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Research Article

Morphological Survey of the Fruits of the Cultivated (*Solanum lycopersicum* Linn.) and Wild (*Solanum pimpinellifolium* Miller) Tomatoes in Ile-Ife, Nigeria

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Abstract: The last few years have recorded an increase in the forms of the cultivated tomato fruits available in Ile-Ife, Osun State, Nigeria. The morphological survey of the fruits of the cultivated garden tomato *Solanum lycopersicum* Linn. and its wild relative, *Solanum pimpinellifolium* Miller was carried out with the aim of documenting the various forms available on the basis of their different shapes and sizes. The qualitative morphological characters observed were, fruit colour and shape while the quantitative data taken were, the number of ribs present on the fruits, length and diameter of fruits. In this study, thirty-one (31) fruit forms were reported for the cultivated species based on the differences in shapes, presence or absence of ribs on fruits, number of ribs and colour of fruits. The shapes observed in *Solanum lycopersicum* were ellipsoid, spheroid, obovate, oblate, rhomboidal, elongate and clavate while the shape for *Solanum pimpinellifolium* was consistently round. The colours observed for *Solanum lycopersicum* were red, red with yellow patches, and yellowish-red while colour in *S. pimpinellifolium* was consistently red. Number of ribs on the fruits of the cultivated species ranged from 0–12 while rib was absent in the wild species. Noteworthy, were the fruit forms with beak-like protrusions at the apices of the cultivated species. The length-to-diameter ratio of fruits of the cultivated species was a reliable parameter for differentiating the elongated fruit forms from the other forms in the cultivated species.

Keywords: Fruits, cultivated, wild, shape, ribs.

1. Introduction

The family Solanaceae has seven sub-families they are Cestroideae, Goetzeoideae, Nicotianoideae, Petunioideae, Schizanthoideae, Schwenckioideae and Solanoideae which is the subfamily where *Solanum esculentum* Linn. belongs (D'Arcy, 1979 & 1991). All tomatoes have 24 numbers of chromosomes (Gould, 1983; Hancock, 1992). Cultivated tomato is self-fertile whereas all other members of the genus are self-incompatible (Simpson and Ogorzaly, 1986), mostly self- but partly cross-pollinated. Bees and bumblebees are the most important pollinators (Tanksley, 2004). All wild tomatoes can be crossed (sometimes with difficulty) to cultivate tomato. This confirms the biological species concept sense, that there are only one species of tomato as intersterility of different species is one of the attributes of distinct species (Okeke, 2004).

There has been controversy about the number of species in the group of *Solanum* section *Lycopersicon*, their inter-relationships and their treatment as to whether it should be *Solanum* L. or *Lycopersicon* Miller (Nyananyo, 2007). Spooner *et al*., (1993) provided a chloroplast DNA (cpDNA) restriction site phylogeny and morphological phylogeny that supported the sinking of *Lycopersicon* into *Solanum.* The majority of taxonomists is adopting *Solanum* as the genus for tomato proffering *Solanum lycopersicum* L. as the proper citation for the garden tomato (Nyananyo, 2007).

Tomato is a commercially important vegetable throughout the world, both for the fresh market and the processed food industries. A tomato fruit is classified as a fleshy berry and is composed of an epidermis, a thick pericarp and placental tissue surrounding the seeds (Tanksley, 2004). Most cultivars produce red fruit, but a number of cultivars with yellow, orange, pink, green, black, or white fruit are also available. Multi-coloured and striped fruits can also be quite striking. Tomatoes grown for canning and sauces are often elongated, 7-9cm

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long and 4-5cm in diameter, they are known as plum tomatoes and have a lower water content (Allen, 2008).

A number of phylogenetically diverse plant taxa have been domesticated for the production of edible fruits. Moreover, in most instances, domestication resulted in both a dramatic increase in fruit sizes and enhanced variation in fruit shapes (Doganlar *et al*., 2002). The tomato genus, *Solanum*, comprises nine species, of which only *L. esculentum* (now *Solanum lycopersicum*) was domesticated. It is only in this domesticated species that one finds any significant phenotypic variation in fruit size and shape, the other eight wild species all produce fruits that are almost invariably round and small (Tanksley, 2004). Up until recent years, there were largely only two shapes of the cultivated tomato fruits in the markets in Southwestern Nigeria, most especially in Ile-Ife, Osun State, Nigeria. But more and more shapes are being observed now in our markets. This study aims to document the various shapes and sizes of the cultivated garden tomato in Ile-Ife and compare this with the shape and size of the wild tomato (*Solanum pimpinellifolium* Miller).

