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Characterization of Tomato (*Solanum lycopersicon* Mill.) Genotypes for Morphological and Disease Resistance Traits

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ABSTRACT

The characterization of germplasm is very important for the seed material (breeding) and development of improved varieties. The seed material is collected from the Noble Seeds Pvt Ltd, Yelhanka few of them are resistant to ToLCV, where Ty gene background is inserted, five genotypes are non-resistant to ToLCV and one check Arka Vikas and conducted the research at Kestur Village Doddballapura during *kharif* 2021. The genotypes were morphologically characterized according to DUS guidelines. The 20 qualitative and 22 quantitative traits were characterised, where only 25 traits observed with the variations and all the quantitative traits are found with variation among the genotypes.

Keywords Tomato genotypes, Morphology, Characterization, ToLCV, Resistance.

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INTRODUCTION

Tomato (*Solanum lycopersicon* Mill., 2n=2x=24) is the most important Solanaceous vegetable crops grown in every corner of the world. It is mainly used for cooking, processing forms viz., salad, puree, paste, ketchup, sauce and soup (Peralta *et al.* 2008). When compared to other fruits and vegetables, tomatoes are low in antioxidant content but routine intake makes a physiologically relevant source of antioxidants and few chemo-protective compounds (Boches *et al.* 2011). To plan for the breeding program by breeders there is an importance of characterization of genotypes and this morphological characterization is the primary for evaluation of genetic diversity, plays a role in conservation and preservation of resources (Osei *et al.* 2014 and Sacco *et al*. 2015).

The wild tomatoes are important for breeding, as sources of desirable traits for evolutionary studies. The descriptors display a large range of variation, distinct varietal groups and describe phenotypic and morphological diversity with the support of biochemical assessment (Mohan *et al.* 2018 and Pereira-Dias *et al.* 2020). The characterization consists of characters that are highly heritable which can be distinguished by our naked eye that expresses in all the environment. The evaluation of the phenotypic traits viz., plant morphology, leaf characters, fruit morphology, color intensity, firmness are challenging and time-consuming because of the quantitative nature of the traits. Therefore, to identify tomato cultivars with descriptors are even published by International Union for Protection of New Plant Varieties (Fiorani and Schurr 2013).

The characterization of genotypes is one of the effective ways to find promising gene sources and utilize them for the creation of improved varieties (Grozeva *et al*. 2020 and Corrado *et al.* 2014). The aim of the current work is to characterize a tomato collection, comprised of 30 genotypes using morphological, fruit quality, biochemical and virus resistance traits. Our specific objectives were a) To characterize these genotypes for morphological, fruit quality, biochemical and virus resistance traits; b) Identify accessions those have a high yield, enhanced fruit quality and resistance to ToLCV. Selected genotypes with unique and valuable traits could be used in a subsequent breeding program for the development of tomato varieties with improved fruit quality and high yield.

MATERIALS AND METHODS

a) **Source of seeds** – The seeds are collected from the Noble Seeds Pvt Ltd, Yelhanka. The seeds of 30 genotypes are differed for resistance against ToLCV of Ty-gene background.

15 lines - Ty-3 gene
05 lines - Without any resistant genes against ToLCV
01 line - Ty-2 gene
03 lines - Ty-6 gene
03 lines - Ty-2 and Ty-3 genes
03 lines - Ty-2, Ty-3 and Ty-5 genes

b) **Experimental design** – The field experiment was carried out at the Kestur village, Doddballapura,

Table 1. Morphological characterization of tomato genotypes having Ty genes.

