Annals of Plant Sciences
ISSN: 2287-688X
OPEN ACCESS
www.annalsofplantsciences.com

Original Research Article

Characterization of Tomato Cultivars Based On Morphological Traits

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Received for publication: July 05, 2014; **Accepted:** October 17, 2014.

Abstract: The ability to distinguish and clearly identify varieties of cultivated species is fundamental for the operational aspects in the seed trade. In the present study 24 tomato cultivars were characterized based on morphological markers. Among 17 quantitative and 36 qualitative morphological characters studied variation was observed in all quantitative characters and 31 qualitative characters. While, only 15 traits showed substantial variation among cultivars. Every cultivar showed one or more distinct characters which could be used to identify the same. However, it was difficult to identify all the cultivars based on single morphological trait.

Key Words: Tomato, Varietal Charecterization, Morphological traits

Introduction

Tomato (*Lycopersicon esculentum* L.) is the world's largest vegetable crop and known as productive and protective food because of its special nutritive value and wide spread production. Although it was introduced to India in the 18th century, its commercial cultivation began towards the end of last century. It is economically important for its edible fruits and preserved products like ketch-up, sauce, chutney, soup, paste, puree etc. Tomato is a rich source of minerals, vitamins and organic acids, essential amino acids and dietary fibers. It is also rich source of vitamin A and C, it contains minerals like iron, phosphorus and pigments lycopene and beta-carotene. Tomato belongs to family solanaceae and is native to South America, Peru and Galapagos Islands (Rick, 1969) and grown all over the world. It ranks second among the vegetables next to potato.

In the changing global scenario of the post-GATT era, large number of varieties and hybrids with special regard to yield, fruit quality, resistant to biotic and abiotic stresses are under cultivation throughout the country. In recent years public institutions and private companies introduced many hybrids/varieties one after the other for commercial cultivation. The enactment of Plant Varieties Protection and Farmers Right Act called as PPV and F R Bill, 2001, by the Government of India, that provide protection to new varieties and germplasm. To qualify for protection under this Act, the variety must be evaluated for its DUS (Distinctness, Uniformity and Stability) and VCU (Value for Cultivation and Use) tests. Hence, discrimination of tomato varieties, especially by examination of the plant / seed morphology is increasingly important in order to protect the breeders and farmers rights (Wang *et al.,* 2000) and to ensure genetic purity or genuineness of variety which is most important characteristic of a quality seed. Therefore, to identify tomato cultivars relative taxonomical descriptors are published by International bodies like International Union for Protection of New Plant Varieties (UPOV, 1992) and these morphological descriptors have traditional significance and have been adopted as classical taxonomic approach for identification of crop varieties. Further keys for identification could be developed on the basis of these morphological traits which could serve as a data base for identification of cultivars as well as genetic purity test (Vishwanath *et al.,* 2013).

Materials and Methods

Seed samples of twenty four cultivars which are under cultivation in the state were collected from public and private organizations (Table 1). Many quantitative characters which are continuously variable are recorded on a 1-9 scale according to UPOV (1992) guidelines.

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Table 1: Cultivars of tomato used for varietal characterization

S.No.	Cultivar	Developed institute /company	S.No.	Cultivar	Developed institute/ company
1.	Arka Alok	IIHR	13.	Nandi	UASB
2.	Arka Vikas	IIHR	14.	Sankranthi	UASB
3.	Arka Ahuti	IIHR	15.	Vybhav	UASB
4.	Arka Ashish	IIHR	16	NS-2535	Namdhari Seeds
5.	Arka Abha	IIHR	17	Mruthyunjaya -2	Sasya Seeds
6.	Arka Megali	IIHR	18	US-618	U.S. Agriseeds
7.	Arka Saurab	IIHR	19	J.K. Desi	J.K. Agrigenetics
8.	Arka Shresta	IIHR	20	J.K. Asha	J.K. Agrigenetics
9.	Arka Abijeet	IIHR	21	Ronco	Bejo Seeds
10.	Pusa Ruby	IARI	22	A-32/63	Indosem Seeds
11.	Pusa Early Dwarf	IARI	23	128/M 131	Indosem Seeds
12.	PKM-1	TNAU	24	M-03/868	Indosem Seeds

Seed morphology: Seed samples of the 24 cultivars were evaluated for characters like 1000 seed weight, seed colour and hairiness of seed.

