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Cover Page Footnote

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Morphological Evaluation of Tomato (*Solanum lycopersicum* Linn.) Cultivars

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Abstract

Tomato (*Solanum lycopersicum* Linn.) is widely cultivated and is economically beneficial. Tomato cultivars were obtained from traditional agriculture systems, and their morphological characters were evaluated. The cultivars included Pepper tomato [ED/CH/01], Edo local [ED/CH/02], Golden tomato [ED/CH/03] and Derica tomato [ED/CH/04]. Results of the principal component analyses of 27 morphological characters indicated that two characters accounted for 94.65 % of the observed variations. Scatter plots suggested good tendency of grouping for the four accessions. In the dendrogram, two clusters were formed with ED/CH/01, ED/CH/02 and ED/CH/03 grouped together whereas ED/CH/04 clustered separately. The clustering pattern implicated a common origin and/or gene pool for the cultivars. Cultivars ED/CH/01, ED/CH/03 and ED/CH/04 showed determinate growth type, while ED/CH/02 showed a semi-determinate growth pattern. Further, in terms of plant size, ED/CH/01 and ED/CH/02 were intermediate, while ED/CH/03 and ED/CH/04 were large. The characteristics of the flower and fruits exhibited diversity in terms of the corolla color, style, shape, fruit size at maturity, exterior color of the mature fruit, fruit shoulder, fruit cross-sectional shape, and fruit blossom end shape. These cultivars collectively possess characteristics that can be used by plant breeders. We recommend that further characterization using molecular techniques as well as conservation attention for these local germplasms should be conducted.

Abstrak

Evaluasi Morfologi Beberapa Kultivar Tomat (Solanum Lycopersicum Linn.). Tomat (*Solanum lycopersicum* Linn.) dibudidayakan secara umum dan menguntungkan secara ekonomi. Kultivar tomat dibudidayakan melalui sistem pertanian tradisional, dan karakter morfologinya dievaluasi. Kultivar meliputi *Pepper tomato* [ED/CH/01], *Edo local* [ED/CH/02], *Golden tomato* [ED/CH/03] dan *Derica tomato* [ED/CH/04]. Hasil analisa komponen utama (*PCA*) dari ke-27 karakter morfologi menunjukkan bahwa dua karakter menghasilkan 94,65% dari seluruh variasi yang diamati. Plot sebaran menunjukkan kecenderungan pengelompokan yang baik untuk keempat aksesi. *Dendogram,* memperlihatkan adanya dua kelompok, dimana ED/CH/01, ED/CH/02 dan ED/CH/03 berada dalam satu kelompok dan ED/CH/04 berada dalam kelompok terpisah. Pola pengelompokan tersebut mengimplikasikan asal usul dan / atau gen pool bersama untuk kultivar. Kultivar ED/CH/01, ED/CH/03 dan ED/CH/04 menampakkan tipe *determinate growth*, sementara ED/CH/02 memperlihatkan pola *semi-determinate growth.* Lebih lanjut, sehubungan dengan ukuran tanaman, ED/CH/01 dan ED/CH/02 berukuran sedang, sementara ED/CH/03 dan ED/CH/04 berukuran besar. Karakteristik bunga dan buahnya menunjukkan keragaman, dalam hal warna kelopak bunga, jenis, bentuk, dan ukuran buah saat matang, warna luar dari buah yang matang, *fruit shoulder,* bentuk penampang buah, dan bentuk buah saat ranum. Kultivar-kultivar ini secara umum memiliki karakteristik yang dapat dimanfaatkan oleh pemulia tanaman. Karakterisasi lebih lanjut menggunakan teknik molekuler dan juga dengan konservasi terhadap plasma nutfah lokal perlu dilakukan.

