions, Ogo-mega, Akw-01 and Akw-03 showed the highest coefficient of similarity (about 0.74) and were clustered together with the accessions, Akw-02, Ugwu-Lng and Jos-vari in cluster I. The accessions, Ogo-mega, Akw-01 and Akw-03 had Jaccard dissimilarity coefficient of about 0.165 with Akw-02, Ugwu-Lng and Jos-vari. The accessions, Awka-RV and Uvu-watt (green and watty), collected from the derived savanna were grouped together in cluster II with similarity coeffifient of 0.42. Cluster III consisted of two accessions viz; Ngwo-watt and Ugwu-Rnd (from the derived savanna) at 0.50 similarity coefficient (Figure 4).

Using the qualitative characteristics, the 10 accessions of Cucurbita evaluated were grouped into three species (that is, *C. pepo, C. moschata* and *C. maxima*). Table 7 showed the values of the species' richness, relative abundance, Shannon diversity index and the evenness in the plant population. The relative abundance of C. pepo, C. moschata and C. maxima in the ecosystem were 72, 144 and 144, respectively. The Shannon diversity index, HS was 4.136. *C. moschata* had the highest Shannon index value (1.559), followed by *C. maxima* (1.474) and *C. pepo* (1.103) in that order. The evenness of *C. pepo, C. moschata* and *C. maxima* were 0.187, 0.265 and 0.250, respectively.

Correlation

The linear correlation coefficients (r) among the traits are given in Table 8. Significant and positive correlations were found between weight of harvested fruits and days to 50% flowering (r = 0.435*), number of male flowers (r = 0.562**), number female flowers (r = 0.501**), number of fruits per plant (r = 0.567**), number of healthy fruits (r =0.591**), fruit diameter (r = 0.544**), fruit length (r =0.431*), number of seeds per fruit (r = 0.505**), 100 seed weight (r = 0.480**) and seed weight (r = 0.545**). However, the relationships between the weight of harvested fruits and seed length, number of leaves, vine length, girth size, number of branches and weight of damaged fruits were not significant. The seed weight per fruit had a significant positive correlation with days to 50% flowering (r = 0.484*), number of female flowers (r = 0.382*), number of fruits per plant (r = 0.388*), fruit