Seedling morphology: Seed samples were drawn from the seed stock of 24 genotypes were sown in thumb pots filled with enriched coir pith media (coco-peat) and observations were taken when the seedling primary leaves are fully opened and the terminal bud is around 5 mm in size.

Plant morphology: Seedling raised in thumb pots for recording seedling morphology were transplanted at 30th day to the field at University of Agricultural Sciences, Bangalore. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The crop was raised by providing recommended package of practices. (Anon, 2010). Ten plants were selected at random from each variety and were observed for various stable and distinguishable characters according to UPOV guidelines (UPOV, 1992). Various morphological traits on plant, inflorescence, and fruit were recorded at different plant growth stages. Data was analysed statistically by adopting "Fishers Analysis of Variance Technique". Critical difference values were calculated at 5 per cent probability level wherever 'F' test was significant (Panse and Sukhatme1978).

Results and Discussion

Seed and seedling morphology: Seed morphological traits were used in several crops by different workers to distinguish the cultivars (Atanassova *et al.,* 2004, Garcia-Gusana *et al.,* 2004). Only two cultivars viz., Arka Vikas and Arka Ashish exhibited light (<2.20g) 1000 seed weight and Arka Abha, Ronco, M-03/868 distinct by their very heavy test weight, while JK Asha was the lone cultivar distinct with medium 1000 weight. The variation in 1000 seed weight is due to their genetical makeup; such variations in test weight were noticed in several crops like linseed (Joshi *et al.,* 1999) and vegetable pea (Singh *et al.,* 1997). However, very often it may be influenced by mother plant nutrition and environmental conditions prevailing during seed development and maturation. To employ test weight as trait for characterization of cultivars, seed should be obtained from identical climatic condition. Seed colour also varied among the cultivars and showed six colour groups when compared with Munsell colour chart. Pusa Ruby and Arka Vikas were unique from rest of the cultivars by their dark yellowish brown and brownish colour respectively. Seed colour, which is a heritable character, has been used by several workers to distinguish several crop varieties. (Yadav and Srivastava, 2002). Although seed colour is a useful character to distinguish cultivars it is influenced by environmental conditions during ripening, after ripening, besides the genetic effect (Pascual *et al.,* 1993). Some time seed deterioration and fungal infection also resulted in difference in seed colour. Therefore, it is important to note that such comparison are valid only if the crop is not adversely affected by rain, moulds or any other biotic and abiotic stress. In tomato fermentation method and duration also affects the colour of the seed and care should be taken before comparison of different cultivars.

Another heritable character, hairiness of seed has also been used by various researchers to characterize the cultivars (Nethra *et al.,* 2007, Atanassova *et al.,* 2004). Among studied cultivars only two cultivars viz., Sankranthi and Vybav did not show hairs on seeds (Fig 1). However, seed

characters are not unique to most of the studied cultivars and could not able to identify the cultivars unequivocally except Sankranthi and Vybav. Hence these characters can be used only for grouping the cultivars and to identify few cultivars.

Figure 1: Seed Hairiness

Seedling Morphology: Expression of different characteristics of seedlings like pubescence, pigmentation *etc.,* are found to be varietal specific and helps in early identification of tomato cultivars at seedling stage itself and there by saves time. Purple pigmentation was absent only in Nandi, Sankranthi and Vybav and can be readily employed as an efficient marker to identify these cultivars(Fig 2). With respect to intensity of pigmentation only four cultivars viz., Arka Alok, Pusa Early Dwarf, 128/M 131 and M-03/868 exhibited high hypocotyl colour intensity. As all the cultivars exhibited hypocotyl pubescence, this trait was not useful even for grouping of the cultivars and only hypocotyl colour and its intensity could be used to differentiate tomato cultivars at seedling stage. Thus seedling morphological traits were found to be useful only for broader classification of genotypes into different groups but not for identification of individual cultivar. Although, these characters are in use for a long time till today (Arya and Saini, 1976 in chilli; and Harris and Beever and 2000, in cabbage) for varietal characterization, their utility appears to be doubtful as these characters are quantifiable in nature and are subjected to environmental fluctuations.

