

**BIOCHEMICAL ANALYSIS OF PARENTS AND F<sub>1</sub>  
HYBRID TOMATOES**

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**DEPARTMENT OF PLANT BIOTECHNOLOGY  
UNIVERSITY OF AGRICULTURAL SCIENCES  
BENGALURU  
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*Thesis submitted to the*  
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*Affectionately dedicated*

*to my beloved parents*

*Sri. Thyagaraju, Smt.*

*Shyla, my Husband Sri.*

*GURUPRASAD my*

*Daughter Thrishika and*

*my guide K.M*

*Harinikumar.*

**DEPARTMENT OF PLANT BIOTECHNOLOGY  
UNIVERSITY OF AGRICULTURAL SCIENCES  
GKVK, BENGALURU**

**CERTIFICATE**

This is to certify that the thesis entitled “**BIOCHEMICAL ANALYSIS OF PARENTS AND F<sub>1</sub> HYBRID TOMATOES**” submitted by **Ms. POOJA, T. ID. No. PALB 5260/old PALB 1216** in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (Agriculture)** in **PLANT BIOCHEMISTRY** to the University of Agricultural Sciences, Bengaluru, is a record of research work carried out by her during the period of her study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any other degree, diploma, associateship, fellowship or any other similar titles.

Bengaluru  
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**(Pooja, T.)**

## **BIOCHEMICAL ANALYSIS OF PARENTS AND F<sub>1</sub> HYBRID TOMATOES**

**Pooja, T.**

### **Abstract**

Tomato (*Solanum lycopersicum* L.) is an important source of several minerals, vitamins, antioxidants and exhibits wide degree of variability with respect to growth habit, fruit size, fruit shape, fruit color and yield per plant etc. A total of twenty five lines including parental varieties, germplasm and F<sub>1</sub> hybrids were subjected to morphological and biochemical studies. Diversity in fruit colour like yellow, light orange, orange red, red, deep red and shapes like oval, spherical elongated was observed. The F<sub>1</sub> hybrid (Sankranthi x 169) recorded higher fruit weight (68.67g/fruit), the germplasm L102 showed higher fruit length (5.81cm) and higher fruit pericarp thickness (0.63cm), germplasm L121 recorded higher fruit width (5.42 cm) and higher locules number (6.67). The fruit yield among the twenty five lines analyzed ranged from 0.346 kg/pl to 2.546 kg /pl, among them F<sub>1</sub> hybrid (Vaibhav x169) showed higher fruit yield (2.546 kg /pl). The biochemical parameters analyzed, TSS ranged from 2.47 to 4.8<sup>0</sup> Brix, lycopene content ranged from (0.41 to 5.09 mg/100g fresh.wt), phenols (2.33 to 9.33 µg/ml of juice) and ascorbic acid (4 to 23mg/100g fresh.wt). Higher TSS was recorded in germplasm L15 (4.8<sup>0</sup> Brix), higher lycopene content was recorded in the F<sub>1</sub> hybrid (34 × L121) (5.09 mg/100g fresh. wt.), higher phenolic content was recorded in the F<sub>1</sub> hybrid tomato (127 × L121) (9.33 µg/ml of juice), higher ascorbic content was recorded in the F<sub>1</sub> hybrid (Sankranthi x 34) (23 mg/100g fresh. wt.) and higher fruit pulp pH was noticed in parent germplasm L121 (4.74).

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**Dr. K. M. HARINIKUMAR**  
(Major advisor)

ಟೋಮೋಟೋದ ಪೋಷಕ ಹಾಗೂ ಎಫ್‌ಗ ಮಿಶ್ರತಳಿಗಳ ಹಣ್ಣಿನ ಗುಣ ಲಕ್ಷಣಗಳು ಮತ್ತು  
ಜೀವರಾಸಾಯನಿಕ ವಿಶ್ಲೇಷಣೆ.

ಪೂಜ. ಟಿ.

ಪ್ರಭಂಧದ ಅಮೂರ್ತಿ

ಟೋಮೋಟೋ (ಸೋಲಾನಂ ಲೈಕೋಪರ್ಸಿಕಮ್ ಲ) ಒಂದು ಪ್ರಮುಖ ವಾಣಿಜ್ಯ ಬೆಳೆಯಾಗಿದ್ದು, ಖನಿಜಗಳು ಹಾಗೂ ಜೀವಸತ್ವಗಳು, ಉತ್ಪರ್ಷಣ ನಿರೋಧಕಗಳ ಒಂದು ಪ್ರಮುಖ ಮೂಲವಾಗಿದೆ ಮತ್ತು ಅದರ ಬೆಳವಣಿಗೆಯ ಸ್ವಭಾವ ಸಂಬಂಧಿಸಿದಂತೆ ಹಣ್ಣಿನ ಗಾತ್ರ, ಆಕಾರ, ಹಣ್ಣಿನ ಬಣ್ಣ ಮತ್ತು ಸಸ್ಯ ಬೆಳವಣಿಗೆ ಹಾಗೂ ಹಣ್ಣಿನ ಇಳುವರಿಯಲ್ಲಿ ವ್ಯತ್ಯಾಸ ಕಂಡುಬಂದಿದೆ.

ಪೋಷಕ ಪ್ರಭೇದಗಳು ವಂಶವಾಹಿ ರೇಖೆಗಳು ಮತ್ತು ಎಫ್‌ಗ ಮಿಶ್ರತಳಿಗಳು ಸೇರಿದಂತೆ ಒಟ್ಟು ಇಪ್ಪತ್ತೈದು ರೇಖೆಗಳ ಸ್ವರೂಪದ ಮತ್ತು ಜೀವರಾಸಾಯನಿಕ ಅಧ್ಯಯನಕ್ಕೆ ಒಳಪಡಿಸಲಾಯಿತು. ಹಣ್ಣಿನ ಬಣ್ಣ ಹಳದಿ, ತಿಲಕಿತ್ತಳೆ, ಕೆಂಪು, ಗಾಢ ಕೆಂಪು ಮತ್ತು ಆಕಾರದಲ್ಲಿ ಗೋಲಾಕಾರ, ಅಂಡಾಕಾರ, ಉದ್ದನೆಯ ವೈವಿಧ್ಯತೆಯನ್ನು ಗಮನಿಸಲಾಗಿದೆ. ಎಫ್‌ಗ ಮಿಶ್ರತಳಿಯಾದ (ಸಂಕ್ರಾಂತಿ-೧೬೯) ಹಣ್ಣಿನಲ್ಲಿ ಹೆಚ್ಚಿನ ತೂಕ (೬೮.೬೭ ಜಿಎಮ್ /ಹಣ್ಣು), ವಂಶವಾಹಿ ರೇಖೆ ೧೦೨ ಹೆಚ್ಚಿನ ಹಣ್ಣಿನ ಉದ್ದ (೫೮೧ ಸೆಂ) ಮತ್ತು ಹೆಚ್ಚಿನ ಅಂಡಾಶಯದ ಆವರಣವನ್ನು (೦.೬೩ ಸೆಂ) ಹೊಂದಿದೆ. ವಂಶವಾಹಿ ರೇಖೆ ಎಲ್ ೧೨೧ ಹೆಚ್ಚಿನ ಹಣ್ಣಿನ ಅಗಲ (೫೪೨ ಸೆಂ) ಮತ್ತು ಹಣ್ಣಿನ ಹೆಚ್ಚಿನ ಲೋಕ್ಯೂಲ್ ಸಂಖ್ಯೆ (೬.೬೭) ಹೊಂದಿದೆ. ಇಪ್ಪತ್ತೈದು ಸಾಲುಗಳ ನಡುವೆ ಹಣ್ಣಿನ ಇಳುವರಿ ೦.೩೬ ಕೆ ಜಿ / ಸಸ್ಯಕ್ಕೆ ವ್ಯತ್ಯಾಸಗಳನ್ನು ತೋರಿಸಿದೆ,ಇದರಲ್ಲಿ ಎಫ್‌ಗ ಮಿಶ್ರತಳಿ (ವೈಭವ್-೧೬೯) ಹೆಚ್ಚಿನ ಹಣ್ಣಿನ ಇಳುವರಿ ನೀಡಿದೆ.

ಜೀವರಾಸಾಯನಿಕ ನಿಯತಾಂಕಗಳಲ್ಲಿ ಟಿಎಸ್‌ಎಸ್ (೨.೪೭ ರಿಂದ ೪.೮೦ ಬ್ರಿಕ್ಸ್), ಲೈಕೋಪಿನ್ (೦.೪೧೫ ರಿಂದ ೫.೦೬ ಎಮ್ ಜಿ/೧೦೦ ಗ್ರಾಂ ಎಫ್ ಡಬ್ಲ್ಯೂ) ಫೀನಾಲ್ (೨೫೩ ರಿಂದ ೯.೩೩ ರಸ ಮೆಗ್ರಾಂ/ ಮಿಲೀ) ಹಾಗೂ ಆಸ್ಕೋರ್ಬಿಕ್ ಆಮ್ಲ (೪.೨೩ ಮಿಗ್ರಾಂ/೧೦೦ ಎಫ್ ಡಬ್ಲ್ಯೂ) ಕಂಡುಬಂದಿದೆ. ಹೆಚ್ಚಿನ ಟಿಎಸ್‌ಎಸ್ ವಂಶವಾಹಿ ರೇಖೆ ೧೫ ರಲ್ಲಿ (೪೮ ಡಿಗ್ರಿಬ್ರಿಕ್ಸ್) ಮತ್ತು ಹೆಚ್ಚಿನ ಲೈಕೋಪಿನ್ ಪ್ರಮಾಣ (೫.೦೯ ಮಿ/೧೦೦ ಗ್ರಾಂ ಎಫ್ ಡಬ್ಲ್ಯೂ) ಎಫ್‌ಗ ಮಿಶ್ರತಳಿ (೩೪\*ಎಲ್‌೧೨೧) ಯಲ್ಲಿ ದಾಖಲಾಗಿದೆ. ಹೆಚ್ಚಿನ ಫೀನಾಲ್ (೯.೩೩ ಮ್ಯೋಗ್ರಂ / ಮಿ ಲೀ ರಸ) ಎಫ್‌ಗ ಮಿಶ್ರತಳಿ (೧೨೭\*ಎಲ್‌೧೨೧) ಹಣ್ಣಿನಲ್ಲಿ ಹಾಗೂ ಹೆಚ್ಚಿನ ಆಸ್ಕೋರ್ಬಿಕ್ ಆಮ್ಲ (೨೩ ಮಿಗ್ರಾಂ/೧೦೦ನ್ ಎಫ್ ದ್ವು ಬ ) ಎಫ್‌ಗ ಮಿಶ್ರತಳಿ (ಸಂಕ್ರಾಂತಿ-೩೪) ಹಣ್ಣಿನಲ್ಲಿ ಮತ್ತು ಹೆಚ್ಚಿನ ಹಣ್ಣಿನ ತಿರುಳಿನ ರಸಸಾರವನ್ನು ವಂಶವಾಹಿ ರೇಖೆ ಎಲ್‌೧೨೧ (೪.೭೪) ಯಲ್ಲಿ ಗಮನಿಸಲಾಗಿದೆ.

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ಡಾ// ಕೆ. ಎಂ. ಹರಿಣೀಕುಮಾರ್  
ಪ್ರಧಾನ ಮಾರ್ಗದರ್ಶಕರು

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## I INTRODUCTION

Tomato (*Solanum lycopersicum* L), is an economically important crops in Mediterranean region. It belongs to family Solanaceae ( $2n = 24$ ) and it is a native of Central, South and Southern North America (Olympios, 2001). Tomato stands second most consumed vegetable worldwide, after potato (Georgé *et al.*, 2011). The current world production is about 129 million tons produced on 3.7 million hectares. In India, tomato is grown in 8, 79,632 hectares with a production of 1, 82, 26,635 MT and productivity of 20.70 MT/Ha. The top five states producing tomato are Andhra Pradesh (5218.10 MT), Karnataka (1,916.60 MT), Madhya Pradesh (1845.00 MT) Orissa (1,382.78 MT) and Gujarat (1,156.72MT) (National Horticulture Board, 2013).

Tomato fruits are commonly consumed as a fresh fruit or used in curries or canned, frozen, preserved and dried foods as powder. Cultivated tomatoes vary in size from cherry tomatoes (1-2 cm) to beefsteak tomatoes (10 cm). The most commercial tomatoes grown tend to be in the range of 5-7 diameters (Olympios, 2001). Tomato fruit can be bilocular or multilocular and is comprised of skin, pericarp, columella and locular contents. The locular cavities are filled with seeds that are surrounded with jelly parenchyma cells. Tomato dry matter normally varies between 5 and 10 percent, of which about 75 percent is soluble, and about 1 to 3 percent consist of skin and seeds (Shi and Le Maguer, 2000).

Water content of ripe tomato fruit depends on many factors such as the genotype, the nutritional status, the environment where the plant is grown and, the nature of the postharvest treatment (Hobson and Grierson, 1993). Nearly half of the total dry matter consists of reducing sugars, principally glucose and fructose (glucose 22 percent, fructose 25 percent and sucrose 1 percent), and about 10 to 13 percent of organic acids with citric as the dominant one (Yin *et al.*, 2010).

Tomato has been an excellent model system for both basic and applied plant research. This has been due to many reasons, including ease of culture under a wide range of environments, short life cycle, photoperiod insensitivity, high self-fertility and homozygosity, great reproductive potential, ease of controlled pollination and hybridization, diploid species with a rather small genome (~0.95 pg/1C, 950 Mbp), lack of gene duplication, amenability to asexual propagation and whole plant regeneration, the ability to develop haploids, and availability of a wide array of mutants and genetic stocks. Tomato's regenerative plasticity also allows easy grafting; an attribute that facilitates certain developmental and practical studies (Foolad, 2009).

Lycopene mainly accumulates in the final period of ripening, giving the fruit its attractive red color although its content is not linearly related to color changes. The

lycopene pigment has attracted much interest among researchers because of its biological and physicochemical properties, especially related to its effect as a natural antioxidant and its various benefits for human health. Lycopene as well as  $\beta$ -carotene are apparently the main tomato micro constituents responsible for the effect of tomato products on antioxidant status. Tomatoes are also a concentrated source of phenolic compounds, such as flavonoids and hydroxyl cinnamonic acid derivatives, containing 98 percent of the total flavonols in tomato skin as conjugated forms of quercetin and kaempferol. The flavanone naringenin is present in small quantities in tomatoes in its conjugated form. Many of these phytochemicals present in tomatoes have antioxidant properties and in combination with lycopene may contribute to the numerous health benefits (Hernández *et al.*, 2007, Ray *et al.*, 2011).

Besides lycopene, tomatoes also contain  $\alpha$ ,  $\beta$ ,  $\gamma$ ,  $\delta$ -carotene, zeaxanthin and lutein and also neurosporene, phytoene and phytofluene (Capanoglu *et al.*, 2010, Ray *et al.*, 2011).

Tomatoes contain a multitude of vitamins and minerals that act to support human health. They are an excellent source of vitamins C, E, B6, folic acid, niacin, potassium and trace elements i.e. selenium, copper, manganese and zinc, which are cofactors of antioxidant enzymes (Luthria *et al.*, 2006 and Borguini, *et al.*, 2013). It is assumed that these trace elements play a key role in the protection mechanisms by scavenging free radicals (Fernandez *et al.*, 2011).

The nutritional importance of tomato indicates that it is necessary to formulate breeding programme and to develop cultivars rich in antioxidant compounds, processing traits with high quality of fruit as well as yield (Dar and Sharma, 2011). New tomato varieties with improved nutritional content and potential health benefits are being developed. As a result, at present, there are a large number of tomato cultivars with a wide range of morphological and sensorial characteristics which determine their use (Fernández *et al.*, 2011; Pinela *et al.*, 2012). Therefore, it is becoming increasingly important to assess their nutritional value in terms of content.

Thus, a study entitled **Biochemical Analysis of Parents and F<sub>1</sub> Hybrid Tomatoes** was carried out to screen the genetic diversity present in tomato using parental varieties, germplasms and F<sub>1</sub> hybrid tomatoes developed by Dr. Ramanjini Gowda prof. Department of Plant Biotechnology, GKVK, which are having high self-life of tomato up to 40 days. These tomato parental varieties, germplasms and F<sub>1</sub> hybrid fruits were evaluated for morphological traits along with biochemical traits with the following objectives:

1. Comparison of parental varieties, germplasm and F<sub>1</sub> hybrid tomatoes for morphological characters.
2. Comparison of parental varieties, germplasm and F<sub>1</sub> hybrid tomatoes for biochemical characters.

## II REVIEW OF LITREATURE

Tomato (*Solanum lycopersicum* L.) occupies important place on worldwide scale both in production and consumption. It continues to dominate both fresh market and as a component in a variety of processed foods and pharmaceutical products (Rao, 2002; Barba *et al.*, 2006; Rao and Rao 2007; Georgé *et al.*, 2011). Evolutionary adaptations in nature are the result of a species genetic variability paired with environmental and genetic influences. The yield and quality is influenced by variety and growing conditions. The previous studies pertaining to above variation were compiled. Therefore, an attempt has been made to review the literature pertaining to the morphological and biochemical traits in tomato, under the following headings.

### **2.1 Morphological traits based genetic variability among tomato parental varieties, germplasm and F<sub>1</sub> hybrids**

2.1.1 Fruit morphological parameters like (fruit weight, fruit length, fruit color, fruit pericarp thickness, number of locules etc...)

