

Original Research Article

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Evaluation of Tomato (*Solanum lycopersicon* L.) Hybrids for Fruit Yield Characters in Hill Region of Uttarakhand, India

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ABSTRACT

Keywords

Tomato, *Solanum lycopersicon* L., Hybrid.

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Tomato is a premier vegetable crop of round the year and one of the prominent eco-industrial crops of India generating sizeable employment. The present study which consist 22 F₁ including commercial 6 hybrids of tomato. The experiment was laid out in Randomized Block Design (RBD) with three replications during summer- rainy season, 2014 at Vegetable Block of VCSG Uttarakhand University of Horticulture and Forestry, Ranichauri, Tehri-Garhwal. Analysis of variance (ANOVA) revealed significant differences among the hybrids for all the characters. The hybrid viz., Utkal Urwasi X Gujrat Tomato-3 proved the best with respect to fruit yield (6935.08 g) whereas, Utkal Urwasi X Palam Pink was promising for number of fruit per plant (79.82), number of flower cluster per plant (14.13), number of flower per cluster (8.0) and fruit set percentage (85.71 %). The hybrid Marglobe X Pusa Sadabhar was the best for earliest picking (43.0 DAT) and highest fruit weight (106.74 g).

Introduction

Tomato (*Solanum lycopersicon* L.) is one of the most popular and widely grown vegetable in the world. It belongs to the family Solanaceae. It is originated in a wild from in the Peru-Ecuador Bolivia region of the Andes in South America. Tomato was first introduced in Europe in the middle of the sixteenth century and in India it is introduced during seventeenth century probably by Portuguese (Kalloo, 1991). It is a major source of vitamins and minerals particularly vitamin C (31.0 mg), vitamin A (321 IU), protein (1.98g), moisture (93.1g), minerals (0.6 g), fibre (0.7g), sulphur (24 mg), chlorine (38 mg) and calcium (20 mg) on per 100 g fresh weight basis.

The pulp and juice are digestible mild aperients and blood purifier. It has antiseptic properties against intestinal infections.

India is the second largest tomato producing country in the world after China and contributes about 11.5 % to the global tomato production. As per NHB report 2015-16, in India, tomato is grown in an area of 0.767 m ha with annual production of 16.385 m tonnes and productivity of 21.36 t/ha.

Andhra Pradesh, Karnataka, Madhya Pradesh, Telangana and Odisha are the five major tomato growing states of the country (Anonymous, 2015).

Genetic variability is defined as “The occurrence of a high degree of variation differences among individuals due to differences in their genetic composition and of the environment in which they are raised” (Falconer and Mackay 1996). The basic requirement for genetic improvement of a crop is to utilize the available or created genetic variability. The genus *Lycopersicon* has two subgenera, *Eulycopersicon*, red fruited and self –compatible, and *Eriopersicon*, green–fruited and self-incompatible. In tomatoes three types of growth habit are found. In Indeterminate types of tomato the terminal bud ends in leafy bud and there is a continuous vegetative growth. The determinate types of tomato have terminal bud ending in a floral bud and further vegetative growth is checked and the semi-determinate types are in between determinate and indeterminate and have varying number of nodes between two consecutive inflorescences. Tomato flower is normally perfect. There are four to eight flowers in each compound inflorescence. There is a light protective anther cone surrounding the stigma leading to self-pollination. In tomato, anthesis and dehiscence occur between 7.00-8.00 am and 9.00-11.00 am respectively, Pollen fertility is maximum on the day of anthesis and stigma is fully receptivity at 16 hrs before anthesis to the day of anthesis (Sindhu *et al.*, 1980).

Wild tomatoes have a large genetic diversity, especially within the self- incompatible species like *L. chilense* and *L. peruvianum* (Rick, 1998). The genetic variation present in the wild species has been investigated intensively for the specific traits and is being exploited in tomato breeding (Larry and Joanne, 2007). Advance in tomato breeding for resistant are due to mostly the incorporation of major resistant genes identified from the *Lycopersicon* species (Rajdan and Mattoo, 2006). Resistance to

most important insect in tomatoes has been reported in wild species, particularly *L. hirsutum* that possesses resistant to at least eighteen pest species (Momotaz *et al.*, 2005) and *L. pennellii* (Muigai *et al.*, 2002).

Utilization of desirable genes conferring resistance to biotic and abiotic stress available in different wild and cultivated gene pool could be possible through hybrid breeding programmes. In addition to resistance characteristics quantum rise in fruit yield has also been taken place in tomato in last two decades. The basic force behind such a miracle achievement in relation to production and productivity of this crop was development of F₁ hybrids suitable for different agro-climatic conditions. The tomato hybrids got quick popularity due to occurrence heterosis for fruit yield characteristics.

The agro-climatic conditions of Uttarakhand hills are known for its variability, uncertainty and extremity. This region is ‘hot spot’ of almost all the biotic and abiotic stresses, like early or late onset of Monsoon, flush rains, erratic and unevenly distributed rainfall, leaf blight, bacterial wilt, fruit rot, fruit borer etc. With these colleges cultivation of conventional varieties of tomato prone to be uneconomical enterprise. Hybrid have been found to be more suitable for ensured yield under such extreme agro-ecological situation of hills.