Keywords: tomato (Solanum lycopersicum), morphological characterization, fruit vegetable, cultivar

Introduction

Tomato (*Solanum lycopersicum Linn*.) is an important fruit vegetable crop grown for its edible part. It belongs to the family Solanaceae and order Solanales [1]. *S. lycopersicum* has two widely distributed varieties: the cultivated *S. lycopersicum* var. *lycopersicum*, and the weedy *S. lycopersicum* var. *cerasiforme* [2]. It is popular

worldwide because of its high consumption, availability, and health benefits [3]. The fruits and leaves of tomato are consumed in several ways [4]. Olaniyi *et al*. [5] reported that it is the world's most commonly consumed vegetable crop after potato and sweet potato and is the most commonly canned vegetable. Despite its economic importance, some aspects of its origin remain unclear [2]. It is exotic to Africa but ranks among the most consumed and domesticated fruit vegetables [6].

Domestication has reduced the gene pool, resulting in a need for conservation, characterization, and utilization of its genetic resources [7]. By contrast, Figàs *et al.* [8] state that local varieties of tomato have been grown and selected by farmers under specific conditions in a limited geographical area and have provided the genetic background for breeding new improved varieties. In Nigeria, the cultivation is dominated by the northern states, where the fields have several landraces that are recognizable morphologically. The increased demand for high quality tomato products by consumers has resulted in the need to collect, characterize and evaluate unknown tomato germplasms. The relevance of plant collection and characterization for the conservation of germplasms has been described by Osawaru and Ogwu [9, 10]; Ogwu *et al*. [11, 12]. Traditional agriculture acts as a custodian of ethnobotanical knowledge, practices, and plant varieties, most of which have not been studied. Therefore, the collection and characterization of these cultivars may contribute to food security, plant breeding and conservation. Morphological characterization describes plant species using expressed phenotypes. This technique highlights the important agronomic characters that may be beneficial for crop production, breeding, as well as germplasm conservation and utilization.

In this study, tomato cultivars were obtained from traditional agriculture systems with the aim of evaluating their morphological characters. These features are important to supplement and promote the conservation efforts of the germplasm in Nigeria and Africa while contributing to food security. Tomato landraces may comprise several closely related morphotypes that differ from each other only in some attributes [7]. These attributes are investigated in this study to highlight their distinctive qualities. Morphological characters are important not only to distinguish plant species, but also to promote their economic relevance.

Materials and Methods

Study/Sampling Areas. Edo State is situated between Latitude 05^0 44^1N and 07^0 34^1N and Longitude 06^0 04^1E (Figure 1), spanning a land area of approximately 1.97 million hectares. The climate is humid form in the south, sub-humid in the central region and dry in the north. The rainfall model is of two types; and reduces from >2,000 mm in the southeast to 1,000 mm per annum in the north, while the mean daytime temperature ranges from 25 °C to 34 °C [13]. The researches of Osawaru and Ogwu [9], Osawaru and Ogwu [10] present a detailed description of the study area. The sampling sites were selected due to their proximity to northern Nigeria, where tomato cultivation is dominant. Moreover, there is high tomato production in these areas.

Planting Materials. Collection missions were conducted twice in 2015 to identify and collect tomato germplasms from the areas highlighted in Figure 1. The first mission was undertaken during the planting season to identify the cultivars in the field and discuss the planting conditions and strategies with the farmers. The four varieties selected for the study are cultivated widely in the sampling areas (north-eastern part of Edo State). The actual collection was done over two weeks during the harvest season. Seeds were collected from ripe, mature fruits of four varieties of tomato obtained from the local farmers. The cultivars included Pepper Tomato, Derica Tomato, Golden Tomato and Edo local (Table 1, Plate 1, 2, 3 and 4).