Genotype	Anthocyanin coloration	Plant growth habit	Leaf serration	Leaf altitude	Leaf color	Stem pubescence	Stem thickness	Length of internode	Length of stem at first inflorescence
NBLTM-1	Present	SD	Highly	Semi-erect	Dark Green	Present	Weak	Medium	Medium
NBLTM-2	Present	SD	Highly	Horizontal	Dark Green	Present	Weak	Short	Short
NBLTM-3	Absent	SD	Highly	Semi-erect	Green	Present	Medium	Medium	Medium
NBLTM-4	Absent	SD	Highly	Semi-erect	Dark Green	Present	Weak	Medium	Medium
NBLTM-5	Absent	SD	Less	Semi-erect	Dark Green	Present	Weak	Short	Short
NBLTM-6	Present	SD	Less	Semidrooping	Dark Green	Present	Medium	Medium	Medium
NBLTM-7	Present	SD	Less	Horizontal	Dark Green	Present	Medium	Medium	Medium
NBLTM-8	Present	SD	Less	Horizontal	Green	Present	Medium	Short	Short
NBLTM-9	Absent	SD	Less	Horizontal	Green	Present	Medium	Medium	Medium
NBLTM-10	Absent	ID	Less	Semi-erect	Dark Green	Present	Medium	Medium	Medium
NBLTM-11	Present	SD	Less	Horizontal	Dark Green	Present	Medium	Medium	Medium
NBLTM-12	Present	D	Less	Semi-erect	Dark Green	Present	Weak	Medium	Medium
NBLTM-13	Absent	SD	Less	Semi-erect	Dark Green	Present	Strong	Short	Short
NBLTM-14	Absent	SD	Less	Semi-erect	Dark Green	Present	Weak	Medium	Medium
NBLTM-15	Present	SD	Highly	Horizontal	Dark Green	Present	Weak	Medium	Medium
NBLTM-16	Present	SD	Highly	Horizontal	Dark Green	Present	Medium	Medium	Medium
NBLTM-17	Present	SD	Highly	Semi-erect	Green	Present	Medium	Medium	Medium
NBLTM-18	Absent	SD	Less	Semi-erect	Dark Green	Present	Strong	Medium	Medium
NBLTM-19	Present	SD	Less	Semi-erect	Green	Present	Strong	Long	Long
NBLTM-20	Absent	SD	Less	Semi-erect	Dark Green	Present	Medium	Medium	Medium
NBLTM-21	Absent	SD	Highly	Semi-erect	Dark Green	Present	Strong	Medium	Medium
NBLTM-22	Absent	SD	Less	Semi-erect	Green	Present	Weak	Short	Short
NBLTM-23	Absent	D	Less	Semi-erect	Dark Green	Present	Weak	Long	Long
NBLTM-24	Absent	SD	Less	Semi-erect	Dark Green	Present	Medium	Medium	Medium
NBLTM-25	Present	SD	Highly	Semi-erect	Dark Green	Present	Medium	Medium	Medium
NBLTM-26	Absent	SD	Less	Semi-erect	Green	Present	Weak	Medium	Medium
NBLTM-27	Present	ID	Less	Semi-erect	Dark Green	Present	Medium	Medium	Medium
NBLTM-28	Absent	SD	Less	Semi-erect	Dark Green	Present	Strong	Medium	Medium
NBLTM-29	Absent	ID	Highly	Semi-erect	Green	Present	Strong	Medium	Medium
NBLTM-30	Absent	ID	Highly	Semi-erect	Dark green	Present	Medium	Medium	Medium

SD: Semideterminate, ID- Determinate, D- Determinate.

Table 2. Morphological characterization of tomato genotypes having Ty genes.

Genotype	Days to 50% flowering	Inflorescence type	Length of inflores-cence	Fruit set on inflores-cence	Number of fruits on second inflorescence	Flower colour	Style position	Calyx size	Style pubes-cence	Number of inflorescence
NBLTM-1	Early	Uniparous	Long	Medium	Weak	Yellow	Non-exerted	Medium	Absent	Medium
NBLTM-2	Early	Multiparous	Short	Weak	Weak	Yellow	Non-exerted	Small	Absent	Few
NBLTM-3	Early	Uniparous	Long	Strong	Strong	Yellow	Non-exerted	Medium	Absent	Medium
NBLTM-4	Early	Multiparous	Long	Medium	Medium	Yellow	Non-exerted	Medium	Absent	Many
NBLTM-5	Early	Uniparous	Medium	Medium	Weak	Yellow	Non-exerted	Small	Absent	Medium
NBLTM-6	Early	Multiparous	Long	Medium	Medium	Yellow	Non-exerted	Small	Absent	Many
NBLTM-7	Early	Uniparous	Long	Medium	Medium	Yellow	Non-exerted	Small	Absent	Medium
NBLTM-8	Early	Uniparous	Long	Medium	Medium	Yellow	Non-exerted	Medium	Absent	Many
NBLTM-9	Early	Uniparous	Long	Medium	Medium	Yellow	Non-exerted	Small	Absent	Medium
NBLTM-10	Early	Uniparous	Long	Strong	Medium	Yellow	Non-exerted	Medium	Absent	Many
NBLTM-11	Early	Multiparous	Long	Weak	Strong	Yellow	Non-exerted	Medium	Absent	Medium
NBLTM-12	Early	Uniparous	Long	Medium	Medium	Yellow	Non-exerted	Medium	Absent	Many
NBLTM-13	Early	Uniparous	Long	Medium	Medium	Yellow	Non-exerted	Large	Absent	Many
NBLTM-14	Early	Uniparous	Long	Medium	Weak	Yellow	Non-exerted	Medium	Absent	Many
NBLTM-15	Early	Uniparous	Long	Weak	Weak	Yellow	Non-exerted	Medium	Absent	Many
NBLTM-16	Early	Multiparous	Long	Weak	Strong	Yellow	Non-exerted	Medium	Absent	Medium
NBLTM-17	Early	Multiparous	Long	Medium	Medium	Yellow	Non-exerted	Small	Absent	Medium
NBLTM-18	Early	Uniparous	Long	Medium	Medium	Yellow	Non-exerted	Small	Absent	Many
NBLTM-19	Early	Multiparous	Long	Medium	Medium	Yellow	Non-exerted	Large	Absent	Many
NBLTM-20	Early	Multiparous	Long	Medium	Medium	Yellow	Non-exerted	Small	Absent	Medium
NBLTM-21	Early	Multiparous	Long	Medium	Medium	Yellow	Non-exerted	Medium	Absent	Many
NBLTM-22	Early	Multiparous	Long	Strong	Medium	Yellow	Non-exerted	Medium	Absent	Many
NBLTM-23	Early	Uniparous	Long	Medium	Medium	Yellow	Non-exerted	Small	Absent	Many
NBLTM-24	Early	Multiparous	Long	Medium	Medium	Yellow	Non-exerted	Small	Absent	Many
NBLTM-25	Early	Multiparous	Long	Weak	Weak	Yellow	Non-exerted	Medium	Absent	Many
NBLTM-26	Early	Multiparous	Long	Weak	Weak	Yellow	Non-exerted	Medium	Absent	Medium
NBLTM-27	Early	Uniparous	Long	Weak	Weak	Yellow	Non-exerted	Large	Absent	Medium
NBLTM-28	Early	Multiparous	Long	Strong	Strong	Yellow	Non-exerted	Medium	Absent	Medium
NBLTM-29	Early	Multiparous	Long	Medium	Medium	Yellow	Non-exerted	Large	Absent	Medium
NBLTM-30	Early	Multiparous	Long	Weak	Weak	Yellow	Non-exerted	Medium	Absent	Medium