### **2.2 Biochemical traits based genetic variability among tomato parental varieties, germplasm and F<sub>1</sub> hybrids**

2.2.1 Lycopene content

2.2.2 Ascorbic acid content

2.2.3 TSS

2.2.4 Phenolic content

2.2.5 Fruit pH

### **2.1 Morphological traits based genetic variability among tomato parental varieties, germplasm and F<sub>1</sub> hybrids**

#### **2.1.1 Fruit morphological parameters:**

Nine tomato genotypes for the variability in their agronomic characteristics and lycopene content were evaluated by (Ibitoye *et al.*, 2009). Fruit weight ranged between 0.256g and 0.003g with 'NH Big local' having the highest, while 'NH Cherry' had the lowest respectively. Genotype 'NH Leader' flowered the earliest with a mean number of days of 40.28, while 'NH Cherry' flowered latest with a mean number of days of 72.389.

'NH Cherry' had the highest number of fruits per truss and fruits per plant with a mean of 5.111 and 6.056, respectively. The content of Lycopene an important phytonutrient was also evaluated among the genotypes and it ranged from 70.25 to 147.29 µg/g, with 'NH Lindo' having the lowest and 'NH Leader' having the highest.

Kaushik *et al.*, (2011) reported morphological variations in ten genotypes the fruit yield varied between (424 to 825 qtl/ha) and minimum fruit width was varied between (4.1 to 5.6 cm). The magnitude of genotypic and phenotypic coefficient of variation was higher for number of leaves (21.2 and 22.3), fruit length (19.6 and 19.7cm) and fruit yield (19.6 and 19.6). Shankar *et al.*, (2013) used twenty four hybrids along with eleven parents to study genetic variability plant height (153.63cm), number of primary branches/plant (10.60), number of flowers/cluster, fruit length, fruit width, average fruit weight and yield/plant.

Reddy *et al.*, (2013) evaluated nineteen tomato varieties. The varieties exhibited a wide range of variability like plant height (138.125cm), number of primary branches/plant (30.146), yield/plant, number of flowers/cluster (8.363), fruit length (6.704cm), fruit width (4.558cm), average fruit weight (102.333 g) and fruit yield/plant (2.721kg/plant).

Amarnath (2014) evaluated twenty five accessions of tomato for best morphological characters among them EC-614998 showed higher fruit weight of 104.00 g, EC-614997 showed high fruit yield of 6.30 kg/per plant, ten accessions of tomato exhibited orange red color, followed by nine light yellow and six exhibited deep red color at ripened stage of the fruits. The length of the fruit was higher in EC-620543 (6.91 cm), the width of the fruit was higher in EC-620481 (6.45 cm), and number of locules per fruit recorded varied from 2.00 to 9.80, with a mean of 4.04 locules per fruit.

Shemu *et al.*, (2014) did field experiment the experiment consisted of four level of Tomatotone, viz. H0: no Tomatotone (control), H1: 1% Tomatotone, H2: 2% Tomatotone and H3: 3% Tomatotone. The longest plant (86.6cm), maximum number of leaves (50.2), maximum number of flowers per plant (63.4), highest number of fruits per plant (41.0), highest length of fruit (5.2 cm), highest weight of individual fruit (41.9 g), highest yield per plant (4.4 kg) and highest yield (22.7 t/ha) was found form H2. On the other hand, lowest plant height, lowest yield, lowest number of leaves, flower and fruits was found form H0 (control).

Brijesh (2015) reported twenty accessions of tomato for best morphological characters, among them EC-620545 showed higher fruit weight of 162.00 g, the length of the fruit was higher in EC-620521 (6.67 cm) and the width of the fruit was higher in EC-617059 (7.05 cm) four accessions of tomato exhibited orange red color, followed by five

red color, one exhibited pink color and ten exhibited deep red color at ripened stage of the fruits.

## **2.2 Biochemical traits based genetic variability among tomato parental varieties, germplasm and F<sub>1</sub> hybrids**

### **2.2.1 Lycopene content**

Lycopene in fresh tomato fruits occurs mainly in the all-trans form, which is the most prominent isomer (Stahl and Sies, 1996). The main causes of tomato lycopene degradation during processing and storage are isomerization and oxidation.

According to Shi and Le Maguer (2000) there is clinical evidence that characterizes lycopene as a micronutrient with important health benefits, moreover, lycopene can be considered as the vitamin of the twenty-first century” because of its significant physiological effect in the human diet.

Shi and Le Maguer (2000) reported that lycopene represents 80 to 90% of total carotenoids. The lycopene content in the analysed samples varies from 64.09 to 80.48%. These results confirm the existence of a good linear correlation between lycopene and total carotenoid contents ( $r= 0.94$ ).

Isomerization of all-trans-isomers to cis-isomers results in an unstable, energy-rich state due to additional energy input (Shi and Le Maguer, 2000). Degradation of lycopene is undesirable because it directly affects the quality and the nutritional status of tomato products.

Levy and Sharoni (2004) reported lycopene is a red-colored, fat-soluble carotenoid, which gives tomatoes and several other fruits their deep red color. Lycopene having various benefits on human health can be explained based on its properties of antioxidant activity, inhibition of cancer cell proliferation, interference with growth factor stimulation, inducing phase II enzymes, regulation of transcription and restoration of gap junctions.

Tomato is the principal model system used to study lycopene assay methods and carotenoid biosynthesis due to many color changes that occur during fruit development (Arias *et al.*, 2000; Choudhary *et al.*, 2009). In the early stages, the chlorophyll imparts a green color to fruits. When the ripening process starts, the chlorophyll is degraded and carotenoids are synthesized, mainly consisting of  $\beta$ -carotene, lutein, and violaxanthin. At the next stage of ripening, called the “breaker stage”, lycopene begins to accumulate due

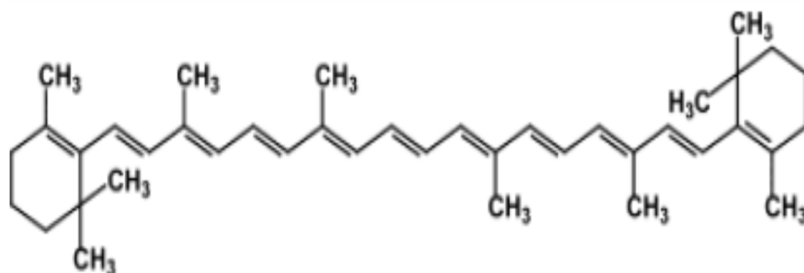
to the enzyme cyclase that converts lycopene to  $\beta$ -carotene and lycopene concentration increases dramatically between the stage pink and the stage red fruit (Arias *et al.*, 2000; Ronen *et al.*, 2000).

Lycopene concentrations in tomato varieties vary from 3.90mg/100g (Nattih) to 7.70mg/100g (Marmande). Lycopene contents of the eight analysed varieties were significantly different ( $p < 0.05$ ). The study performed by Martínez-Valverde *et al.*, (2002) on Spanish varieties showed variations of the lycopene concentrations from 1.8 to 6.5mg/100g. Contents from 0.5 to 6.3mg/100g are obtained by Kuti and Konuru (2005).

The color of tomatoes is one of the most important marketing factors that affect the buying decision of the consumer. Tomatoes and tomato products, are considered as an important source of dietary lycopene and  $\beta$ -carotene (Shi and Le Maguer, 2000; Schofield and Paliyath, 2005), so their content greatly influences the quality of ripe tomato fruit. The fresh tomato fruits have wide range of lycopene concentration, which varies from 30 to 200 mg/kg on a fresh weight basis (FW) and from 430 to 2,950 mg/kg on a dry basis (DW) (Topal *et al.*, 2006).

In nature, lycopene exists in all-trans form and seven of the eleven bonds can isomerize from the Trans form to the mono or poly cis form under the influence of heat, light, or certain chemical reactions (Shi and Le Maguer, 2000). Cis-lycopene is more bioavailable than trans-isomers due to increased solubility in micelles (Karakaya and Yilmaz, 2007).

Chemically lycopene is an open-chain hydrocarbon chromophore with eleven conjugated double bonds and has the highest degree of unsaturation among carotenoids (Topal *et al.*, 2006) (Fig. 1). It occurs in the form of all-trans and cis isomers with the all-trans lycopene being thermodynamically the most stable form.



**Fig 1: Structure of lycopene (source: Rao and Rao, 2007).**

Most of the lycopene is attached to the insoluble and fibrous parts of the tomatoes, as the skins can contain about five times more lycopene (540mg/kg on FW) than the tomato pulp (110mg/kg) (Dumas *et al.*, 2003; Topal *et al.*, 2006).

Unlike some other carotenoids, lycopene does not have pro-vitamin A properties, but it displays the highest antioxidant capacity compared to them, because it is the most effective on singlet oxygen quenching and on peroxy radical scavenging (Rao and Rao 2007).

The large variation of lycopene content of tomato indicates that its accumulation depends on many factors, like tomato variety, maturity at the harvesting stage, the environmental conditions under which the fruit was developed and technical processes for extraction and assay (Scott *et al.*, 1996; Stahl and Sies, 1996; Dumas *et al.*, 2003; Bicanic *et al.*, 2005). Moreover, carotenoid accumulation in ripening fruits is affected by environmental factors both before and after harvest.

Frusciante *et al.*, (2007) and Pinela *et al.*, (2012) reported lycopene content for tomato varieties cultivated in Italy (2.33-16.9mg/100g) and Portuguese farmer varieties cultivated in home gardens (10.9-18.6mg/100g), respectively.

Lopez *et al.*, (2007) reported lycopene content ranges from 51mg/kg in Bodar tomato cultivar to 37 mg/kg in cocktail cultivar.

Alda *et al.*, (2009) reported that lycopene content of samples of fresh tomatoes was approximately 12 mg/100g. In tomato products the lycopene content had the following values: in tomato paste approximately 16 mg/100g, in tomato boiled sauce approximately 4 mg/100g, tomato Ketchup 17 mg/100g and spaghetti sauce 16 mg/100g.

Lycopene attracts attention due to its biological and physicochemical properties particularly in relation to its powerful, natural antioxidant property, that protects against free radical damage of cells (Gupta *et al.*, 2010).

Aghel *et al.*, (2011) recorded average quantity of extracted pure lycopene was calculated as 2.313 mg per 100 g tomato paste.

Rath and Math (2001) recorded lycopene content from tomato ranges from 150 to 250mg/kg. Gupta *et al.*, (2011) reported 27.82 mg/100g of lycopene content in raw tomatoes. Lycopene content in raw tomato slurry ranged between 311 mg to 670mg/100g of tomato.

Nour *et al.*, (2013) reported relatively higher than those for tomato cultivars grown in southwestern Romania (1.2-4.9mg/100g).

The greenhouse grown tomatoes are found to have lower levels of ascorbic acid than those grown outdoors because of the lower light intensity in the greenhouses (Dumas *et al.*, 2003).

Malviya (2014) also noticed quantity of isolated pure lycopene from papaya, tomato and watermelon ranged from 1.14mg -3.18mg per 100 gm.

Mostapha *et al.*, (2014) reported the ascorbic acid contents of the analysed tomato samples varied from 6.94 (Agora) to 16.70mg/100g (Nattih). The ascorbic acid contents of the varieties present significant differences ( $p < 0.05$ ), except Marmande and Tafna. These results are similar to those of Toor *et al.*, (2006) on New Zealand tomatoes.

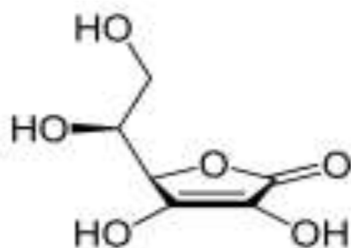
Lilwani and Nair (2015) reported the maximum purified lycopene content in cherry tomato (88.87 mg/kg) as compared to Pakistani tomato (55.84 mg/kg) and watermelon (74.53 mg/kg).

### **2.2.2 Ascorbic acid content**

The ascorbic content of tomato has been shown to provide a significant contribution to dietary intake. The ascorbate concentration increases, when the tomato ripens, but decarities slightly in overripe tomato (Islam *et al.*, 1996).

According to Dumas *et al.*, (2003) the ascorbic acid content range from 0.084 to 0.59 mg/100 gm, noted that citric acid content in tomato fruit range from 2 to 8.5 mg, oxalic's from 0.06 to 0.58 mg. The biologically-active isomer of ascorbic acid (vitamin C) is L-ascorbic acid, while D-ascorbic acid (isoascorbic acid) has only 5% of the antiscorbutic effect of ascorbic (Novakova *et al.*, 2008). Ascorbic acid is rapidly oxidized to dehydroascorbic acid (DHA) due to the presence of two hydroxyl groups in its structure.

Oxidation reactions can be induced by exposure to increased temperatures, high pH and light, presence of oxygen or metals and enzymatic action. These reactions reversible and a principal step in the antioxidant activity of ascorbic acid. Ascorbic acid cannot be synthesized by the human body, so vegetables and fruits are the major sources of vitamin C for the human diet.



**Fig. 2: Structures of ascorbic acid (source: Wikipedia).**

Leong and Shui (2002) recorded (37 mg/kg) and Opara (2010) (~30 mg/kg). The ascorbic acid content of the flesh of yellow-fleshed watermelon was significantly lower than that of the red-fleshed watermelon but was higher than that of the yellow-fleshed watermelon (55.2 mg/100 gm) in the study of Isabelle *et al.*, (2010).

Revanasiddappa (2008) evaluated BIP F2 and BIP F3 populations for quality parameters during a study. Total soluble solids, ascorbic acid and total titratable acidity observed were 4.407<sup>0</sup>Brix, 19.092 mg/100g and 0.564 per cent, respectively.

Mohammed *et al.*, (2009) reported vitamin C (ascorbic acid) in various fruits and vegetables at Koya area in Kurdistan Region. The content of vitamin C was 1.868 to 51.74 mg/10g in fruits and 0.841 to 17.416 mg/10g in vegetables.

The quality parameters like ascorbic acid, total titratable acidity, per cent juice recovery and total soluble solids were studied by Kulkarni (2006) for seven parents and twenty one hybrids. The ascorbic acid content ranged from 16.42 to 27.00 mg/100g in parents and 3.92 to 17.08 mg/100g hybrids. While, the total titratable acidity ranged from 0.27 to 0.43 for parents and 0.27 to 0.44 mg/100g for hybrids. Per cent juice recovery ranged from 27.92 to 39.5 percent for parents and 19.37 to 40.67 per cent for hybrids. While, the total soluble solids ranged from 3.47 to 6.23 percent and 4.00 to 6.37 percent in parents and hybrids respectively.

The ascorbic acid content of the flesh of red-fleshed watermelon (86.32 mg/kg) was the highest. This value was lower than the ascorbic acid contents of red-ripe stage of red-fleshed watermelon cultivars (119.7-204.0 mg/kg) in the study of Tlili *et al.*, (2011) However, the ascorbic acid content of the red-fleshed watermelon in this study was higher than those reported by Isabelle *et al.*, (2010) (39.1 mg/kg).

Choo and Sin (2012) reported Ascorbic acid content in two varieties of seeded watermelon, red-fleshed and yellow fleshed watermelon. The flesh of red-fleshed watermelon had higher ascorbic acid (86.32 mg/kg) to the ascorbic acid content (52.05

mg/kg) of the flesh of yellow-fleshed watermelon. The whole fruit of red-fleshed watermelon had similar ascorbic acid contents.

Kapur *et al.*, (2012) reported ascorbic acid in twenty-one different samples of fruits and vegetables. The contents of ascorbic acid were found between 9 and 49 mg/100 g of fresh fruits, also 3 and 90 mg/100 g of fresh vegetables.

### **2.2.3 Combined quality trait:**

The various components of tomato fruit quality *viz.*, total soluble solids, lycopene, ascorbic acid, total titratable acidity and pH are essential in relation to specifications for grades and standards, selections in breeding programs and evaluation of fruit responses to various environmental factors.

Plant breeders in collaboration with physiologists should continue to select genotypes that have good flavor (i.e., high total soluble solids and acid contents and good potential for development of volatiles associated with desirable tomato flavor). Work on improving the nutritional quality of tomatoes via increased ascorbic acid content should be an integral part of tomato improvement programmes.

Tomato fruits with high total soluble solids, pH less than 4.5, high ascorbic acid, lycopene and total acidity content are preferred for processing purpose (Bose *et al.*, 2002). While the fruits usually red but vary in color, less total soluble solids and total titratable acidity are preferred for fresh market purpose.

Prashanth (2003) evaluated different quality parameters like total soluble solids, total titratable acidity, pH, for different tomato genotypes. He observed that the total soluble solids ranging from 3.19<sup>0</sup> Brix to 5.83<sup>0</sup> Brix, total titratable acidity from 0.21 per cent to 0.70 per cent and pH ranged from 4.07 to 5.33.

Ashwini (2005) evaluated parents and hybrids for total soluble solids and pH content of tomato. She observed that, the total soluble solids content of fruits from parents ranged from 2.91 to 4.96<sup>0</sup> Brix, while for hybrids it ranged from 3.15 to 5.34<sup>0</sup>Brix. Whereas, pH content for parents ranged from 3.21 to 4.34 and for hybrids from 3.04 to 4.89.

Kulkarni (2006) reported total titratable acidity and total soluble solids for seven parents and twenty one hybrids. The total titratable acidity ranged from 0.27 to 0.43 for parents and 0.27 to 0.44 mg/100 g for hybrids, while the total soluble solids ranged from 3.47 to 6.23<sup>0</sup> Brix and 4.00 to 6.37<sup>0</sup> Brix in parents and hybrids, respectively.