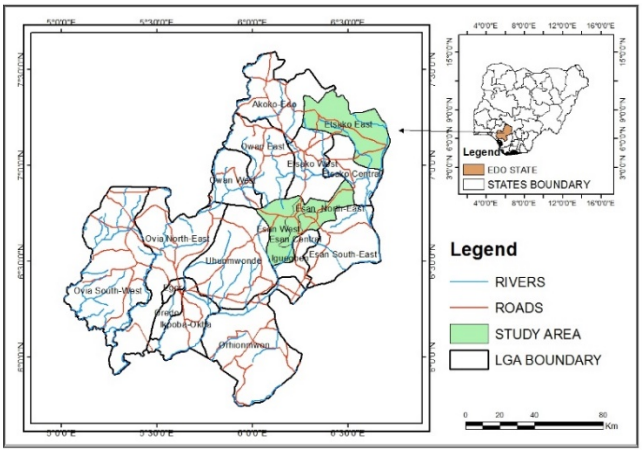

Figure 1. Map of the Study Area and the Sampling Sites

Table 1. Accession and Varieties of Tomato

S/N	Accession Number	Cultivar
1	ED/CH/01	Pepper tomato
2	ED/CH/02	Edo local
3	ED/CH/03	Golden tomato
4	ED/CH/04	Derica tomato

Plate 1. Pepper Tomato Fruits [ED/CH/01]

Plate 2. Edo Local Tomato Fruits [ED/CH/02]

Plate 3. Golden Tomato Fruits [ED/CH/03]

Plate 4. Derica Tomato Fruits [ED/CH/04]

Pepper Tomato. These fruits are medium to large in size with an average weight of 42.5 g. They have a "pepper shape" therefore, they are named pepper tomatoes. They are bright red in color when ripe and have a smooth, thick cuticle with many seeds and no growth cracks.

Edo Local. These fruits are small in size with an average weight of 20.4 g and an oval cylindrical shape. The fruits are bright red when ripe, glossy, and with a thin smooth cuticle. They have no growth cracks and few seeds.

Golden Tomato. These fruits are very large with an average weight of 53.3 g and the fruit shape is oval-cylindrical with four to six longitudinal grooves and ridges running from the top to the bottom of the fruit. The fruits are bright red when ripe, glossy, and with very smooth cuticles and many seeds; there are no growth cracks.

Derica Tomato. This is an example of the improved variety cultivated within the study area, popularly known as "Hausa tomato". The fruits are medium to large in size with an average weight of 52.4 g. These fruits are firm and bright red in color when ripe and globose with smooth and thick cuticles and no growth cracks.

Field trials. The seeds extracted from the four cultivars were sun dried for one month. Field trials were conducted from March to July, 2016. Using a randomized complete block design, the dried seeds were cultivated in the experimental field beside the botanical garden in the Department of Plant Biology and Biotechnology, University of Benin, Benin City (6.20 ^{o}N and 5.37 ^{o}E), Nigeria. A detailed description of the cultivation site has been reported by Ogwu and Osawaru [14]; Osawaru *et al.* [15]; Ogwu *et al.* [16]. Seeds were sown directly in the soil; using six seeds per hill. The Seedlings were thinned to one plant per stand two weeks after germination. Standard agronomic practices such as weeding and watering were conducted as per the method described by Remison [17].

Morphological Characterization of Tomato. The variations in plant growth type, plant size, stem pubescence density, foliage density, degree of leaf dissection, leaf shape (Figure 2), corolla color, style shape, style position, exterior color of immature fruit, presence of green trips in the fruit, fruit pubescence, fruit size at maturity, predominant fruit shape (Figures 3 and 4), exterior color of the mature fruit, fruit shoulder shape, fruit cross-sectional shape and fruit blossom end shape were easily recognized by the visual approach by using the colour chart in IBPGR [18] descriptor list for *S. Lycopersicum*. The morphological characterization was performed for the four varieties to determine the important traits necessary for plant breeding that would ultimately facilitate sustainable development in Nigeria, West Africa and other African regions. The parameters measured and the IBPGR descriptor keys are presented in Table 2.