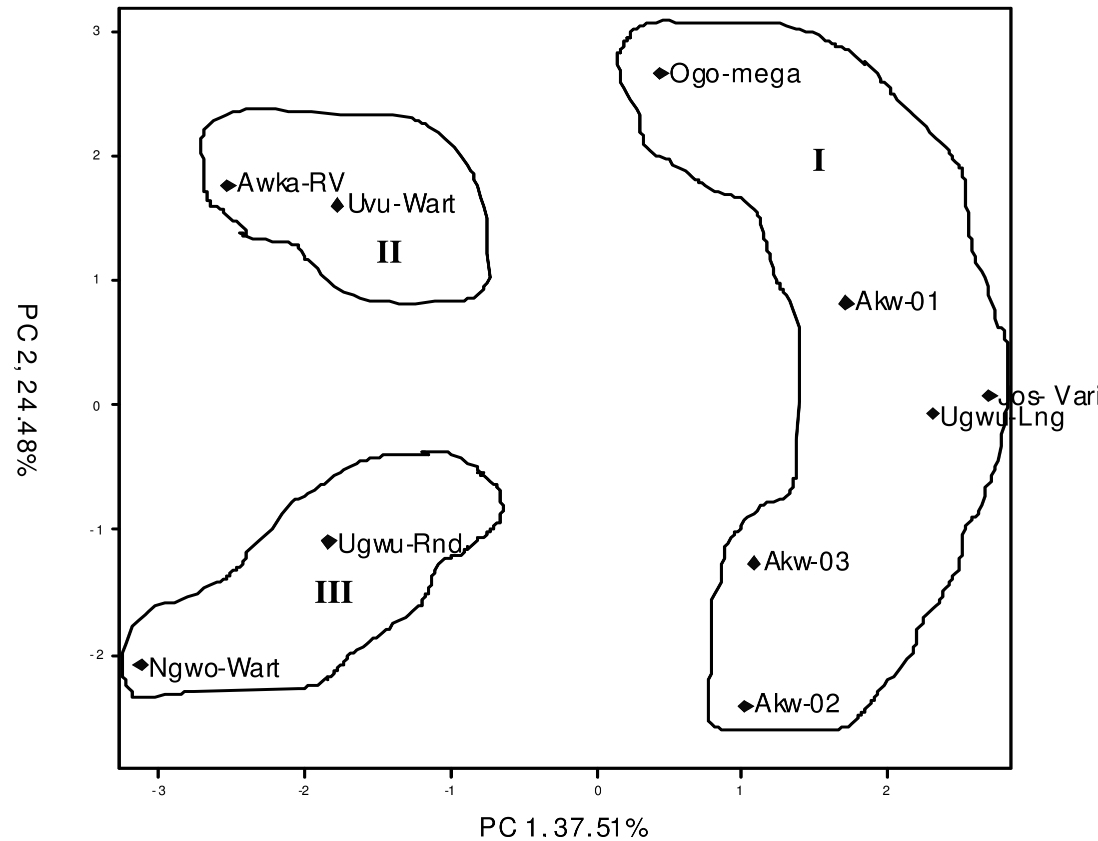

Figure 3. First and second principal component scores (PC1 and PC2) for the identification of *Cucurbita* accession performance on the 14 qualitative traits.

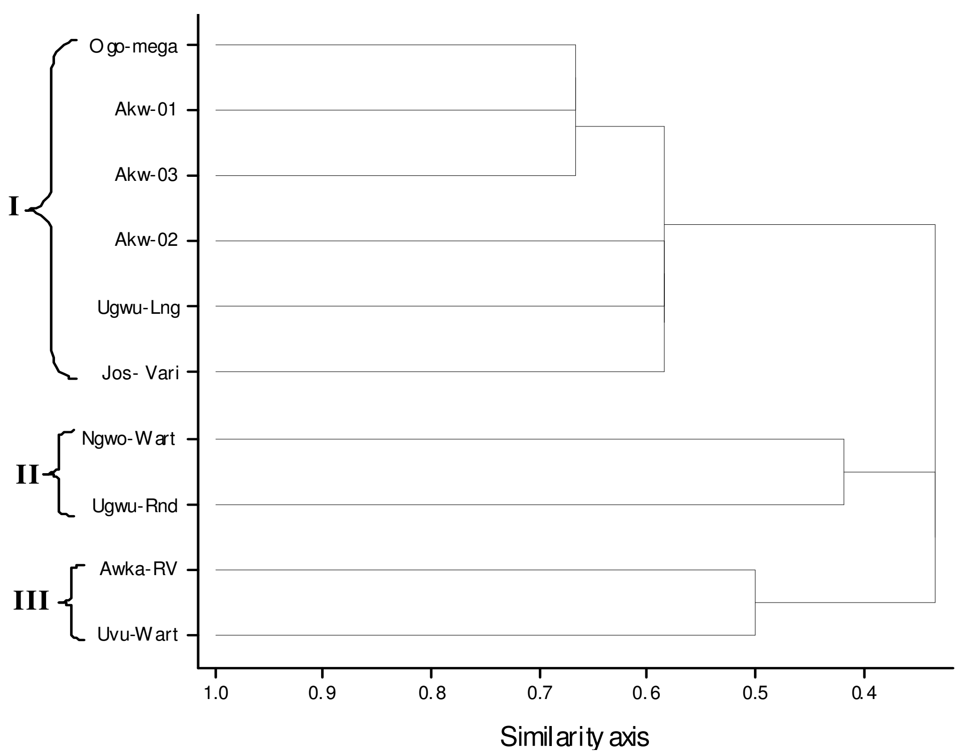

Figure 4. Dendrogram of 10 *Cucurbita* accessions based on qualitative characters.