2. Materials and Methods

Various forms of the cultivated tomato fruits (*Solanum lycopersicum* Linn.) were bought from markets in Ile-Ife, Osun State, Nigeria. A big basket of tomato fruits from the northern part of the country was also bought from stadium market, Ile-Ife within latitudes 07°30'N and 7°32'N and longitudes 4°40'E and 4°35'E. The different fruit forms were sorted out and selected for the study. The fruits of the wild species, *Solanum pimpinellifolium* were collected from the wild. The qualitative characters studied were colour of fruits and shape of fruits. Fruit length (stylar end to peduncular end) and fruit diameter (equatorial) were measured using a ruler, the length to diameter ratio were also calculated and documented. Number of ribs present on the surface of the fruits were also noted and documented. Descriptive terms of shapes of fruits used were, according to Parker (1995).

3. Results and Observations

A total of thirty-one (31) different forms of the cultivated tomato fruits were observed and documented while only one (1) fruit form was observed and documented for the wild species.

3.1 Description of the thirty-one forms observed for *Solanum lycopersicum* (Plates 1,2, & 3; Table 1)

- **Form one:** Shape ellipsoid, colour red and three faint ribs appearing on top (Plate 1(1)). Length: 7.50cm; Diameter: 16.50cm; Fruit Length/Diameter: 0.45.
- **Form two:** Shape high spheroid, colour red with yellow patches on top, three faint ribs present on it (Plate 1(2)). Length: 8.20cm; Diameter: 14.90cm; Fruit Length/Diameter: 0.55.
- **Form three:** Shape spheroid, red colour and without any obvious ribs (Plate 1(3)). Length: 7.50cm; Diameter: 12.60cm; Fruit Length/Diameter: 0.60
- **Form four:** Shape obovate, colour yellow on top, red below with three faint ribs on it (Plate 1(4)). Length: 7.30cm; Diameter: 15.50cm; Fruit Length/Diameter: 0.47.
- **Form five:** Shape oblate, colour red, body smooth, with two ribs on top of it (Plate 1(5)). Length: 8.10cm; Diameter: 18.00cm; Fruit Length/Diameter: 0.45.
- **Form six:** Shape rhomboidal, colour red, pointed tip, two faint ribs on top of it. (Plate 1(6)). Length: 6.30cm; Diameter: 14.40cm; Fruit Length/Diameter: 0.44.
- **Form seven:** Shape oblate, colour red, two traces of ribs dividing the tomato into nearly two sides (Plate 1(7)). Length: 5.80cm; Diameter: 15.60cm; Fruit Length/Diameter: 0.37.
- **Form eight:** Shape high spheroid, colour yellowish red, with two ribs dividing the tomato into two (Plate 1(8)). Length: 7.10cm; Diameter: 15.30cm; Fruit Length/Diameter: 0.46.
- **Form nine:** Shape obovate, colour red, a faint rib, with sharp pointed beak (Plate 1(9)). Length: 7.00cm; Diameter: 12.50cm; Fruit Length/Diameter: 0.56.
- **Form ten:** Shape rhomboidal, colour red with yellow on top with two ribs that are not deep (Plate 1(10)). Length: 8.70cm; Diameter: 16.30cm; Fruit Length/Diameter: 0.53.
- **Form eleven:** Shape spheroid, colour red with yellow patches, two faint ribs, smooth flesh (Plate 1(11)). Length: 7.20cm; Diameter: 16.30cm; Fruit Length/Diameter: 0.44.
- **Form twelve:** Shape ellipsoid, colour red, three faint ribs present (Plate 1(12)). Length: 7.30cm; Diameter: 17.80cm; Fruit Length/Diameter: 0.41.
- **Form thirteen:** Shape obovate, colour red, two ribs present (Plate 1(13)). Length: 7.70cm; Diameter: 17.90cm; Fruit Length/Diameter: 0.43.
- **Form fourteen:** Shape rhomboidal, colour yellowish red, without ribs (Plate 1(14)). Length: 7.10cm; Diameter: 18.20cm; Fruit Length/Diameter: 0.39.
- **Form fifteen:** Shape narrowly obovate, colour yellowish red, without ribs has a small blunt beak (Plate 1(15)). Length: 5.90cm; Diameter: 11.90cm; Fruit Length/Diameter: 0.50.
- **Form sixteen:** Shape spheroid, colour red with yellow patches on top, with five faint ribs, (Plate 1(16)). Length: 6.30cm; Diameter: 15.50cm; Fruit Length/Diameter: 0.41.