Vijitha and Mahendran (2010) reported TSS and Vit. C content in control plant and water stressed plant is 5.5<sup>0</sup> Brix and 6<sup>0</sup> Brix, 15.9 and 8.9 mg/100 g respectively.

Naz *et al.*, (2011) found maximum TSS in cultivar 'Avinash' (5.5<sup>0</sup> Brix) followed by Yaqui (5.4<sup>0</sup> Brix) whereas it was found to be minimum in Roma (4.9<sup>0</sup> Brix) cultivar. 'Lyreka' have the most abundant ascorbic acid (16.03 mg/100gm) followed by 'Rio Grand' (15.86 mg/100 g). The highest titratable acidity was found in 'Yaqui' (0.38 %) while 'Rio Grand' had the lowest (0.31 %) in this respect.

Shankar *et al.*, (2013) found a range of TSS (5-3.170 Brix), Vit-C (40.67- 14.67 mg/100 g) and lycopene content (11.73-2.07 mg/100 g) in twenty four hybrids along with their eleven parents. Reddy *et al.*, (2013) evaluated nineteen tomato genotypes with varied quantity of ascorbic acid (37.46 mg/100 g), acidity (0.87 %), TSS (10.35<sup>0</sup> Brix), shelf life (34.50 days).

#### **2.2.4 Phenolic content**

Phenolic compounds play a role of protection against insects and other animals to the plants. The different types of bond between the glycosyl residue and the flavonoids, such as anthocyanin, also lead to the different derivatives that add colors and color gradation to flowers. Phenols, sometimes called phenolics, are one of the main secondary metabolites present in the plant kingdom. They are commonly found in both edible and non-edible plants (Kähkönen *et al.*, 1999).

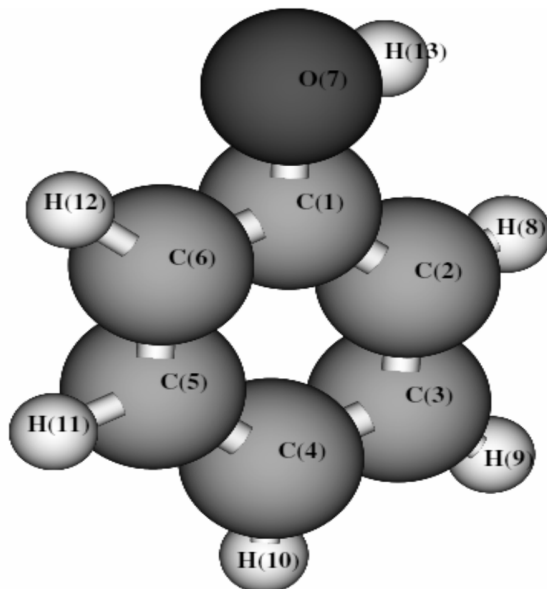
Most plants phenolic compounds are synthesized through the phenylpropanoid pathway. The combination of both pathways leads to the formation of flavonoids, the most plentiful group of phenolic compounds in nature

Phenolic compounds are essential to the physiology and cellular metabolism. They are involved in many functions in plants, such as sensorial properties (color, aroma, taste and astringency), structure, pollination, resistance to pests and predators, germinative processes of seed after harvesting and growth as well as development and reproduction among others.

Phenolic compounds proceed of two metabolic pathways: the shikimic acid pathway where, phenylpropanoid are formed and the acetic acid pathway, in which the main products are the simple phenol (Moreno, 2002).

Phenol is the parent substance of a homologous series of compounds containing a *hydroxyl group* bound directly to the aromatic ring. Phenol, in shorthand notation, belongs to the family of *alcohols* due to the presence of the OH group and it is in fact the simplest aromatic member of this family. The hydroxyl group of phenol determines its

acidity whereas the benzene ring characterizes its basicity. Thus, it is formally the *enol* form of the *carbonyl group* (see Fig. 3).



**Fig. 3: Chemical structure of phenol**

Phenolic contents in methanolic extracts of the samples of tomato varied from 20.64mg/100g (Marmande) to 49.55mg/100g (Joker). The Sammichele, Agora, Zahra and Tafna varieties contain closer concentrations, approximately 24mg/100g. The extraction by 50% methanol resulted in contents ranging between 17.96 and 37.80mg/100g. The quantities of phenolic compound extracted by this solvent are significantly different, except Agora and Sammichele, the extraction with absolute ethanol gives a contents in Phenolic compounds ranging between 22.53 (Marmande) and 51.58mg/100g (Joker).

Agora and Zahra have phenolic levels; however, phenolic contents of the other varieties are significantly different ( $p < 0.05$ ). The concentrations from 20 to 30.25 mg/100g were found for 50% ethanol extracts. Joker and Nattih varieties have similar contents; the values of Marmande and Zahra are also similar concentrations are reported by Martínez-Valverde *et al.*, (2002) in Spanish tomato.

The phenolic content reported by Kaur and Kapoor (2002) in Indian tomato is 68mg/100g.

Giovanelli *et al.*, (2002) presented total phenolics content of between 21.3 and 36.40mg/100 g (moist basis), expressed as gallic acid equivalent. The Italian tomato varieties, analysed by Minoggio *et al.*, (2003) contain 2.25 to 25.84mg/100g.

Caris-Veyrat *et al.*, (2004) found rutin and naringen in content that was respectively 170 and 12.5 % higher in organic tomatoes than in the conventional ones.

Toor *et al.*, (2006), who found a higher level of total phenolics in organically fertilized tomatoes than in those that, received conventional fertilization.

Maurya and Singh (2010) estimated total phenols with the Folin-Ciocalteu reagent from *Adhatoda vasica* leaves. Gallic acid was used as a standard compound and the total phenols were expressed as mg/g gallic acid equivalents. The total phenol varied from 63.95±2.1 to 92.4±0.14 mg/g in the extracts. The maximum phenolic content was found in the aqueous extract (92.4±0.14 mg/g).

Banu *et al.*, (2011) reported the total phenolic content of the methanolic extract of leaves of *Barleria montana* belonging to the family Acanthaceae. The total phenolic content measured by Folin-Ciocalteu was found to be 0.9628 for gallic acid and 1.061 for tannic acid respectively.

Cindric *et al.*, (2011) reported total content of phenolic compounds from apple juice ranged from 400 to 650 mg gallic acid equivalent from Folin-Ciocalteu method and antioxidative capacity from 1.0 to 1.6 mM.

Stankovic (2011) reported total phenolic content from the *Marrubium peregrinum*L. The total phenolic content ranged from 27.26 to 89.78 mg/g of dry weight of extract, expressed as gallic acid equivalents.

Sharma *et al.*, (2011) estimated total phenolic contents from *Aegle marmelos* seeds. The amount of total phenols, were analyzed based on Folin-Ciocalteu reagent. The total phenols varied from 27.12 ± 0.6 to 65.20 ± 0.2 in extracts. The maximum phenolic content was found in the methanolic extract 65.20 ± 0.2 mg/g.

Sasic *et al.*, (2012) reported the total phenolic content varied from 7.3 mg GAE/100 ml for aloe vera juice to 71.8 mg GAE/100 ml for cranberry juice.

Borguini *et al.*, (2013) reported organic tomatoes presented higher content of ascorbic acid and total phenolics (641.39 and 4466.66 mg/100 g EAG on dry wt basis) than did the conventional tomatoes (510.16 and 3477.50 mg/100 g EAG on dry weight basis, respectively).

Nour *et al.*, (2013) reported concentrations of 30-55.9mg/100g in cultivars grown in southwestern Romania. For tomato Portuguese cultivars, Pinela *et al.*, (2012) and Vinha *et al.*, (2014) have obtained phenolic levels of 24.5-31.3mg/100g and 22.6-79.3mg/100g, respectively

Genwali *et al.*, (2013) reported phenolics from different extracts of medicinal herbs such as *Adhatoda vasica* Nees, *Bergeniaciliata*, *Phyllanthus emblica*, *Terminalia bellirica*, *Terminalia chebula* and *Vitex negundo*. All the investigated plant extracts contained high amount of phenolics but the highest amount was detected in 70% acetone extract of *B. ciliata* (357.08 mg GAE/g sample) and the lowest amount was detected in 50% aqueous methanol extract of *T. bellirica* (108.69 mg GAE/g sample).

Khatoon *et al.*, (2013) recorded highest total phenolic content of  $449.18 \pm 18.41$  mg of gallic acid equivalent/g from *Albizia procera* leaves.

King *et al.*, (2013) screened methanol extracts of *Ageratina adenophora* leaves. The methanol extract leaves revealed a total phenolic content of 30.0 mg gallic acid equivalent/g and 510.0 mg quercetin equivalent/g.

Sahu and Saxena (2013) extracted total phenol content from conventional and non-conventional species of *curcuma*. The total phenol content of all three species ranged from  $92.30 \pm 0.05$  to  $260 \pm 0.025$  mg gallic acid equivalent/g and total flavonoid content ranged from  $22.52 \pm 0.015$  to  $79.36 \pm 0.01$  mg quercetin equivalent/g.

Kamtekar *et al.*, (2014) reported total phenolic content was found to be  $3.5725 \pm 0.2336$  mg of GAE/ 100 g (aqueous extract),  $2.9616 \pm 0.2563$  mg of GAE/ 100 g (hydroalcohol extract),  $4.6683 \pm 0.4199$  mg of GAE/ 100 g (ethanol extract).

Decne *et al.*, (2015) evaluated phenol contents of the *Ephedra alata*. The total phenolic content in the ethanolic extract was 19.175 mg gallic acid while was the highest in the methanolic extract which was 47.62 mg gallic acid equivalent/g of extract powder.

### III MATERIAL AND METHODS

An investigation on “Biochemical analysis of parents and F<sub>1</sub> hybrid tomatoes” was carried out at the Department of Plant Biotechnology, GKVK, University of Agricultural Sciences, Bengaluru using the parental varieties, germplasms and F<sub>1</sub> hybrids and F<sub>1</sub> hybrids developed by Dr. Ramanjini Gowda prof. Department of Plant Biotechnology, GKVK, Bengaluru. The 4 parental varieties, 7 germplasm and 14 F<sub>1</sub> hybrids were selected for the study.

The details pertaining to the experimental location, materials used, observations recorded, laboratory procedures followed for analysis of lycopene, total soluble solids, phenolic content and ascorbic acid content, along with statistical procedures adopted for analysis of the data are briefly presented below.

The observations were recorded on plants chosen at randomly in each parental varieties, germplasms and F<sub>1</sub> hybrids and in each replication. Data were recorded on the quantitative and qualitative characters. The average values were computed as treatment mean under each replication. The characters studied and techniques adopted to record the observations are given below.

The characters studied and techniques adopted to record the observations are given below

3.1 Morphological trait based genetic variability among tomato parental varieties, germplasm and F<sub>1</sub> hybrids

3.2 Biochemical trait based genetic variability among tomato parental varieties, germplasm and F<sub>1</sub> hybrids

#### **3.1 Morphological trait based genetic variability among tomato parental varieties, germplasm and F<sub>1</sub> hybrids**

Tomato parental varieties, germplasm and F<sub>1</sub> hybrid seeds were obtained from Dr. Ramanjini Gowda, Professor of Department of Plant Biotechnology, GKVK. University of Agricultural Sciences, Bengaluru. All the tomato parental varieties, germplasm and F<sub>1</sub> hybrids were assessed for morphological and biochemical characters and observations were recorded.

Experimental design: CRD

No. of replications: 3

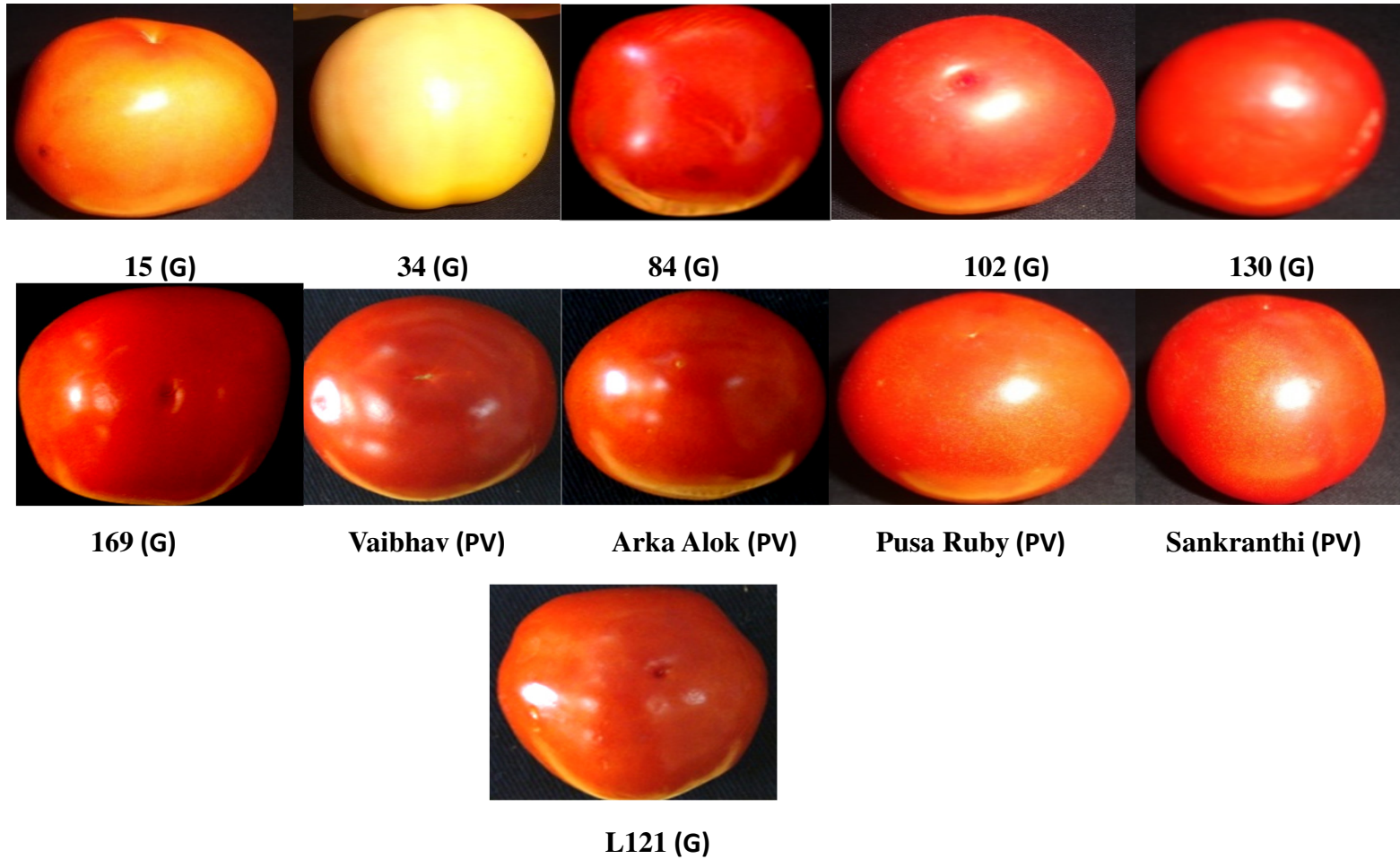
Number of tomato parental varieties, germplasm and F<sub>1</sub> hybrids: 25 (Table 1)