Noble Seeds Pvt Ltd, Yelhanka. Tomato seedlings was transplanted during *kharif* 2021 with 25-30 cm, 50 cm and 110 cm plant to plant, row to row, and between row distance, respectively. Application of fertilizers, irrigation and microclimate were the same for all genotypes.. Every accession was represented by 10 plants in each replicate.

c) **Characterization:** All genotypes were morphologically for vegetative and reproductive traits, biochemically and ToLCV evaluated for 42 traits by DUS guidelines, PPV and FRA.

RESULTS

Plant morphological traits

The plant morphological traits of 30 genotypes were recorded at different stages of plant growth. The data pertaining to these traits have been presented in Tables 1-5.

Among 30 genotypes studied, anthocyanin coloration is observed in 13 genotypes and remaining 17 genotypes does not have anthocyanin coloration at seedling stage (Fig. 1). The two genotypes have shown determinate type of plant growth habit (NBLTM-12 and NBLTM-23), four genotypes are observed indeterminate growth habit (NBLTM-10, NBLTM-27, NBLTM-29 and NBLTM-30) and remaining 24 genotypes exhibited semi determinate growth habit among genotypes studied (Fig. 2). Out of the genotypes studied, 11 genotypes are observed under highly serrated and 19 genotypes are found less serrations on leaf (Fig. 3). The 22 genotypes are

Table 3. Morphological characterization of tomato genotypes having Ty genes.

Genotype	Anther color	Presence of jointless pedicel	Green shoulder	Fruit depression at peduncle end	Uniformity of fruit on plant	Fruit shape	Intensity of green color on fruit	Shape at blossom end
NBLTM-1	Yellow	Absent	Absent	Shallow	Non-uniform	Heart	Light	Pointed
NBLTM-2	Yellow	Absent	Absent	Shallow	Non-uniform	Heart	Light	Pointed
NBLTM-3	Yellow	Present	Absent	Absent	Uniform	Cylindrical	Light	Indented flat
NBLTM-4	Yellow	Absent	Absent	Deep	Non-uniform	Slightly Flattened	Light	Flat pointed
NBLTM-5	Yellow	Absent	Present	Shallow	Uniform	Obovoid	Medium	Flat
NBLTM-6	Yellow	Absent	Present	Medium	Uniform	Circular	Medium	Flat
NBLTM-7	Yellow	Present	Absent	Absent	Uniform	Obovoid	Light	Flat
NBLTM-8	Yellow	Present	Absent	Shallow	Uniform	Heart	Light	Flat pointed
NBLTM-9	Yellow	Absent	Absent	Absent	Uniform	Heart	Light	Pointed
NBLTM-10	Yellow	Absent	Present	Deep	Uniform	Pear	Dark	Flat
NBLTM-11	Yellow	Present	Absent	Medium	Uniform	Rectangular	Light	Flat pointed
NBLTM-12	Yellow	Present	Absent	Absent	Uniform	Circular	Light	Flat
NBLTM-13	Yellow	Absent	Absent	Shallow	Uniform	Obovoid	Medium	Pointed
NBLTM-14	Yellow	Absent	Absent	Shallow	Uniform	Ovoid	Medium	Indented flat
NBLTM-15	Yellow	Absent	Absent	Medium	Uniform	Heart	Medium	Flat pointed
NBLTM-16	Yellow	Absent	Absent	Deep	Uniform	Slightly flattened	Light	Indented flat
NBLTM-17	Yellow	Absent	Absent	Shallow	Uniform	Cylindical	Light	Indented flat
NBLTM-18	Yellow	Absent	Absent	Shallow	Uniform	Obovoid	Medium	Flat pointed
NBLTM-19	Yellow	Absent	Absent	Absent	Non-uniform	Obovoid	Medium	Indented flat
NBLTM-20	Yellow	Absent	Absent	Deep	Uniform	Ovoid	Medium	Pointed
NBLTM-21	Yellow	Absent	Present	Deep	Uniform	Flattened	Light	Indented
NBLTM-22	Yellow	Absent	Present	Shallow	Uniform	Rectangular	Medium	Indented flat
NBLTM-23	Yellow	Present	Present	Medium	Uniform	Heart	Medium	Flat pointed
NBLTM-24	Yellow	Absent	Absent	Deep	Uniform	Circular	Medium	Flat
NBLTM-25	Yellow	Absent	Absent	Shallow	Uniform	Slightly flattened	Light	Indented flat
NBLTM-26	Yellow	Present	Absent	Absent	Uniform	Circular	Light	Flat
NBLTM-27	Yellow	Absent	Absent	Medium	Uniform	Slightly flattened	Dark	Indented flat
NBLTM-28	Yellow	Absent	Absent	Shallow	Uniform	Obovoid	Light	Pointed
NBLTM-29	Yellow	Absent	Absent	Medium	Uniform	Slightly flattened	Light	Flat pointed
NBLTM-30	Yellow	Absent	Absent	Deep	Uniform	Slightly flattened	Dark	Indented

