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RESEARCH ARTICLE

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Phenotypic characterization of tomato *Solanum lycopersicum* L. cultivars from Southern Nigeria using morphology

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ABSTRACT

Cultivated tomato (*Solanum lycopersicum* L.) has few intraspecific diversities unlike in the wild. This study used morphology to characterize four cultivars of *S. lycopersicum,* comprising two local cultivars (BNL and EKL) obtained from traditional agriculture system and two improved cultivars (IMPA and IMPB) obtained from a research institute. The cultivars were cultivated in experimental field of the University of Benin, Nigeria. Thirty-two qualitative and quantitative characters based on International Plant Genetic Resources Institute descriptors for the crop were used to enumerate their phenotype. The germination rate and number of days to flowering was the same across the four cultivars. The principal component analysis of the characters suggest vine length, fruit weight, ribbing at calyx end, plant size, leaf attitude, fruit size and fruit shape contributed most to the variation among the four cultivars. The local cultivars had purple hypocotyl while the two improved cultivars had green hypocotyl. Semi determinate growth was observed in all the cultivars except in BNL. Therefore, the results suggests that the four cultivars studied are morphologically distinct. The study indicates that the two local cultivars have good fruit quality and yield attributes, which may be exploited in future plant breeding and genetic improvement of tomato germplasm in Nigeria.

Keywords: *Solanum lycopersicum*, traditional agriculture, food security, plant conservation, morphological characterization

1. INTRODUCTION

Tomato (*Solanum lycopersicum* L.) belongs to the Solanaceae family and is widely consumed. The plant was discovered late because men thought it was poisonous. It has since been domesticated and remained under cultivation in almost all continents. The center of origin has been established as the Andes region of South America. Tomato is a frost intolerant plant and requires moderate rainfall and temperature. High rainfall lead to lower productivity as it promotes foliar diseases [1,2]. Fruits set between 15-30^{o}C temperatures [3]. High night time temperatures (above 30^{o}C) lead to poor fruit setting [3,4]. They grow well in soils with optimum pH of 5-8 otherwise fertilizer use is recommended. There are numerous cultural practices to adhere to including regular irrigation and weeding.

Characterization involves describing plant features using specific keys such as their phenotype, which may reflect genetic variability in tomato. Characterization is necessary because it

creates awareness of inherent diversity in plants, which may be explored for greater value [5,6,7]. Conservation of plant genetic resources is also greatly reliant on characterization [6].

Wild relatives of tomato provide a great resource for their agronomic and yield improvement [8]. Yield components that may be improved by breeding with the wild relatives include fruit size, fruit color, and resistance to diseases and harsh environmental elements [8]. Thus, morphological characterization of tomato elucidates the inherent genetic diversity of the crop. Molecular characterization is also a useful characterization method. The work of Ezekiel *et al*. [9] is a typical example of molecular characterization of tomato. It should be mentioned that aside the natural diversity of tomato in the wild, breeding programs and genetic engineering are major sources of diversity. Breeding programs have led to greater diversity in fruit size, fruit color, growth type and other important traits of tomato. This study aims to contribute to the conservation efforts on tomato by exploring the phenotypic characters of four cultivars of tomato. Phenotypic characters of the fruit contribute to the economic value of crop and if it will be selected for subsequent cultivation. Through this study, we hope to highlight the diversity in the fruits of indigenous tomato germplasms in Southern Nigeria. We hypothesize that the key to the preference of these cultivars is the variability in their phenotype especially fruit shape, size, quality, vine length, plant size and growth pattern. Therefore, the study will also provide useful insights to key descriptive characters, which may be exploited for future tomato breeding programs.

2. MATERIALS AND METHODS

2.1. Seed collection and study area

Seeds of two varieties from previous harvest season were obtained from traditional agriculture system in Udo community, Edo state Nigeria and two improved varieties were obtained from the gene bank of Nigerian Horticultural Institute, Ibadan, Nigeria. The passport data of the samples are present in Table 1.

2.2. Experimental design

The experimental plot was the experimental field of Department of Plant Biology and Biotechnology, University of Benin, Benin City (06° 23.829N, 005° 36.973E). Plants were cultivated (between January to April, 2016) in a randomized complete block design with three replicates per variety. Standard agronomic and cultural practices were adopted from Remison [10]. The seeds were nursed in the Screen house within the experimental field and transplanted after four weeks.

2.3. Morphological characterization

In the nursery, data was collected on the germination date; first secondary leaf appearance date; 50 % germination date; plant height after 2 weeks and 4 weeks.