**Table1. Details of the tomato parental varieties, germplasm and F1 hybrids used in the experiment:**

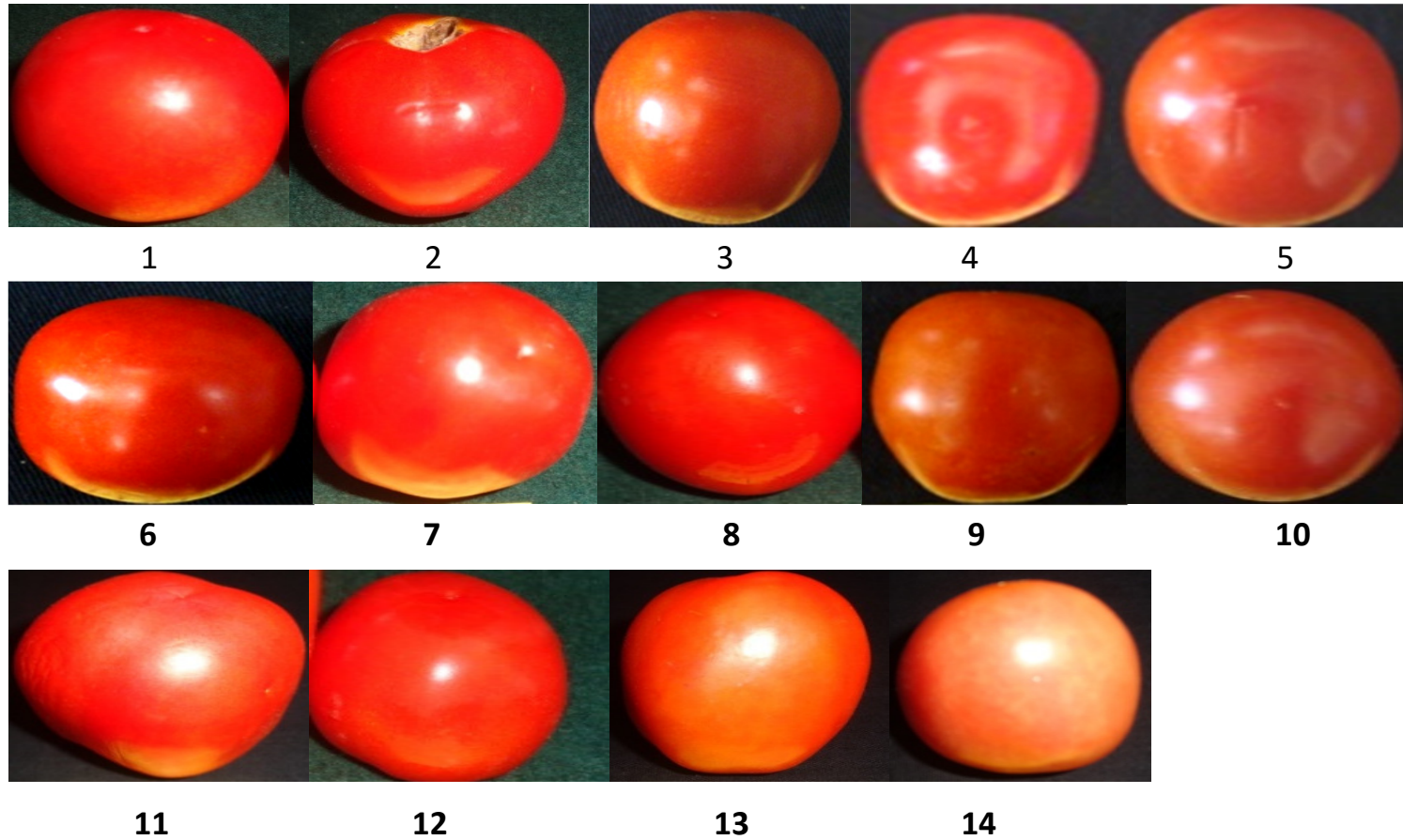
SL. No.	Tomato parental varieties/germplasm/hybrids
1	15 (G)
2	34 (G)
3	84 (G)
4	102 (G)
5	130 (G)
6	169 (G)
7	L121 (G)
8	Vaibhav (PV)
9	Sankranthi (PV)
10	Pusa Ruby (PV)
11	Arka Alok (PV)
12	Arka Alok×102 (H)
13	Vaibhav×130 (H)
14	Vaibhav×15 (H)
15	Vaibhav×102 (H)
16	Vaibhav×169 (H)
17	Vaibhav×84 (H)
18	Sankranthi×34 (H)
19	Sankranthi×169 (H)
20	Sankranthi×102 (H)
21	Pusa Ruby×169 (H)
22	Arka Alok×169 (H)
23	Pusa ruby ×102 (H)
24	34 × L121 (H)
25	127 × L121 (H)

**Legend:**

PV- parental varieties, G- germplasm and H- hybrids



**Plate 1: Tomato parental varieties (PV) and germplasms (G) used in the experiment.**



**Plate 2: F<sub>1</sub> hybrid tomatoes used in the experiment.**

**F<sub>1</sub> hybrids:** 1. Arka Alok×102, 2. Vaibhav×130, 3. Vaibhav×15, 4. Vaibhav×102, 5. Vaibhav×169, 6. Vaibhav×84, 7. Sankranthi×34, 8. Sankranthi×169, 9. Sankranthi×102, 10. Pusa Ruby×169, 11. Arka Alok×169, 12. Pusa ruby ×102, 13. 34 × L121, 14. 127 × L121

### **3.1 Morphological trait based genetic variability among tomato parental varieties, germplasm and F<sub>1</sub> hybrids**

#### **3.1.1 Fruit weight (g/fruit)**

The weight of single fruit was recorded and expressed in grams, the weight of twenty five fruits in each tomato parental varieties, germplasm and F<sub>1</sub> hybrids was also recorded and mean of it was expressed as mean fruit weight.

#### **3.1.2 Fruit length (cm)**

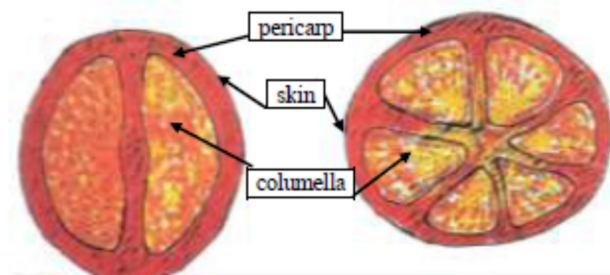
Fruit length was recorded from three randomly selected fruits in all the tomato parental varieties, germplasm and F<sub>1</sub> hybrids using measuring scale and was expressed in centimeters.

#### **3.1.3 Fruit width (cm)**

Fruit width was recorded for three random fruits in all the tomato parental varieties, germplasm and F<sub>1</sub> hybrids and was expressed in centimeters.

#### **3.1.4 Fruit pericarp thickness (cm)**

Fruit pericarp thickness was recorded for three random fruits in all the tomato parental varieties, germplasm and F<sub>1</sub> hybrids the fruits were cut opened horizontally and the fruit pericarp thickness per fruit was recorded by using Refractometer in centimeters.



**Fig 4:Structure of vertical section of tomato fruit**

Tomato fruits: The fruit pericarp was the tissue used for diverse analyses in the current study (Olympios, 2001)

### **3.1.6 Fruit shape:**

Variation in fruit shape was noticed as spherical, oval and elongated and the same was noted down in different tomato parental varieties, germplasm and F<sub>1</sub> hybrids at fully ripened stage.

### **3.1.7 Fruit color:**

Variation in fruit color was noticed as deep red, orange red and light yellow, the same was noted down in different tomato parental varieties, germplasm and F<sub>1</sub> hybrids at fully ripened stage on the basis of visual observation.

## **3.2 Biochemical traits based genetic variability among tomato parental varieties, germplasm and F<sub>1</sub> hybrids**

### 3.2.1 Lycopene Content (mg/100gm)

### 3.2.2 Total soluble solids (<sup>o</sup>Brix)

### 3.2.3 Phenolic content

### 3.2.4 Ascorbic acid content (mg/100gm)

### 3.2.5 Fruit pH

#### **3.2.1 Lycopene (mg/100g)**

Lycopene is responsible for red color of tomato, its content varies depending on the potential of the varieties to accumulate the same, and hence the lycopene content was estimated using the protocol proposed by Ranganna (1976).

The carotenoids in the sample are extracted in acetone and then taken up in petroleum ether. Lycopene has absorption maxima at 473nm and 503nm. One mole of lycopene is dissolved in one liter light petroleum (40-60<sup>o</sup>C) and measured in a spectrophotometer at 503nm in 1cm light path gives an absorbance of 17.2X 10<sup>4</sup>. Therefore, a concentration of 3.1206µg lycopene/ml gives unit absorbance.

#### **3.2.1.1 Materials:**

Acetone (AR grade)

Petroleum ether 40-60 (AR)

Anhydrous Sodium sulphate

5% Sodium sulphate

### **3.2.1.2 Procedure:**

1. Three-four tomato fruits were taken in a waring blender and pulped it well to a smooth consistency.
2. 5-10g of this pulp was weighed.
3. Extracted the pulp repeatedly with acetone using pestle and mortar or a waring blender until the residue was colorless.
4. Pooled the acetone extracts and transferred to a separating funnel containing about 20ml of petroleum ether and mixed it gently.
5. Add 20ml of 5% Sodium sulphate solution and shaken the separating funnels gently. (Volume of petroleum ether might be reduced during these processes because of its evaporation, so add 20 ml more of petroleum ether to the separating funnels for clear separation of two layers). Most of the color was noticed in the upper petroleum ether layer.
6. Separated the two phases and re-extracted the lower aqueous phase with additional 20ml petroleum ether until the aqueous phase was colorless.
7. Pooled the petroleum ether extracts and washed once with a little distilled water.
8. Poured the washed petroleum ether extract containing carotenoids into a brown bottle containing about 10 g anhydrous sodium sulphate. Kept it aside for 30 min or longer.
9. Decanted the petroleum ether extract into a 100ml volumetric flask through a funnel containing cotton wool. Washed sodium sulphate slurry with petroleum ether until it was colorless and transferred the washings to the volumetric flask.
10. Made up the volume and measured the absorbance in a spectrophotometer at 503nm using petroleum ether as blank.

### **3.2.1.3 Calculation:**

Absorbance (1 unit) = 3.1206 $\mu$ g lycopene/ml.

31.206 X Absorbance

mg lycopene in 100gm sample = -----

Wt. of sample (g)

### 3.2.2 Total Soluble Solids (TSS)

Sugars are the major soluble solids in fruit juice. Other soluble materials include organic and amino acids, soluble pectins, etc. Soluble solids concentration (SSC%, °Brix) can be determined in a small sample of fruit juice using a hand held Refractometer.

#### Principle:

Refractometer instrument measures the refractive index, which indicates how much a light beam is "bent" when it passes through the fruit juice.

Temperature of the juice is a very important factor in the accuracy of reading. All materials expand when heated and become less dense. For a sugar solution, the change is about 0.5% sugar for every 10<sup>0</sup> F. Good quality Refractometer have a temperature compensation capability.

#### Procedure:

##### A. Extract clear juice from fruit to be sampled.

1. Sugar levels often vary within the fruit, being higher at the stem-end and lower at the calyx-end. For this reason, it is important to use longitudinal slices of fruit.
2. Place a drop of juice on Refractometer prism.
3. Lower cover plate and read.
4. Rinse prism between samples with distilled water and dry with a soft, lint-free tissue

##### B. Refractometer maintenance and calibration.

1. Adjust reading to 0<sup>0</sup> Brix if necessary with the small set-screw on the back.
2. Verify accuracy with a drop of 5 or 10% sucrose solution (5 grams sugar in 100 ml of distilled water).

3. Do not submerge the Refractometer when cleaning. If water gets into the instrument it will need to be sent out for repair and resealing.

Total Soluble Solids content was recorded from three randomly selected fruits from all varieties by squeezing the juice on Erma hand Refractometer (0-32<sup>0</sup> Brix) at room temperature followed by Garner, *et al.*, (2008)

### **3.2.3 Estimation of total phenolic content by Gallic acid**

Phenolic compounds are secondary metabolites that are derivatives of the pentose phosphate, shikimate, and phenylpropanoid pathways in plant.

These compounds play an important role in growth and reproduction, providing protection against pathogens and predators besides contributing towards the color and sensory characteristics of fruits and vegetables.

#### **Principle**

Phenols react with phosphomolybdic acid in Folin-Ciocalteu reagent to produce a blue-colored complex in alkaline medium, which can be estimated spectrophotometrically at 738nm (Singleton and Rossi, 1965)

#### **Procedure:**

- Solution of 1mg/ml of Gallic acid was prepared in distilled water.
- From this various concentrations ranging from 1-10µg/ml were prepared.
- To this 1.5ml FC reagent was added and kept for 5 min and then 4ml of 20% sodium carbonate solution was added and made up to 10ml with distilled water.
- The mixture was kept for 30 min and absorbance was measured at 738nm.

### **3.2.4 Ascorbic acid content (mg/100g)**

Ascorbic Acid is a natural water-soluble vitamin (Vitamin C). Ascorbic acid is a potent reducing and antioxidant agent that functions in fighting bacterial infections, in detoxifying reactions, and in the formation of collagen in fibrous tissue, teeth, bones, connective tissue, skin, and capillaries. Found in citrus and other fruits, and in vegetables, vitamin C cannot be produced or stored by humans and must be obtained in the diet.

Ascorbic acid content was recorded in the ripened fruits of each varieties by using indophenol indicator method as per the protocol given by Johnson, (1948).

### **Principle:**

Ascorbic acid is a strong reducing agent. It gets oxidized to dehydro ascorbic acid by 2, 6 dichlorophenol indophenol dye. At the same time the dye gets reduced to a colorless compound. So the reaction with end point can easily be determined. The reaction was conducted in the presence of metaphosphoric-acetic acid mixture.

#### **3.2.4.1 Reagents**

##### **A. Indophenol solution:**

Dissolve 42mg of  $\text{NaHCO}_3$  and 52mg of 2, 6-dichlorophenol indophenol in 50 ml of water. Diluted to 200ml with water and stored in the refrigerator for not more than 3 days. Dissolved 100mg of ascorbic acid in metaphosphoric acid – acetic acid solution and made up the volume of the solution to 100ml using the acid mixture.

##### **B. Metaphosphoric acid – acetic acid mixture:**

15 grams of stick metaphosphoric acid was dissolved in a mixture of 50 ml of glacial acetic and 450ml of water.

##### **C. Standard ascorbic acid solution:**

Dissolved 100mg of ascorbic acid in metaphosphoric acid – acetic acid solution and made up the volume to 100 ml using the acid mixture.

#### **3.2.4.2 Procedure:**

##### **I) Standardization of indophenol solution**

1. 1ml of standard ascorbic acid pipetted out into a 100ml conical flask and titrate it against indophenol solution.
2. The indophenol solution is decolorized when it reacts with ascorbic acid.
3. The end point is reached when a pink color which persists for 5 seconds is obtained.
4. Suppose 'X' ml of indophenol solution is run down from the burette, then 'X' ml of indophenol solution is equivalent to 1 mg of ascorbic acid.

## II) Estimation of Ascorbic acid in an unknown solution

1. Sample was extracted in metaphosphoric acid – acetic acid mixture to get a 10% solution.
2. After filtering through a cheese cloth, the filtered sample was used for titration.
3. 5ml of the sample pipetted out into a 100ml conical flask. 5ml of metaphosphoric acid – acetic acid mixture is added and titrate the solution against standard indophenol solution.
4. Using the dye equivalent standard of ascorbic acid the amount of ascorbic acid in given solution was calculated.

### I) Standardization of dye

Standard Ascorbic acid V/s Dye

Indicator: Self

X ml of indophenol = 1mg of ascorbic acid

### II) Estimation of Ascorbic acid

Standardized dye Vs. Ascorbic acid

Indicator: Self

#### 3.2.4.3 Calculation

Let ‘Y’ ml of indophenol is required to titrate the ascorbic acid in 5ml of the unknown solution.

We know that, X ml of indophenol = 1mg of ascorbic acid

Therefore,

Y ml of indophenol = Y/X mg of ascorbic acid

100 ml of the unknown contain  $\frac{Y}{X} \times \frac{100}{5}$  mg of ascorbic acid

### 3.2.5 Fruit pulp pH:

It was determined by using pH meter, a probe dipped in a homogenate fruit solution from each tomato parental varieties, germplasms and F<sub>1</sub> hybrids and expressed value was determined as fruit pulp pH.

### 3.3. Analysis of morphological data

#### 3.3.1 Analysis of variance

Analysis of variance (ANOVA) was computed for all quantitative traits to detect the variability present among the twenty five tomato accessions along with the check variety Vaibhav. The variances were analysed following the standard procedure applicable to complete randomized design as suggested by Gomez and Gomez (1984).

#### 3.4 Analysis of variance

The mean values of genotypes in each replication were used for analysis of variance. The analysis of variance and covariance for individual character and for the character pairs respectively, were carried out using the mean values of each plot following the method given by Panse and Sukhatme (1967). The significance of the differences among all the genotypes was tested by F-test using the error variance.

##### 3.4.1 ANOVA

**Table 2. Analysis of variance (ANOVA) for quantitative characters of twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids with 3 replications.**

SL. NO	Source of variation	Degree of freedom	Mean sum of square	Cal F
1.	Replication	(r-1)	RMSS	
2.	Genotype	(g-1)	TMSS	TMSS/EMSS
3.	Error	(r-1)(g-1)	EMSS	
4.	Total (rg-1)			

Where,

r = number of replications

g = number of treatments (genotypes)

TMSS = Mean sum of square due to genotypes

EMSS = Mean sum of square due to error

The standard error was calculated as

$$SE.m = \frac{\sqrt{EMSS}}{r}$$

After testing for significance of the differences among the means of different genotypes for each character, further computations were done as detailed below.

### **3.4.2 Duncan multiple range test**

This new multiple range test, for determining the homogeneity of a set of n values in an analysis of variance in a population. A series of tests paralleling the methods of multiple range tests have been termed multiple F tests, which use protection levels based on degrees of freedom (Duncan, 1996).

## IV EXPERIMENTAL RESULTS

The success of crop improvement programme depends on the extent of genetic variability existing in the population or germplasm. The magnitude of genetic variability can determine the pace and quantum of genetic improvement through selection or through hybridization followed by selection. Phenotypic variance measures the magnitude of variation arising out of differences in phenotypic values, while the genotypic variance measures the magnitude of variation due to difference within the genotypic values.

Selection of genetically distant parents for hybridization is a basic need for screening of accessions with desirable characters. Genetic diversity between accessions indicates differences in the gene frequencies. The statistical module has been employed widely to resolve genetic divergence at inter varietal and species level in classifying crop plants.

The results obtained from the present investigation on “Biochemical analysis of parents and F<sub>1</sub> hybrids” are presented under the following headings.

### **4.1 Morphological trait based genetic variability among tomato parental varieties, germplasm and F<sub>1</sub> hybrids**

4.1.1 Fruit weight (individual)

4.1.2 Fruit length (cm)

4.1.3 Fruit width (cm)

4.1.4 Fruit pericarp thickness (cm)

4.1.5 Number of locules

4.1.6 Fruit color

4.1.7 Fruit shape

4.1.8 Fruit yield/plant

## **4.2 Biochemical trait based genetic variability among tomato parental varieties, germplasm and F<sub>1</sub> hybrids**

4.2.1 Lycopene content (mg/100g)

4.2.2 TSS (<sup>o</sup>Brix)

4.2.3 Phenolic content (µg/ml)

4.2.4 Ascorbic acid (mg/100g)

4.2.5 Fruit pH

## **4.1 Morphological trait based genetic variability among tomato parental varieties, germplasm and F<sub>1</sub> hybrids**

### **4.1.1 Fruit weight (individual):**

The weight of individual fruit was recorded among the twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids the weight of fruit was significantly higher in F<sub>1</sub> hybrid tomatoes like (Sankranthi×169) (68.67 g) followed by (Arka Alok×169) (66.67g) and lower fruit weight was recorded in parent tomato germplasm 169 (27.33g) (Table 3; Fig.5; Plate 3).