Table 7. Shannon diversity indices and evenness for 13 qualitative charactersitics of *Cucurbita* species collected from three agro-ecological regions of Nigeria.

Characters	*C. pepo*	*C. moschata*	*C. maxima*
Growth habit	0.119	0.100	0.100
Stem colour	0.119	0.128	0.100
Leaf pubescent	0.008	0.128	0.115
Leaf colour	0.119	0.100	0.128
Leafiness	0.119	0.128	0.115
Petiole colour	0.119	0.119	0.115
Branching pattern	0.008	0.115	0.115
Fruit shape	0.008	0.128	0.115
Fruit texture	0.008	0.119	0.100
Immature fruit colour	0.119	0.128	0.115
Mature fruit colour	0.119	0.138	0.128
Seed shape	0.119	0.100	0.100
Seed colour	0.119	0.128	0.128
Species richness =	360		
Relative abundance =	72	144	144
$Hs_{species}$ =	1.103	1.559	1.474
Evenness =	0.187	0.265	0.250

length(r = 0.503**), seed length (r = 0.559**), vine length (r = 0.399*), girth size (r = 0.399*) and 100 seed weight (r = 0.782**). Weight of damaged fruits positively correlated and significant with days to 50% flowering (r = 0.376*), number male flowers (r = 638**), fruit diameter (r = 0.629**), nunmber of seeds per fruit (r = 0.593**), and seed length (r = 0.427**). The result revealed significant positive correlation (r = 0.786**) between the number of fruits per plant and number of female flowers. Number of seeds per plant also correlated positively with the number of male flowers (r = 0.615**) and fruit diameter(r = 0.631**). However, negative and significant relationship was observed between days to 50% emergence and days to 50% flowering (r = - 0.479**), number of female flowers (r = - 0.392*), fruit length (r = - 0.591**), seed length (r = - 0.491) and 100 seed weight (r = -0.378*).

DISCUSSION

The level of variability in Nigerian pumpkins observed in this study supports the earlier reports (Whitker and Bemis, 1964, 1975) that the Nigerian landraces are extremely diverse. The *Cucubita* species are reproductively isolated from each other by genetic barriers and are therefore identified using morphological characters (Whitaker and Bemis, 1964, 1975).

The significant differences in days to emergence observed could be attributed to the differences in the thickness of the seed coat and tissue layers. This agrees with the earlier findings on bottle gourd (Lagenaria siceraria) (Sivaraj and Pandravada, 2005) and on Cucurbita L. (Cucurbitaceae) (Agbagwa and Ndukwu, 2004). The variation observed on the days to 50% flowering was largely due to varietal differences among the *Cucurbita* species evaluated. This result was in agreement with that reported by Agbagwa and Ndukwu (2004) that flowering in *C. moschata* occurred 8 weeks after planting, and in *C. maxima* and *C. pepo*, flowering occurred 11 and 13 weeks after seed sowing, respectively. The significant genotype effect of the number of male flowers is an indication of varietal differences existing among the Cucurbita species studied. The differences observed in the number of fruits per plant, 100-seed weight and fruit weight among the genotypes, is in agreement with earlier reports by Rahman et al. (1990), Abdullah et al. (2003) and Precheur et al. (2007) who reported that differences in the fruit number were mostly influenced by the variety. The variation on the fruit length, fruit diameter and number of fruits per plant could be attributed to genetic differences existing among the genotypes. Nee, (1990) and Abdullah et al. (2003) reported that Cucurbita genotypes produce fruits of various sizes as dictated by the genetic constitution. Similarly, Mondal et al. (1989) reported wide range of variability in watermelon for fruit length, fruit diameter and number of fruits per plant.

