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Y Sravani
Ph.D. Scholar, Department of Vegetable Science, College of Horticulture, Dr. YSR Horticultural University, Venkataramannagudem, Andhra Pradesh, India

E Padma
Associate Professor, Department of Horticulture, College of Horticulture, Dr. YSR Horticultural University, Venkataramannagudem, Andhra Pradesh, India

K Mamatha
Principal Scientist, Department of Horticulture, HRS, Dr. YSR Horticultural University, Venkataramannagudem, Andhra Pradesh, India

M Ravindra Babu
Senior Scientist, Department of Horticulture, HRS, Dr. YSR Horticultural University, Venkataramannagudem, Andhra Pradesh, India

T Naga Lakshmi
Senior Scientist, Department of Plant Pathology, HRS, Dr. YSR Horticultural University, Venkataramannagudem, Andhra Pradesh, India

K Uma Krishna
Professor, Department of Statistics, College of Horticulture, Dr. YSR Horticultural University, Venkataramannagudem, Andhra Pradesh, India

Corresponding Author:
Y Sravani
Ph.D. Scholar, Department of Vegetable Science, College of Horticulture, Dr. YSR Horticultural University, Venkataramannagudem, Andhra Pradesh, India

Morphological trait analysis in tomato germplasm: Exploring essential descriptors

Y Sravani, E Padma, K Mamatha, M Ravindra Babu, T Naga Lakshmi and K Uma Krishna

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Abstract
This study evaluates tomato germplasm lines acquired from ICAR-NBPGR, India, and various vegetable research stations, characterized under field conditions using a Randomized Block Design (RBD). Thirty genotypes were assessed based on ten qualitative traits, including leaf color, leaf pubescence, petiole pubescence, stem type, stem thickness, stem pigmentation, flower size, flower color, fruit size, and fruit shape. Significant variations among genotypes were observed, highlighting their unique morphological characteristics. These distinctive traits serve as valuable morphological markers for selection in segregating populations and for varietal identification in DUS (Distinctness, Uniformity, and Stability) testing. The findings suggest potential applications in breeding programs aimed at improving tomato cultivars through various breeding strategies. The unique combinations of these traits can significantly contribute to the development of superior tomato varieties with desirable horticultural characteristics.

Keywords: ICAR-NBPGR, breeding strategies, DUS testing, morphological and diversity

Introduction
Wild tomato species are invaluable for breeding programs, serving as reservoirs of desirable traits and as subjects for evolutionary studies. Often dubbed the "poor man's orange" in several regions due to their appealing appearance and high nutritional value, tomatoes are a crucial dietary component. A single medium-sized fresh tomato (135 g) provides approximately 47% of the Recommended Dietary Allowance (RDA) of vitamin C, 22% of the RDA for vitamin A, and contributes significantly to daily caloric intake. This fruit also offers essential vitamins, minerals, and other nutrients. They are consumed both fresh and in processed forms, such as soups, ketchups, and sauces, contributing significantly to global dietary intake of lycopene, ascorbic acid, and beta-carotene.

Characterization of tomato genotypes is fundamental for varietal improvement, enabling the selection of superior lines for breeding. This process involves recording heritable traits that are easily observable and consistent across different environments. The assessment of phenotypic traits such as fruit morphology, color intensity, nutritional quality, firmness, flavor, and aroma presents considerable challenges and is time-intensive due to the inherently quantitative nature of these characteristics (IPGRI, 1996; Fiorani and Schurr, 2013) [5, 4]. Despite these challenges, the examination of phenotypic attributes is crucial, as these parameters are extensively utilized for the evaluation of genetic diversity, breeding potential, and yield capacity in crops (Dharmatti *et al.*, 2001; Mohanty *et al.*, 2001; Parthasarathy *et al.*, 2002; Naveen *et al.*, 2018; Srivastava *et al.*, 2019; Pidigam *et al.*, 2019) [3, 6, 8, 7, 10, 9]. Effective morphological characterization helps safeguard genetic resources, informs breeding programs, and promotes the development of new varieties suited to specific uses and environments. The present investigation aimed to characterize and assess the morphological variability of 30 tomato genotypes.

