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*RESEARCH PAPER*

# Predicting magnitude of variability and genetic divergence for yield and quality traits in tomato (*Solanum lycopersicum* L.)

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**Abstract :** Thirty genotypes of tomato including one check cultivar (*Solan lalima*) were planted in Randomized Complete Block Design, during *Kharif*, 2014 and were assessed to know the nature and magnitude of variability and genetic divergence for 17 horticultural traits. The experimental results revealed a wide range of variability for all the traits under study. High heritability coupled with high genetic gain was observed for marketable fruit yield (89.60 and 56.02%), lycopene content (92.40 and 50.40%) and buckeye rot incidence (80.00 and 56.12%), which offers the better scope for improvement through selection. Based on the Mahalanobis $D^2$ statistics, 30 genotypes of tomato were grouped into four clusters. Maximum number of genotypes were accommodated in the cluster-IV (13) followed by cluster-III (8), cluster-II (7) and I (2). Highest inter cluster distance (8.789) was recorded between cluster I and III, hence, crossing between the genotypes of these cluster is expected to yield more heterotic hybrids. On the other hand, five genotypes *viz.*, LC-8, AVTO9001, LC-9, Punjab Chhuhara and AVTO0201 belonging to cluster-III performed better for most of the horticultural traits under study. These genotypes need further testing to be released as a substitute of already existing tomato varieties or these can be crossed with diverse genotypes of other clusters for the development of superior varieties /hybrids in tomato.

**Key Words :** Clusters, Diversity, Genetic variability, Quality, Tomato

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## INTRODUCTION

Tomato belonging to the family solanaceae is an important vegetable crop of the world and ranks next to potato in terms of its importance. It has wider adaptability, high yielding potential and multipurpose uses in fresh as well as processed food industries. Therefore, identification and development of new cultivars is important to improve production and productivity of

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tomato (Kumar *et al*., 2013a). Planning and execution of a breeding programme for the improvement of quantitative traits depends, to a great extent, upon magnitude of genetic variability (Kumar *et al*., 2013b). Genetic variability for yield and its component traits is essential in the base population for successful crop improvement (Allard, 1960). Tomato has a wide range of variability, which provides a tremendous scope for genetic improvement of its economic traits (Singh and Ramanujam, 1981). An improvement in yield and quality of tomato is normally achieved by selecting the genotypes with desirable trait combinations existing in nature or by hybridization. The crop improvement also depends upon the extent to which desirable traits are heritable. Heritable variation can effectively be studied in conjunction with genetic advance. High heritability alone is not enough to make efficient selection in segregation, unless the information is accompanied for substantial amount of genetic advance (Johnson *et al.*, 1955). Further, information on genetic diversity is used to identify the promising diverse genotypes, which may be used in further breeding programmes. Therefore, keeping in view the above facts in mind the present study has been conducted to obtain information on the extent of genetic variability and divergence among 30 genotypes of tomato and to assess their utility in developing heterotic combinations for commercial use.