observed as semi-erect group, seven genotypes are observed with horizontal type and one genotype is observed under semi drooping type of leaf altitude out of 30 genotypes studied. Among genotypes studied,

Fig. 1. Anthocyanin coloration at seedling stage in tomato.

Table 4. Morphological characterization of tomato genotypes having Ty genes.

Genotype	Color at maturity	Color of flesh at maturity	Fruit weight	Size at blossom	Size of locules	Length of fruit stalk	Number of locules	Fruit width	Fruit length	Fruit thickness of pericarp
NBLTM-1	Red	Red	Very small	Medium	Medium	Medium	Bilocular	Medium	Small	Thick
NBLTM-2	Red	Red	Very small	Small	Large	Medium	Bilocular	Small	Small	Medium
NBLTM-3	Red	Red	Very small	Large	Large	Long	Bilocular	Small	Medium	Thick
NBLTM-4	Red	Red	Very small	Medium	Large	Small	Multilocular	Medium	Small	Thick
NBLTM-5	Red	Red	Very small	Medium	Large	Medium	Bilocular	Small	Medium	Medium
NBLTM-6	Red	Red	Very small	Medium	Medium	Long	Trilocular	Small	Small	Medium
NBLTM-7	Red	Red	Very small	Large	Large	Long	Trilocular	Medium	Medium	Thick
NBLTM-8	Red	Red	Very small	Large	Large	Long	Bilocular	Small	Small	Thick
NBLTM-9	Red	Red	Very small	Large	Medium	Long	Trilocular	Small	Medium	Medium
NBLTM-10	Red	Red	Very small	Large	Large	Medium	Multilocular	Medium	Small	Medium
NBLTM-11	Red	Red	Very small	Medium	Medium	Long	Bilocular	Medium	Medium	Thick
NBLTM-12	Red	Red	Very small	Medium	Medium	Long	Bilocular	Small	Medium	Thick
NBLTM-13	Red	Red	Very small	Medium	Medium	Long	Bilocular	Medium	Small	Thick
NBLTM-14	Orange	Orange	Very small	Medium	Medium	Long	Bilocular	Small	Medium	Thick
NBLTM-15	Red	Red	Very small	Medium	Medium	Long	Trilocular	Medium	Medium	Thick
NBLTM-16	Red	Red	Very small	Medium	Large	Medium	Multilocular	Medium	Medium	Thick
NBLTM-17	Red	Red	Very small	Medium	Large	Long	Trilocular	Medium	Small	Thick
NBLTM-18	Red	Red	Very small	Medium	Medium	Medium	Bilocular	Small	Medium	Thick
NBLTM-19	Red	Red	Very small	Medium	Medium	Long	Trilocular	Small	Medium	Thick
NBLTM-20	Red	Red	Very small	Medium	Medium	Long	Bilocular	Medium	Medium	Thick
NBLTM-21	Red	Red	Very small	Medium	Large	Medium	Multilocular	Medium	Small	Medium
NBLTM-22	Red	Red	Very small	Medium	Large	Long	Bilocular	Medium	Medium	Thick
NBLTM-23	Red	Red	Very small	Medium	Medium	Medium	Trilocular	Medium	Small	Thick
NBLTM-24	Red	Red	Very small	Medium	Large	Long	Multilocular	Medium	Small	Thick
NBLTM-25	Red	Red	Very small	Medium	Large	Medium	Multilocular	Large	Small	Thick
NBLTM-26	Red	Red	Very small	Medium	Large	Medium	Multilocular	Medium	Small	Medium
NBLTM-27	Red	Red	Very small	Medium	Large	Long	Multilocular	Medium	Small	Thick
NBLTM-28	Red	Red	Very small	Medium	Medium	Long	Bilocular	Medium	Medium	Thick
NBLTM-29	Red	Red	Very small	Medium	Large	Medium	Trilocular	Medium	Small	Thick
NBLTM-30	Red	Red	Very small	Medium	Large	Long	Multilocular	Medium	Small	Thick

the 22 genotypes are observed for dark green leaves and eight genotypes are noticed green color. The stem pubescence is present in all 30 genotypes.