The variations among the genotypes in number of seeds per fruit, seed length, seed width, 100-seed weight and the mean seed weight per plant indicate that the characteristics are genetically controlled as reported earlier by Stephenson et al. (1988) and Mondal et al. (1989). Kasrawi (1995) evaluated 41 half–sib families of summer squash (*C. pepo* L.) for 17 morphological and horticultural traits and observed large diversity for many of the traits within and among families. It is evident that fruits containing more seeds achieved greater size. Genotype Akw-01 had the highest fresh fruit weight (8.73 kg) and the highest number of seed (524 seeds) when compared with the rest of the genotypes, while Ugwu-Rnd had the least fresh fruit weight of 2.21 kg with low seed number of seeds per fruit (297 seeds). This findings agrees with Stephenson et al. (1988) who experimentally reported that fruits containing more seeds grew faster and achieved greater size. Similar results have been reported by other workers (Ercan and Kurum, 2003; Abdullah et al., 2003).

The principal justification for plant collection is to obtain natural variability that can be useful in organizing germplasm pool for crop improvement. The Cucurbits have diverged from the original descendant of their common proginator (Bennett, 1970). From the principal component analysis, traits such as seed weight, weight of healthy fruits, days to 50% flowering, fruit diameter, girth size, number of damaged fruits, number of healthy fruits and vine length showed maximum contribution towards total divergence among the genotypes. However, these aforementioned characteristics have been used to

Table 8. Correlation coefficients among the agronomic and yield traits in *Cucurbita* landraces.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. Days to 50% emergence	1																		
2. Days to 50% flowering	-0.479**	1																	
3. Number of male flowers	-0.110	0.351	1																
4. number of female flowers	-0.392*	0.268	0.034	1															
5. Number of fruits/plant	-0.216	0.143	0.147	0.786**	1														
6. Number of healthy fruits	-0.208	0.208	0.289	0.175	0.211	1													
7. Number of damaged fruits	0.065	-0.109	-0.182	0.309	0.404*	-809**	1												
8. Fruit diameter	-0.325	0.368*	0.514**	0.276	0.344	-0.025	0.230	1											
9. Fruit length	-0.591**	0.468**	0.330	0.241	0.145	0.745**	-0.609**	0.007	1										
10. Number of seeds/fruit	0.003	0.222	0.615**	0.126	0.181	0.161	-0.041	0.631**	0.069	1									
11. Seed length	-0.491**	0.611**	0.292	0.088	0.239	0.341	-0.175	0.443*	0.461*	0.180	1								
12. Number of leaves	0.328	-0.092	-0.103	-0.043	0.059	-0.055	0.087	0.073	-0.308	-0.67	-0.060	1							
13. Vine length	0.088	0.018	0.282	-0.001	0.180	0.373*	-0.241	-0.037	0.340	-0.086	0.245	0.168	1						
14. Girth size	0.075	0.284	0.236	-0.161	-0.041	0.522**	-0.513**	-0.147	0.429*	0.204	0.266	-0.232	0.211	1					
15. Number of branches	0.137	-0.085	0.101	0.176	0.045	0.264	-0.220	-0.138	0.223	0.147	-0.089	-0.077	0.013	0.138	1				
16. Weight of damaged fruits	-0.293	0.376*	0.638**	-0.010	0.053	-0.072	0.100	-629**	0.115	0.593**	0.427*	-0.148	0.126	0.146	-0.293	1			
17. 100-seed weight	-0.378*	0.629**	0.272	0.187	0.283	0.272	-0.085	0.311	0.460*	0.192	0.705**	-0.109	0.211	0.406*	0.054	0.315	1		
18. Seed weight	-0.308	0.484**	0.193	0.382*	0.388*	0.359	-0.103	0.224	0.503**	0.167	0.559**	-0.012	0.399*	0.380*	0.234	0.229	0.782**	1	
19. Weight of harvested fruits	-0.198	0.435*	0.562**	0.501**	0.567**	0.591**	-0.213	0.544**	0.431*	0.505**	0.328	0.037	0.185	0.276	0.187	0.271	0.480**	0.545**	1

* significant at the 0.05 level (2-tailed) and ** significant at the 0.01 level (2-tailed).

characterize the *Cucubita* genotypes (Rahman et al., Kasrawi, 1995).