2.4. Number of days of 50 % germination

This was done separately and calculated as the number of days to 50 % germination using 10 sown seeds per variety. The mean value was used to represent days to 50 % germination per variety.

2.5. Number of days to flowering

This was taken as the number of days it took each variety to flower.

2.6. Number of Days to fruiting

This was taken as the number of days it took each variety to fruit.

2.7. Number of Leaves at maturity

This was taken as the number of leaves on each variety 5 weeks after transplanting.

2.8. Number of Branches at maturity

This was taken as the number of branches on each variety 5 weeks after transplanting. Other descriptors were collected from the field using the International Plant Genetic Resource Institute [11] descriptors. Thirty two morphological characters were scored. The characters are summarized in Table 2.

2.9. Statistical analysis

Multivariate statistical analyses were applied in this study to trace the possible relation between qualitative and quantitative morphological characters and cultivars. Data collected were analyzed using SPSS (version 20.0) and PAST (paleontological statistics, version 1.34). Analysis of variance was done for qualitative and quantitative morphological characters to locate significant difference among the accession. Principal Component Analysis (PCA) and Paired Group Cluster Analysis (PGCA) were used to determine the extent of genetic variation and percentage similarities within and between cultivars. Eigen-values and factor scores were obtained from PCA, which were used to determine the relative discriminative power of

Table 1. Varieties of tomato and their source

S/N	Code	Source	Location	Status
1	BNL	Udo community	6°30'N and 6°00'E	Traditional cultivar
2	EKL	Udo community	6°30'N and 6°0'E	Traditional cultivar
3	IMPa	NIHORT	7°20'N and 3°52'E	Improved variety
4	IMPb	NIHORT	7°20'N and 3°52'E	Improved variety

Table 2. Code used in morphological characterization.

S/N	Character	Parameter Code	Character Code
1	Hypocotyl Color	HCO	1 – Green, 2 – ¼ purple from the base, 3 – ½ purple from the base, 4 – Purple
2	Hypocotyl color intensity	HCI	3 – Low, 5 – Intermediate, 7 – High
3	Hypocotyl pubescence	HPB	0 – Absent, 1 – Present
4	*Plant growth type	PGT	1 – Dwarf, 2 – Determinate, 3 – Semi-determinate, 4 – Indeterminate
5	Plant size	PSZ	3 – Small, 5 – Intermediate, 7 – Large
6	Vine length (cm)	VLT	
7	Stem pubescence density	SPD	3 – Sparse, 5 – Intermediate, 7 – Dense
8	Foliage density	FDY	3 – Sparse, 5 – Intermediate, 7 – Dense
9	Number of leaves under first inflorescence	NLI	3 – Few, 7 – Many
10	Leaf attitude	LAT	3 – Semi-erect, 5 – Horizontal, 7 – Drooping
11	Leaf type	LTY	1 – Dwarf, 2 – Potato leaf type, 3 – Standard, 4 – Peruvianum, 5 – Pimpinellifolium, 6 – Hirsutum, 7 – others
12	Anthocyanin coloration of leaf veins	ACL	1 – Obscure vein, 2 – Normal (clear)
13	Inflorescence type	ITY	1 – Generally uniparous, 2 – Both (partly uniparous, partly multiparous), 3 – Generally multiparous
14	Corolla color	COC	1 – White, 2 – Yellow, 3 – Orange, 4 – others
15	Corolla blossom type	CBT	1 – Closed, 2 – Open
16	Petal length (mm)	PTL	
17	Style shape	STS	1 – Simple, 2 – fasciated, 3 – divided
18	Style hairiness	SHN	0 – Absent, 1 – Present
19	*Exterior color of immature fruit	ECI	1 – Greenish-white, 3 – Light