The 10 genotypes are observed for weak stem thickness, 14 genotypes considered medium stem thickness and strong stem thickness is noticed in six

Determinate **Semi-determinate** **Indeterminate**

Fig. 2. Genotypes having different plant growth habit.

Table 5. Morphological characterization of tomato genotypes having Ty genes.

Genotype	Fruit firmness	TSS	Days to maturity	Disease infection
NBLTM-1	Firm	High	Early	Resistant
NBLTM-2	Firm	High	Early	Immune
NBLTM-3	Firm	Very high	Early	Resistant
NBLTM-4	Firm	High	Early	Immune
NBLTM-5	Firm	Medium	Early	Moderately susceptible
NBLTM-6	Firm	Very high	Early	Immune
NBLTM-7	Firm	Very high	Early	Resistant
NBLTM-8	Firm	Very high	Early	Immune
NBLTM-9	Medium	Very high	Early	Resistant
NBLTM-10	Firm	Medium	Early	Moderately susceptible
NBLTM-11	Firm	Very high	Early	Moderately susceptible
NBLTM-12	Firm	High	Early	Immune
NBLTM-13	Firm	Very high	Early	Moderately susceptible
NBLTM-14	Firm	Medium	Early	Moderately susceptible
NBLTM-15	Firm	Very high	Early	Immune
NBLTM-16	Firm	Very high	Early	Immune
NBLTM-17	Firm	Very high	Early	Resistant
NBLTM-18	Firm	Very high	Early	Resistant
NBLTM-19	Firm	High	Early	Moderately susceptible
NBLTM-20	Firm	Very high	Early	Moderately susceptible
NBLTM-21	Firm	Very high	Early	Moderately susceptible
NBLTM-22	Firm	Very high	Early	Immune
NBLTM-23	Firm	High	Early	Susceptible
NBLTM-24	Firm	High	Early	Moderately Susceptible
NBLTM-25	Medium	Very high	Early	Susceptible
NBLTM-26	Firm	Very high	Early	Immune
NBLTM-27	Firm	High	Early	Immune
NBLTM-28	Firm	Very high	Early	Moderately susceptible
NBLTM-29	Firm	Very high	Early	Immune
NBLTM-30	Firm	Very high	Early	Highly susceptible

genotypes. The short intermodal length and medium internodal length is observed in 5 and 23 genotypes respectively. Whereas, longer intermodal length is observed in two genotypes. The 5 genotypes are observed under short stem, medium stem in 23 and 2 genotypes are having long stem at first inflorescence. All 30 genotypes are observed under early flowering habit.

The fourteen genotypes are observed for uniparous type and 16 genotypes are noticed multiparous type inflorescence (Fig. 4). Pertaining to the length of inflorescence, short (NBLTM-2) and medium (NBLTM-5) are observed in one genotype each. However, the remaining 28 genotypes are noticed with long length of inflorescence. The few inflorescences are observed in one genotype NBLTM-2 and 14 are noticed medium number and many number of inflorescence are reported in 15 genotypes. The eight genotypes are considered under weak set of fruits on inflorescence, medium fruit set observed in eighteen and the remaining four genotypes are noticed strong fruit set. Weak fruiting is observed in nine genotypes, eighteen genotypes are observed with medium fruiting and three genotypes are noticed strong fruiting. All the 30 genotypes are noticed under yellow color flower. The non-exerted stigma group is present in all the 30 genotypes. No pubescence on style is found in all the 30 genotypes. The ten genotypes are observed with smaller calyx, sixteen were medium sized calyx and large calyx was noticed in four genotypes. Anther colour is observed in all the 30 genotypes.

Fig. 3. Genotypes showing serrations on leaf.

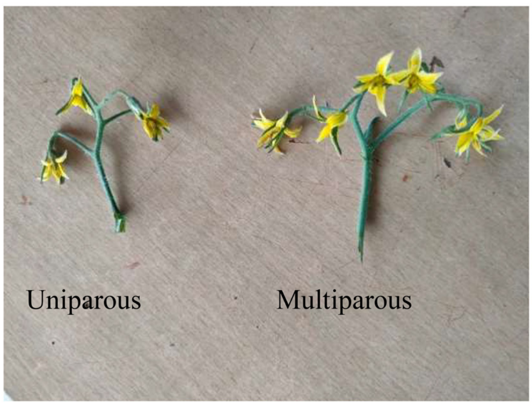

Fig. 4. Genotypes having inflorescence type.