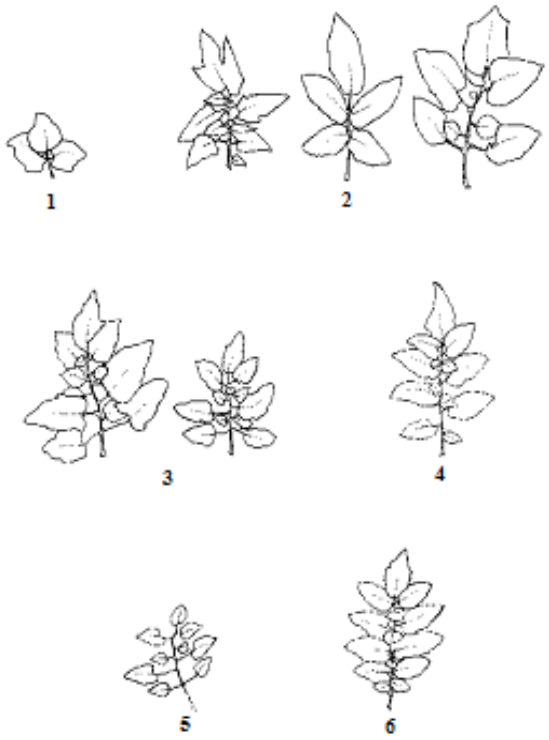

Figure 2. Leaf Shape of the Tomato Plants. 1–Dwarf, 2–Potato Leaf Type, 3–Standard, 4–Peruvianum, 5–Pimpinellifolium, 6–Hirsutum (Source: [18])

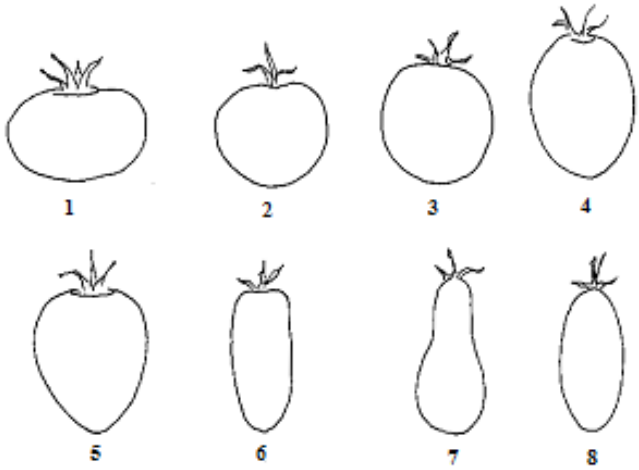

Figure 3. Fruit Shape of the Tomatoes. 1–Flattened (oblate), 2–Slightly Flattened, 3–Rounded, 4–High Rounded, 5–Heart-Shaped, 6-Cylindrical (Long Oblong), 7–Pyriform, 8–Ellipsoid (Plum-Shaped) (Source: [12])

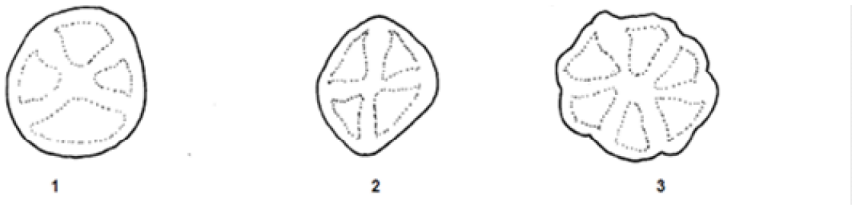

Figure 4. Fruit Cross-sectional Shape of the Tomato Fruits. 1–Round, 2–Angular, 3–Irregular (Source: [18])