With the view to combat these problems, evaluation of hybrid in rain fed temperate hills of Uttarakhand is indispensable for boosting the production of tomatoes in the state and as such, an experiment has been planned to evaluate the available hybrids of tomato with objectives of to evaluate the commercial as well as newly developed hybrids for plant growth and fruit yield characters.

Materials and Methods

The material for present study consisted of 22 hybrids of tomato. The experiment was evaluated at Vegetable Research Block, VCSG Uttarakhand University of Horticulture and Forestry, Ranichauri Campus, Tehri Garhwal in the month of summer-rainy season March-August in 2014. Tehri Garhwal situated at 2000 m altitude, 78°24 E longitude and 30°18'N latitude receiving average annual rainfall of 1230 mm with maximum and minimum temperature of 26.6°C and 9.9°C, respectively. The Ranichauri Campus experiences humid and temperate type of climate with chilled winters. During cropping season of tomato the mean maximum temperature varied from 19.6°C to 26.6°C and mean minimum temperature from 9.9°C to 16.9°C. The average annual rainfall 1278.4 mm was experienced. Major portion of annual rainfall (about 61%) occurs during monsoon. Winter rains and snowfall occur during December-February and hailstorms are frequent from mid-April to May. The experiment was laid out in a Randomized Block Design (R.B.D.) with 3 replications and 22 number of treatments. The 30 days old seedlings transplanted into the field keeping the row-to-row and plant-to-plant distances of 60 and 45 cm, respectively. Observations were taken days to first flowering, internodal length (cm), plant height at first flowering (cm), plant height at first picking (cm), number of primary branches, number of secondary branches, leaf area (cm²), node number of first flowering, number of flower cluster per plant, number of flower per cluster, fruit set percentage, days to first picking, fruit length (cm), fruit diameter (cm), fruit pericarp thickness (mm), number of fruit locules, fruit weight (g), fruit volume (cm³), specific gravity of fruit (g/cm³), number of fruit per plant and fruit yield per plant (g) were recorded on five randomly selected plant basis.

Results and Discussion

Days to first flowering

The mean value of hybrids for this trait depicted that Omnia was the earliest to exhibit first flowering (26.33 DAT) followed by Himshikhar (27 DAT), Gujrat Tomato-3 x Pusa Sheetal (28.33 DAT), NDT-7 x S-2 (28.33 DAT), Abhilash (28.33 DAT) and VS-2853 (28.66 DAT) which were statistically *at par* with each other. The maximum number of days to first flowering was found in CO-3 x Pusa Sadabahar (41.66 DAT). The population mean was found to be 31.71 DAT. Earlier flowering hybrids could be used for production of early fruits for higher remuneration particularly in hills where off-season production enable higher profit. Variability in days to first flowering has also been reported by Ali *et al.*, (2012) from 42.00 to 56.00 DAS, Shankar *et al.*, (2013) from 28.00 to 37.00 DAT, Singh *et al.*, (2013) from 49.88 to 53.92 DAS and Said *et al.*, (2014) from 29 to 41 DAS in tomato (Table 1).

Internodal length (cm)

Significant difference for internodal length among the hybrids was noted (Table 1). The maximum internodal length was recorded in Palam Pink x Pusa Sadabahar (8.50 cm) followed by check Pusa Hybrid-1 (8.35 cm), CO-3 x Utkal Urwasi (8.25 cm) and Punjab Chuhara x Pusa Uphar (8.25 cm) with *at par* values. Minimum internodal length was recorded in S-2 x Utkal Uphar and Utkal Kumari x Utkal Uphar (4.25 cm). While the population mean was found to be 6.45 cm. Internodal length is a character which decides growth habit of the plants. For example, indeterminate types with higher internodal length grow tall utilizing vertical space and give more fruit yield for longer time. Similar results on internodal length have also been reported by Chaurasia *et al.*, (2001) from 6.5

cm to 7.9 cm in two hybrids (BSS-40 and ARTH-4) of tomato.

Number of flower clusters per plant

The number of flower clusters per plant is an important yield determining trait. Higher number of flower clusters may lead to greater number of fruits per plant in favorable conditions. The data on number of flower clusters per plant indicated that the mean value for this trait ranged from 7.33 to 14.13. The hybrids differed significantly for number of flower clusters per plant. Among all the hybrids, maximum number of flower clusters per plant was observed in Utkal Urwasi x Palam Pink (14.13) followed by statistically *at par* values in NDT-7 x S-2 (13.83) and check Pusa Hybrid-1 (13.53). Whereas, minimum number of flower clusters per plant was observed in Gujrat Tomato-3 x Swarna Lalima (7.33). The population mean for this trait was 11.48. The results of present investigation could also be compared with findings of Sekhar *et al.*, (2009) (19.47 to 36.27), Alam *et al.*, (2010) from (5.7 to 7.5) and Singh *et al.*, (2014) (6.00 to 8.33) in tomato hybrids (Table 1).