Figure 2: Seedling Hypocotyl Colour

Plant morphological traits: Plant morphology has been in use since very long time. Carollus Linneaus used morphological characters for taxonomical classification of plants. Gregor Johann Mendel (1866) also used morphological traits in his genetical research. Plant morphology, the classical taxonomic approach is being used for both varietal purity testing and varietal identification. Plant morphological characters have been used for classification several crop varieties like lettuce (Rodenburg, 1975), chilli (Arya and Saini, 1976) and cabbage (Harris and Beever, 2000). This is a traditional method of varietal identification in which plants have to be maintained till maturity. In the present study 47 morphological characters were studied for their suitability for identification of different tomato cultivars and are discussed below.

Plant growth traits: In the present study eight plant growth traits were studied viz., plant growth habit, plant size, vine length, stem pubescence density, stem internodal length, foliage density, leaf attitude and leaf type (Table 2). Pusa Ruby was the lone cultivar with indeterminate type of growth habit. Pusa Ruby and US-618 showed larger plant size. Hence, growth habit and plant size could be used for the identification of Pusa Ruby and plant size to identify US-618 from rest of the studied cultivars. Variation in vine length could also be used for identification of offtypes at the time of field inspection. Vine length of studied cultivars ranged from 44.31 cm (Arka Ashish) to 100.83 cm (Pusa Ruby) followed by US-618

(82.06 cm). Indeterminate growth habit and larger plant size of Pusa Ruby and US-618 was resulted in increased vein length. Like vine length, stem internodal length also varied significantly between cultivars ranging from 3.60 cm (128/M 131) to 7.31 cm (Arka Saurab). Plant growth habit and plant size are clearly visible characters and hence can be utilized for identification of offtypes during field inspection in these cultivars. Such difference in plant morphology among the cultivars was noticed by Patel *et al.,* (2001) in brinjal, Yadav and Srivastava (2002) in chick pea and Stomel and Giresach (1993) in capsicum.

Table 2: Seed and seedling characteristics of different cultivars of tomato

S.No	Genotypes	1000Seed weight (g)	Vine length (cm)	Stem internodal length (cm)	Petal Length (mm)	Sepal length (mm)	Stamen length (mm)	Fruit size (cm^3)	Fruit weight (g)	Fruit length (mm)
1.	Arka Alok	1.92	78.86	6.66	9.33	12.6	6.3	4.11	78.99	41.4
2.	A. Vikas	2.30	68.33	4.88	10.3	14.6	7.1	6.10	91.88	51.7
3.	A. Ahuti	2.01	62.66	4.96	10.3	11.7	7.4	4.92	71.51	57.8
4.	A Ashish	2.25	44.31	4.88	10.8	11.8	7.7	5.40	62.66	53.3
5.	A Abha	3.03	67.86	4.11	7.0	9.6	7.2	4.56	112.50	46.2
6.	A Megali	2.47	68.66	5.33	9.25	11.3	8.1	5.33	100.79	40.5
7.	A Saurab	2.46	56.26	7.31	11.3	12.0	6.6	4.99	61.08	46.4
8.	A. Shresta	1.32	69.36	7.26	9.75	12.2	6.3	6.15	107.16	51.9
9.	A. Abijeet	2.97	62.00	6.60	10.0	11.7	6.5	5.19	96.18	42.8
10	P. Ruby	1.91	100.83	4.21	6.0	7.9	6.4	4.09	47.16	30.8
11.	PED	1.66	78.30	6.26	8.1	11.1	8.8	4.18	48.80	33.0
12.	PKM-1	2.28	64.06	4.66	7.81	10.4	7.7	4.69	49.83	33.8
13.	Nandi	2.07	58.91	6.36	8.8	12.6	7.8	4.94	49.52	41.6
14.	Sankranthi	1.71	62.08	5.60	8.4	12.5	7.1	4.92	59.70	51.3
15.	Vybhav	2.16	73.26	5.60	8.5	11.0	8.6	4.62	52.16	59.1
16.	NS-2535	2.93	55.33	3.84	10.4	12.7	7.5	5.71	81.43	56.2
17.	M-2	2.57	75.36	6.86	11.0	14.5	9.0	5.30	67.41	55.8
18.	US -618	2.08	82.06	8.46	10.85	12.8	7.8	5.36	85.66	43.1
19.	JK Desi	2.03	72.40	5.53	9.92	12.2	7.6	4.72	54.02	40.2
20.	JK Asha	2.40	75.10	6.10	9.75	13.4	8.7	5.08	87.36	51.5
21.	Ronco	3.10	68.46	5.33	9.88	13.5	8.2	5.35	69.72	52.4
22.	A 32/63	1.95	52.90	4.40	11.70	12.8	9.0	5.59	86.56	55.6
23.	128/M 131	1.79	42.53	3.60	10.25	11.9	6.5	4.66	48.27	52.6
24.	M-03/868	3.10	54.06	5.26	13.50	14.2	7.5	5.78	76.36	60.6
SEm±		0.89	4.16	0.69	0.575	0.471	0.390	0.51	7.16	2.388
CD(p=0.05)		2.5	11.83	1.97	1.632	1.33	1.106	1.45	20.33	6.78
CV (%)		6.68	11.14	22.16	9.972	6.607	8.717	16.12	17.26	8.86