### **4.1.2 Fruit length (cm):**

The fruit length recorded in all twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids. The length of the fruit was maximum in tomato germplasm 102 (5.81 cm) followed by F<sub>1</sub> hybrid tomato (Sankranthi×169) (5.66 cm) and the length of fruit was lower in tomato germplasm 34 (2.98 cm) (Table 3; Fig.6; Plate 4).

### **4.1.3 Fruit width (cm):**

The width of the fruit was higher in tomato germplasm L121 (5.42 cm) followed by F<sub>1</sub> hybrid tomato (34 × L121) and the least fruit width was recorded in parent tomato variety Vaibhav (3.53 cm) and the mean fruit width was 4.23 cm. (Table 3; Fig.7; Plate 5).

### **4.1.4 Fruit pericarp thickness (cm):**

Fruit pericarp thickness in all twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids was recorded. It was significantly higher in tomato germplasm 102 (0.63

cm) followed by F<sub>1</sub> hybrid tomato (Vaibhav×15) (0.59cm) and least fruit pericarp thickness was found in F<sub>1</sub> hybrid tomato (Vaibhav×169) (0.26 cm) and the mean fruit pericarp thickness was (0.44 cm) (Table 4; Fig.8; Plate 6).

#### **4.1.5 Number of locules:**

Number of locules per fruit recorded in all the twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids varied from 2.00 to 6.67, with a mean of 3.07 locules per fruit. The locules number was more in tomato germplasm L121 (6.67) followed by germplasm 34 (5.00) Arka Alok×102 (4.33) and it was less in tested tomato varieties, germplasm and F<sub>1</sub> hybrids (Table 3; Fig.7; Plate 7).

Among twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids studied in the present investigation, the fruit color varied at physiological maturity, starting from deep red, light orange, yellow, orange red and red color, among the twenty five parental varieties, germplasms and F<sub>1</sub> hybrids, one germplasm exhibited yellow, one germplasm and one F<sub>1</sub> hybrid exhibited light orange color, one germplasm, three parental varieties and four F<sub>1</sub> hybrids exhibited red color, followed by four germplasms, one parental varieties and five F<sub>1</sub> hybrids exhibited deep red color and four F<sub>1</sub> hybrids exhibited orange red color (Table 4).

#### **4.1.7 Fruit shape:**

Among twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids studied in the present investigation, the fruit shape varied at physiological maturity, starting from spherical, oval, elongated and spherical wrinkle. Among the twenty five tomato parental varieties, germplasms and F<sub>1</sub> hybrids, six tomato germplasms, two parental varieties and six F<sub>1</sub> hybrids exhibited spherical shape, one germplasm, one parental varieties and five F<sub>1</sub> hybrids exhibited elongated shape and one parental varieties and three F<sub>1</sub> hybrids exhibited oval shape at ripened stage of the fruits (Table 5).

#### **4.1.8 Fruit yield:**

Among twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids studied in the present investigation, the maximum fruit yield was observed in F<sub>1</sub> hybrid (Vaibhav× 169) (2.546 kg yield/pl.) and minimum yield were found in F<sub>1</sub> hybrid (Arka Alok× 169) (0.346 kg yield/pl.).

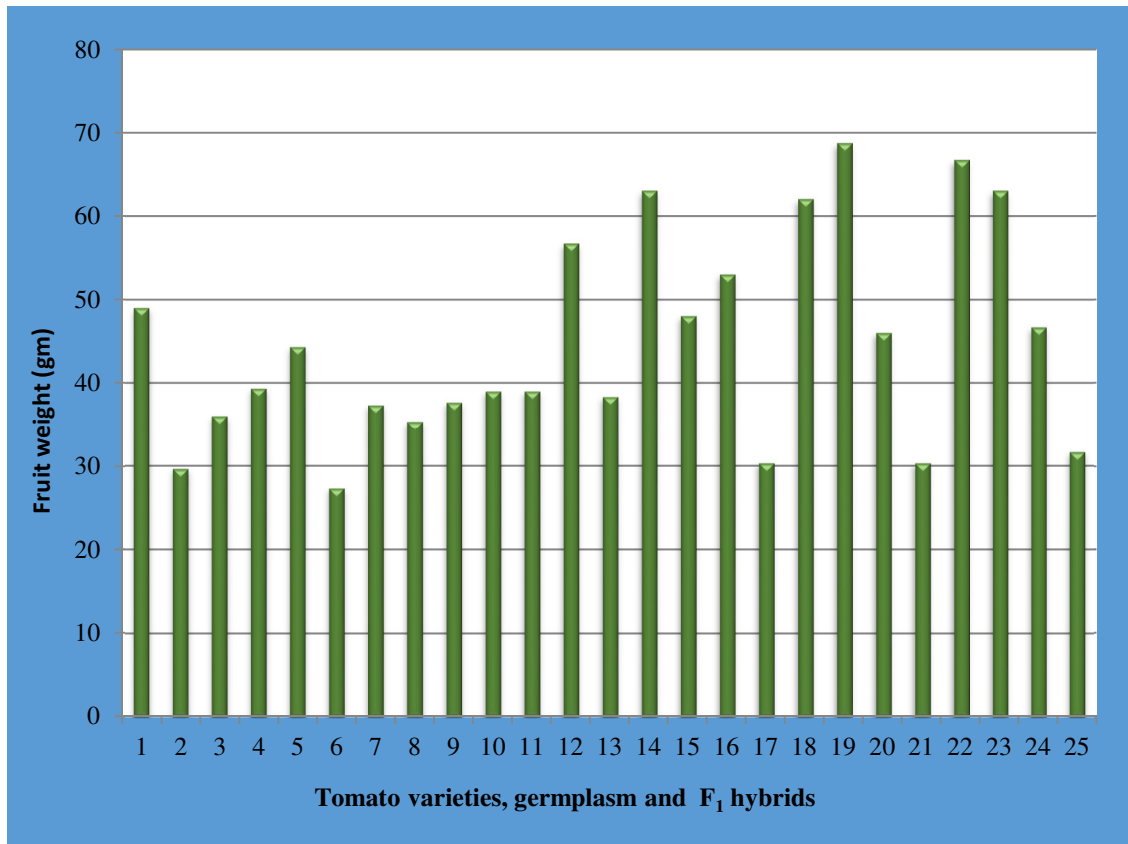
**Table 3. Observation recorded on fruit weight, fruit length and fruit width in various tomato parental varieties, germplasm and F1 hybrids:**

SL. No.	Tomato parental varieties/ germplasm/hybrids	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)
1	15 (G)	49.00 b	4.69 b	4.15 c
2	34 (G)	29.67 c	2.98 e	4.01 c
3	84 (G)	36.00 c	3.87 d	4.31 c
4	102 (G)	39.33 b	5.81 a	4.39 b
5	130 (G)	44.33 b	4.01 c	3.92 c
6	169 (G)	27.33 c	4.20 c	4.29 c
7	L121 (G)	37.33 c	4.12 c	5.42 a
8	Vaibhav (PV)	35.33 c	4.44 c	3.53 d
9	Sankranthi (PV)	37.67 c	4.29 c	3.65 d
10	Pusa Ruby (PV)	39.00 b	3.10 e	4.04 c
11	Arka Alok (PV)	39.00 b	3.33 e	3.61 d
12	Arka Alok×102 (H)	56.67 a	4.12 c	4.65 b
13	Vaibhav×130 (H)	38.33 c	3.55 d	4.29 c
14	Vaibhav×15 (H)	63.00 a	4.81 b	4.36 c
15	Vaibhav×102 (H)	48.00 b	4.81 b	4.81 b
16	Vaibhav×169 (H)	53.00 b	4.12 c	4.21 c
17	Vaibhav×84 (H)	30.33 c	4.68 b	3.92 c
18	Sankranthi×34 (H)	62.00 a	4.45b	4.44 b
19	Sankranthi×169 (H)	68.67 a	5.66 a	4.75 b
20	Sankranthi×102 (H)	46.00 b	4.14 c	3.84 d
21	Pusa Ruby×169 (H)	30.33 c	4.73 b	3.55 d
22	Arka Alok×169 (H)	66.67 a	4.36 c	4.29 c
23	Pusa ruby ×102 (H)	63.00 a	4.85 b	4.10 c
24	34 × L121 (H)	46.67 b	3.99c	4.87 b
25	127 × L121 (H)	31.67 c	3.86 d	4.45 b
	Mean	44.73	4.28	4.23
	SE.m	5.05	0.16	0.17
	CD (0.01)	19.11	0.60	0.64
	CD (0.05)	14.33	0.44	0.48

**Legend:**

PV- parental varieties, G- germplasm and H- hybrids

Similar alphabets do not differ significantly

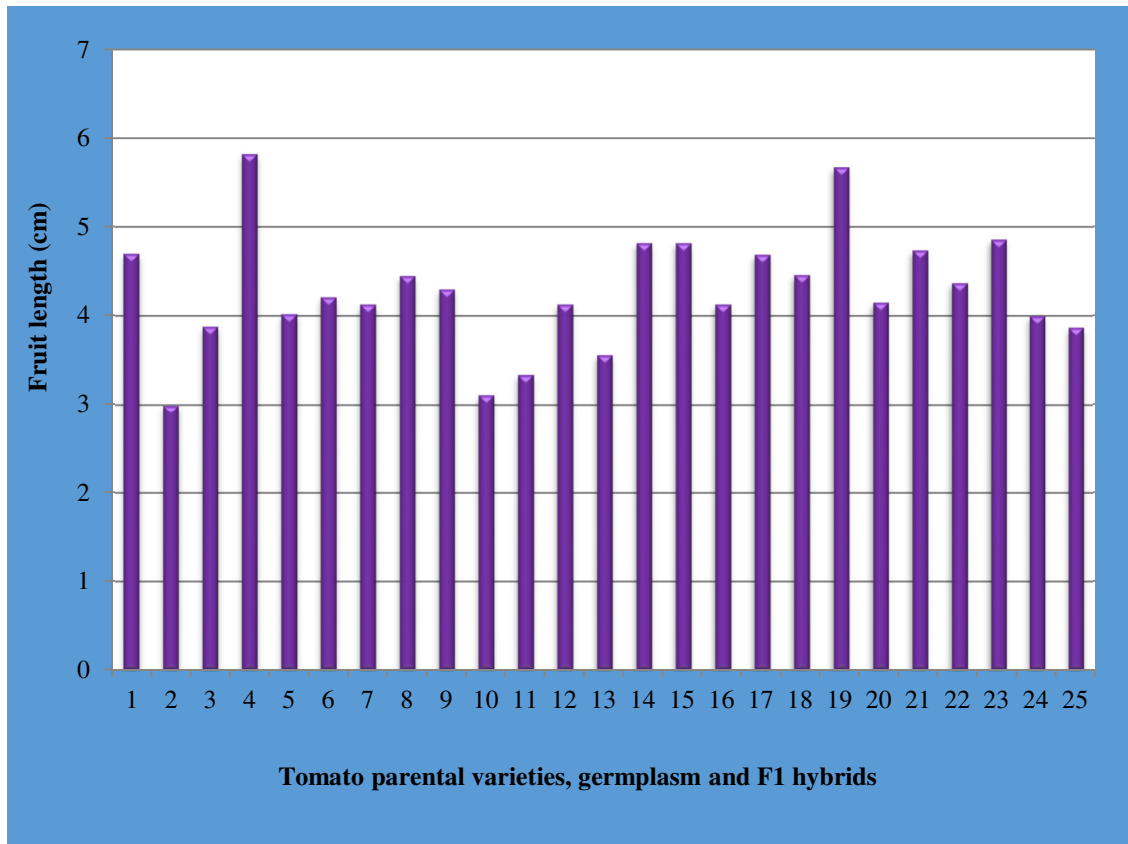


**Fig.5. Graph showing tomato fruit weight (g) of parental varieties, germplasm and F<sub>1</sub> hybrids**

**Germplasm:** 1. 15, 2. 51, 3. 34, 4. 84, 5. 130, 6. 169, 7. L121

**Parental tomato varieties:** 8. Vaibhav, 9. Sankranthi, 10. Pusa Ruby, 11. Arka Alok

**F<sub>1</sub> hybrids:** 12. Arka Alok×102, 13. Vaibhav×130, 14. Vaibhav×15, 15. Vaibhav×51, 16. Vaibhav×169, 17. Vaibhav×84, 18. Sankranthi×34, 19. Sankranthi×169, 20. Sankranthi×102, 21. Pusa Ruby×169, 22. Arka Alok×169, 23. Pusa ruby ×102, 24. 34 × L121, 25. 127 × L121

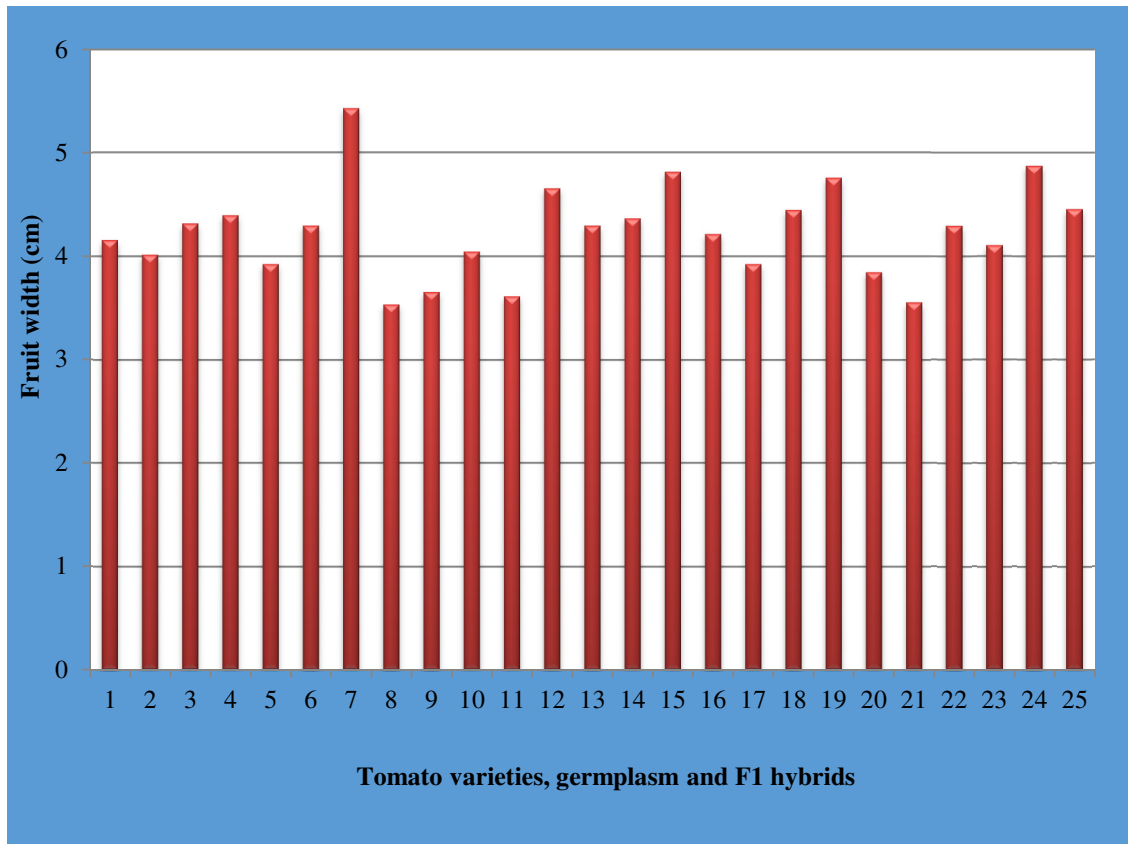


**Fig. 6. Graph showing tomato fruit length (cm) of parental varieties, germplasm and F1 hybrids**

**Germplasm:** 1. 15, 2. 51, 3. 34, 4. 84, 5. 130, 6. 169, 7. L121

**Parental tomato varieties:** 8. Vaibhav, 9. Sankranthi, 10. Pusa Ruby, 11. Arka Alok

**F1 hybrids:** 12. Arka Alok×102, 13. Vaibhav×130, 14. Vaibhav×15, 15. Vaibhav×51, 16. Vaibhav×169, 17. Vaibhav×84, 18. Sankranthi×34, 19. Sankranthi×169, 20. Sankranthi×102, 21. Pusa Ruby×169, 22. Arka Alok×169, 23. Pusa ruby ×102, 24. 34 × L121, 25. 127 × L121