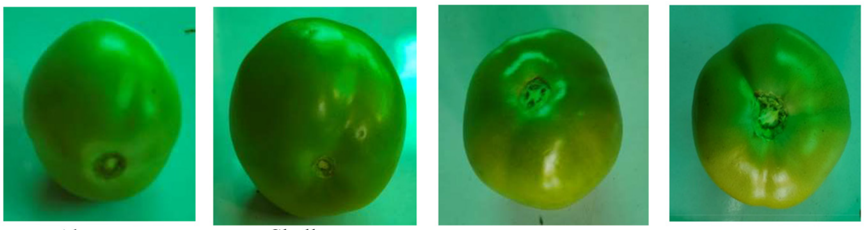

Fig. 5. Genotypes having fruit depression at peduncle end.

Fig. 6. Genotypes having presence of green shoulder.

The absence of fruit depression is noticed in six genotypes, shallow for eleven genotypes, six genotypes are observed for medium fruit depression and for seven genotypes are found for deep fruit depression at the peduncle end (Fig. 5). The six genotypes have been observed for presence of green shoulder and the remaining 24 genotypes are noticed for absence of green shoulder (Fig. 6). The presence of jointless pedicel is noticed in seven genotypes. Whereas, twenty-three genotypes were absence of jointless pedicel (Fig. 7). The uniformity of fruits was observed in 26 genotypes and non-uniformity of fruits on plants are noticed in four genotypes.

Fig. 7. Presence of jointless pedicel in different genotypes.

Out of 30 genotypes, two genotypes were noticed indented shape, eight were indented flat, seven observed with flat blossom end, seven are found flat-pointed and pointed blossom end is noticed in six genotypes (Fig. 8). Pertaining to the color of fruit at maturity, red color of fruit was found in twenty-nine genotypes and only one genotype NBLTM-14 was noticed with orange color. The color of flesh at maturity, the red color of flesh was found in twenty-nine genotypes and orange color flesh was observed in only one genotype NBLTM-14 (Fig. 9). The bilocular, trilocular and multilocular locule number were observed in thirteen, eight and nine genotypes respectively (Fig. 10).

The flattened shape of fruit is observed in genotype NBLTM-21, the genotypes NBLTM-4, NBLTM-16, NBLTM-25, NBLTM-27, NBLTM-29 and NBLTM-30 were slightly flattened fruit shape. Whereas, circular fruit shape is observed in NBLTM-12, NBLTM-24 and NBLTM-26.

Fig. 8. Genotypes are exhibiting the shape at blossom end.

Fig. 9. Color of fruit and flesh of fruits at maturity.

Rectangular fruit shape is observed in NBLTM-11 and NBLTM-22. The genotypes NBLTM-3 and NBLTM-17 were cylindrical fruit shape while, NBLTM-1, NBLTM-2, NBLTM-8, NBLTM-9, NBLTM-15 and NBLTM-23 were having heart shaped fruit. The obovoid fruit shape is observed in genotypes of NBLTM-5 NBLTM-7, NBLTM-13, NBLTM-18, NBLTM-19 and NBLTM-28. In NBLTM-14 and NBLTM-20 were observed ovoid fruit shape and pear shaped fruit is found in NBLTM-10 (Fig. 11).

Intensity of green color on fruit is light in 16 genotypes, medium intensity was observed in 11 genotypes and in three genotypes dark color intensity is noticed. The fruit weight considered was very small category as the weight of each fruit was less than 100g in all the genotypes. The smaller size at blossom end was observed in one genotype, medium sized blossom end was noticed in 23 genotypes and large sized blossom end was found in five genotypes. The thirteen genotypes were to be considered under

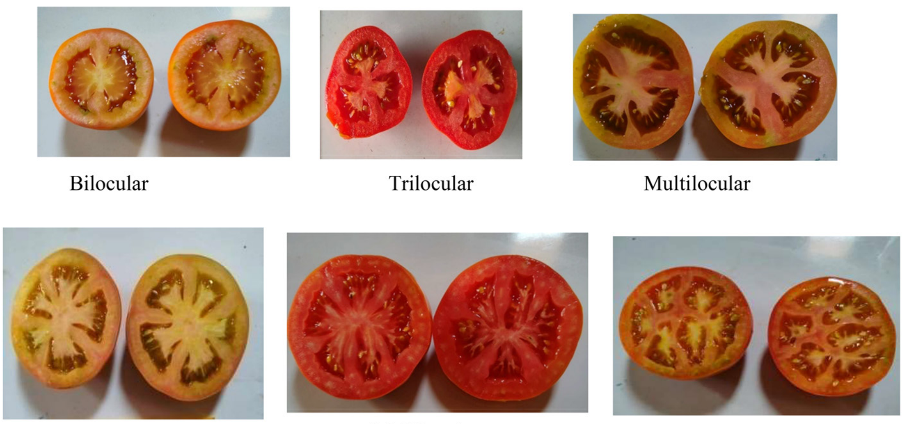

Fig. 10.. Genotypes indicating the number of locules.