Cultivars were categorized into three groups based on stem pubescence density i.e. sparse, intermediate and dense. This character also helped only in grouping of cultivars rather than clear cut differentiation as noticed by EL-Tahir (1993) in tomato. Based on foliage density most of the studied cultivars were grouped either into intermediate or dense. Photosynthesis rates of cultivars mainly depend on their leaf orientation towards sunlight. Leaf attitude of studied cultivars was either semi-erect or horizontal, only one cultivar A 32/63 showed drooping type of leaf attitude which can be readily employed for its identification. Sivieero *et al.,* (2001) in capsicum, Patel *et al.,* (2001) in *Solanum sp.* noticed such differences of leaf attitude. Based on leaf type only Pusa Ruby was distinct by its potato leaf type character and rest of the cultivars was grouped under either standard / Peruvianum / Pimpinellifolium type. Again this trait also was helpful only in grouping of cultivars as noticed by Patel *et. al.,* (2001) in egg plant.

Inflorescence descriptors: Inflorescence traits are important characters, which have influence on pollination, fruiting, fruit and seed yield. In this study nine inflorescence characters were studied of which three were quantitative and six were qualitative. Corolla colour and style hairiness did not show any differences among cultivars. Among cultivars, fourteen cultivars showed uniparous type of inflorescence while ten cultivars showed both uniparous and multiparous type. All the cultivars showed yellow colour but its intensity varied among cultivars. Nandi, JK Asha and Ronco differed from other cultivars by their dark corolla colour intensity. While, rest of the cultivars showed either light (9 cultivars) or medium (11 cultivars) corolla colour intensity. Sepal

length was also useful in differentiating cultivars and showed positive correlation with petal length. Arka Abha and Pusa Ruby showed lower petal length as well as sepal length likewise M-03/868 showed higher sepal and petal length. Arka Abha, Pusa Ruby and Arka Vikas, Mruthyunjaya-2 and M-03/868 can be differentiated by their lower and higher sepal length respectively.

Style position is an important character influencing pollination behavior of crop plants and is also helpful in deciding the pollination method/time (Ramao, 1999). This character was useful to characterize Pusa Ruby, PKM-1, Vybav, JK Desi and Arka Vikas from Arka Megali by their slightly and highly exerted stigma respectively, while rest of the cultivars showed either same level (11 cultivars) or inserted habit (8 cultivars). Cultivars Arka Shresta, Arka Abijeet, Arka Saurab, Sankranthi and Ronco were differentiated by absence of style hairiness. Stemen length also influences the pollination behavior of crop/cultivar. Stemen length varied significantly among cultivars and ranged between 6.3 mm (Arka Alok) to 9.00 mm (A 32/63). Such variation in floral characters was also used for varietal identification by Rochell (1977) and Gill *et al.,* (1997).