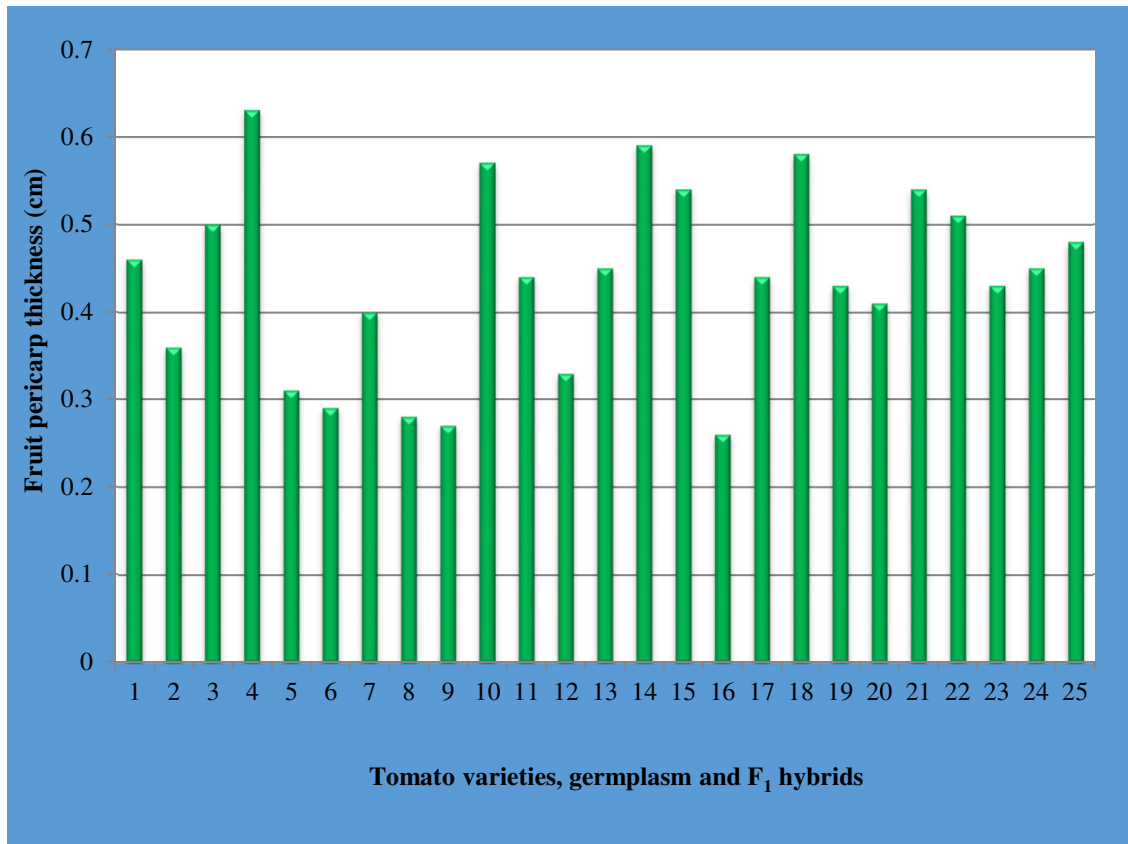


**Fig.7. Graph showing tomato fruit width (cm) of parental varieties, germplasm and F1 hybrids**

**Germplasm:** 1. 15, 2. 51, 3. 34, 4. 84, 5. 130, 6. 169, 7. L121

**Parental tomato varieties:** 8. Vaibhav, 9. Sankranthi, 10. Pusa Ruby, 11. Arka Alok

**F1 hybrids:** 12. Arka Alok×102, 13. Vaibhav×130, 14. Vaibhav×15, 15. Vaibhav×51, 16. Vaibhav×169, 17. Vaibhav×84, 18. Sankranthi×34, 19. Sankranthi×169, 20. Sankranthi×102, 21. Pusa Ruby×169, 22. Arka Alok×169, 23. Pusa ruby ×102, 24. 34 × L121, 25. 127 × L121

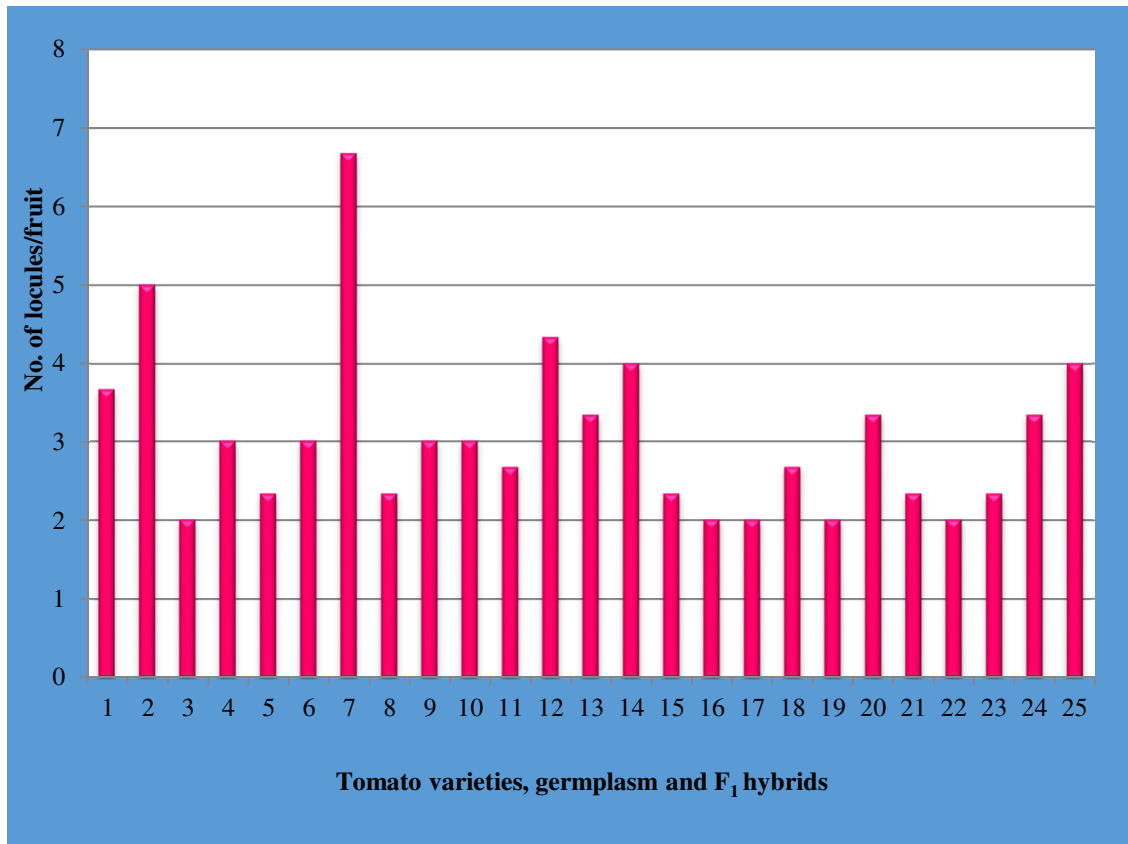


**Fig.8. Graph showing tomato fruit pericarp thickness (cm) of parental varieties, germplasm and F<sub>1</sub> hybrids**

**Germplasm:** 1. 15, 2. 51, 3. 34, 4. 84, 5. 130, 6. 169, 7. L121

**Parental tomato varieties:** 8. Vaibhav, 9. Sankranthi, 10. Pusa Ruby, 11. Arka Alok

**F<sub>1</sub> hybrids:** 12. Arka Alok×102, 13. Vaibhav×130, 14. Vaibhav×15, 15. Vaibhav×51, 16. Vaibhav×169, 17. Vaibhav×84, 18. Sankranthi×34, 19. Sankranthi×169, 20. Sankranthi×102, 21. Pusa Ruby×169, 22. Arka Alok×169, 23. Pusa ruby ×102, 24. 34 × L121, 25. 127 × L121



**Fig.9. Graph showing number of locules / fruit of parental varieties, germplasm and F1 hybrids**

**Germplasm:** 1. 15, 2. 51, 3. 34, 4. 84, 5. 130, 6. 169, 7. L121

**Parental tomato varieties:** 8. Vaibhav, 9. Sankranthi, 10. Pusa Ruby, 11. Arka Alok

**F1 hybrids:** 12. Arka Alok×102, 13. Vaibhav×130, 14. Vaibhav×15, 15. Vaibhav×51, 16. Vaibhav×169, 17. Vaibhav×84, 18. Sankranthi×34, 19. Sankranthi×169, 20. Sankranthi×102, 21. Pusa Ruby×169, 22. Arka Alok×169, 23. Pusa ruby ×102, 24. 34 × L121, 25. 127 × L121



**Sankranthi×169 (68.67g)**



**Arka Alok×169 ( 66.67g)**

**Plate 3: F<sub>1</sub> hybrid tomatoes with higher fruit weight**



**102 (5.81cm)**



**Sankranthi×169 ( 5.66cm)**

**Plate 4: Tomato germplasm and hybrid with higher fruit length**



**L121(5.42cm)**



**34 × L121 (4.87cm)**

**Plate 5: Tomato germplasm and F<sub>1</sub> hybrid with higher fruit width**



**102 (0.63cm)**



**Vaibhav×15 (0.59cm)**

**Plate 6: Tomato germplasm and F<sub>1</sub> hybrid with higher fruit pericarp thickness**

**Table 4. Observation recorded on fruit pericarp thickness and no. of locules/fruit in various tomato parental varieties, germplasm and F1 hybrids**

SL. No.	Tomato parental varieties/ germplasm/hybrids	Fruit pericarp thickness (cm)	No. of locules/ fruit
1	15 (G)	0.46 b	3.67 c
2	34 (G)	0.36 b	5.00 b
3	84 (G)	0.50 a	2.00 d
4	102 (G)	0.63 a	3.00 c
5	130 (G)	0.31 c	2.33 d
6	169 (G)	0.29 c	3.00 c
7	L121 (G)	0.40 b	6.67 a
8	Vaibhav (PV)	0.28 c	2.33d
9	Sankranthi (PV)	0.27 c	3.00 c
10	Pusa Ruby (PV)	0.57 a	3.00 c
11	Arka Alok (PV)	0.44 b	2.67 c
12	Arka Alok×102 (H)	0.33 c	4.33 b
13	Vaibhav×130 (H)	0.45 b	3.33 c
14	Vaibhav×15 (H)	0.59 a	4.00 c
15	Vaibhav×102 (H)	0.54 a	2.33 d
16	Vaibhav×169 (H)	0.26 c	2.00 d
17	Vaibhav×84 (H)	0.44 b	2.00 d
18	Sankranthi×34 (H)	0.58 a	2.67 c
19	Sankranthi×169 (H)	0.43 b	2.00 d
20	Sankranthi×102 (H)	0.41 b	3.33 c
21	Pusa Ruby×169 (H)	0.54 a	2.33 d
22	Arka Alok×169 (H)	0.51 a	2.00 d
23	Pusa ruby ×102 (H)	0.43 b	2.33 d
24	34 × L121 (H)	0.45 b	3.33 c
25	127 × L121 (H)	0.48 b	4.00 c
	Mean	0.44	3.07
	SE.m	0.05	2.32
	CD (0.01)	0.19	1.01
	CD (0.05)	0.14	0.76

**Legend:**

PV- parental varieties, G- germplasm and H- hybrids

Similar alphabets do not differ significantly

**Table 5. Observation recorded on fruit shape and fruit color in various tomato parental varieties, germplasm and F1 hybrids**

SL. No.	Tomato parental varieties/ germplasm/hybrids	Fruit shape	Fruit color
1	15 (G)	Spherical	Light orange
2	34 (G)	Spherical	Yellow
3	84 (G)	Spherical	Deep red
4	102 (G)	Elongated	Deep red
5	130 (G)	Spherical	Deep red
6	169 (G)	Spherical	Deep red
7	L121 (G)	Spherical	Red
8	Vaibhav (PV)	Oval	Deep red
9	Sankranthi (PV)	Elongated	Red
10	Pusa Ruby (PV)	Spherical	Red
11	Arka Alok (PV)	Spherical	Red
12	Arka Alok×102 (H)	Spherical	Deep red
13	Vaibhav×130 (H)	Oval	Deep red
14	Vaibhav×15 (H)	Spherical	Orange red
15	Vaibhav×102 (H)	Elongated	Red
16	Vaibhav×169 (H)	Spherical	Red
17	Vaibhav×84 (H)	Elongated	Orange red
18	Sankranthi×34 (H)	Spherical	Deep red
19	Sankranthi×169 (H)	Oval	Deep red
20	Sankranthi×102 (H)	Elongated	Orange red
21	Pusa Ruby×169 (H)	Elongated	Red
22	Arka Alok×169 (H)	Oval	Red
23	Pusa ruby ×102 (H)	Elongated	Deep red
24	34 × L121 (H)	Spherical	Orange red
25	127 × L121 (H)	Spherical	Light orange

**Legend:**

PV- parental varieties, G- germplasm and H- hybrids



L121 (6.67)



Arka Alok×102 (4.33 )

**Plate 7: Tomato germplasm and F<sub>1</sub> hybrid with higher number of locules/ fruit**



15 (4.80 °Brix)



Vaibhav (4.53 °Brix)

**Plate 8: Tomato germplasm and varieties with higher fruit total soluble solids**

## **4.2 Biochemical trait based genetic variability among tomato parental varieties, germplasm and F<sub>1</sub> hybrids**

### **4.2.1 TSS (<sup>0</sup>Brix):**

Among all the twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids studied, the total soluble solids (TSS <sup>0</sup>Brix) was significantly higher in tomato germplasm 15 (4.8 <sup>0</sup> Brix) followed by parent variety Vaibhav (4.5<sup>0</sup> Brix). The minimum amount of total soluble solids was recorded in F<sub>1</sub> hybrid tomato (Vaibhav×51) (2.47<sup>0</sup> Brix) (Table 6; Fig 10; Plate 8).

### **4.2.2 Lycopene content (mg/100g):**

Among all the twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids, the content of lycopene was significantly higher in F<sub>1</sub> hybrid tomato (34 × L121) (5.09 mg/100g) followed by tomato germplasm 169 (3.97 mg/100g). The minimum amount of lycopene was observed in parent tomato variety Sankranthi (0.41mg/100g) (Table 6; Fig.11; Plate 9).

### **4.2.3 Phenolic content (µg/ml):**

Among all the twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids the phenolic content was higher in (127 × L121) (9.33 µg/ml) followed by F<sub>1</sub> hybrid tomato (Vaibhav×169) (8.33 µg/ml). The minimum amount of phenolic content was observed in two F<sub>1</sub> hybrid tomato (Sankranthi×102), (34 × L121) and tomato germplasm 34 (2.33µg/ml) (Table 7; Fig 12; Plate 10).

### **4.2.4 Ascorbic acid (mg/100g):**

Among all the twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids the ascorbic content was higher in F<sub>1</sub> hybrid tomatoes like (Sankranthi×34) (23 mg/100g) followed by (34×L121) (20.33mg/100g). The minimum amount of ascorbic was observed in tomato germplasm L121 (4.00 mg/100g). (Table 7; Fig 13; Plate 11)

### **4.2.5 Fruit pulp pH:**

Among all the twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids fruit pulp pH was found in parent tomato germplasm L121 (4.74) followed by tomato germplasm 169 (4.68) and least fruit pH was found in F<sub>1</sub> hybrid tomato (Vaibhav×169) (3.97) with mean pH (4.39) (Table 7; Fig.14; Plate 12).

**Table 6. Observation recorded on fruit total soluble solids and lycopene content various tomato parental varieties, germplasm and F1 hybrids**

SL. No.	Tomato parental varieties/ germplasm/hybrids	Total soluble solids (°Brix)	Lycopene content (mg/100g)
1	15 (G)	4.80 a	1.93 e
2	34 (G)	3.53 b	1.08 f
3	84 (G)	3.93 b	3.01 d
4	102 (G)	3.27 b	0.94 g
5	130 (G)	3.27 b	0.72 g
6	169 (G)	4.30 a	3.97 b
7	L121 (G)	4.33 a	2.32 e
8	Vaibhav (PV)	4.53 a	3.42 c
9	Sankranthi (PV)	3.03 c	0.41 g
10	Pusa Ruby (PV)	3.33 b	0.49 g
11	Arka Alok (PV)	3.95 b	0.58 g
12	Arka Alok×102 (H)	3.13 c	2.32 e
13	Vaibhav×130 (H)	3.77 b	1.96 e
14	Vaibhav×15 (H)	4.13 b	2.64 d
15	Vaibhav×102 (H)	2.47 c	0.63 g
16	Vaibhav×169 (H)	3.27 b	0.50 g
17	Vaibhav×84 (H)	4.40 a	3.29 c
18	Sankranthi×34 (H)	3.03 c	0.64 g
19	Sankranthi×169 (H)	3.33 b	0.42 g
20	Sankranthi×102 (H)	3.97 b	1.08 f
21	Pusa Ruby×169 (H)	3.10 c	2.33 e
22	Arka Alok×169 (H)	4.10 a	0.74 f
23	Pusa ruby ×102 (H)	3.20 c	0.67 g
24	34 × L121 (H)	4.00 b	5.09 a
25	127 × L121 (H)	4.43 a	3.84 b
	Mean	3.70	1.80
	SE.m	0.27	0.14
	CD (0.01)	1.02	0.52
	CD (0.05)	0.76	0.39