			green, 5 – Green, 7 – Dark green, 9 – Very dark green
20	*Presence of green trips on fruit	PGF	0 – Absent (uniform ripening), 1 – Present
21	*Predominant fruit shape	FSH	1 – Flattened (oblate), 2 – Slightly flattened, 3 – Rounded, 4 – High rounded, 5 – Heart-shaped, 6 - Cylindrical (long oblong), 7 – Pyriform, 8 – Ellipsoid (plum-shaped), 9 – Other (specify)
22	*Fruit size	FRS	1 – Very small (<3 cm), 2 – Small (3 – 5 cm), 3 – Intermediate (5.1 – 8 cm), 4 – Large (8.1 – 10 cm), 5 – Very large (>10 cm)
23	*Fruit size homogeneity	FRH	3 – Low, 5 – Intermediate, 7 – High
24	*Fruit weight (g)	FWT	
25	Exterior color of mature fruit	ECM	1 – Green, 2 – Yellow, 3 – Orange, 4 – Pink, 5 – Red, 6 – Other (Specify)
26	Intensity of exterior color	IEC	3 – Light, 5 – Intermediate, 7 – Dark
27	Ribbing at calyx end	RBE	1 – Very weak, 3 – Weak, 5 – Intermediate, 7 – Strong
28	Easiness of fruit wall to be peeled	EFP	3 – Easy, 5 – Intermediate, 7 – Difficult
29	Skin color of ripe fruit	SRF	1 – Colorless, 2 – Yellow
30	Fruit cross-sectional shape	FCS	1 – Round, 2 – Angular, 3 – Irregular
31	Number of locules	NLO	
32	Shape of pistil scar	SPC	1 – Dot, 2 – Stellate, 3 – Linear, 4 – Irregular

Table 3. Growth parameters of four accession of *Solanum lycopersicum*.

Character	EKL	BNL	IMPA	IMPB
Number of days of 50% germination	4	4	4	4
Number of days to flowering	18	18	19	18
Total number of leaves at maturity	40	42	31	34
Total number of branches at maturity	7	9	5	7

Table 4. Morphological characterization.

Character	Parameter Code	EKL	BNL	IMPA	IMPB
Hypocotyl color	HCO	4	4	1	1
Hypocotyl color intensity	HCI	3	3	3	3
Hypocotyl pubescence	HPB	1	1	1	1
Plant growth type	PGT	3	2	3	3
Plant size	PSZ	7	5	7	7
Vine length (cm)	VLT	96.20	84.25	76.56	81.20
Stem pubescence density	SPD	5	5	5	5
Foliage density	FDY	5	5	5	5
Number of leaves under first inflorescence	NLI	7	7	7	7
Leaf attitude	LAT	5	5	7	3
Leaf type	LTY	3	2	4	2
Anthocyanin coloration of leaf veins	ACL	2	2	2	2
Inflorescence type	ITY	1	1	1	1
Corolla color	COC	2	2	2	2
Corolla blossom type	CBT	2	2	2	2

Petal length (mm)	PTL	5.50	6.00	6.16	6.38
Style shape	STS	1	1	1	1
Style hairiness	SHN	1	1	1	1
Exterior color of immature fruit	ECI	1	1	3	1
Presence of green trips on fruit	PGF	0	0	0	0
Predominant fruit shape	FSH	1	3	7	6
Fruit size	FRS	3	1	3	3
Fruit size homogeneity	FRH	7	7	3	5
Fruit weight (g)	FWT	29.79	8.90	21.25	16.31
Exterior color of mature fruit	ECM	5	5	5	5
Intensity of exterior color	IEC	7	7	5	5
*Ribbing at calyx end	RBE	7	1	1	1
Easiness of fruit wall to be peeled	EFP	3	3	3	3
Skin color of ripe fruit	SRF	2	2	2	2
Fruit cross-sectional shape	FCS	3	1	1	1
Number of locules	NLO	9	7	6	10
Shape of pistil scar	SPC	1	2	3	2

Table 5. Principal Component Analysis (PCA) of 32 morphological characters of both qualitative and quantitative characters among 4 cultivars of tomatoes.

Character Code	**PC 1**	**PC 2**
HCO	0.0779	-0.1922
HCI	1.132E-17	7.924E-17
HPB	2.038E-17	1.17E-16
PGT	0.0177	0.0597
PSZ	0.0354	0.1195
VLT	0.6627	-0.5250
SPD	0	0
FDY	0	0
NLI	0	0
LAT	-0.0026	0.1108
LTY	0.0164	0.1152
ACL	0	0
ITY	0	0
COC	0	0
CBT	0	0
PTL	-0.0295	0.0159
STS	0	0
SHN	0	0
ECI	-0.0273	0.1195
PGF	0	0
FSH	-0.1789	0.2606
FRS	0.0354	0.1195
FRH	0.0792	-0.2476
FWT	0.6523	0.6794
ECM	0	0
IEC	0.0519	-0.1281
RBE	0.2620	-0.0260
EFP	0	0
SRF	0	0
FCS	0.0873	-0.0087
NLO	0.0639	-0.0554
SPC	-0.0573	0.0641
Eigen Value	130.36	46.45
% Variance	71.03	25.31

Table 6. The Standardized Principal Component Scores.