Fruit Descriptors: Fruit descriptors are more apparent and promising which can be utilized to differentiate cultivars (Natarajan *et al.,* 1994, Patel *et al.,* 2001 and Arvindkumar *et al.,* 2003). It is important to identify cultivars at early stages of fruiting which saves time without waiting till maturity of crop. Grouping of cultivars based on exterior colour of immature fruit was employed. PKM-1, US-618 were distinct by their dark green colour while, Pusa Early Dwarf and A 32/63 by their green colour. This character can be employed to identify these cultivars before maturity. All other cultivars were grouped into either greenish white or light green colour. Cultivars Arka Ashish, Pusa Ruby, Mruthunjaya-2, US-618 and A 32/63 can be identified by presence of green shoulder fruit and were further subdivided based on the intensity of green shoulder into strong (Pusa Ruby) and light (Arka Ashish, Mruthunjaya-2, US-618, A 32/63) (Fig 3). Consumer preference depends on fruit shape and size. It is also important for transportation purpose. Fruit shape is the most promising character which can be visualized by naked eye and can be utilized for clear cut identification of tomato cultivars during field inspection. In present study wide variation was observed in fruit shape among the cultivars (Fig 4). Arka Ahuti and Arka Ashish showed ellipsoid and pyriform fruit shape respectively and was unique to these cultivars. Four cultivars (Arka Vikas, Arka Megali, Pusa Ruby and PKM-1) showed flattened shape and three cultivars (Arka Abijeet, US-618 and JK Desi) showed slight flattened fruit shape, three cultivars (Arka Shresta, Pusa Early Dwarf and Nandi) had round shape and four cultivars (Arka Alok, Arka Abha, Sankranthi, A 32/63) with heart shaped, while, six cultivars (Vybav, NS-2535, Mruthunjaya-2, Ronco, 128/M 131 and M-03/868) showed cylindrical shape. This character is promising as it is stable and not influenced by biotic and abiotic stresses and more useful in cultivar differentiation as shown by Garcia-Gusana *et al.,* (2004) in tomato, Arya and Saini (1976), Natarajan *et al.,* (1994), Gill *et al.,* (1997) in okra and Patel *et al.,* (2001) in brinjal. However, differences were not very apparent between secondary fruit shape and primary fruit shape and were almost same.

Fruit size varied significantly among the cultivars studied and ranged between 4.09 cm^3 (Pusa Ruby) to 6.15 cm^3 (Arka Shresta). All the cultivars were grouped in either small (12 cultivars) or intermediate (12 cultivars). No cultivars exhibited very small, large and very large fruit size. This character is useful only for broad classification of cultivars. Fruit homogeneity is the most important character for marketing of fruits. Cultivars Pusa Early Dwarf, PKM-1, Nandi, Mruthunjata-2 and 128/M 131 showed high fruit homogeneity while, remaining 14 cultivars showed intermediate homogeneity. This character may be influenced by environmental factors like biotic and abiotic stress, nutritional status etc. and care has to be taken to prevent these extraneous factors for efficient differentiation of cultivars. All the cultivars studied differed significantly among each other for fruit weight. Fruit weight ranged between 47.16 g (Pusa Ruby) to 112.5 g (Arka Abha) showing wide variation among the cultivars. Hence this character could be used to differentiate many cultivars (Kimberly *et al.,* 1991 and Natarajan *et al.,* 1994). However this character is influenced by fertilizers response of cultivars and nutritional status of soil. With some

consciousness this character can be used to identify cultivars.