- **Form seventeen:** Shape spheroid, colour red with yellow on top, with three ribs (Plate 1(17)). Length: 7.10cm; Diameter: 18.40cm; Fruit Length/Diameter: 0.39.
- **Form eighteen:** Shape rhomboidal, colour red, no ribs (Plate 1(18)). Length: 7.30cm; Diameter: 16.40cm; Fruit Length/Diameter: 0.45.
- **Form nineteen:** Shape spheroid, colour red, without ribs (Plate 1(19)). Length: 5.90cm; Diameter: 13.20cm; Fruit Length/Diameter: 0.45.
- **Form twenty:** Shape ellipsoid, colour red, no ribs, with a curved beak (Plate 1(20)). Length: 9.10cm; Diameter: 9.90cm; Fruit Length/Diameter: 0.92.
- **Form twenty-one:** Shape ellipsoid, colour red, with yellow patches, one faint rib (Plate 1(21)). Length: 7.20cm; Diameter: 9.50cm; Fruit Length/Diameter: 0.76.
- **Form twenty-two:** Shape rhomboidal, colour yellowish-red, a large beak, two faint ribs present (Plate 1(22)). Length: 3.10cm; Diameter: 12.30cm; Fruit Length/Diameter: 0.25.
- **Form twenty-three:** Shape spheroid, colour red with yellow patches on top, with four distinct ribs that tend to separate the tomatoes into four parts (Plate 1(23)). Length: 6.00cm; Diameter: 13.20cm; Fruit Length/Diameter: 0.45.
- **Form twenty-four:** Shape spheroid, colour red, with four distinct ribs, (Plate 1(24)). Length: 2.10cm; Diameter: 14.40cm; Fruit Length/Diameter: 0.15.
- **Form twenty-five:** Shape spheroid to ellipsoid, colour red, with twelve ribs (Plate 1(25)). Length: 9.70cm; Diameter: 10.50cm; Fruit Length/Diameter: 0.92.
- **Form twenty-six:** Shape elongated, colour red, has one horizontal rib, curved, pointed beak-like tip present (Plate 1(26)). Length: 6.10cm; Diameter: 7.80cm; Fruit Length/Diameter: 0.78.
- **Form twenty-seven:** Shape elongated, colour red, it has two horizontal ribs or constrictions that seem to divide the tomatoes into two horizontally (Plate 1(27)). Length: 7.70cm; Diameter: 7.10cm; Fruit Length/Diameter: 1.08.
- **Form twenty-eight:** Shape elongated, colour red, it has a curved pointed beak-like tip (Plate 1(28)). Length: 8.60cm; Diameter: 4.50cm; Fruit Length/Diameter: 1.91.
- **Form twenty-nine:** Shape clavate, colour yellowish-red, without any constriction or ribs on it (Plate 1(29)). Length: 6.80cm; Diameter: 5.50cm; Fruit Length/Diameter: 1.23.
- **Form thirty:** Shape elongated, colour red, with no constriction but having a short pointed tip (Plate 1(30)). Length: 7.70cm; Diameter: 5.50cm; Fruit Length/Diameter: 1.40.
- **Form thirty-one:** Shape elongated, colour red, with one horizontal rib, curves inward at the tip with an attached beak inside the curved tip (Plate 1(31)). Length: 7.50cm; Diameter: 6.40cm; Fruit Length/Diameter: 1.17.