Materials and Methods
The experiment was conducted at the College of Horticulture, Dr. Y.S.R. Horticultural University, Venkataramannagudem, Andhra Pradesh, during the *Rabi*, 2022-2023 growing

season. The experimental site, located at an elevation of 34 meters above mean sea level (MSL), is geographically positioned at 16°53'12" N latitude and 81°27'56" E longitude. The trial included 30 tomato accessions, sourced from ICAR-NBPGR, Hyderabad, and various vegetable research stations. The experimental design was a randomized block design (RBD), implemented under field conditions.

Initially, seeds were germinated under controlled conditions, and 30-day-old seedlings were transplanted into the field. Standard agronomic practices, including irrigation, fertilization, pest control, and weeding, were followed throughout the crop growth period. Qualitative data were collected on 10 morphological traits, using minimal descriptors as outlined by the National Bureau of Plant Genetic Resources (NBPGR) (Srivastava *et al.*, 2001) [11]. The qualitative traits assessed included leaf colour, leaf pubescence, petiole pubescence, stem type, stem thickness, stem pigmentation, flower size, flower colour, fruit size, and fruit shape. Detailed trait descriptions, classifications, and scoring stages are presented in Table 1.

Table 1: Classification and stage of scoring of 10 qualitative traits in tomato

S. No	Minimal Descriptors	Classification	Stage of scoring
1.	Leaf colour	Dark Green Green Light Green	At full foliage stage
2.	Leaf pubescence	Absent Sparse Medium Dense	At full foliage stage
3.	Petiole pubescence	Absent Sparse Medium Dense	At full foliage stage
4.	Stem type	Round Angular	At full foliage stage
5.	Stem thickness	Thin Medium Thick	At full foliage stage
6.	Stem pigmentation	Green Red	At full foliage stage
7.	Flower size	Small Medium Large	At full blossom stage
8.	Flower colour	Light yellow Deep yellow Reddish yellow Orange	At full blossom stage
9.	Fruit size	Small Medium Medium large Large Very large	Fully developed fruit
10.	Fruit shape	Flat round Slightly flattened Round Oval Heart shaped Lengthened cylindrical (banana type) Pyriform Plum shaped	At near maturity stage

Results and Discussion

In the present study, thirty genotypes of tomato germplasm were evaluated based on ten qualitative traits, providing a comprehensive characterization that highlights significant genetic variability. These findings are essential for breeding programs aimed at improving various horticultural attributes. (Table 2)

Leaf Colour

The assessment of leaf colour across the genotypes revealed three distinct categories: dark green, green, and light green). Specifically, 7 genotypes (EC-605711, EC-241148, EC-161245, EC-620401, Arka Vikas, Arka Meghali, and PKM-1) exhibited dark green leaves. This trait is often associated with higher chlorophyll content and potential photosynthetic efficiency, which may be advantageous under suboptimal light conditions. Eight genotypes (EC-164656, EC-620414, EC-635520, EC-636482, Local collection, EC-806566, EC-164650, and EC-11885) showed green leaves, while the remaining 15 genotypes (EC-620408, EC-620407, EC-620360, EC-617083, EC-617090, EC-620775, EC-631396, EC-631406, EC-631410, EC-631415, EC-654286, EC-806571, EC-806572, EC-620403, and EC-620410) had light green leaves. Light green foliage may indicate lower chlorophyll concentration, which could impact growth vigor and yield potential under high light intensity conditions.