Figure 3: Exterior colour of immature fruit

Fruit length differed significantly among the cultivars which ranged between 3.08cm (Pusa Ruby) to 5.91cm (Vybav). Pusa Ruby, Pusa Early Dwarf, PKM-1 showed shorter fruit length (3.0-4.0cm) and was mainly due to their flattened nature of fruits. Fruit dimensions can be effectively used to characterize the cultivars as shown in several crops like tomato (Garcia-Gusana *et al.,* 2004; ArvindKumar *et al.,* 2003). Exterior colour of mature fruit was not useful in identification of any of the cultivars since all the studied cultivars showed red colour. Easiness to detach the fruit from pedicel is also a significant character for harvesting of fruits. Based on this, the cultivars were categorized into four groups viz., easy, intermediate and difficult. 13, 6 and 5 genotypes appeared under each group respectively. Based on fruit shoulder shape cultivars were grouped into flat (8 cultivars) slightly depressed (9 cultivars) moderately depressed (4 cultivars) and strongly depressed (3 cultivars). This character can be used to identify Arka Vikas, Pusa Ruby and PKM-1, which showed strongly depressed fruit shoulder shape, Width of pedicel scar differed significantly among cultivars ranging between 4.3 mm (Arka Ahuti) to 8.6 mm (Arka Vikas). Arka Ahuti was distinct from all other cultivars for its lower width of pedicel scar (4.3mm). Nandi had unique characteristic of size of corky area (5.1mm) around pedicel scar. Based on easiness of fruit skin to peel cultivars were grouped into easy (5 cultivars) intermediate (8 cultivars) and difficult (10 cultivars). Uniformly ripened fruits should be taken while peeling of skin other wise classification goes wrong and this character was useful for broad classification only. Skin colour of ripe fruit was not useful to differentiate or to classify cultivars because all other cultivars showed yellow colour. Blossom end shape is promising and unaltered trait and more useful in cultivar identification. Cultivars Arka Ashish, Sankranthi were distinct from others by their pointed fruit blossom end shape could be used as marker and Arka Megali, Pusa Ruby, Pusa Early Dwarf, PKM-1, Mruthunjaya-2, JK Desi, JK Asha, and 128/M 131 with indented fruit blossom end shape while, rest of cultivars showed flat shape. Firmness of fruit is an imperative character which is required for long transportation and storage. Pusa Ruby, Pusa Early dwarf and PKM-1 were distinct from others by its soft fruit nature and these cultivars were suitable only for local markets while, rest of the cultivars showed either firm or intermediate nature of fruit firmness. This character is also helpful in designing the crushing technique for fermentation of tomato fruits. Fruit firmness has direct correlation with fruit wall thickness and easiness of fruit wall to be peeled. As wall thickness increase, peeling of fruit wall becomes difficult, but prolongs the shelf life of the fruits.

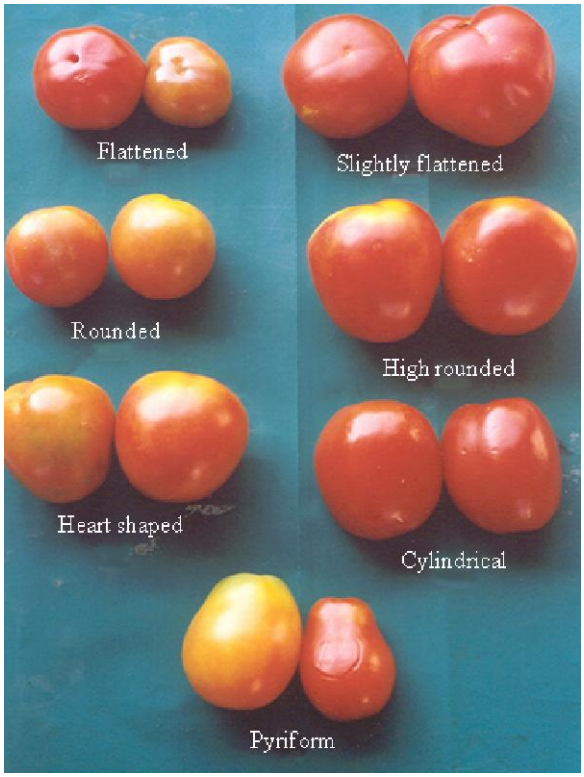

Figure 4: Predominant fruit shape

Among the fruit characteristics fruit shape, exterior colour of immature fruit, presence of green shoulder, size of corky area around pedicel scar, size of core, number of locules, fruit blossom end shape can be