3.2 Description of the fruit of the wild species (*Solanum pimpinellifolium* Miller)

Shape round, colour red, without any constriction or ribs on it (Plate 1(32)). Length: 1.26cm; Diameter: 3.78cm; Fruit Length/Diameter: 0.33.

Plate 1: Description of the fruits of the cultivated tomato (*Solanum lycopersicum* Linn.):

1. Shape ellipsoid, colour red and three faint ribs appearing on top.
2. Shape high spheroid, colour red with yellow patches on top, three faint ribs present on it.
3. Shape spheroid, colour red, without any obvious ribs.
4. Shape obovate, colour yellow on top red below with three faint ribs on it.
5. Shape oblate, colour red, body smooth, with two ribs on top of it.
6. Shape rhomboidal, colour red, pointed tip, two faint ribs on top of it.
7. Shape oblate, colour red, two traces of ribs dividing the tomato into nearly two sides.
8. Shape high spheroid, colour yellowish red, with two ribs dividing the tomato into two.

(Magnification: 1cm represents 0.5cm).

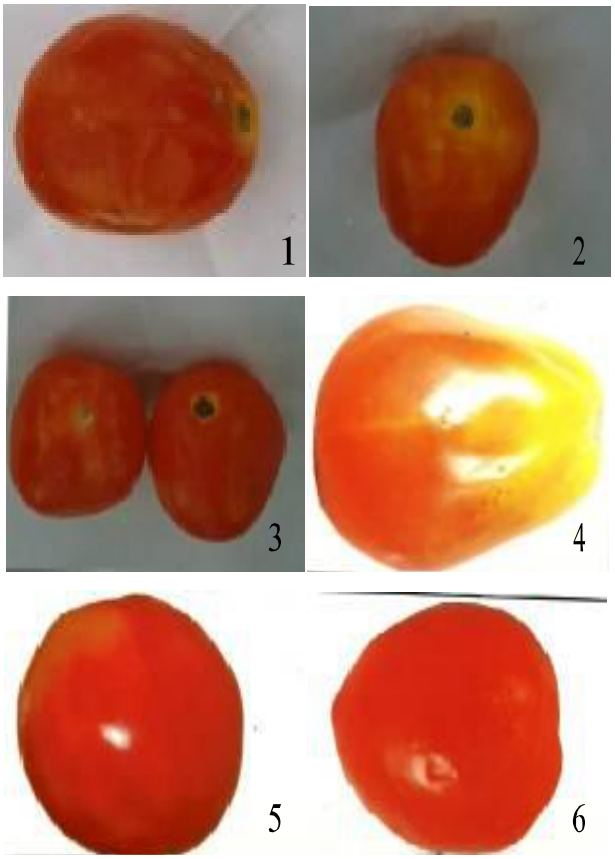
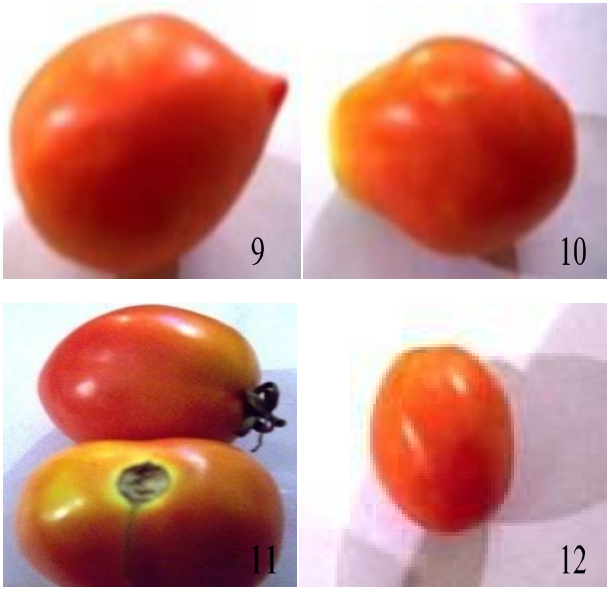


Plate 1 continued: Description of the fruits of the cultivated tomato (*Solanum lycopersicum* Linn.):