Leaf Pubescence

Leaf pubescence was categorized into absent, sparse, and medium. Notably, only two genotypes (EC-611885 and Arka Vikas) had no pubescence. Twenty genotypes displayed sparse pubescence, which included EC-620414, EC-620408, EC-617083, EC-617090, EC-620775, EC-631396, EC-631406, EC-631410, EC-631415, EC-635520, EC-636482, EC-654286, Local collection, EC-806571, EC-605711, EC-241148, EC-164650, EC-161245, Arka Meghali, and PKM-1. The remaining eight genotypes (EC-164656, EC-620407, EC-620360, EC-806566, EC-806572, EC-620401, EC-620403, and EC-620410) exhibited medium pubescence. Leaf pubescence can affect pest resistance by creating a physical barrier against herbivorous insects, and medium pubescence may offer optimal protection without compromising photosynthesis.

Petiole Pubescence

Analysis of petiole pubescence showed sparse, medium, and dense categories among the genotypes. Twenty genotypes (including EC-617083, EC-617090, EC-620775, EC-631396, EC-631406, EC-631415, EC-635520, EC-636482, EC-654286, Local collection, EC-806571, EC-605711, EC-241148, EC-164650, EC-611885, EC-161245, EC-620401, EC-620410, Arka Vikas, and PKM-1) had sparse pubescence. Six genotypes exhibited medium pubescence, and four genotypes (EC-164656, EC-631410, EC-806566, and Arka Meghali) had dense pubescence. The degree of petiole pubescence can influence moisture retention and plant microclimate, impacting overall plant health and susceptibility to diseases.

Stem Type

Stem morphology was evaluated and categorized as round or angular. Sixteen genotypes, including EC-164656, EC-620414, EC-620408, EC-620407, EC-620360, EC-631396, EC-631410, EC-636482, EC-654286, Local collection, EC-806571, EC-611885, EC-161245, Arka Vikas, Arka Meghali, and PKM-1, displayed round stems. Conversely, 14 genotypes had angular stems, suggesting a genetic predisposition that might affect plant stability and resistance to mechanical stress.

Stem Thickness

Stem thickness was recorded as thin, medium, and thick. Three genotypes (Local collection, EC-164650, and EC-806572) had thin stems, which could be prone to lodging. Fifteen genotypes showed medium thickness, and 12 genotypes had thick stems. Thick stems are typically advantageous for supporting heavier fruit loads and reducing the risk of lodging, which is crucial for high-yielding cultivars.

Stem Pigmentation

Stem pigmentation was classified as green or red. Twenty genotypes, including EC-164656, EC-620414, EC-620407, EC-620360, EC-617083, EC-631415, EC-635520, EC-654286, EC-806566, EC-605711, EC-241148, EC-164650, EC-611885, EC-161245, EC-620401, EC-620403, EC-620410, Arka Vikas, Arka Meghali, and PKM-1, exhibited green pigmentation. The remaining 10 genotypes displayed red pigmentation. The presence of red pigmentation can indicate higher levels of anthocyanins, which provide increased protection against UV radiation and pathogen attack.

Flower Size

Flower size varied among the genotypes. Three genotypes (EC-241148, EC-611885, and EC-620401) had small flowers. Fifteen genotypes displayed medium-sized flowers, and 12 genotypes exhibited large flowers. Larger flowers are often correlated with greater attractiveness to pollinators, potentially enhancing cross-pollination and fruit set.

Flower Colour

Flower colour was divided into deep yellow and light yellow categories. Seven genotypes (EC-164656, EC-620360, EC-617090, EC-631415, EC-806566, EC-605711, and Arka Vikas) had deep yellow flowers, which are particularly effective in attracting pollinators such as bees. The other 23 genotypes exhibited light yellow flowers. The colour intensity of flowers plays a crucial role in pollinator behavior and can significantly impact pollination efficiency and fruit set.