utilized to characterize few cultivars. Fruit size, fruit size homogeneity, fruit weight, length, width, intensity of exterior colour of mature fruit, secondary fruit shape, easiness of fruit to detach from the pedicel, fruit shoulder shape, easiness of fruit skin to peel were useful only in grouping of studied cultivars. Thickness of fruit wall varied significantly among the cultivars ranging between 3.6 mm (PKM-1) to 8.4 mm (Ronco). Pusa Early Dwarf, PKM-1 and Nandi have thinnest fruit wall (<4.0 mm) and Mruthunjaya-2, Ronco, A 32/63, 128/M 131, M-03/868 have thickest wall (>8.0 mm) (Table 3). When we correlate the thickness of wall and fruit firmness there is positive correlation between them. Based on flesh colour of pericarp, cultivars were grouped into only two categories viz., Pink (13 cultivars) and red (11 cultivars). While, based on flesh colour intensity, cultivars were grouped into three categories viz., light (8 cultivars), intermediate (10 cultivars) and dark (6 cultivars). Based on fruit cross sectional shape, the cultivars was grouped into round (11 cultivars), angular (8 cultivars) and irregular (5 cultivars). These results indicated that above three characters could be used in broad classification of genotypes and no one character could identify individual cultivar. Size of core is the most important character in tomato processing industry. Size of core differed significantly among cultivars ranging from 1.73 (Arka Ahuti) to 3.22cm (Arka Shresta). Arka Vikas and Arka Shresta were distinct from other cultivars by its larger core size (>3.0cm) while, Arka Ahuti was distinct from all other cultivars by its narrow core size (<2.0cm) and these cultivars can be identified by core size, however it is further depends on fruit size. Number of locules varied among cultivars and even within the cultivar. Only Arka Vikas was distinct by its higher number of locules (>6) while, Arka Alok and Arka Ashish and Vybav had lower number of locules (only 2). Number of locules is correlated with fruit shape. In general fruits with flattened shape showed more number of locules and it was lower in fruits with cylindrical or pyriform fruit. Shape of pistil scar also promising character could be used to identify many cultivars. Arka Abha, Pusa Early Dwarf, PKM-1 and Arka Vikas were distinct by their star shape of pestle scar while, Arka Megali, Arka Saurab, NS-2535 and A 32/63 by their irregular shape and rest of the cultivar showed dot shape.

Table 3: Seed and seedling characteristics of different cultivars of tomato

S.No.	Genotypes	Fruit width (mm)	Width of pedicel scar (mm)	Size of corky area around pedicel scar (mm^3)	Thickness of fruit wall (mm)	Size of core (cm)	Number of locules	Number of days to 50 % flowering	Number of days to first ripen fruit	Soluble solids	Susceptibility to TLCV
1.	Arka Alok	41.5	5.8	2.8	4.5	2.41	2	20.0	65.6	4.46	0.00 (0.00)
2.	A. Vikas	66.4	8.6	4.7	4.0	3.15	5-11	22.0	66.6	4.06	86.66 (72.09)
3.	A. Ahuti	45.4	4.3	4.3	6.3	1.73	3	22.3	68.3	4.26	86.66 (72.09)
4.	A Ashish	54.5	6.6	5.0	7.6	2.31	2	22.3	67.3	4.36	60.00 (50.76)
5.	A Abha	45.4	6.4	3.4	6.4	2.59	4-6	22.0	64.6	4.20	10.00 (89.42)
6.	A Megali	61.2	7.9	4.1	6.5	2.77	4-6	21.6	64.6	4.66	66.66 (54.98)
7.	A Saurab	51.8	6.4	3.7	6.9	2.31	3	20.6	64.3	4.33	00.00 (0.00)
8.	A. Shresta	67.1	7.7	4.3	7.9	3.22	3-4	22.6	67.0	4.30	73.33 (59.21)
9.	A. Abijeet	57.3	7.9	4.8	6.0	2.23	3	20.6	65.6	4.66	80.00 (63.43)
10	P. Ruby	47.2	7.6	1.8	4.0	3.14	4-6	19.3	63.6	5.53	100.00 (89.42)
11.	PED	47.2	6.2	2.1	3.9	2.72	3-4	16.3	65.3	5.00	100.00 (89.42)
12.	PKM-1	55.4	7.7	1.0	3.6	2.84	4-6	21.0	65.0	4.60	93.33 (80.76)
13.	Nandi	53.9	7.0	5.1	3.7	2.44	3-4	23.6	64.6	5.60	0.00 (0.00)
14.	Sankranthi	48.3	6.5	0.5	7.0	2.48	2-3	20.0	66.0	5.40	0.00 (0.00)
15.	Vibhav	40.9	5.9	1.7	6.8	2.08	2	21.6	67.3	4.13	0.00 (0.00)
16.	NS-2535	57.6	7.5	2.4	7.4	2.74	2-3	24.6	64.3	4.16	93.33 (80.76)
17.	Mruthunjaya-2	51.7	7.6	1.5	8.3	2.31	2-3	19.3	63.3	5.00	0.00 (0.00)
18.	US -618	59.8	7.8	3.4	6.7	2.68	2-3	20.0	66.3	5.20	0.00 (0.00)
19.	JK Desi	52.6	7.1	1.6	6.0	2.52	3-4	23.6	68.0	5.16	60.00 (50.76)
20.	JK Asha	50.5	7.8	3.3	7.8	2.69	3-4	19.6	64.0	4.50	66.66 (54.98)
21.	Ronco	54.1	6.9	1.7	8.4	2.61	2-3	20.0	67.0	4.80	96.66 (82.86)
22.	A 32/63	56.2	8.1	3.4	8.0	2.87	2-3	23.6	69.3	5.00	100.00 (89.42)
23.	128/M 131	46.3	7.4	1.7	8.1	2.29	3	21.0	69.3	4.00	80.00 (63.43)
24.	M-03/868	56.5	8.4	2.1	8.3	2.71	3	21.3	65.3	5.20	60.00 (50.76)
SEm±		3.2	0.63	0.06	0.46	0.154		0.50	0.38	0.045	5.14
CD (p=0.05)		9.3	1.81	0.19	1.31	0.438		1.43	1.09	0.1303	14.60
CV (%)		10.87	14.80	11.77	12.76	10.49		4.21	1.01	1.709	16.59