9. Shape obovate, colour red, a faint rib, with sharp pointed beak.
10. Shape rhomboidal, colour red with yellow on top with two ribs that are not deep.
11. Shape spheroid, colour red with yellow patches, two faint ribs and smooth flesh.
12. Shape ellipsoid, colour red, three faint ribs present.
13. Shape obovate, colour red, two ribs present.
14. Shape rhomboidal, colour yellowish red, without ribs.
15. Shape narrowly obovate, colour yellowish red, without ribs and has a small blunt beak.
16. Shape spheroids, colour red with yellow patches on top, with five faint ribs.
17. Shape spheroid, colour red with yellow on top, with three ribs.
18. Shape rhomboidal, colour red, no ribs.
19. Shape spheroid, colour red, without ribs.
20. Shape ellipsoid, colour red, no ribs, with a curved beak.
21. Shape ellipsoid, colour red, with yellow patches, one faint rib.
22. Shape rhomboidal, colour yellowish-red, a large beak, two faint ribs.
(Magnification: 1cm represents 0.5cm).



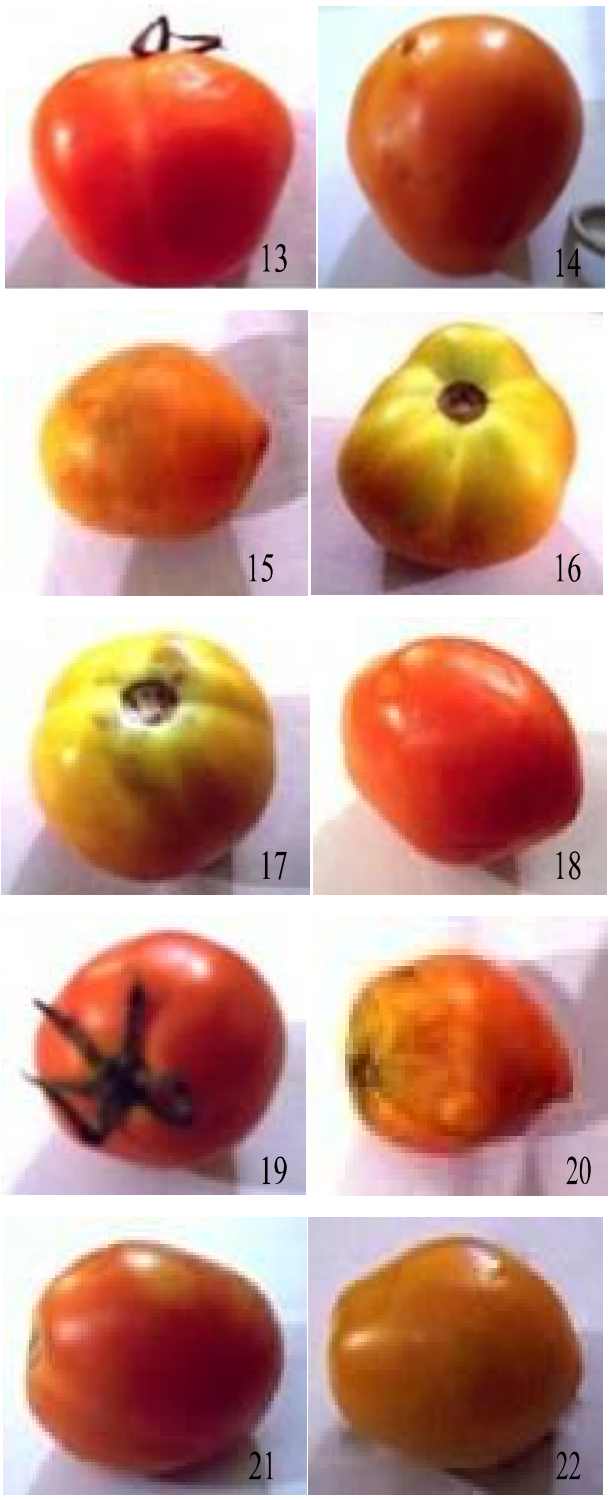


Plate 1 continued: Description of the fruits of the cultivated tomato (*Solanum lycopersicum* Linn.):

23. Shape spheroid, colour red with yellow patches on top, with four distinct ribs that tend to separate the tomato into four parts.
24. Shape spheroid, colour red, with four ribs.
25. Shape spheroid to ellipsoid, colour red, with twelve ribs.