**Legend:**

PV- parental varieties, G- germplasm and H- hybrids

Similar alphabets do not differ significantly

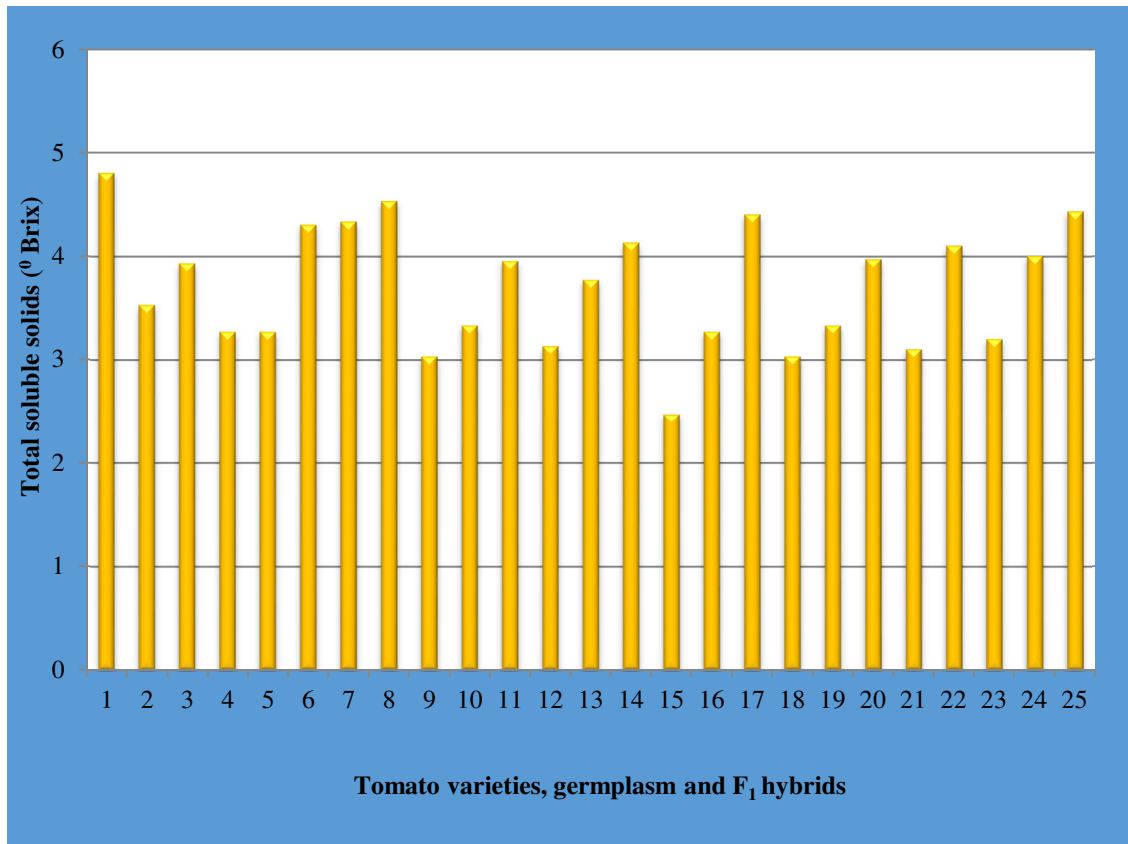
**Table 7. Observation recorded on fruit phenolic content, ascorbic acid content and fruit pulp pH in various tomato parental varieties, germplasm and F1 hybrids**

SL. No.	Tomato parental varieties/ germplasm/hybrids	Phenolic content (µg/ml)	Ascorbic acid content (mg/100g)	Fruit pulp pH
1	15 (G)	5.67 b	11.33 d	4.42 b
2	34 (G)	2.33 c	7.33 e	4.62 a
3	84 (G)	6.00 b	4.67 f	4.24 b
4	102 (G)	6.33 b	4.67 f	4.34 b
5	130 (G)	5.33 b	9.33 d	4.63 a
6	169 (G)	5.67 b	8.00 e	4.68 a
7	L121 (G)	6.67 b	4.00 f	4.74 a
8	Vaibhav (PV)	2.67 c	11.67 d	4.44 b
9	Sankranthi (PV)	3.00 c	8.33 e	4.43 b
10	Pusa Ruby (PV)	3.33 c	9.33 d	4.58 a
11	Arka Alok (PV)	4.33 c	8.00 e	4.43 b
12	Arka Alok×102 (H)	4.67 b	7.33 e	4.29 b
13	Vaibhav×130 (H)	3.00 c	6.00 f	4.30 b
14	Vaibhav×15 (H)	6.33 b	5.67 f	4.36 b
15	Vaibhav×102 (H)	6.00 b	9.67 d	4.07 b
16	Vaibhav×169 (H)	8.33 a	8.67 e	3.97 c
17	Vaibhav×84 (H)	7.67 a	5.33 f	4.63 a
18	Sankranthi×34 (H)	6.00 b	23.00 a	4.61 a
19	Sankranthi×169 (H)	5.67 b	7.67 e	4.32 b
20	Sankranthi×102 (H)	2.33 c	6.33 f	4.09 c
21	Pusa Ruby×169 (H)	4.33 c	6.00 f	4.22 b
22	Arka Alok×169 (H)	3.67 c	7.33 e	4.43 b
23	Pusa ruby ×102 (H)	4.67 b	17.33 c	4.22 b
24	34 × L121 (H)	2.33 c	20.33 b	4.18 c
25	127 × L121 (H)	9.33 a	7.33 e	4.46 b
	Mean	5.03	8.99	4.39
	SE.m	0.77	0.90	0.08
	CD (0.01)	2.92	3.40	0.32
	CD (0.05)	2.19	2.55	0.24

**Legend:**

PV- parental varieties, G- germplasm and H- hybrids

Similar alphabets do not differ significantly

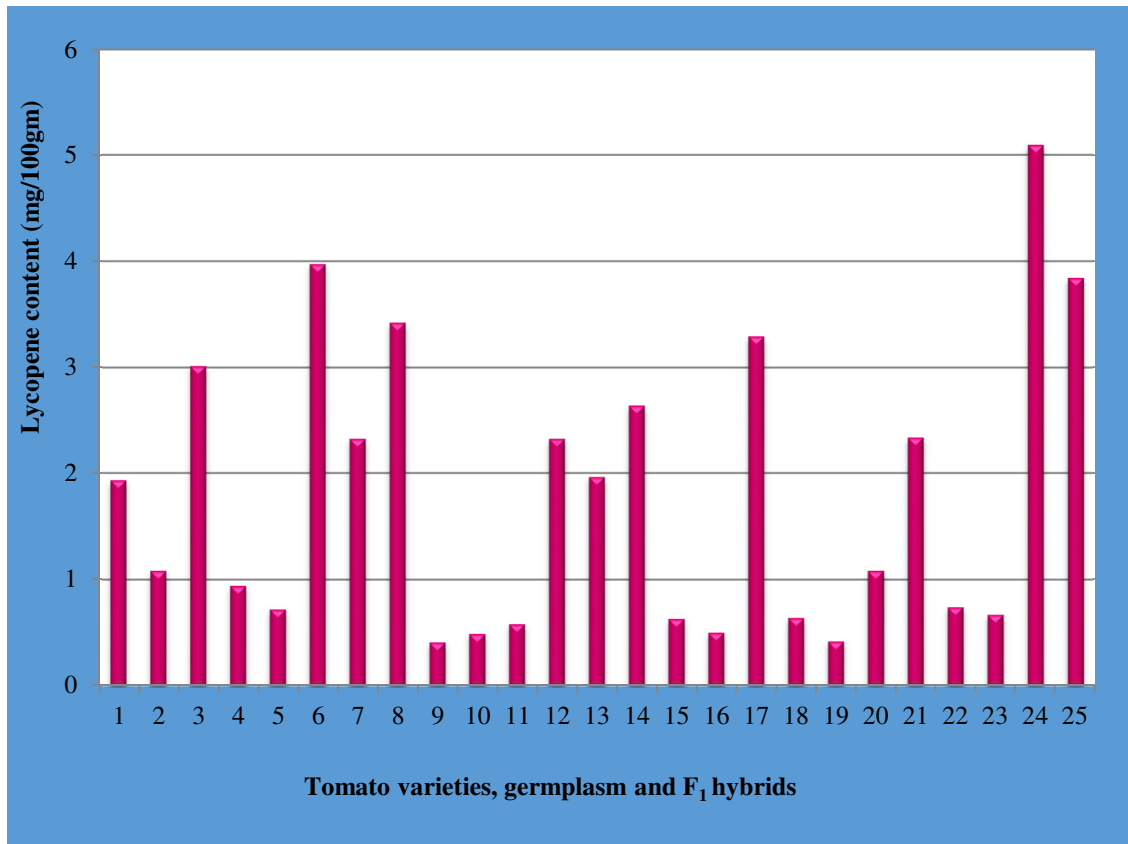


**Fig.10. Graph showing tomato fruit total soluble solid content (° Brix) of parental varieties, germplasm and F1 hybrids**

**Germplasm:** 1. 15, 2. 51, 3. 34, 4. 84, 5. 130, 6. 169, 7. L121

**Parental tomato varieties:** 8. Vaibhav, 9. Sankranthi, 10. Pusa Ruby, 11. Arka Alok

**F1 hybrids:** 12. Arka Alok×102, 13. Vaibhav×130, 14. Vaibhav×15, 15. Vaibhav×51, 16. Vaibhav×169, 17. Vaibhav×84, 18. Sankranthi×34, 19. Sankranthi×169, 20. Sankranthi×102, 21. Pusa Ruby×169, 22. Arka Alok×169, 23. Pusa ruby ×102, 24. 34 × L121, 25. 127 × L121

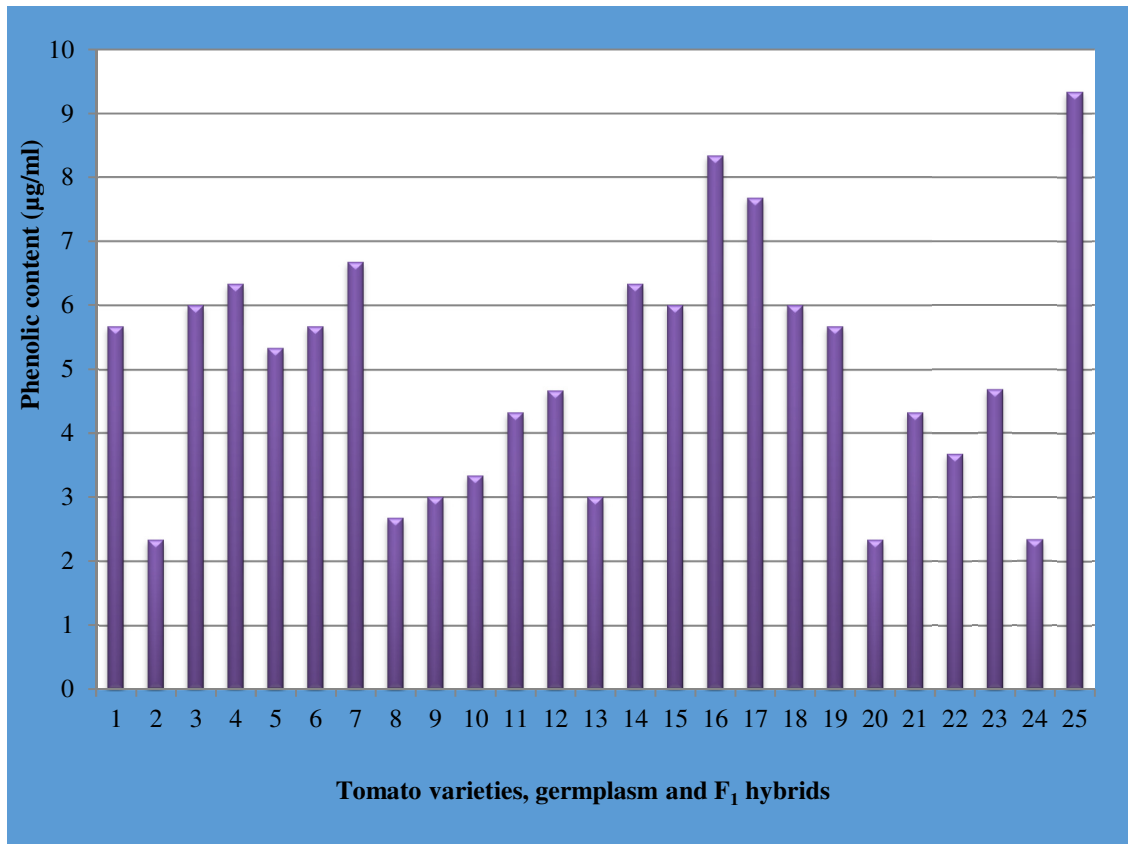


**Fig.11. Graph showing tomato fruit lycopene content (mg/100g) of parental varieties, germplasm and F<sub>1</sub> hybrids**

**Germplasm:** 1. 15, 2. 51, 3. 34, 4. 84, 5. 130, 6. 169, 7. L121

**Parental tomato varieties:** 8. Vaibhav, 9. Sankranthi, 10. Pusa Ruby, 11. Arka Alok

**F<sub>1</sub> hybrids:** 12. Arka Alok×102, 13. Vaibhav×130, 14. Vaibhav×15, 15. Vaibhav×51, 16. Vaibhav×169, 17. Vaibhav×84, 18. Sankranthi×34, 19. Sankranthi×169, 20. Sankranthi×102, 21. Pusa Ruby×169, 22. Arka Alok×169, 23. Pusa ruby ×102, 24. 34 × L121, 25. 127 × L121

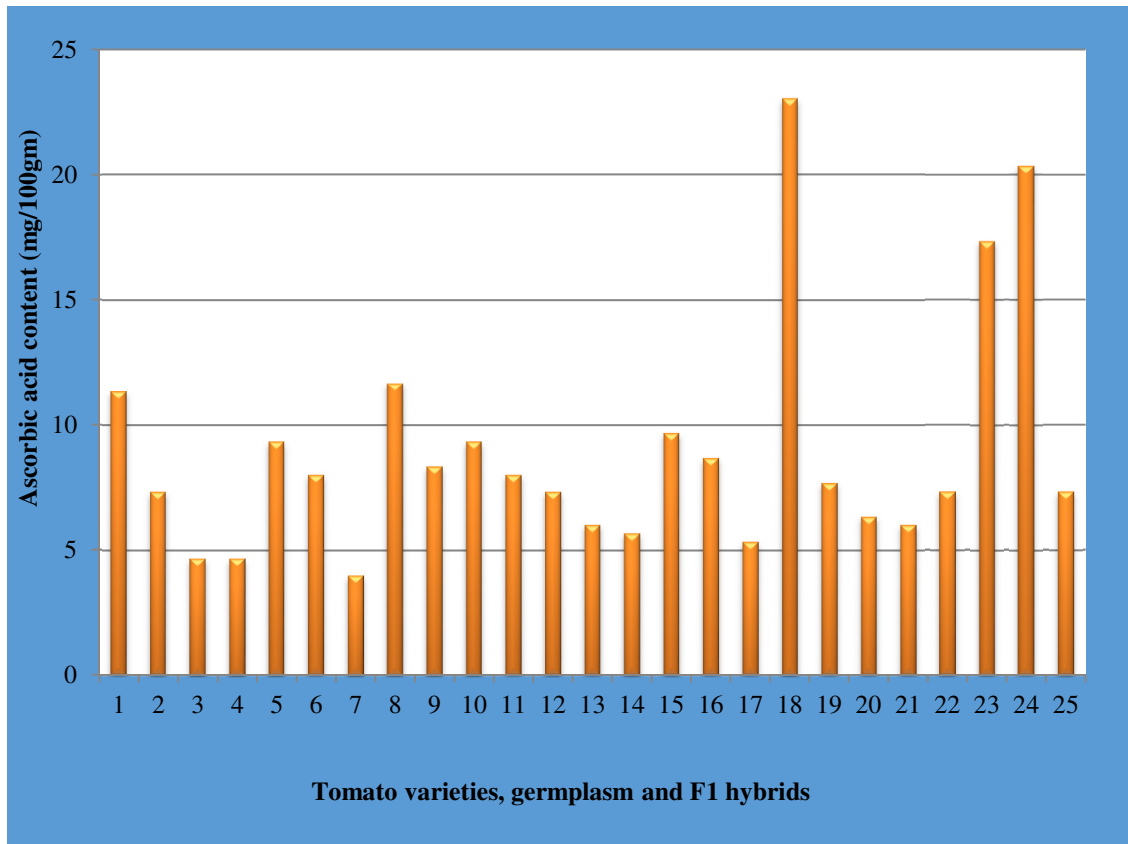


**Fig.12. Graph showing tomato fruit phenolic content ( $\mu\text{g}/100\text{ g}$ ) of parental varieties, germplasm and F<sub>1</sub> hybrids**

**Germplasm:** 1. 15, 2. 51, 3. 34, 4. 84, 5. 130, 6. 169, 7. L121

**Parental tomato varieties:** 8. Vaibhav, 9. Sankranthi, 10. Pusa Ruby, 11. Arka Alok

**F<sub>1</sub> hybrids:** 12. Arka Alok $\times$ 102, 13. Vaibhav $\times$ 130, 14. Vaibhav $\times$ 15, 15. Vaibhav $\times$ 51, 16. Vaibhav $\times$ 169, 17. Vaibhav $\times$ 84, 18. Sankranthi $\times$ 34, 19. Sankranthi $\times$ 169, 20. Sankranthi $\times$ 102, 21. Pusa Ruby $\times$ 169, 22. Arka Alok $\times$ 169, 23. Pusa ruby  $\times$ 102, 24. 34  $\times$  L121, 25. 127  $\times$  L121