The distribution of genotypes along the first two principal axes revealed a reasonable agreement with the hierarchical cluster. The intra-population variability evaluated by hierarchical cluster analysis conducted on the quantitative traits, grouped the accessions into two clusters, indicating sufficient heritable variation that could warrant rational selection. Cluster I and II had four and five genotypes, respectively. The clustering pattern of genotypes revealed that genotypes collected from the Derived Savanna agroecological zone were grouped into cluster I. However, all the genotypes in cluster II except for Ogo-mega were collected from the Guinea savanna agroecological zone. However, Akw-01 alienated itself from the clusters which could suggest that it is genetically independent from the other genotypes. The genotype, Akw-01 is an early flowering cultivars with large fruit size and good performance in the most of the quantitative traits evaluated. Cluster I comprise of early emerging genotypes with high production of male and female flowers, long vine length, less number of damaged fruits and high potentials for the production of heavier fruits and seeds. The genotypes in cluster II are essentially late emerging and early flowering with prolific leaf production and are susceptible to fruit damage. It could be concluded that the genotypes in cluster I and Akw-01 genotype are promising in the production of both male and female flowers with high potential to support more fruits and heavier fruits with more seed and are also less susceptible to fruit damage. Therefore, these genotypes could be recommended for selection and for further breeding program.

The accessions evaluated portrayed some degree of diversity in terms of the qualitative characters such as fruit shape, immature fruit colour, mature fruit colour, seed shape and seed colour. However, plant growth habit and seed shape were constant for all the accessions. This is consistent with the results of Huh et al. (2008) on Korean and Turkish watermelon populations. Bisognin (2002) reported that cucurbits are very similar in aforementioned ground development but have high genetic diversity for fruit shape and other fruit characteristics.

Of the 14 qualitative traits, fruit texture, immature fruit colour, mature fruit colour, branching pattern, leafiness and seed colour, allowed differentiation among the 10 accessions in the first three principal axes. These traits were the principal source of discrimination and characteritization among the *Cucurbita* accessions. Ferriol et al. (2004) previously reported that 47 characterized accessions of *C. moschata* displayed great diversity in the morphological traits like fruit shape, size and colour. Similar results have been reported for winter squash (*C. maxima*) and watermelon by Balkaya et al. (2010) and Levi et al. (2001), respectively. The first two principal components for the aforementioned six qualitative characters were positive, indicating that the six characters made significant contributions in the diversity and would therefore, provide a useful clue in selection programmes for the improvement of Cucurbita accessions. The accessions were separated clearly into three groups by the qualitative characters. However, major accessional discrimination was observed along the PC1 axis, indicating that all accessions collected from Southern Guinea Savanna except Ogo-mega (from Rain Forest) and Ugwu-Lng (from Derived Savanna) were located on the right side part of the PCA graph, while the remaining accessions that came from the Derived Savanna were on the left side of the Figure 4. The dendrogram summarized the interrelationships observed among accessions into three major clusters at 0.31 similarity coefficient. The accessions, Ogo-mega, Akw-01 and Akw-03 showed the highest coefficient of similarity (about 0.74) indicating that they are the closest pair. In cluster I, Ogo-mega, Akw-01 and Akw-03 had Jaccard dissimilarity coefficient of about 0.165 with Akw-02, Ugwu-Lng and Jos-vari. With the exception of Ogo-mega and Ugwu-Lng, all the accessions in cluster I were collected from Southern Guinea Savanna. Awka-RV and Uvu-watt were collections from derived Savanna grouped together in cluster II with similarity coeffifient of 0.42. Cluster III consisted of two accessions such as Ngwo-watt and Ugwu-Rnd (from derived savanna) at 0.50 similarity coefficient