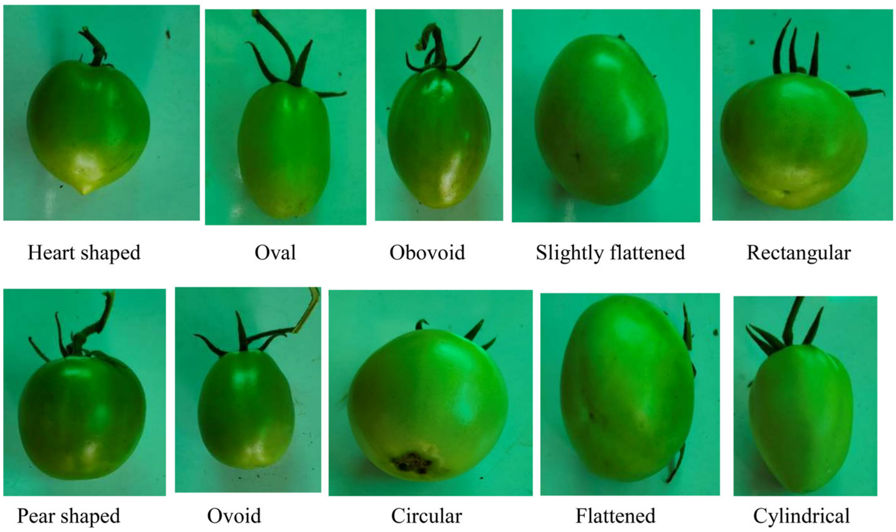

Fig. 11. Genotypes showing the shape of the fruit.

the medium sized locules and remaining seventeen genotypes were under large sized locules.

Pertaining to the length of fruit stalk, one genotype was observed with small, eleven genotypes were observed with medium length of fruit stalk and the remaining eighteen genotypes found for the large fruit stalk. Pertaining to the width of fruits, nine genotypes observed with small, twenty genotypes with medium width and larger fruit width was observed in one genotype NBLTM-25. Pertaining to fruit length, small was observed in sixteen genotypes and medium fruit length was observed in 14 genotypes.

Seven genotypes were observed with medium thickness of pericarp and the remaining 23 genotypes were with thick pericarp. The two genotypes (NBLTM-9 and NBLTM-25) were recorded under medium firmness and remaining all other 28 genotypes were observed under firm fruits. The total soluble solids were found medium in three genotypes, high in eight genotypes and 19 genotypes were observed under very high TSS out of 30 genotypes. All the 30 genotypes were observed under the early maturity.

Response to severity of disease infection among genotypes, eleven were observed under immune, six were resistant, ten were moderately susceptible, two were susceptible and one genotype (NBLTM-30) was highly susceptible.

DISCUSSION

The diversity of a germplasm is critical for the conservation, utilization and varietal development. The crop improvement program and the varietal development is to target yield and yield components, but breeding for early maturity, fruit quality and multiple stresses is equally important. To achieve this balance any breeding program needs to have created for future selection (Grozeva *et al.* 2020).

During the course of study 42 traits were reported. Out of these, 20 quantitative and 22 qualitative traits were recorded. Variations were observed in all quantitative characters and few qualitative characters. Only 25 traits showed substantial variations among cultivars and all the quantitative characters found to be useful for characterization of tomato cultivars. Seed, seedling and plant characters are major components of cultivar identification as they provide good data for differentiating characters among genotypes. However, it is difficult to identify genotypes based on single morphological trait. Instead, a set of morphological traits are essential to distinguish the genotypes.

The tomato genotypes differed for developmental, vegetative and fruit traits. The diversity of genotypes is critical for conservation, utilization and development. The prime importance of breeding program, crop improvement and varietal development that targets to yield and its components that influenced by the morphological traits and innate behavior of genotypes particularly for breeding early maturity, fruit quality and multiple traits. Conventionally, morphological and agronomic traits have been used in phenotypic evaluation (Grozeva *et al.* 2020, Salim *et al.* 2020 and Nankar *et al.* 2020) and the same sets of traits were also found suitable for detailed accession characterization in this study.

The study reveals the diversity across the evaluated genotypes of tomatoes revealed variations for all the traits of seedling, leaf, fruit characters. The collections have agro-morphological variation, which is occurrence of past studies used for agro-morphological traits (Mavromatis *et al.* 2013, Omar *et al.* 2019 and Salim *et al.* 2020) fruit shape, shape at blossom end (Nankar *et al.* 2020a) to characterize the tomato collections. The variability reported for morphometric traits that indicates that producers of tomato prefers peculiar fruit types and the information is used as a base for the development of varieties that has desirable features (Nankar *et al.* 2020b). The traits with low variation within the collection are plant growth habit, stem pubescence, days to 50 % flowering, flower color, style type, style pubescence, anther colour, fruit color at maturity, fruit weight and days to maturity which are typical for *Solanum lycopersicum.* These findings were on par with the findings of Rajae *et al.* (2018). Similar results with a large variation for some fruit characteristics were also reported in previous tomato studies and these findings were also corroborating with the findings of Sushma *et al.* 2020, Salim *et al.* 2020 and Raj Narayan *et al.* 2020.