Cultivars	Axis 1	Axis 2
EKL	**1.4954**	-0.0886
BNL	-0.6059	-1.2215
IMPA	-0.4668	**1.2216**
IMPB	-0.4228	0.0888

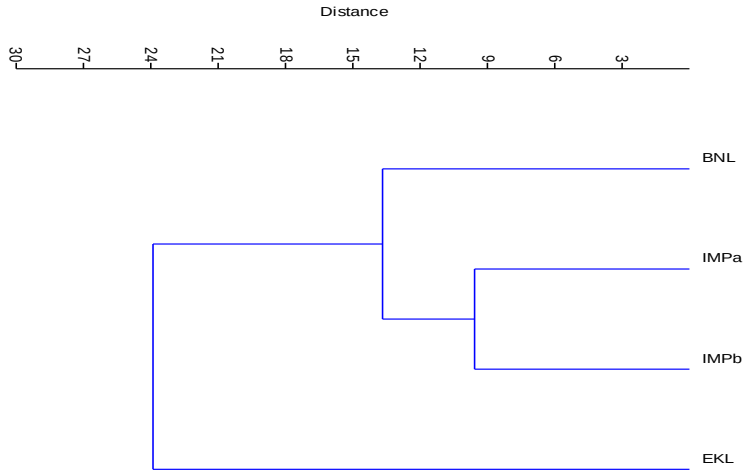

Figure 1. Dendogram based on 32 morphological character based on 29 qualitative and 3 quantitative characters of the four cultivars of *S lycopersicum*.

axes and their associated characters. A dendrogram is generated from the PGCA to display position of cultivars and their distance similarity.

3. RESULTS

Results for morphological characterization are shown in Tables 3, 4, 5 and 6. Results show that the four cultivars are morphologically distinct. The germination rate and number of days to flowering was the same across the four cultivars. BNL had the highest number of leaves and branches at maturity. The two local cultivars (BNL and EKL) have the same hypocotyl color (purple) while the two improved cultivars have the same hypocotyl color (green). The hypocotyl colors are all of moderate intensity [3]. All the cultivars have hypocotyl hairs (pubescence). All the cultivars except BNL which is determinate are of semi-determinate growth. All the cultivars are of intermediate stem pubescence density and foliage density. There is no variation in the inflorescence of the four cultivars. The cultivars had the same score for all the inflorescence descriptors scored. The four cultivars were similar for a number of fruit characters namely: exterior color of immature fruit, presence of green trips on fruit, exterior color of mature fruit, and easiness of fruit wall to be peeled, and skin color of ripe fruit. All the cultivars except BNL which had very small fruit size (< 3 cm) were of intermediate size (5.1 to 8 cm). IMPA was most heterogeneous for fruit size (score 3), while BNL and EKL were most homogenous (score 7). IMPB is intermediate for fruit homogeneity (score 5). The fruit shape is the most distinguishing character among the four cultivars. The distinctiveness of the cultivars lie in the shape of their fruit. EKL is flattened, BNL is rounded, IMPA is Pyriform, and IMPB is cylindrical. The strong calyx end ribbing of EKL is a major distinguishing character of the EKL fruit: it is more like its passport mark. EKL had the largest fruit weight (29.79 g) while BNL had the smallest fruit weight (8.90 g).

The principal component analysis was conducted for 32 characters both for qualitative and quantitative characters among the four cultivars of *Solanum lycopersicum*. This shows that only 2 of the 32 principal component axes had eigen-values greater than the 42.83 Jollife cut-off value. The eigen-value tells the importance of each principal component axis and its contribution to the variability in characters of four cultivars of *S. lycopersicum*. The PCA eigen-

value includes: PCA 1 (130.36), PCA 2 (46.45) and PCA 3 (6.73); 42.83 was taken as the standard.

The loading of each character on the different principal component axes is used to assess their relative contribution in showing variation. The following characters was heavily loaded along PC axis 1; VLT (0.6627), FWT (0.6523), and RBE (0.2620). While PSZ (0.1195), LAT (0.1108), LTY (0.1152), ECI (0.1195), FSH (0.2606), FRS (0.1195) and FWT (0.6794) were loaded along PC axis 2.

Table 6 shows the standardized principal component scores of the various cultivars. The first two principal component axes account for 96.34% of the variance from the 32 characters (axes). PCA 1 loaded characters are possessed by accession EKL and IMPB while PCA 2 loaded characters are best possessed by accession IMPA. Accession EKL, having seen to have a high PCA score in PCA 1 could be well distinguished by characters in PCA 1. For instance, vine length, ribbing at calyx end and fruit weight are seen to be high in EKL and are highly loaded in PCA 1. These characters are outlined in Table 4. From the dendogram (Figure 1) it appears that IMPA and IMPb were bred from BNL or an accession with similar genetic makeup. The dendogram indicates that all the four cultivars are related and that BNL and EKL are the farthest relatives while IMPA and IMPB are the closest relatives.