26. Shape elongated, colour red, has one horizontal rib, curved pointed beak-like tip present.
27. Shape elongated, colour red, with two horizontal ribs or constrictions that seem to divide the tomatoes into two horizontally.
28. Shape elongated, colour red, it has a curved, pointed, beak-like tip.
29. Shape clavate, colour yellowish-red, without any constriction or ribs on it.
30. Shape elongated, colour red, with no constriction but having a short pointed tip.
(Magnification: 1cm represents 0.5cm)

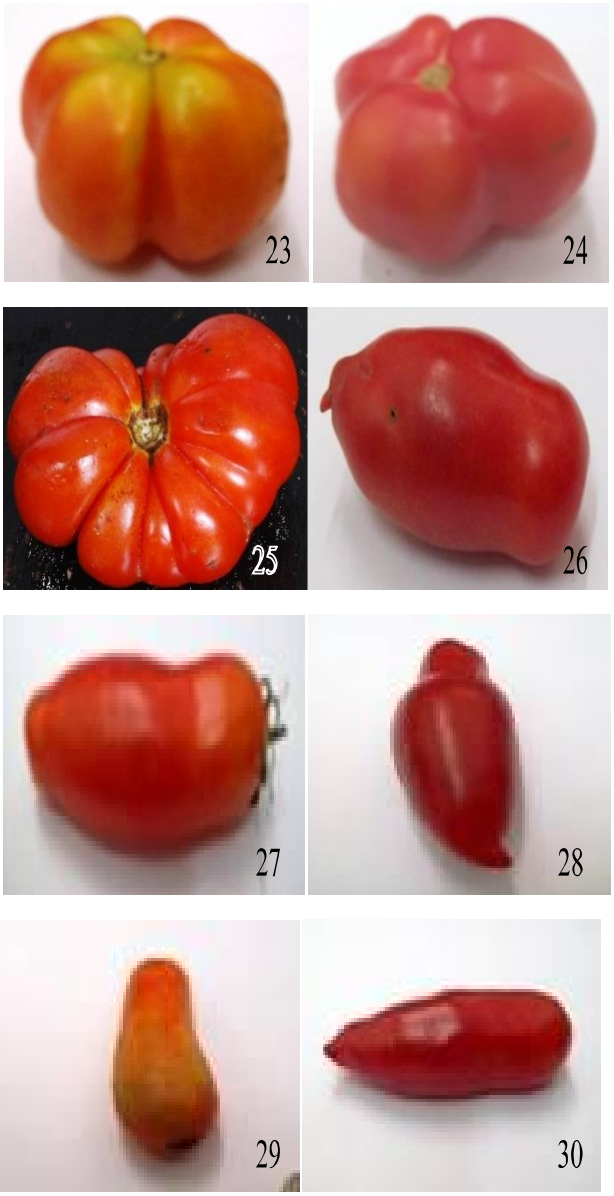


Plate 1 continued: Description of the fruits of the cultivated tomato (*Solanum Lycopersicum* Linn.) and the wild tomato (*Solanum pimpinellifolium*):

31. Shape elongated, colour red curves inward and also having an attached beak at the tip.

32. Description of the fruit of the Wild species (*Solanum pimpinellifolium* Miller):
Shape round, colour red, without any constriction or ribs on it.
(Magnification: Plate 1(31): 1cm represents 0.5cm
Plate 1(32): 1cm represents 0.9cm).

Plate 2: Tomato fruits in groups.
A. Tomato fruits with distinct ribs in group.
B. Tomato fruits with spheroid shape in group.
C. Tomato fruits with obovate shape in group.
D. Tomato fruits with obovate to rhomboid shapes in group.
(Magnification: 1cm represents 0.5cm).