Number of flowers per cluster

Perusal of the data on number of flowers per cluster indicated that maximum number was recorded in Utkal Urwasi x Palam Pink (8.00) followed by Palam Pink x Pusa Sadabahar (7.93), S-2 x Utkal Uphar (7.70), Utkal Urwasi x Gujrat Tomato-3 (7.63), Pusa Uphar x Utkal Kumari (7.63) and CO-3 x Pusa Sadabahar (7.36) which were statistically *at par*. Lowest number of flowers per cluster was noted in NDT-7 x S-2 (5.46). The general mean of the population for this trait was 6.72. More number of flowers per cluster might be associated with more number of fruit setting in a particular hybrid under congenial agroclimatic conditions. Similar results on

variation in number of flowers per clusters have also been reported by Shankar *et al.*, (2013) from 4.53 to 6.37, Cheema *et al.*, (2013) from 4.00 to 9.00 and Sekhar *et al.*, (2009) from 4.87 to 7.20 in tomato hybrids and open pollinated varieties (Table 1).

Fruit set percentage

Significant differences were observed among the hybrids with respect to fruit set percentage. It varied between 33.33% and 85.71%. Utkal Urwasi x Palam Pink had greater potentiality to exhibit maximum fruit setting (85.71%) which was significantly higher than all the other hybrids tested in present investigation. This was a consequence of production of more number of flower cluster per plant and less effect of adverse climatic conditions like rainfall and wind velocity during crop growth and development. The other hybrids with higher fruit set percentage were Marglobe x Palam Pink (75.0%) and Palam Pink x Pusa Sadabahar (75.0%). From the results it is evident that the hybrids exhibiting higher fruit setting percentage had one parent Palam Pink in common. Minimum value for fruit set percentage was observed in Himsona (33.33%). The population mean was 66.71%. Fruit set percentage in tomato is one of the important parameter for the rainy season tomato yield in hills, which is also a measurement of a particular hybrid/variety towards tolerance to low temperature and high rainfall. In the most of cases, fruit setting ability of a particular hybrid/variety determines ultimate fruit yield in tomato (Alam *et al.*, 2010 and Singh *et al.*, 2014). While studying the performance of tomato hybrids, Alam *et al.*, (2010) also reported a range of fruit set percentage from 32.96% to 52.86%, Similarly Singh *et al.*, (2014) reported highest fruit set in cultivar Laxmi (80.50%) and lowest in PS-61 (50.65%) (Table 1).

Plant height at first flowering (cm)

The data pertaining to plant height at first flowering has been given in (Table 1). Maximum plant height was observed in S-2 x Utkal Uphar (20.60 cm) which was followed by Gujrat Tomato-3 x Pusa Sheetal (20.16 cm), Marglobe x Pusa Sadabahar (19.83 cm), NDT-7 x S-2 (19.60 cm), Azad T-6 x Punjab Chuhara (19.30 cm), CO-3 x Utkal Urwasi (18.60 cm), Himshikhar (18.53 cm), Himsona (18.53 cm), Azad T-6 x NDT-7 (18.46 cm), CO-3 x Pusa Sadabahar (18.33 cm), Palam Pink x Pusa Sadabahar (18.33 cm) and Gujrat Tomato-3 x Swarna Lalima (17.46 cm) with *at par* values. The lowest value of plant height was found in Utkal Kumari x Utkal Uphar (13.06 cm). The mean value of population was 17.82 cm.

Plant height at first picking (cm)

The data on plant height at first picking has been depicted in (Table 1). Perusal of the data revealed that the variability in plant height at first picking ranged from (18.50 cm) to (72.26 cm) and the maximum and significantly higher plant height was observed in CO-3 x Pusa Sadabahar (72.26 cm) followed by CO-3 x Utkal Urwasi (68.16 cm), check Pusa Hybrid-1 (68.13 cm), Azad T-6 x Punjab Chuhara (67.53 cm) and Abhilash (65.20 cm). Minimum plant height was observed in Utkal Urwasi x Gujrat tomato-3 (18.50 cm). The population mean for this trait was found to be (42.96 cm). The plant height at flowering and fruiting generally indicates the growth habit of the hybrids and according the potentiality of the cultivar/ hybrid could be guessed. Variable plant height of different hybrids was mainly due to differences in their genetic make-up. Variability in plant height at flowering and fruiting has also been obtained by Alam *et al.*, (2010) from 115.9 cm to 139.5 cm, Ali *et al.*, (2012) from 56.82 cm to 72.00 cm, Shankar *et al.*, (2013) from 48.33 cm to 153.63 cm, Sharma *et al.*, (2013) from 57.9

cm to 162.39 cm, Singh *et al.*, (2013) 53.73 cm to 83.67 cm and Saleem *et al.*, (2013) from 76 cm to 126 cm in hybrid tomatoes.

Number of primary branches

There was significant variation in number of primary branches across the hybrids (Table 2). The mean value for this trait exhibited a range of number of primary branches from 4.80 to 8.00. Maximum number of primary branches was found in S-2 x Utkal Uphar (8.00) followed by Azad T-6 x NDT-7 (7.93), Gujrat Tomato-3 x Swarna Lalima (7.76), check Pusa Hybrid-1 (7.46), Abhilash (7.40) and Gujrat Tomato-3 x Pusa Sheetal (7.13) which were statistically *at par* with each other. Minimum value was found in the Marglobe x Pusa Sadabahar (4.80). The population mean for number of primary branches was observed to be 6.595.

Number of secondary branches

Different hybrids exhibited significant differences in regard to number of secondary branches. The mean value for this trait exhibited a range of 25.46 to 39.23. Maximum number of secondary branches was found in Gujrat Tomato-3 x Swarna Lalima (39.23) which was significantly higher than that in other hybrids. Minimum value of number of secondary branches was found in the VS-2853 (25.46). The population mean for this trait was 32.28.