4. DISCUSSION

Morphological characters have been used to characterize four varieties of tomato. Morphological characterization has been used extensively in elucidating genetic diversity among plants [12; 13; 14]. Results from the study suggest the four cultivars of *Solanum lycoperiscum* studied are distinct. The distinctiveness observed among cultivars may be useful for crop improvement and breeding [15]. At the seedling stage variation among the varieties lie only in the hypocotyl color. All the cultivars have hypocotyl hairs (pubescence) and the hypocotyl colors are all of moderate intensity. The two local cultivars (BNL and EKL) have the same hypocotyl color (purple) while the two improved cultivars (IMPA and IMPB) have the same hypocotyl color (green). There is no difference in the germination rate and number of days to flowering of the four cultivars. This may be due to human preference when developing varieties. All the cultivars except BNL which is determinate are of semi-determinate growth. Determinate varieties require more plant to plant spacing in the field and are more difficult to stake/train especially if the plant grows to a considerable height (a large vine length). So while determinate growth type may be desirable for more fruits, when it is combined with large vine length poses challenges in managing the crop in the field. BNL however has an intermediate vine length (84 cm) and size, so will not pose such difficulty. Semi-determinate cultivars have an appreciable number of branches more than indeterminate cultivars and so may be expected to fruit more than them. However, number of fruits is a plant trait controlled by a gene different from and unlinked to that for branching. Therefore, profuse branching does not translate to bountiful fruiting.

All the cultivars are of intermediate stem pubescence density and foliage density. Stem pubescence provide structural defense against pests and pathogens. In the light of plant defense, dense stem pubescence is a more desirable character. Since the leaves of the tomato plant is not consumed, the amount of leaves (foliage density) is not of much interest although by the principles of plant physiology, increased photosynthesis should be linked to denser foliage. But as is applied to branching, number of fruits is controlled by a gene different from and unlinked to that for foliage density.

It should also be noted that foliage density a character that is greatly affected by the environment especially the proportion of soil Nitrogen [2; 16; 17]. There is no variation in the inflorescence of the four cultivars. The cultivars had the same score for all the inflorescence descriptors scored. The little variation in inflorescence may explain why most authors do not include inflorescence descriptors in their characterization and comparison of varieties and landraces. Variation in the tomato cultivars was most pronounced in the fruit descriptors. This agrees with the works of Blay et al. [18], Naz *et al*. [12], Campos de Melo *et al.* [14], Meena *et al.* [5] and a host of other research work. This great variability in fruit characters is true also for other vegetables and fruits [15; 19; 13; 20]. The enormity of the contribution of fruit morphology to the variability in crop cultivars often requires a computer software to enable easy and accurate scoring of fruit characters [21]. These computer software make use of complex mathematical models and morphometric attributes of the fruits to score the fruits [22]. These software also enable the determination of the quantitative trait loci of plants [23; 24].

The Fruit size is the most important use character of the tomato plant (except when issues of skin texture and taste come into play): consumers delight

in very large fruits. The farmer is therefore interested in tomato cultivars of large fruit size. The largest fruit size recorded for the experiment is 2 scores away from the maximum score (score 5 - very large, > 10 cm). It should however be noted that if proper soil management is done, the fruit size of the fruits will be more market favorable [16,25,26,27]. Fruit size homogeneity is another character of agronomic importance. Homogeneity of fruit size implies a more predictable yield for the farmer.

It was observed that the local accession, BNL gave the highest fruit yield though it had small fruits. The accession also had a fine fruit shape and texture BNL therefore represents a valuable genetic resource to breeders for increased fruit yield and good shape and texture fruits which will be of better market value. The local accession, EKL gave the largest fruit size though it fruit shape is not attractive. Breeders should consider breeding it for better fruit shape. Furthermore, the biochemical properties of the two local cultivars are comparable to those of the two improved cultivars. The study has provided information on both the morphological and biochemical traits of two local cultivars of tomato found in Edo state and thus will serve as baseline data for further research on the cultivars. Considering these traits of the two local cultivars, it is recommended that breeders work to improve the fruit size of BNL and the fruit yield of EKL. It will also be useful to characterize these varieties using other tool.

Conflicts of Interest

There are no conflicts of interest.

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