Table 2. Codes used for Morphological Characterization of Tomato

S/N	Parameter measured	Code	Descriptor keys
1	Plant growth type	PGT	1- Dwarf, 2- Determinate, 3- Semi-determinate, 4- Indeterminate
2	Plant size	PLS	3- Small, 5- Intermediate, 7- Large
3	Stem pubescence density	STD	3- Sparse, 5- Intermediate, 7- Dense
4	Stem internode length	SIL	3- Short, 5- Intermediate, 7- Long
5	Foliage density	FDE	3- Sparse, 5- Intermediate, 7- Dense
6	Leaf attitude	LAT	3- Semi-erect, 5- Horizontal, 7- Drooping
7	Leaf type	LTY	1- Dwarf, 2- Potato leaf type, 3- Standard, 4- Peruvianum, 5- Pimpinellifolium, 6- Hirsutum, 7- Other
8	Degree of leaf dissection	DLD	3- Low, 5- Intermediate, 7- High
9	Anthocyanin coloration of leaf veins	ACV	1- Obscure vein, 2- Normal (clear)
10	Inflorescence type	INT	1- Generally uniparous, 2- Both (partly uniparous, partly multiparous), 3- Generally multiparous
11	Corolla color	COC	1- White, 2- Yellow, 3- Orange, 4- Other
12	Style shape	STS	1- Simple, 2- Fascinated, 3- Divided
13	Style position	SPO	1- Inserted, 2- Same level as stamen, 3- Slightly exserted, 4- Highly exserted
14	Style hairiness	SHA	0- Absent, 1- Present
15	Exterior color of immature fruit	ECI	1- Greenish-white, 3- Light green, 5- Green, 7- Dark green, 9- Very dark green
16	Presence of green (shoulder) trips on the fruit	PGF	0- Absent, 1- Present
17	Fruit pubescence	FPU	3- Sparse, 5- Intermediate, 7- Dense
18	Fruit size at maturity	FSM	1- Very small (<3cm), 2- Small (3-5cm), 3- Intermediate (5.1-8cm), 4- Large (8.1-10cm), 5- Very large (>10cm)
19	Predominant fruit shape	PFS	1- Flattened, 2- Slightly flattened, 3- Rounded, 4- High rounded, 5 – Hear-shaped, 6-Cylindrical, 7- Pyriform, 8- Ellipsoid, 9-Other
20	Exterior color of mature fruit	ECM	1- Green, 2- Yellow, 3- Orange, 4- Pink, 5- Red, 6- Other
21	Fruit shoulder shape	FSS	1- Flat, 3- Slightly depressed, 5- Moderately depressed, 7- Strongly depressed
22	Skin color of ripe fruit	SCF	1- Colorless, 2- Yellow
23	Fruit cross-sectional shape	FCS	1- Round, 2- Angular, 3- Irregular
24	Fruit blossom end shape	FBS	1- Indented, 2- Flat, 3- Pointed
25	Jointless pedicel	JPE	0- Absent, 1- Present
26	Seed shape	SES	1- Globular, 2- Ovate, 3- Triangular with pointed base
27	Seed color	SEC	1- Light yellow, 2- Dark yellow, 3- Grey, 4- Brown, 5- Dark brown

Note: Adapted from [18].

Statistical analyses: Multivariate statistical analyses were performed in this study to assess the possible relationship between qualitative and quantitative morphological characters and accessions. The collected data were analyzed using SPSS (version 20.0) and PAST (PAleontological STatistics, version 1.34). Analysis of variance was conducted for qualitative and quantitative morphological characters to determine the significance of the differences among the accessions. Principal Component Analysis (PCA) and Paired Group Cluster Analysis (PGCA) were used to determine the extent of genetic variation and the percentage similarities within and between the accessions. Eigen-values and factor scores were obtained using the PCA, these were then used to determine the relative discriminative power of the axes and their associated characters. A dendrogram was generated using the PGCA to display the position of the accessions and their distance similarity.