Variability in number of branches in tomato hybrids have also been reported by Alam *et al.*, (2010) from 4.3 to 6.7, Singh *et al.*, (2013) from 15.29 to 24.2 and Shankar *et al.*, (2013) from 5.33 to 10.60 (Table 2).

Leaf area

Leaf area represents photosynthetic plant surface area the product of which is stored in fruits. More leaf area means more

carbohydrate synthesis likely to occur for transformation in the fruits. Therefore, leaf area could also be a yield indicator of the hybrids. The analyzed data on leaf area is presented in (Table 2). Significantly higher value of leaf area was observed in Himsona (26.83 cm²). The other hybrids with higher leaf area were S-2 x Utkal Uphar (22.76 cm²), Utkal Urwasi x Palam Pink (22.50 cm²) and

Utkal Kumari x Utkal Uphar (21.13 cm²). While, minimum value of leaf area was exhibited by check Pusa Hybrid-1 (13.30 cm²). The population mean for this character was 19.09 cm². Variability in leaf area of tomato hybrids has also been reported by Ahmad *et al.*, (2007) from 8.0 to 10.0 cm², Babu *et al.*, (2012) from 10.2 to 18.24 cm² and Ali *et al.*, (2012) from 16.20 to 17.21 cm².

Table.1

| Hybrids | Days to first flower-ing | Internodal length(cm) | Number of flower per cluster | Number of flower cluster Per plant | Fruit set Percentage | Plant height at first flowering (cm) | Plant height at first picking (cm) |
|---------------------------------|--------------------------|-----------------------|------------------------------|------------------------------------|----------------------|--------------------------------------|------------------------------------|
| Gujrat Tomato-3 x Swarna Lalima | 31.00 | 5.25 | 6.69 | 7.33 | 66.66 | 17.46 | 18.90 |
| Azad T-6 x Punjab Chuhara | 34.00 | 6.50 | 6.43 | 8.26 | 66.66 | 19.30 | 67.53 |
| CO-3 X Pusa Sadabahar | 41.66 | 5.50 | 7.36 | 8.50 | 71.42 | 18.33 | 72.26 |
| Azad T-6 X NDT-7 | 35.33 | 5.25 | 6.96 | 9.30 | 71.46 | 18.46 | 26.20 |
| Utkal Kumari x Utkal Uphar | 32.00 | 4.25 | 7.00 | 9.50 | 71.48 | 13.06 | 26.20 |
| Pusa Uphar X Utkal Kumari | 32.66 | 5.75 | 7.63 | 8.56 | 71.50 | 17.00 | 47.93 |
| Marglobe x Palam Pink | 33.00 | 7.25 | 5.69 | 10.20 | 75.00 | 17.26 | 43.43 |
| Palam Pink x Pusa Sadabahar | 33.00 | 8.50 | 7.93 | 11.36 | 75.00 | 18.33 | 44.10 |
| Marglobe x Pusa Sadabahar | 29.00 | 7.75 | 6.73 | 11.90 | 66.66 | 19.83 | 35.20 |
| CO-3 X Utkal Urwasi | 29.33 | 8.25 | 5.83 | 13.36 | 60.00 | 18.60 | 68.16 |
| Utkal Urwasi x Gujrat Tomato-3 | 36.66 | 5.50 | 7.63 | 12.43 | 71.52 | 17.13 | 18.50 |
| S-2 X Utkal Uphar | 33.00 | 4.25 | 7.70 | 11.06 | 71.54 | 20.60 | 37.50 |
| Utkal Urwasi x Palam Pink | 32.00 | 5.75 | 8.00 | 14.13 | 85.71 | 15.00 | 37.06 |
| Gujrat Tomato-3 x Pusa Sheetal | 28.33 | 6.25 | 6.00 | 12.76 | 66.66 | 20.16 | 33.26 |
| NDT-7 x S-2 | 28.33 | 7.50 | 5.46 | 13.83 | 60.00 | 19.60 | 35.93 |
| Punjab Chuhara x Pusa Uphar | 33.00 | 8.25 | 6.46 | 12.43 | 66.66 | 16.86 | 33.06 |
| Abhilash | 28.33 | 6.75 | 6.16 | 12.63 | 60.00 | 16.46 | 65.20 |
| Pusa Hybrid-1 | 32.00 | 8.35 | 6.16 | 13.53 | 60.00 | 17.26 | 68.13 |
| Himshikhar | 27.00 | 6.25 | 6.20 | 13.30 | 60.00 | 18.53 | 57.03 |
| Himsona | 33.00 | 7.75 | 6.26 | 12.63 | 33.33 | 18.53 | 43.20 |
| VS- 2853 | 28.66 | 6.50 | 6.96 | 13.30 | 71.56 | 17.33 | 33.06 |
| Omnia | 26.33 | 7.75 | 6.56 | 12.26 | 60.00 | 17.06 | 33.16 |
| 'F'test | ** | ** | ** | ** | ** | * | ** |
| GM | 31.712 | 6.455 | 6.722 | 11.483 | 66.714 | 17.828 | 42.962 |
| SEM | 0.772 | 0.954 | 0.244 | 0.200 | 0.290 | 1.109 | 1.7554 |
| CD at 5% | 2.205 | 0.27 | 0.696 | 0.571 | 0.828 | 3.165 | 5.010 |
| CV % | 4.22 | 2.57 | 6.288 | 3.020 | 0.753 | 10.77 | 7.077 |