Fruit Size

Fruit size among the genotypes was classified as small, medium, medium-large, and large. Five genotypes (Local collection, EC-164650, EC-611885, EC-161245, and EC-620401) had small fruits. Eighteen genotypes, including EC-164656, EC-620414, EC-620408, EC-617090, EC-620775, EC-631396, EC-631406, EC-631410, EC-631415, EC-635520, EC-654286, EC-806571, EC-806566, EC-241148, EC-620403, EC-620410, Arka Meghali, and PKM-1, exhibited medium-sized fruits. Six genotypes showed medium-large fruits, and one genotype (EC-806572) had large fruits. Fruit size is a critical trait for market acceptance and yield potential, with larger fruits being generally preferred for fresh consumption.

Fruit Shape

The genotypes exhibited diverse fruit shapes, including flat round, slightly flattened, round, oval, heart-shaped, and elongated cylindrical. Genotypes such as EC-631410 and Arka Vikas had flat round shapes, suitable for table use. Genotypes with round fruits are versatile and highly marketable, while other shapes are valuable for processing purposes. The diversity in fruit shape provides a genetic reservoir for breeding programs aiming to improve specific market-driven traits.

Similar reports are made earlier by Ali *et al*., 2017 [1], Anuradha *et al*., 2018 [2], and Sushma *et al.*, 2021 [12] in tomato.

Table 2: Detailed Qualitative Trait Description of 30 Tomato Genotypes Using Minimal Descriptors

S. No.	Accession number	Leaf colour	Leaf pubescence	Petiole pubescence	Stem type	Stem thickness	Stem pigmentation	Flower size	Flower colour	Fruit size	Fruit shape
1	EC-164656	Green	Medium	Dense	Round	Thick	Green	Medium	Deep yellow	Medium	Round
2	EC-620414	Green	Sparse	Medium	Round	Thick	Green	Medium	Light yellow	Medium	Oval
3	EC-620408	Light green	Sparse	Medium	Round	Medium	Red	Medium	Light yellow	Medium	Oval
4	EC-620407	Light green	Medium	Medium	Round	Thick	Green	Large	Light yellow	Medium large	Lengthened cylindrical
5	EC-620360	Light green	Medium	Medium	Round	Medium	Green	Medium	Deep yellow	Medium large	Round
6	EC-617083	Light green	Sparse	Sparse	Angular	Medium	Green	Large	Light yellow	Medium large	Round
7	EC-617090	Light green	Sparse	Sparse	Angular	Thick	Red	Medium	Deep yellow	Medium	Round
8	EC-620775	Light green	Sparse	Sparse	Angular	Medium	Red	Large	Light yellow	Medium	Round
9	EC-631396	Light green	Sparse	Sparse	Round	Medium	Red	Medium	Light yellow	Medium	Round
10	EC-631406	Light green	Sparse	Sparse	Angular	Thick	Red	Large	Light yellow	Medium	Round
11	EC-631410	Light green	Sparse	Dense	Round	Thick	Red	Medium	Light yellow	Medium	Flat round
12	EC-631415	Light green	Sparse	Sparse	Angular	Medium	Green	Large	Deep yellow	Medium	Round
13	EC-635520	Green	Sparse	Sparse	Angular	Medium	Green	Medium	Light yellow	Medium	Round
14	EC-636482	Green	Sparse	Sparse	Round	Thick	Red	Large	Light yellow	Medium large	Round
15	EC-654286	Light green	Sparse	Sparse	Round	Medium	Green	Large	Light yellow	Medium	Lengthened cylindrical

 EC – 164656	 EC – 620407	 EC – 620414
 EC – 620360	 EC – 620408	 EC – 617083
 EC-617090	 EC-631406	 EC-620775
 EC-631410	 EC-631396	 EC-631415
 EC-635520	 Local collection	 EC-636482