It is evident from the high value of the Shannon diversity index (4.136) obtained in this study that the Nigeria *Cucurbita* species are obviously diverse. The high Shannon diversity index value obtained is attributed to the tremendous diversity observed in most of the qualitative characteristics evaluated. Diversity in Cucurbita genotypes according to Bisognin (2002), is as a result of variation in the fruit colour, and shape which agrees with the present findings. Ferriol et al. (2004) reported that characterized accessions of C. moschata displayed great diversity for most of the morphological traits evaluated, particularly fruit colour and fruit shape. The highest diversity index obtained for *C. moschata* suggests that the species is more diverse, followed by *C. maxima* and *C. pepo* in that order. The higher the HS value, the higher the uncertainty level of prediction. The observed values of evenness indicates that the richness of *C. moschata* species in the ecosysyem is highest followed by *C. maxima* and *C. pepo* in that order. The high HS observed for *C. moschata* was attributed to its high evenness value.

Weight of harvested fruits was positively correlated with days to 50% flowering, number of male flowers, number of female flowers, number of fruits per plant, number of healthy fruits, fruit diameter, fruit length, number of seeds per fruit, 100 seed weight and seed weight which illustrated that higher mean values for these traits can increase the weight of harvested fruits. The positive correlation obtained between the weight of harvested fruit and the number of seeds per fruit is in agreement with the results obtained in sweet pepper (*C. annuum* L.) (Rylski, 1973) and tomato (Lycopersicon esculentum Mill.) (Picken, 1984). Positive correlation of seed weight per fruit with days to 50% flowering showed that late flowering would increase the seed weight per plant.

The positive correlation of seed weight per fruit with days to 50% flowering, number of female flowers, number of fruits per plant, fruit length, seed length, vine length, girth size and 100 seed weight was obtained in this study. Pinar et al. (2007) had previously reported a significant positive relationship between seed weight per fruit and seed length in some Turkish *Aethionema* (Brassicaceae). Positive and significant relationships between the weight of damaged fruit and days to 50% flowering, number of male flowers, fruit diameter, number of seeds per fruit, and seed length is an indication of a linear relationship existing between the weight of damaged fruit and the above traits. This means that fruit damage increases with increase in the days to flowering, number male flowers, fruit diameter, number of seeds per fruit, and seed length. The correlation between the number of fruits per plant and number of female flowers per plant was significant and positive which indicates that higher number of fruits per plant were obtained in the genotypes that produced higher number of female flowers per plant.

The number of seeds per fruit increased with increase in the number of male flowers, indicating that the number of seeds produced in *Cucurbita* is influenced by the number of male flowers. Increase in the number of male flowers would result in higher pollen production (pollen load) and therefore, enhance fertilization and seed production. This is in agreement with the observations in tomato, where seed and fruit formation was limited by failure of pollen production, rather than by impaired pollen germination, pollen tube growth, ovule production or fertilization (Picken, 1984). For effective seed yield, improvement in Cucurbita genotypes with higher number of male flowers should be selected. The positive and significant correlation obtained between the number of seeds per plant and fruit diameter is in line with the previous report by Stephenson et al. (1988). They reported that fruits with low seed numbers would be about 17% smaller than fruits with high seed numbers. The negative but significant correlation of days to 50% emergence with days to 50% flowering, number of female flowers, fruit length, seed length and 100 seed weight observed, indicated that early seedling emergence in the crop would lead to the extension of the crops vegetative stage and higher number of female flowers, long fruits and seed length with heavier 100 seed weight. Therefore, rational selection based on early seed emergence in the *Cucurbita* genotypes could be a reliable strategy in the improvement of the aforementioned *Cucurbita* yield attributes.

The result of this study revealed an enormous agro-morphological diversity among the Nigeria *Cucurbita* species, which can be used for the crop improvement. This is an essential factor in crop improvement and it can be exploited advantageously.

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