Thickness of fruit wall, flesh colour of pericarp and its intensity, fruit cross sectional shape and fruit firmness could be fairly used for identification. While, exterior colour of mature fruit and skin colour of ripe fruit were useful neither for identification nor for grouping of cultivars. Arka Ashish and Mruthunjaya-2 were distinct from other cultivars by their greater hollowness of fruit, while rest of the cultivars were grouped under slight (14 cultivars) and intermediate (8 cultivars). Days to 50 per cent flowering differed significantly among the cultivars. Pusa Ruby and Vybav were distinct from all other cultivars which took least (16.33 days) and most (24.66 days) number of days for 50 per cent flowering respectively. This had direct relationship with days to first fruit ripening. Pusa Ruby took least number of days (63.33) to maturity, while cultivars A 32/63 and 128/M 131 took more days (69-70). These two characters could be utilized in identification of few cultivars and grouping of all cultivars. Differences in days to flowering and fruiting were due to genetic makeup and response to different inputs and climatic conditions.

TSS content is the most important character for tomato processing industry and required to decide the fermentation method/duration during seed extraction. TSS content varied significantly among the cultivars and ranged between 4.06 (Arka Vikas) to 5.60 (Nandi). Pusa Ruby and Nandi were distinct from other cultivars by their higher (>5.6) TSS content followed by Sankranthi, US-618, JK Desi and M-03/868 with TSS of >5.1 and other cultivars showed <5.0 TSS. This character can also be used to characterize cultivars because composition of fruit is mainly governed by its genes. Such differences in fruit composition among cultivars were observed in tomato (Garcia-Gusano *et al.,* 2004), Pea (Singh *et al.,* 1997). Significant differences for susceptibility to TLCV were observed among the cultivars. Arka Alok, Arka Abha, Arka Saurab, Nandi, Sankranthi, Vybav, Mruthunjaya-2 and US-618 cultivars showed very low susceptibility, where as Arka Ashish, Arka Megali, JK Desi and JK Asha cultivars had high susceptibility while the remaining cultivars were highly susceptible. Such differences to biotic stress among cultivars were observed by Rodenburg (1975) in cabbage, Gill *et al.,* (1997) and Patel *et al.,* (2001) in okra and brinjal respectively.

Among 17 quantitative and 36 qualitative morphological characters studied variation was observed in all quantitative characters and 31 qualitative characters. While, only 15 traits showed substantial variation among cultivars. Every cultivar showed one or more distinct characters which could be used to identify the same. However, it was difficult to identify all the cultivars based on single morphological trait. The morphological parameters recorded and discussed were prevailed at Bangalore condition, located at altitude of 12^0 58' N and longitude of 77^0 35' E with an altitude of 930 meters above mean sea level.

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Source of support: Nil
Conflict of interest: None Declared