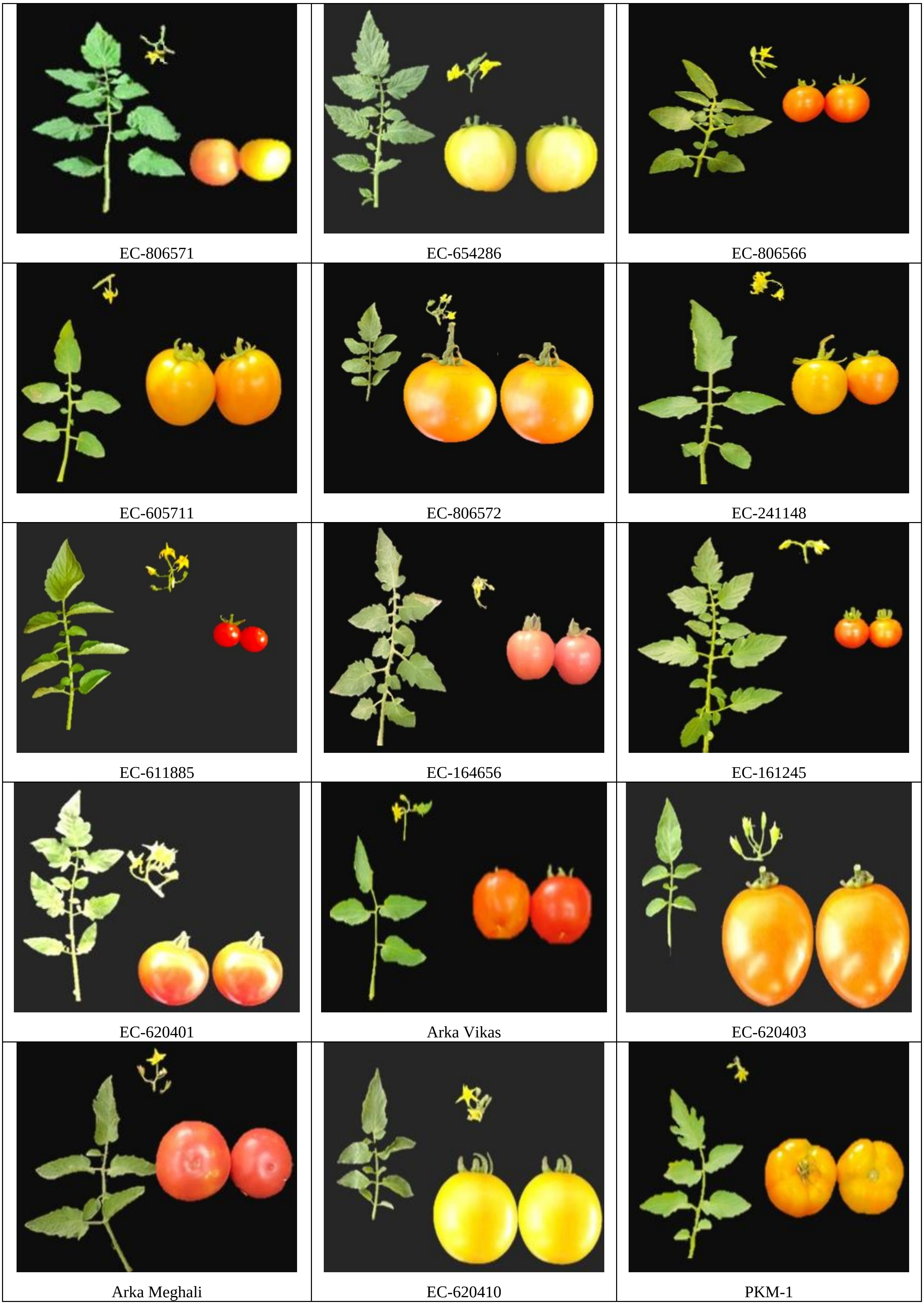

Fig 1: Variation in fruit, leaf, and flower morphology among thirty tomato germplasm accessions

Conclusion

The characterization of the thirty tomato genotypes based on ten qualitative traits revealed substantial genetic diversity. Traits such as leaf colour, pubescence, stem type, and fruit characteristics provide a wealth of genetic resources that can be harnessed for targeted breeding programs. This study underscores the importance of phenotypic evaluation in germplasm characterization, contributing to the development of superior tomato cultivars with desirable horticultural traits.

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