Table.2

| Hybrids | Number of primary branches | Number of secondary branches | Leaf area(cm ²) | Days to first picking | Node number of first flowering | Polar fruit diameter (cm) | Radial Fruit diameter (cm) |
|---------------------------------|----------------------------|------------------------------|-----------------------------|-----------------------|--------------------------------|---------------------------|----------------------------|
| Gujrat Tomato-3 x Swarna Lalima | 7.76 | 39.23 | 15.76 | 46.66 | 5.50 | 3.50 | 10.50 |
| Azad T-6 x Punjab Chuhara | 4.83 | 37.66 | 18.10 | 47.66 | 6.66 | 6.83 | 13.13 |
| CO-3 X Pusa Sadabahar | 6.80 | 36.71 | 20.83 | 60.00 | 11.03 | 8.00 | 15.16 |
| Azad T-6 X NDT-7 | 7.93 | 36.10 | 16.96 | 50.66 | 5.50 | 7.86 | 15.13 |
| Utkal Kumari x Utkal Uphar | 5.96 | 35.93 | 21.13 | 48.33 | 4.33 | 6.66 | 13.53 |
| Pusa Uphar X Utkal Kumari | 6.26 | 34.16 | 14.76 | 46.33 | 4.90 | 8.23 | 11.73 |
| Marglobe x Palam Pink | 6.06 | 34.13 | 22.13 | 48.33 | 6.56 | 7.43 | 14.66 |
| Palam Pink x Pusa Sadabahar | 7.10 | 33.23 | 17.23 | 52.33 | 6.03 | 7.90 | 17.13 |
| Marglobe x Pusa Sadabahar | 4.80 | 28.90 | 18.73 | 43.00 | 6.20 | 8.26 | 16.80 |
| CO-3 X Utkal Urwasi | 6.63 | 26.26 | 18.73 | 47.00 | 7.06 | 8.43 | 16.86 |
| Utkal Urwasi x Gujrat Tomato-3 | 6.76 | 30.33 | 18.70 | 52.31 | 5.50 | 8.30 | 15.70 |
| S-2 X Utkal Uphar | 8.00 | 31.96 | 22.76 | 47.00 | 6.90 | 8.46 | 14.73 |
| Utkal Urwasi x Palam Pink | 6.86 | 29.26 | 22.50 | 46.00 | 7.06 | 8.70 | 16.60 |
| Gujrat Tomato-3 x Pusa Sheetal | 7.13 | 29.70 | 18.03 | 44.00 | 5.20 | 8.53 | 16.46 |
| NDT-7 x S-2 | 6.20 | 33.10 | 18.93 | 47.66 | 6.16 | 11.33 | 14.73 |
| Punjab Chuhara x Pusa Uphar | 5.93 | 32.23 | 19.20 | 52.66 | 6.56 | 7.76 | 14.53 |
| Abhilash | 7.40 | 31.83 | 19.16 | 44.32 | 5.50 | 7.50 | 15.70 |
| Pusa Hybrid-1 | 7.46 | 30.56 | 13.30 | 48.00 | 5.00 | 8.50 | 15.56 |
| Himshikhar | 7.03 | 27.93 | 16.06 | 44.00 | 6.56 | 9.26 | 16.60 |
| Himsona | 5.86 | 32.80 | 26.83 | 47.00 | 6.86 | 8.49 | 14.53 |
| VS- 2853 | 6.00 | 25.46 | 19.56 | 45.33 | 6.06 | 8.09 | 15.23 |
| Omnia | 6.20 | 32.76 | 20.63 | 46.66 | 6.06 | 10.16 | 20.86 |
| 'F'test | ** | ** | ** | ** | ** | ** | ** |
| GM | 6.595 | 32.287 | 19.095 | 47.969 | 6.3575 | 8.102 | 15.269 |
| SEM | 0.306 | 0.303 | 0.422 | 0.896 | 0.481 | 0.220 | 0.780 |
| CD at 5% | 0.876 | 0.867 | 1.205 | 2.55 | 1.373 | 0.630 | 2.227 |
| CV % | 8.061 | 1.630 | 3.831 | 3.23 | 13.07 | 4.718 | 8.852 |