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Results and Discussion

Results are presented in Tables 3-5 and Figures 2-3. The 27 studied morphological characters and their abundance scores in each cultivar are presented in Table 3. The PCA conducted for 27 morphological characters among the four *S. lycopersicum* cultivars show that two of the 27 principal component axes had eigen-values >7.54 as per Joliffe cut-off value (Table 4). The eigen-value indicates the importance of each principal component axis and its contribution in the variation in the characters of the four cultivars of *S. lycopersicum*. The PCA eigen-values were as follows: PCA 1 (22.10), PCA 2 (8.50), and PCA 3 (1.73); 7.40 was taken as the reference **(?).** This suggest that 95.65% of the observed variation are accounted for by PC 1 and 2. The loading of each character on the different principal component axis was performed to assess their relative contribution in the variation. The following characters were heavily loaded along the PC axis 1: PFS (0.61), FSS (0.58), and FPU (0.20); PC axis 2: FSM (0.22), ECI (0.68), STS (0.29), and PC axis 3; FBS (0.62).

Table 5 shows the standardized PCA scores of the various accessions. The first two principal component axes account for 94.65 % of the variation in the 27 morphological parameters (axes). The PCA 1 loaded characters are possessed by accession ED/CH/01, ED/CH/03, and ED/CH/04 respectively. PCA 2 loaded characters are best possessed by accession ED/CH/02 only. Accession ED/CH/04 that was observed to have a high PCA score in PCA 1 could be well distinguished by the characters

Table 3. Scores of the Morphological Characters in the Four Tomato Cultivars

	Cultivars			
Morphological characters	ED/CH/01	ED/CH/02	ED/CH/03	ED/CH/04
PGT	3	2	3	3
PLS	5	5	7	7
STD	5	7	5	5
SIL	7	7	7	7
FDE	7	5	5	5
LAT	3	5	5	3
LTY	2	2	2	2
DLD	7	5	5	5
ACV	2	2	2	2
INT	1	1	1	1
COC	3	1	2	2
STS	1	3	2	1
SPO	1	1	1	4
SHA	0	0	0	0
ECI	1	5	1	1
PGF	1	0	1	0
FPU	3	3	3	5
FSM	3	4	3	2
PFS	9	9	9	3
ECM	3	3	1	5
FSS	7	3	7	1
SCF	2	2	2	2
FCS	2	1	3	1
FBS	3	3	1	2
JPE	0	0	0	0
SES	3	3	3	3
SEC	1	1	1	1

Key: PGT- plant growth type; PLS- plant size; STD- stem pubescence density; SIL- stem internode; FDE- foliage density; LAT- leaf attitude; LTY- leaf type; DLD- degree of leaf dissection; ACV- anthocyanin coloration of leaf veins; INT- inflorescence type; COC- corolla color; STS- style shape; SPO- style position; SHA- style hairiness; ECI- exterior color of immature fruit; PGF- presence of green (shoulder) trips on the fruit; FPU- fruit pubescence; FSM- fruit size at maturity; PFS- predominant fruit shape; ECM- exterior color of mature fruit; FSS- fruit shoulder shape; SCF- skin color of ripe fruit; FCS- fruit cross-sectional shape; FBS- fruit blossom end shape; JPE- joint less pedicel; SES-seed shape; SEC- seed color

in PCA 1. For instance, the style shape, fruit size at maturity, fruit shoulder shape, fruit cross-sectional shape, fruit blossom end shape and corolla color were observed to be high in cultivars ED/CH/01, ED/CH/03 and ED/CH/04 and highly loaded in PCA 1. These characters are outlined in Table 3.

Morphological evaluations of 27 morpho-agronomic characters of tomato germplasms were conducted. Genetic variability, as reflected by the morpho-agronomic characters is the basis of crop breeding on which selection depends to evolve superior genotypes; therefore, the higher the variation expressed for a character in the breeding material, greater is the scope for its improvement through selection [19,20]. Characterization of tomato germplasms is very important for the work of current and future agronomists and genetic improvement specialists [21]. Characterization therefore aids the documentation of the genetic variability existing in a population [22]. Variation is an important attribute of breeding programs [20,23]. Morphological traits are important diagnostic features that can be used for distinguishing genotypes. The characters assessed in this study are listed in IBPGR [18] as key characters for the crop, and our results suggest these may be exploited in the four tomato cultivars for tomato breeding in Nigeria and worldwide. A considerable proportion of Nigerian farmers practice traditional agriculture and are knowledgeable about plant resources with potentially useful agronomic characters [11,24].