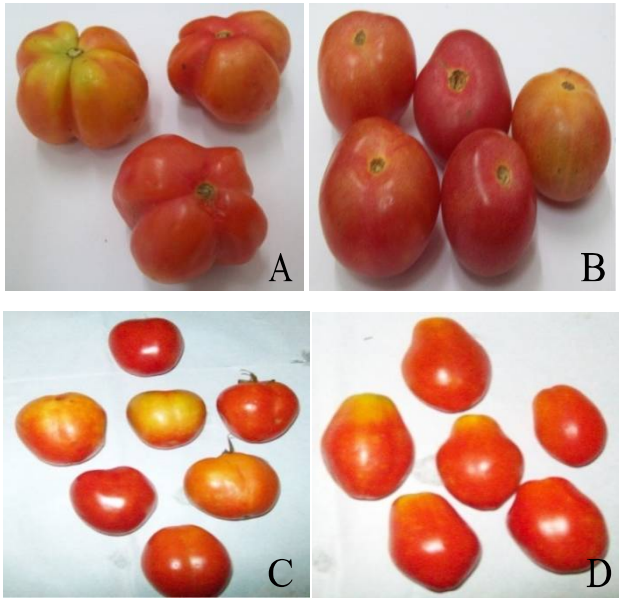
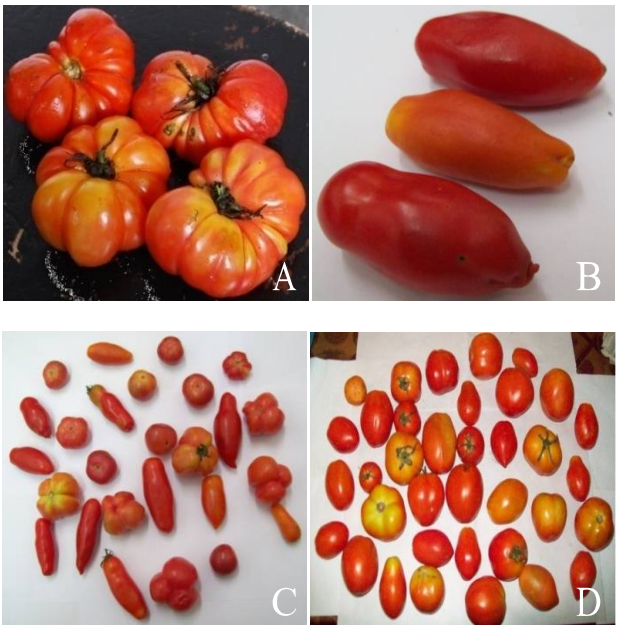


Plate 3: Shapes of tomato fruits in groups.
A. Tomato fruits with many ribs in group.
B. Tomato fruits with elongated shape in group.
C. Different fruits shape of Tomatoes in group.
D. Different fruits shape of Tomatoes in group.
(Magnification: A & B: 1cm represents 0.5cm; C & D: 1cm represents 0.2cm).



4. Discussion and Conclusion

There has been a very high increase in the number of fruit shapes of the cultivated tomato species, *Solanum lycopersicum* in the past few years in Ile-Ife, Osun State Nigeria and generally in the South-western part of the country. In the past, only the round, ribbed or not ribbed and the round with many rib forms were available in Ile-Ife but now many forms are available. In this study, thirty-one (31) fruit forms are reported for the cultivated species based on the differences in shapes and sizes, presence or absence of ribs on fruits, number of ribs and colour of fruits while only one (1) fruit form is reported for the wild species.

Fruits from domesticated species often have been tremendously enlarged over that normally found in the progenitor wild species (Tanksley, 2004). In this study, the fruit length for the cultivated species ranged from 2.10cm to 9.10cm, while the diameter ranged from 4.50cm to 18.20cm while the maximum length and diameter for the wild species are 1.26cm and 3.78cm respectively. The length-to-diameter ratio of fruits in the cultivated forms separates out the elongated fruit forms from the other forms. In addition, to increase in fruit size, the domestication of fruit-bearing species often has resulted in tremendous shape variation. Wild and semi-wild forms of tomato bear fruits that are almost invariably round, whereas cultivated tomatoes come in a wide variety of shapes: round, oblate, pear-shaped, torpedo-shaped and bell pepper-shaped (Tanksley, 2004). In this study, fruit shapes observed in *Solanum lycopersicum*, the cultivated species range from ellipsoid to spheroid, obovate, oblate, rhomboidal, elongate and valvate while the only round shape was observed in the wild species *Solanum pimpinellifolium.*

Table 1. Fruit dimensions in *Solanum lycopersicum* (cultivated, fruit forms 1-31) and *Solanum pimpinellifolium* (wild, number 32) species.