Table.3

| Hybrids | Fruit pericarp thickness | Number of fruit locules | Fruit volume (cm ³) | Specific gravity (g/cm ³) | Number of fruit per plant | Fruit weight (g) | Fruit Yield Per Plant (g) |
|--------------------------------|--------------------------|-------------------------|---------------------------------|---------------------------------------|---------------------------|------------------|---------------------------|
| Gujrat Tomato-3 x Swarn Lalima | 6.81 | 2.65 | 67.25 | 1.10 | 77.25 | 74.04 | 5784.59 |
| Azad T-6 x Punjab Chuhara | 2.72 | 3.00 | 30.31 | 2.69 | 71.25 | 80.71 | 5815.58 |
| CO-3 X Pusa Sadabahar | 3.14 | 2.33 | 36.25 | 2.60 | 66.65 | 93.77 | 6224.77 |
| Azad T-6 X NDT-7 | 5.60 | 4.66 | 52.81 | 1.20 | 62.20 | 106.17 | 6578.77 |
| Utkal Kumari x Utkal Uphar | 5.57 | 6.00 | 44.41 | 1.45 | 74.44 | 64.22 | 4825.53 |
| Pusa Uphar X Utkal Kumari | 3.94 | 6.00 | 73.25 | 0.98 | 73.25 | 71.62 | 5281.16 |
| Marglobe x Palam Pink | 4.09 | 3.00 | 62.52 | 1.51 | 65.45 | 93.82 | 6115.51 |
| Palam Pink x Pusa Sadabahar | 7.61 | 5.66 | 44.42 | 1.78 | 75.62 | 78.54 | 5954.19 |
| Marglobe x Pusa Sadabahar | 4.74 | 4.66 | 73.50 | 1.46 | 64.23 | 106.74 | 6855.91 |
| CO-3 X Utkal Urwasi | 6.04 | 2.25 | 62.50 | 1.40 | 69.25 | 87.18 | 6017.21 |
| Utkal Urwasi x Gujrat Tomato-3 | 5.52 | 2.66 | 51.50 | 1.86 | 73.25 | 94.95 | 6935.08 |
| S-2 X Utkal Uphar | 4.66 | 3.00 | 50.25 | 2.05 | 67.25 | 102.86 | 6897.33 |
| Utkal Urwasi x Palam Pink | 3.93 | 3.33 | 62.65 | 1.71 | 79.82 | 62.50 | 5008.75 |
| Gujrat Tomato-3 x Pusa Sheetal | 4.04 | 4.66 | 67.50 | 1.03 | 76.65 | 69.02 | 5310.38 |
| NDT-7 x S-2 | 4.71 | 3.00 | 85.81 | 1.01 | 64.25 | 86.66 | 5587.90 |
| Punjab Chuhara x Pusa Uphar | 5.33 | 6.00 | 66.50 | 1.24 | 69.25 | 82.21 | 5713.04 |
| Abhilash | 3.59 | 4.66 | 41.50 | 2.44 | 60.80 | 100.18 | 6075.94 |
| Pusa Hybrid-1 | 4.64 | 2.50 | 51.35 | 1.30 | 71.80 | 66.33 | 4787.49 |
| Himshikhar | 5.80 | 2.00 | 60.50 | 1.21 | 64.80 | 72.77 | 4740.49 |
| Himsona | 6.86 | 3.33 | 56.82 | 1.81 | 60.65 | 101.50 | 6130.97 |
| VS- 2853 | 3.87 | 2.23 | 55.86 | 1.30 | 65.25 | 71.97 | 4721.04 |
| Omnia | 7.03 | 5.66 | 106.80 | 0.86 | 59.25 | 106.12 | 5423.00 |
| 'F'test | ** | * | ** | ** | ** | ** | ** |
| GM | 5.006 | 3.77 | 59.075 | 1.582 | 68.666 | 84.481 | 5628.84 |
| SEM | 0.250 | 0.254 | 0.238 | 0.761 | 0.312 | 0.433 | 63.205 |
| CD at 5% | 0.714 | 0.725 | 0.681 | 0.217 | 0.889 | 1.237 | 180.38 |
| CV % | 8.656 | 11.67 | 0.699 | 8.333 | 0.787 | 0.889 | 1.94 |

Days to first picking

Tomato hybrids under this study exhibited significant difference for days to first picking in a range of 43 DAT to 60 DAT (Table 2). Minimum number of days to first picking were observed in Marglobe x Pusa Sadabahar (43.0 DAT) followed by Gujrat Tomato-3 x Pusa Sheetal (44.0 DAT), Himshikhar (44.0 DAT), Abhilash (44.32 DAT) and VS-2853 (45.33 DAT) which were statistically *at par* in early picking. The population mean for days to first picking was 47.0 DAT. The less number of days to first flowering and picking indicated earliness of the hybrid. The growing season of tomato in hills starts from March-April and ends in July-August, early hybrids or varieties are essentially required for better yield as during rainy season the crop is adversely affected by foliar diseases and low temperature.

Variability in days to first picking has also been observed by Alam *et al.*, (2010) from 89 to 99 DAT and Sharma *et al.*, (2013) from 62 to 82 DAT in tomato hybrids.

Node number of first flowering

There was significant difference among different hybrids for node number of first flowering. The mean values for node number of first flowering ranged from 4.33 to 11.03 (Table 2). The minimum value for node number of first flowering was observed in Utkal Kumari x Utkal Uphar (4.33) followed by Pusa Uphar x Utkal Kumari (4.90), check Pusa Hybrid-1 (5.00), Gujrat Tomato-3 x Pusa Sheetal (5.20), Abhilash (5.50), Utkal Urwasi x Gujrat Tomto-3 (5.50), Gujrat Tomato-3 x Swara Lalima (5.50) which were statistically *at par* with each other. The hybrid CO-3 x Pusa Sadabahar exhibited higher value for node number of first flowering (11.03). The population mean was 6.35. The node number of first flowering is an indicator

of earliness of the hybrid. Flower cluster initiation at lower nodes in certain hybrids indicated early bearing habit of those hybrids. Variability for node number of first flowering has also been reported by Chaurasia *et al.*, (2001) from 17.8 to 35.6 in hybrid tomato and Tasisa *et al.*, (2011) 11.70 to 25.00 in open pollinated tomato.