Cultivars ED/CH/01, ED/CH/03 and ED/CH/04 showed determinate plant growth type while variety ED/CH/02 showed semi-determinate growth type. The plant sizes of ED/CH/01 and ED/CH/02 are intermediate while those of ED/CH/03 and ED/CH/04 are large. The determinate nature and large plant size of tomato allow larger and continuous fruit harvest. This is beneficial when the price of vegetable fluctuates [25]. The determinate growth type and large plant size could be incorporated into the variety ED/CH/02 to produce tomato plants with determinate growth type and large plant size.

Table 4. Principal Component Analysis (PCA) of the 27 Morphological Characters of the Four Accessions *Solanum lycopersicum* Cultivars

Character code	PC 1	PC 2	PC 3
ACV	0.0000	0.0000	0.0000
INT	-2.205E-17	-7.966E-17	-9.934E-17
COC	0.0348	-0.2313	0.3270
STS	0.06732	0.2783	-0.3025
SPO	-0.3062	-0.1407	-0.0736
SHA	8.497E-35	1.191E-33	3.574E-33
ECI	0.0270	0.6845	-0.0138
PGF	0.0953	-0.1242	0.0280
FPU	-0.2041	-0.09381	-0.0490
FSM	0.1088	0.2180	0.0211
PFS	0.6124	0.2814	0.1471
ECM	-0.3118	0.0342	0.5422
FSS	0.5854	-0.4031	0.1609
SCF	0.0000	0.0000	0.0000
FCS	0.1491	-0.1882	-0.2677
FBS	-0.0056	0.1749	0.6158
JPE	0.0000	0.0000	0.0000
SES	0.0000	0.0000	0.0000
SEC	0.0000	0.0000	0.0000
Eigen Value	22.10	8.50	1.73
% Variance	68.36	26.29	5.35

Key: ACV- anthocyanin coloration of leaf veins; INT- inflorescence type; COC- corolla color; STS- style shape; SPO- style position; SHA- style hairiness; ECI- exterior color of immature fruit; PGF- presence of green (shoulder) trips on the fruit; FPU- fruit pubescence; FSM- fruit size at maturity; PFS- predominant fruit shape; ECM- exterior color of mature fruit; FSS- fruit shoulder shape; SCF- skin color of ripe fruit; FCS- fruit cross-sectional shape; FBS- fruit blossom end shape; JPE- joint less pedicel; SES-seed shape; SEC- seed color.

Table 5. The Standardized Principal Component Analysis Scores

Accession	PCA 1	PCA 2	PCA 3
ED/CH/01	2.7518	-1.5356	1.6791
ED/CH/02	0.4479	4.3645	-0.0179
ED/CH/03	3.5681	-1.6326	-1.5340
ED/CH/04	-6.7678	-1.1963	-0.1272

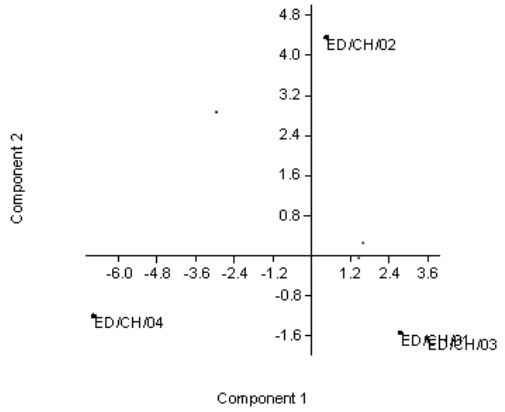

Figure 5. PCA Scatter Diagram Produced by Plotting the First PC Against the Second PC for 27 Morphological Characters of the four Accessions of *Solanum lycopersicum*