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REFERENCES

Boches P, Peterschmidt B, Myers JR (2011) Evaluation of a subset of the *Solanum lycopersicum* var *cerasiforme* core collection for horticultural quality and fruit phenolic content. *Hort Sci* 46(11): 1450-1455.

Corrado G, Caramante M, Piffanelli P, Raoa R (2014) Genetic diversity in Italian tomato landraces:Implications for the development of a core collection. *Sci Hortic* 168: 138-144.

Fiorani F, Schurr U (2013) Future scenarios for plant phenotyping. *Ann Rev Pl Biol* 64:267-291.

Grozeva S, Nankar AN, Ganeva D, Tringovska I, Pasev G, Kostova D (2020) Characterization of tomato accessions for morphological, agronomic, fruit quality and virus resistance traits. *Can J Pl Sci* pp1-14.

Mavromatis AG, Athanasouli V, Vellios E, Khah E, Georgiadou E C, Pavli OI, Arvanitoyannis IS (2013) Characterization of tomato landraces grown under organic conditions based on molecular marker analysis and dissemination of fruit quality parameters. *J Agric Sci* 5(2): 2013-2115.

Mohan V, Gupta S, Thomas S, Mickey H, Charakana C, Chauhan VS, Sharma K, Kumar R, Tyagi K, Sarma S, Gupta SK, Kilambi HV, Nongmaithem S, Kumari A, Gupta P, Sreelakshmi Y, Sharma R (2018) Tomato fruits show wide phenomic diversity but fruit developmental genes show low genomic diversity. *PLoS ONE* 11(4): e0152907.

Nankar AN, Todorova V, Tringovska I, Pasev G, Radeva-Ivanova V, Ivanova V, Kostova D (2020a) A step towards Balkan *Capsicum anuum* L. core collection: Phenotypic and biochemical characterization of 180 accessions for agronomic, fruit quality, and virus resistance traits. *PloS one* 15(8):237741-237769.

Nankar AN, Tringovska I, Grozeva S, Ganeva D, Kostova D (2020b) Tomato phenotypic diversity determined by combined approaches of conventional and high-throughput tomato analyzer phenotyping. *Plants* 9(2):197-218.

Omar TC, Vianney TW, Larbouga B, Albert R (2019) Agromor phological evaluation within a collection of local tomato (*Solanum lycopersicum* L.) populations collected in Burkina Faso and Mali. *Afr J Agric Res* 14(33): 1726-1736.

Osei MK, Bonsu KO, Agyeman A, Choi HS (2014) Genetic diversity of tomato germplasm in Ghana using morphological characters. *Int J Pl Soil Sci* 3(3): 220-231.

Peralta IE, Spooner DM, Knapp S (2008) Taxonomy of wild tomatoes and their relatives (*Solanum lycopersicon*). *Am Soc Pl Taxonomists,* pp 151–160.

Pereira-Dias L, Fita A, Vilanova S, Sanchez-Lopez E, Rodriguez-Burruezo A (2020) Phenomics of elite heirlooms of peppers (*Capsicum annum* L.) from the Spanish center of diversity: Conventional and high throughput digital tools towards varietal typification. *Sci Hortic* 265: 109245.

Raj Narayan, Kishor A, Tiwari VK, Mer MS, Singh RK (2020) Performance of tomato (*Solanum lycopersicum* L.) Genotypes under naturally ventilated polyhouse in Kumaon hills of Uttarakhand. *Appl Biol Res* 22(1): 1-10.

Rajae A, Mohamed A, Dominique M, Ahmed E, Hana SC, Aatika M, Malika A (2018) Morphological, molecular, and physico-chemical characterization of traditional Moroccan tomato (*Solanum lycopersicum* L.) genotypes. *J Biotech Res* 9:58-69.

Sacco A, Ruggieri V, Parisi M, Festa G, Rigano MM, Picarella M E, Mazzucato A, Barone A (2015) Exploring a tomato landraces collection for fruit-related traits by the aid of a high-throughput genomic platform. *PLoS ONE* 10(9): 1-20.

Salim MMR, Rashid MH, Hossain MM, Zakaria M (2020) Morphological characterization of tomato (*Solanum lycopersicum* L.) genotypes. *J Saudi Soc Agric Sci* 19: 233–240.

Sushma K, Saidaiah P, Sudini H, Geetha A, Ravinder K (2020) Evaluation of qualitative traits in tomato (*Solanum lycopersicum* L.) germplasm. *J Pharmacog Phytochem* 10 (1): 2050-2054.