Polar fruit diameter (cm)

Significant difference for fruit length was noted among the hybrids evaluated. The mean value for the fruit length in different hybrids exhibited a range of 3.50 cm to 11.33 cm. Maximum fruit length was recorded in hybrid NDT-7 x S-2 (11.33 cm) which was significantly higher than that in other hybrids. The minimum value of fruit length was observed in Gujrat Tomato-3 x Swarna Lalima (3.50 cm). The population mean for fruit length was found 8.102 cm (Table 2). Fruit length was mainly due genetic make-up of the hybrids. Variability in fruit length of tomato hybrids has also been reported by Ali *et al.*, (2012) from 5.50 cm to 7.80 cm, Saleem *et al.*, (2013) from 4.04 cm to 6.75 cm, Shankar *et al.*, (2013) from 3.00 cm to 6.10 cm and Said *et al.*, (2014) from 3.9 cm to 6.5 cm.

Radial fruit diameter (cm)

There was a significant variation in fruit diameter across the hybrids (Table 2). Maximum fruit diameter was found in Omnia (20.86 cm) which was significantly higher than that in all other hybrids tested in present investigation and minimum value was recorded in Gujrat Tomato-3 x Swarna Lalima (10.50 cm). The population mean for fruit diameter was 15.269 cm. Fruit diameter and fruit length jointly contribute to fruit size which ultimately is related to fruit yield. Existence of variability among the hybrids for fruit size factors (fruit length and diameter)

may provide opportunity to select a hybrid with desirable fruit size.

Fruit pericarp thickness (mm)

The perusal of results on pericarp thickness indicated significant variation among the hybrids for this character. The mean value of the fruit pericarp thickness revealed a range of 2.72 mm to 7.61 mm. The maximum pericarp thickness was recorded in Palam Pink x Pusa Sadabahar (7.61 mm) which was statistically *at par* with that in Omnia (7.03 mm), Himsona (6.86 mm) and Gujrat Tomato-3 x Swarna Lalima (6.81 mm). Whereas, minimum pericarp thickness was observed in Azad T-6 x Punjab Chuhara (2.72 mm) (Table 3). Thick pericarp is a useful character in respect of postharvest handling of fruits during transportation. Since, pericarp cells contain a number of starch grains, therefore the cultivars where accumulation of assimilates in the pericarp was more, the thickness was also high. Almost similar findings on variability in fruit pericarp thickness of tomato hybrids have also been observed by Sekhar *et al.*, (2009) from 5.5 mm to 7.0 mm, Sharma *et al.*, (2013) from 3.44 mm to 6.79 mm, Cheema *et al.*, (2013) from 3.5 mm to 5.5 mm, Shankar *et al.*, (2013) from 3.83 mm to 6.70 mm and Singh *et al.*, (2014) from 3.10 mm to 5.89 mm.

Number of fruit locules

The analysed data on number of fruit locules presented in (Table 3) indicated that there was significant difference among the hybrids. The population mean was 3.77. The mean values on number of fruit locules showed a range between 2.00 to 6.00. The maximum number of fruit locules was observed in hybrids Punjab Chuhara x Pusa Uphar, Pusa Uphar x Utkal Kumari and Utkal Kumari x Utkal Uphar (6.00) followed by Omnia (5.66) and Palam Pink x Pusa Sadabahar (5.66) which

were statistically *at par* with each other. The minimum number of fruit locules was observed in Himshikhar (2.00). Similar results on variability in number of fruit locules have been obtained by Kurain *et al.*, (2001) from 2.4 to 5.0, Sekhar *et al.*, (2009) from 2.70 to 4.00, Shankar *et al.*, (2013) from 2.33 to 6.50 and Cheema *et al.*, (2013) from 2.00 to 4.50 in hybrid tomatoes. Variability in fruit diameter has also been reported by Singh *et al.*, (2013) from 3.36 cm to 6.47 cm polar diameter and 4.47 cm to 6.65 cm radial diameter, Singh *et al.*, (2014) from 3.13 cm to 5.43 cm and Degade *et al.*, (2015) from 10.58 cm to 12.42 cm in tomato hybrids.

Fruit volume (cm³)

The analysed data on fruit volume depicted that F₁ Omnia registered maximum value of fruit volume (106.80 cm³) which was significantly superior to the rest of hybrids. Minimum value of fruit volume (30.31 cm³) was observed in Azad T-6 x Punjab Chuhara. The grand mean of the population was noted as 59.075 cm³ (Table 3). Corresponding results on variability in fruit volume of tomato hybrids have also been reported by Shibli *et al.*, (1995) from 58.8 cm³ to 257.00 cm³.