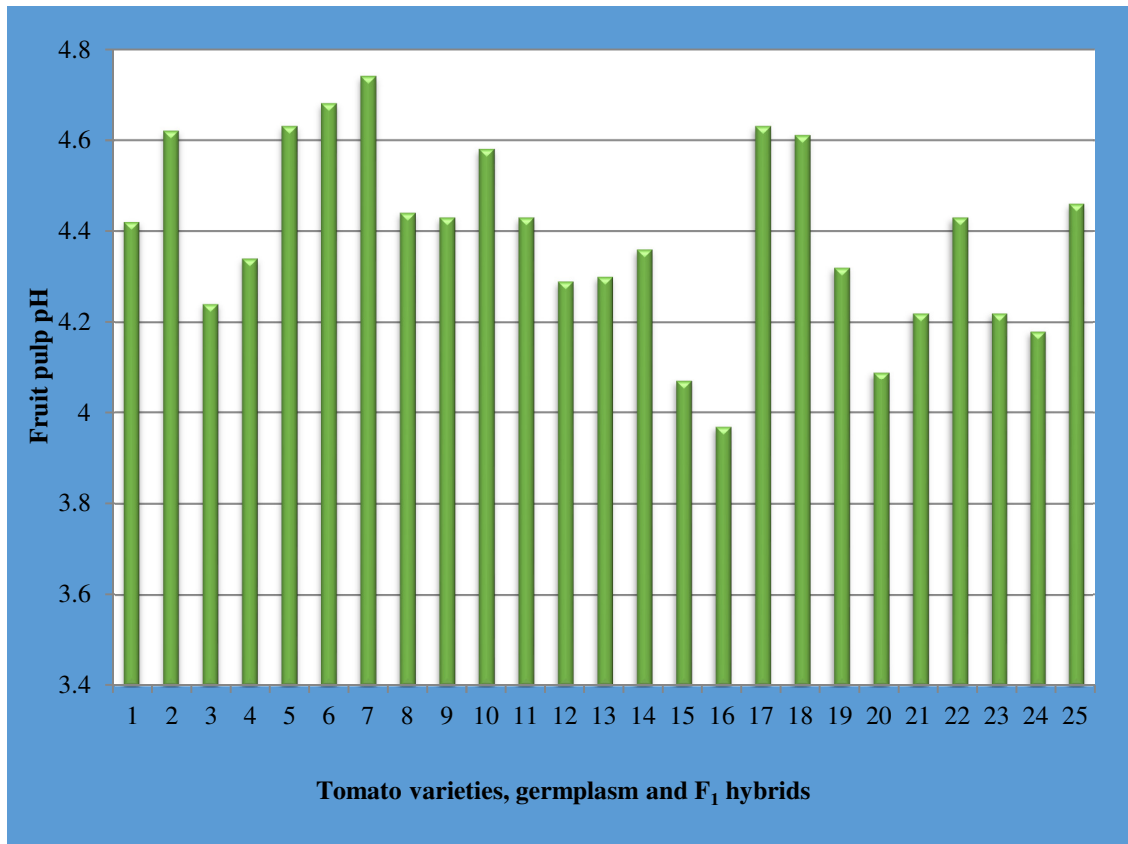


**Fig.13. Graph showing tomato fruit ascorbic acid content (mg/100g) of parental varieties, germplasm and F1 hybrids**

**Germplasm:** 1. 15, 2. 51, 3. 34, 4. 84, 5. 130, 6. 169, 7. L121

**Parental tomato varieties:** 8. Vaibhav, 9. Sankranthi, 10. Pusa Ruby, 11. Arka Alok

**F1 hybrids:** 12. Arka Alok×102, 13. Vaibhav×130, 14. Vaibhav×15, 15. Vaibhav×51, 16. Vaibhav×169, 17. Vaibhav×84, 18. Sankranthi×34, 19. Sankranthi×169, 20. Sankranthi×102, 21. Pusa Ruby×169, 22. Arka Alok×169, 23. Pusa ruby ×102, 24. 34 × L121, 25. 127 × L121



**Fig.14. Graph showing fruit pulp pH of parental varieties, germplasm and F<sub>1</sub> hybrids**

**Germplasm:** 1. 15, 2. 51, 3. 34, 4. 84, 5. 130, 6. 169, 7. L121

**Parental tomato varieties:** 8. Vaibhav, 9. Sankranthi, 10. Pusa Ruby, 11. Arka Alok

**F<sub>1</sub> hybrids:** 12. Arka Alok×102, 13. Vaibhav×130, 14. Vaibhav×15, 15. Vaibhav×51, 16. Vaibhav×169, 17. Vaibhav×84, 18. Sankranthi×34, 19. Sankranthi×169, 20. Sankranthi×102, 21. Pusa Ruby×169, 22. Arka Alok×169, 23. Pusa ruby ×102, 24. 34 × L121, 25. 127 × L121



**34 × L121 (5.09 mg/100gm)**



**169 (3.97mg/100gm)**

**Plate 9: Tomato F<sub>1</sub> hybrid and germplasm with higher lycopene content**



**127 × L121 (9.33 µg/ml)**



**Vaibhav×169 (8.33 µg/ml)**

**Plate 10 : F<sub>1</sub> hybrid tomatoes with higher phenolic content**



**Sankranthi×34 (23.00 mg/100gm)**



**34 × L121 (22.33mg/100gm)**

**Plate 11: : F<sub>1</sub> hybrid tomatoes with higher ascorbic acid content**



**L121 (4.74)**



**169 (4.68)**

**Plate 12: Tomato germplasms with higher fruit pH**

## VI DISCUSSION

Tomato is considered as fruit and vegetable, ranks second in its importance next to potato in the world. It has wider adaptability to various environmental conditions with high yield potential. The fruit has multiple uses both in fresh form as well as in the processed form. Thus, the systematic study and evaluation of germplasm for the agronomic traits and fruit quality plays an important role in the development of varieties/hybrids with desirable characteristics. The land races and exotic varieties exhibit considerable genetic variations for quantitative and qualitative characteristics Frankel *et al.* (1995).

The success of crop improvement programme depends on the extent of genetic variability existing in the population or germplasm. The magnitude of genetic variability can determine the pace and quantum of genetic improvement through selection or through hybridization followed by selection. The present study on characterization of tomato varieties for morphological and biochemical traits were undertaken. The results obtained from the above study are discussed under the following headings in light of the previous research work carried out in tomato by various scientists in different research stations.

- 5.1 Morphological trait based genetic variability among tomato parental varieties, germplasm and F<sub>1</sub> hybrids.
- 5.2 Biochemical trait based genetic variability among tomato parental varieties, germplasm and F<sub>1</sub> hybrids.

### **5.1 Morphological trait based genetic variability among tomato parental varieties, germplasm and F<sub>1</sub> hybrids**

Fruits represent important part of human diet and exhibit extensive variation in size, shape, and color between and within cultivars /species. Thus in the present study also the predominant fruit shapes among the twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids, one germplasm exhibited yellow, one germplasm, one F<sub>1</sub> hybrid exhibited light orange color, one germplasm, three parental varieties and four F<sub>1</sub> hybrids exhibited red color, followed by four germplasms, one parental variety and five F<sub>1</sub> hybrids exhibited deep red color and four F<sub>1</sub> hybrids exhibited orange red color. Similar variation in tomato have been studied by Amarnath (2014) reported ten accessions of tomato exhibited orange red color, followed by nine light yellow and six exhibited deep red color at ripened stage of the fruits. Brijesh (2015) reported four accessions of tomato exhibited orange red color, followed by five red colors, one exhibited pink color and ten exhibited

deep red color and he also reported thirteen accessions exhibited flat shape, followed by three round shape, two exhibited ellipsoid, one exhibited heart and oxheart. These shapes and color are preferred commercially owing to attractive shape and color.

Fruit morphological parameters (fruit weight, fruit length, fruit pericarp thickness, number of locules etc...) are also important for selection of crops for further studies. Thus in the present investigation morphological traits recorded varied from fruit weight 68.67 g to 27.33g, fruit length 5.81 cm to 2.98 cm, fruit width 5.42 cm to 3.53 cm, fruit pericarp thickness 0.63 cm to 0.26 cm, number of locules 2.00 to 6.67. Among twenty five tomato parental varieties, germplasms and F<sub>1</sub> hybrids studied in the present investigation, the fruit yield maximum were observed on F<sub>1</sub> hybrid (Vaibhav× 169) (2546 kg yield/pl.) and minimum yield were found in F<sub>1</sub> hybrid (Arka Alok× 169) (0.346 kg yield/pl.), observation taken based on another lab mate research work. Similar reports are made by Reddy *et al.*, (2013) evaluated nineteen tomato varieties. The varieties exhibited a wide range of variability like plant height (138.125 cm), number of primary branches/pl. (30.146), yield/pl. number of flowers/cluster (8.363), fruit length (6.704 cm), fruit width (4.558 cm), average fruit weight (102.333 g) and fruit yield/pl. (2.721 kg/pl).

## **5.2 Biochemical trait based genetic variability among tomato parents and F<sub>1</sub> hybrids**

Tomato is considered as both fruit and vegetable as extensively used in fresh consumption as well as in several preliminary preparations. The fruits are rich in carotenoid which is due to lycopene pigment present in the fruits and has been proved to be potential antioxidants with several health benefits.

Thus in the recent years, many studies are oriented towards screening of tomato varieties or cultivars for their lycopene content. In one of such studies, however in the present study the twenty five varieties, germplasm and F<sub>1</sub> hybrids were screened for lycopene content. Lycopene was significantly higher in hybrid tomato (34 × L121) (5.09 mg/100g) followed by tomato germplasm 169 (3.97 mg/100g). Similar reports on the lycopene content are made by Yogendra and Gowda (2013) in Indian cultivars *viz.*, Sankranti (0.81 mg/100 g) and Vaibhav (0.84 mg/100 g). Rao and Rao (2007) reports lycopene content varying from 8.82-42.0 mg/100 g compared to report made by Takeoka *et al.*, (2001) about the lycopene content in fresh tomato harvested in northern California with lycopene content ranging from 80.27 to 120.67 mg/100 g, Lilwani *et al.*, (2015) reported the purified lycopene content was found to be the maximum in cherry tomato (88.87 mg/kg) as compared to Pakistani tomato (55.84 mg/kg) and watermelon (74.53 mg/kg), Aghel *et al.*, (2011) recorded average quantity of extracted pure lycopene was calculated as 2.313 mg /100 g tomato paste.

The fruit quality plays an important role for the above purpose. The sugar acid blend determines the quality of fruits for fresh consumption and processing. As per the report made by several authors the total soluble solids content ranged from 3.17 to 5.0<sup>0</sup> Brix (Shankar *et al.* 2013); 3.38 to 10.25<sup>0</sup> Brix (Reddy *et al.*, 2013); 5.58 to 7.53<sup>0</sup> Brix (Manna and Paul, 2012). Similarly, in present study also the TSS found to be in the range of 4.80<sup>0</sup> Brix to 2.47<sup>0</sup> Brix.

The fruit pulp pH, total soluble solids and ascorbic acid content plays an important role in the development of tomato cultivars for processing purpose (Bose *et al.*, 2002). Thus in the present experiment fruit pH was ranged from 4.74 to 3.97 and ascorbic acid content 20.33 mg/100g to 4.00 mg/100g. Similar reports were made by Kulkarni (2006) for seven parents and twenty one hybrids. The ascorbic acid content ranged from 16.42 to 27.00 mg/100g in parents and 3.92 to 17.08 mg/100g hybrids. While, the total titratable acidity ranged from 0.27 to 0.43 for parents and 0.27 to 0.44 mg/100g for hybrids. Percent juice recovery ranged from 27.92 to 39.5 per cent for parents and 19.37 to 40.67 per cent for hybrids. While, the total soluble solids ranged from 3.47 to 6.23 and 4.00 to 6.37 in parents and hybrids respectively. Ashwini (2005) evaluated parents and hybrids for total soluble solids and pH content of tomato. She observed that, the total soluble solids content of fruits from parents ranged from 2.91 to 4.96<sup>0</sup> Brix, while for hybrids it ranged from 3.15 to 5.34<sup>0</sup> Brix. Whereas, pH content for parents ranged from 3.21 to 4.34 and for hybrids from 3.04 to 4.89. Prashanth (2003) evaluated different quality parameters like total soluble solids, total titratable acidity, pH for different tomato genotypes. He observed that the total soluble solids ranging from 3.19<sup>0</sup> Brix to 5.83<sup>0</sup> Brix, total titratable acidity from 0.21 percent to 0.70 per cent and pH ranged from 4.07 to 5.33. Vijitha and Mahendran (2010) reported TSS and Vit. C content in control plant and water stressed plant is 5.5<sup>0</sup> Brix and 6<sup>0</sup> Brix, 15.9 and 8.9 mg/100 g respectively.

Phenolic content plays an important role as plants act as a defensive mechanism and also important for processing purpose of tomato cultivars. Thus in the present experiment phenolic content ranged from 9.33 µg/ml to 2.33 µg/ml. Similar reports were made by Caris-Veyrat *et al.*, (2004) found rutin and naringenin in content that was respectively 170 and 12.5 % higher in organic tomatoes than in the conventional ones. Toor *et al.*, (2006), who found a higher level of total phenolics in organically fertilized tomatoes than in those that received conventional fertilization. Borguini *et al.*, (2013) reported organic tomatoes exhibited higher content of ascorbic acid and total phenolics (641.39 and 4466.66 mg/100 g EAG on dry wt basis) than did the conventional tomatoes (510.16 and 3477.50 mg/100 g EAG on dry wt basis, respectively). Decne *et al.*, (2015) evaluated phenol contents of the *Ephedra alata*. The total phenolic content in the ethanolic extract was 19.175 mg gallic acid while was the highest in the methanolic extract which was 47.62 mg gallic acid equivalent/g of extract powder. King *et al.*, (2013) screened methanol extracts of *Ageratina adenophora* leaves. The methanol extract leaves revealed a total phenolic content of 30.0 mg gallic acid equivalent/g and 510.0 mg quercetin

equivalent/g. Banu *et al.*, (2011) reported the total phenolic content of the methanolic extract of leaves of *Barleria montana* belonging to the family Acanthaceae. The total phenolic content measured by Folin-Ciocalteu was found to be 0.9628 and 1.061 for gallic acid and tannic acid respectively.

## V SUMMARY

Tomato (*Solanum lycopersicum* L.) is an important source of several minerals and vitamins which can be effectively used in improving livelihood and alleviating the nutritional status of the people. The tomato exhibits wide degree of variability with respect to growth habit, fruit size, fruit shape, fruit color and yield per plant etc., Thus in the present study, the 4 parental varieties, 7 germplasm and 14 F<sub>1</sub> hybrids were screened for variability in terms of morphological and biochemical traits.

- The weight of individual fruit was recorded among the twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids the weight of fruit was significantly higher in tomato F<sub>1</sub> hybrid tomatoes like (Sankranthi×169) (68.67 g) followed by (Arka Alok×169) (66.67g).
- The fruit length recorded in all twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids. The length of the fruit was maximum in tomato germplasm 102(5.81 cm) followed by F<sub>1</sub> hybrid tomato (Sankranthi×169) (5.66 cm).
- Among all the twenty five parental varieties, germplasm and F<sub>1</sub> hybrids, the width of the fruit was higher in tomato germplasm L121 (5.42 cm) followed by F<sub>1</sub> hybrid (tomato 34 × L121).
- Fruit pericarp thickness in all twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids was recorded. It was significantly higher in tomato germplasm 102(0.63 cm) followed by F<sub>1</sub> hybrid tomato (Vaibhav×15).
- Among all the twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids studied, The locules number was more in tomato germplasm L121 (6.67) followed by (Arka Alok×102) (4.33)
- Among twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids studied in the present investigation, the fruit color varied at physiological maturity, one germplasm exhibited yellow, one germplasm, one F<sub>1</sub> hybrid exhibited light orange color, one germplasm, three parental varieties and four F<sub>1</sub> hybrids exhibited red color, followed by four germplasm, one parental variety and five F<sub>1</sub> hybrids exhibited deep red color and four F<sub>1</sub> hybrids exhibited orange red color.
- Among twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids studied in the present investigation, six tomato germplasm, two parental varieties and six F<sub>1</sub> hybrids exhibited spherical shape, one germplasm, one parental variety and

five F<sub>1</sub> hybrids exhibited elongated shape and one parental variety and three F<sub>1</sub> hybrids exhibited oval shape at ripened stage of the fruits respectively.

- Among twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids studied in the present investigation, the fruit yield maximum were observed on F<sub>1</sub> hybrid (Vaibhav× 169) (2546 yield/pl.) and minimum yield were found in F<sub>1</sub> hybrid (Arka Alok× 169) (0.346 yield/pl.).
- Among all the twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids studied, the total soluble solids (TSS<sup>0</sup> Brix) was significantly higher in tomato germplasm 15 (4.80<sup>0</sup> Brix) followed by parental variety Vaibhav (4.53<sup>0</sup> Brix).
- Among all the twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids, the content of lycopene was significantly higher in F<sub>1</sub> hybrid tomato (34 × L121) (5.09 mg/100g) followed by tomato germplasm 169 (3.97 mg/100g).
- Among all the twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids the phenolic content was higher in F<sub>1</sub> hybrid (127 × L121) (9.33 µg/ml) followed by F<sub>1</sub> hybrid tomato (Vaibhav×169) (8.33 µg/ml).
- Among all the twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids, the ascorbic content was higher in F<sub>1</sub> hybrid tomatoes like (Sankranthi×34) (23 mg/100g) followed by (34×L121) (20.33 mg/100g).
- Among all the twenty five tomato parental varieties, germplasm and F<sub>1</sub> hybrids higher fruit pulp pH was found in parent tomato germplasm L121 (4.74) followed by tomato germplasm 169 (4.68).

### **Future line of work**

The accessions with good fruit quality traits such as high lycopene content, high TSS, high fruit ascorbic acid and acidic pH coupled with high yield per plant can be screened for processing purpose.

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