Fruit Form.	Fruit Length (cm)	Fruit Diameter (cm)	Fruit Length/Diameter
1	7.50	16.50	0.45
2	8.20	14.90	0.55
3	7.50	12.60	0.60
4	7.30	15.50	0.47
5	8.10	18.00	0.45
6	6.30	14.40	0.44
7	5.80	15.60	0.37
8	7.10	15.30	0.46
9	7.00	12.50	0.56
10	8.70	16.30	0.53
11	7.20	16.30	0.44
12	7.30	17.80	0.41
13	7.70	17.90	0.43
14	7.10	18.20	0.39
15	5.90	11.90	0.50
16	6.30	15.50	0.41
17	7.10	18.40	0.39
18	7.30	16.40	0.45
19	5.90	13.20	0.45
20	9.10	9.90	0.92
21	7.20	9.50	0.76
22	3.10	12.30	0.25
23	6.00	13.20	0.45
24	2.10	14.40	0.15
25	9.70	10.50	0.92
26	6.10	7.80	0.78
27	7.70	7.10	1.08
28	8.60	4.50	1.91
29	6.80	5.50	1.23
30	7.70	5.50	1.40
31	7.50	6.40	1.17
32	1.26	3.78	0.33

Fruit shape is one of the most important physical properties of all agricultural produce. Moreover, classification of fruit shapes is vital in evaluating agricultural produce, meeting quality standards and increasing market value. It is also helpful in planning, packaging, transportation and marketing operations (Rashidi & Seyfi, 2007). In tomatoes, shape is chiefly differentiated early in development, but during later growth, there is a slight added divergence since width increases a little faster than length (Tanksley, 2004).

There may be several explanations for the phenomenon of increase in fruit shape variation. Firstly, selection for increased fruit size may have led to changes in fruit shape attributable to pleiotropy. There is good supporting evidence for this hypothesis with regard to the mutations that have led to increased fruit size through increases in carpel/locule number (Lippman & Tanksley, 2001). Secondly, mutations that affect fruit shape may have greater phenotypic effects in large-fruited versus

small-fruited genetic backgrounds. Several lines of experimental evidence support this notion. For example, a highly significant correlation was found between fruit size and fruit shape, such that larger fruit displayed more extreme shapes than did their small-fruited counterparts (Van der Knaap & Tanksley, 2003). The third factor that is on record that may have contributed to changes in fruit shape are the demands in agriculture.

Recent genetic studies have shown that the change in shape and the associated increased firmness were the results of mutations in three genes which affect changes in fruit shape through modulations of early stages of carpel development. Finally, some of the extreme tomato fruit shapes such as extremely long-fruited, pear-shaped or bell pepper-shaped tomatoes may reflect the human inclination toward valuing novelty.

Genetic studies, some dating back to the early parts of the last century, have established that tomato fruit size and shape are largely quantitatively inherited. A number of Quantitative Trait Locus (QTL) studies have been conducted involving crosses between wild tomatoes and cultivated tomatoes of various sizes and shapes (Grandillo *et al.*, 1999). The conclusion of this research is that approximately thirty QTLs account for most of the variation in both tomato fruit size and shape. However, these loci are not equal to the magnitude of their effects. Based on all of the genetic/mapping studies conducted to date, it is estimated that less than ten loci, mapping to seven of the twelve chromosomes, account for the majority of the changes in size and shape associated with tomato domestication/agriculture (Grandillo *et al.*, 1999).

Most modern tomato cultivars fruits are smooth surfaced, but some older tomato cultivars and most modern beefsteak often show the pronounced ribbing (Allen, 2008). In this study, the number of ribs in the domesticated/cultivated species ranged from 0-12 while no ribbing was observed in the wild species. A feature that may have been common to virtually all commercial tomato varieties is the red colour, but some tomato cultivars, especially heirlooms produce fruit in colours other than red including yellow, orange, pink, black, brown, ivory white and purple (Allen, 2008). In this study, it was observed that the fruit colour in the wild species was consistently red while colour in the cultivated species varied from red to red with yellow patches and yellowish-red. Fruit forms with beak-like protrusions at their apices are also reported in this work.

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