The flowers and fruits displayed great diversity in terms of the corolla color, style shape, fruit size at maturity, exterior color of the mature fruit, fruit shoulder, fruit cross-sectional shape, and fruit blossom end shape. Brightly colored flowers attract more pollinators. The varieties ED/CH/01, ED/CH/03 and ED/CH/04 showed yellow and orange corolla. These two colors tend to attract more pollinators than the ones with white corolla. Pollinators play a crucial role in plant reproduction and because pollination leads to fertilization, resulting in fruit formation. Fruits characteristics such as large fruit size, red and orange color of the mature fruit (exterior), flat or slightly depressed fruit shoulder shape, and pointed fruit blossom end shape are desirable in the Nigeria markets. The ED/CH/02 variety displays such characteristics; therefore, this variety can be selected for breeding by crossbreeding ED/CH/02 with ED/CH/01, ED/CH/03 and ED/CH/04 that possess some of the characteristics appreciated in the Nigeria markets. Diversity within Lycopersicon species has been investtigated by several researchers [20, 26]. They found that several characters of members of the genus such as size of fruit, fruit color at maturity, fruit cross-sectional shape, fruit shoulder shape and fruit blossom end shape are inherited in a simple manner, suggesting that these characters are controlled by relatively few genes.

The 27 morphological characters among the four cultivars were standardized, analyzed and subjected to PCA, scatter plot analysis, and single linkage cluster analysis (SCLA). The use of statistical model and tests provide an informative conclusion about several phenomena by observing a small representative sample [19, 27]. The PCA method shows the pattern of variation of characters among the individual samples [28, 29]. It tends to reduce the dimension of the multivariate data by removing inter-correlation among the variables and allows a multi-dimensional relationship to be plotted on two or three principal component axes [28, 30]. The relative discriminating power of the axes and their associated characters were measured by eigen-value and factor scores, respectively. The loading of each character on the different principal component axes is shown in Table 4 and was used to assess their relative contribution in the variation. PCA 1 was significantly loaded with characters such as predominant fruit shape, fruit shoulder shape, and fruit pubescence. PCA 2 was affected by characters such as fruit size at maturity; exterior color of the immature fruit, and style shape. PCA 3 was significantly affected by fruit blossom end shape. These characters account for the high variability observed in the studied cultivars.

To complement this result; a scatter diagram was plotted to determine the grouping tendency within the genus Solanum as per the method used by Wickremasinghe and Herat [31]. SCLA was also employed to classify the variation and show the relationship pattern among the five accessions, as used by Ariyo and Odulaja [32]. The scatter plot PC 1 versus PC 2 (Figure 2) indicates a good grouping tendency of the four cultivars. ED/CH/01, ED/CH/02, and ED/CH/03 were grouped together, while ED/CH/04 was put in a separate group, indicating that the accessions in the same group are to an extent, related morphologically. The accessions were grouped into two distinct cluster groups (Figure 3) that could be indicative of them having similar ancestral origin with a common gene pool. This variation within the genus Solanum can be used for breeding where the required traits can be incorporated. Therefore, crossbreeding is recommended between accessions in different cluster groups.

Conclusion

Supercapacitor electrodes made of TiO_2/CNT/AC This study emphasized the importance of morphology in plant characterization and conservation. The germplasms investigated in this study possess characters that could be of interest to plant breeders. They are highly marketable because of the characteristics of their fruits portraying a possible linkage between the fruit and vegetable industry and future research efforts on these germplasms. Till date, these resources have not been given any conservation attention and are only held by traditional farmers. This requires attention to enhance future utilization. The need for conservation of these resources and knowledge to complement and balance utilization is crucial [32, 33, 34]. The characteristics of the flowers and fruit of the tomato cultivars have been highlighted in this study as key descriptors of tomato

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