Specific gravity of fruits (g/cm³)

Specific gravity of fruits in tomato indicates the quantity of food reserved in the cells and thus, specifies the nutritive value of fruits. There was significant difference in the specific gravity of fruits of different hybrids. The mean values for this character indicated a range of 0.86 g/cm³ in Omnia to 2.69 g/cm³ in Azad T-6 x Punjab Chuhara. The maximum value for this trait observed in the hybrid Azad T-6 x Punjab Chuhara (2.69 g/cm³) was followed by that in CO-3 x Pusa Sadabahar (2.60 g/cm³), Abhilash (2.44 g/cm³) and S-2 x Utkal Uphar (2.05 g/cm³). The minimum specific gravity of fruits was observed in

Omnia (0.86 g/cm³). The population mean for this trait was 1.58 g/cm³) (Table 3). A corresponding range of variability in specific gravity of fruits have also been realized by Shibli *et al.*, (1995) from 0.95 g/cm³ to 1.95 g/cm³ in tomato hybrids

Number of fruits per plant

The difference among the hybrids with respect to number of fruits per plant was highly significant which varied from 59.25 to 79.82. Maximum number of fruits per plant was observed in Utkal Urwasi x Palam Pink (79.82) which was significantly higher than that in all the other hybrids tested in present investigation. The other hybrids with comparatively higher number of fruits per plant were Gujrat Tomato -3 x Swarna Lalima (77.25), Gujrat Tomato-3 x Pusa Sheetal (76.65), Palam Pink x Pusa Sadabahar (75.62), Utkal Kumari x Utkal Uphar (74.44), Pusa Uphar x Utkal Kumari and Utkal Urwasi x Gujrat Tomato-3 (73.25). Minimum number of fruits per plant was found in the Omnia (59.25). The population mean for this trait was 68.66 (Table 3). In this investigation variation in the number of fruit per plant was due to the genetic make-up of the hybrids as all the hybrids tested were given almost similar type of cultural atmospheric and edaphic environments. The results of present study were in accordance with those reported by Sekhar *et al.*, (2009) who noted variability in number of fruits per plant from 27.00 to 73.53, Singh *et al.*, (2013) from 20.89 to 22.50, Saleem *et al.*, (2013) from 48 to 95 and Cheema *et al.*, (2013) from 7.50 to 32.00 in tomato hybrids and/or genotypes.

Fruit weight (g)

There was a highly significant difference among 22 hybrids with respect to fruit weight (Table 3). The fruit weight ranged between 62.50 g to 106.74 g. Maximum fruit weight

was registered in Marglobe x Pusa Sadabahar (106.74 g) followed by *at par* value in Azad T-6 x NDT-7 (106.17 g). The other hybrids with higher fruit weight were S-2 x Utkal Uphar (102.86 g), Himsona (101.50 g) and Abhilash (100.18 g). Minimum value for fruit weight was observed in Utkal Urwasi x Palam Pink (62.50 g). The population mean was 84.48. Generally, fruit weight is inversely associated with number of fruits per plant although both of these traits are principal yield attributing traits. The fruit weight which is a function of fruit size (fruit length and diameter) may be subject of consumer's or market choice but fruit number is independent of the purpose of end use. Therefore, preference should be given to the hybrids with higher number of fruits per plant rather than those having big and bulking fruits. Corresponding to above results variability in average fruit weight and inverse association with number of fruits per plant have also been reported by Sekhar *et al.*, (2009) from 38.86 g to 67.14 g, Sharma *et al.*, (2013) from 30.77 g to 77.80 g, Singh *et al.*, (2013) from 65.00 g to 72.27 g, Cheema *et al.*, (2013) from 30.00 g to 52.50 g, and Degade *et al.*, (2015) from 16.80 g to 24.69 g in tomato hybrids. Said *et al.*, (2014) from 23.0 g to 69.8 g in open pollinated tomato.

Fruit yield per plant (g)

The fruit yield is supposed to be the ultimate economic trait in tomato as well as other fruit vegetables. Fruit yield per plant is an accurate assessment of potentiality of a particular hybrid at individual plant level. The data on fruit yield per plant exhibited a wide variability among the hybrids evaluated. Highest fruit yield per plant was observed in Utkal Urwasi x Gujrat Tomato-3 (6935.08 g) followed by statistically *at par* values in S-2 x Utkal Uphar (6897.33 g) and Marglobe x Pusa Sadabahar (6830.91 g). The F₁S VS-2853, Himshikhar and check Pusa Hybrid-1

exhibited comparatively lower fruit yield per plant *i.e.* 4721.04 g, 4740.49 g and 4787.49 g, respectively. The mean of population for this trait was 5628.84 g (Table 3). The results indicated that certain hybrids developed from crosses between commercial grown open-pollinated varieties were more heterotic as compared to commercial F₁ hybrids developed by different organizations. The cumulative results of fruit weight, number of fruit per plant and fruit yield per plant proved that the hybrids exhibiting maximum number of fruits per plant (Utkal Urwasi x Palam Pink) or maximum fruit weight (Azad T-6 x NDT-7) did not have maximum fruit yield per plant. This was because of the fact that the hybrid with highest number of fruit per plant had lower fruit weight and *vice versa*. The hybrid having highest fruit yield per plant *i.e.* Utkal Urwasi x Gujrat Tomato-3 (6935.08 g) had comparatively higher number of fruits per plant (73.25) as well as heavier fruits (94.95 g). Variability in fruit yield per plant in tomato hybrids have also been reported by Sharma *et al.*, (2013) from 681.00 g to 1278.19 g, Singh *et al.*, (2013) from 1000.36 g to 1000.63 g, Saleem *et al.*, (2013) from 1000.93 g to 3000.72 g, Shankar *et al.*, (2013) from 1000 g to 3000.90 g.

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