## MATERIAL AND METHODS

The present investigation was carried out at Vegetable Research and Demonstration block of College of Horticulture, VCSG Uttarakhand University of Horticulture and Forestry, Bharsar during *Kharif* 2014. The site of experiment is located at latitude of 30.056$^{o}$ N and longitude 78.99$^{o}$ E and at an elevation of 1900-2200 meters above mean sea level. This region falls in sub-humid, sub-temperate and mid-hill zone of Uttarakhand. The maximum temperature is recorded during May-June (30$^{o}$C-35$^{o}$C), however, nights are cool. December and January are the coldest months with minimum temperature ranges between -4$^{o}$C to 1$^{o}$C. Relative humidity is normally highest during rainy season (July-August), which is often recorded near to the saturation point (92-97%) (Bisht and Sharma, 2014). The soil of experimental site was sandy loam in nature. The experimental materials comprised of 30 genotypes of tomato (LC-1, LC-2, LC-3, LC-4, LC-5, LC-6, LC-7, LC-8 LC-9, LC-10, Arka Alok, Arka Abha, Arka Meghali, Arka Vikas, Arka Saurabh, Punjab Chhuhara, Pant T-3, Roma, Sioux, Solan Lalima, AVTO0201, AVTO9803, AVTO9001, AVTO0101, AVTO1173, AVTO1002, AVTO1130, AVTO1219, AVTO1314 and AVTO1315) collected from different indigenous and exotic sources. The experiment was laid out in Randomized Complete Block Design at a spacing of 60 cm × 45 cm in the plots having size 1.8 m × 1.8 m, accommodating 12 plants of each genotype and replicated thrice. The standard agronomic practices were followed to maintain healthy crop stand. The observations were recorded from five randomly selected plants of each replication of every genotype on fifteen traits *viz.*, days to first fruit harvesting (days), fruit length (cm), fruit breadth (cm), average fruit weight (g), number of fruit clusters per plant, number of fruits per cluster, number of fruits per plant, harvest duration (days), marketable fruit yield per plant (kg), shelf- life (days), pericarp thickness (mm), lycopene content (mg/100g), total soluble solids ($^{o}$Brix), buckeye rot incidence (%) and fruit borer incidence (%). The mean values of data were subjected to the analysis of variance as per the procedure described by Gomez and Gomez (1983). The genotypic and phenotypic co-efficients of variation were calculated as per formulae given by Burton and De-Vane (1953). Heritability and genetic advance were calculated according to Allard (1960) and genetic gain was estimated as per the method given by Johnson *et al.* (1955). Multivariate analysis was done utilizing Mahalanobis $D^2$ statistics and genotypes were grouped into different clusters following Tochers method as described by Rao (1952) and Mahalanobis (1936).

## RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

**Variability studies:**

The analysis of variance revealed significant differences among different genotypes for all the traits under study (Table 1), which revealed the existence of good amount of variability in the available germplasm. The mean performance of different genotypes as given in Table 2 revealed a wide range of variability for all the horticultural traits under study *viz*., days to first fruit harvesting (64.00-80.00 days), fruit length (3.10-6.22 cm),

fruit breadth (2.74-6.35 cm), average fruit weight (22.98-75.90 g), number of fruit clusters per plant (3.53-7.50), number of fruits per cluster (2.74-5.61), number of fruits per plant (15.10-34.61), harvest duration (21.33-49.33 days), marketable fruit yield per plant (0.43-1.98 kg), per plot (5.20-23.74 kg) and per hectare (128.48-586.11 q), shelf life (13.33-31.00 days), pericarp thickness (1.59-7.05 mm), lycopene content (3.41-9.02 mg/100g), total soluble solids (3.17-5.60 $^{o}$Brix), buckeye rot incidence (9.73-32.15 %) and fruit borer incidence (9.38-30.75 %), which again revealed the existence of good deal of variability in the germplasm and offers the opportunity for improvement in yield and quality traits of tomato. Similar results for different horticultural traits had also been reported earlier by Kumari *et al*. (2007); Buckseth *et al*. (2012); Iqbal *et al*. (2013); Kumar *et al*. (2013a); Patel *et al*. (2013) and Reddy *et al*. (2013) in tomato.

The estimation of phenotypic and genotypic co-efficients of variation gave a clear picture of amount of variations present in the available germplasms (Table 3). For all the traits studied, phenotypic co-efficients of variation were higher in magnitude than genotypic co-efficients of variation, though difference was very less in majority the cases. Thus, showing that these traits are less influenced by environmental factors. Generally, coefficients of variation varied in magnitude from character to character (either low or moderate or high). Therefore, it indicated that there was a great diversity in the experimental material used. The genotypic co-efficients of variation (GCV) were recorded high for buckeye rot incidence, whereas moderate GCV was observed for marketable fruit yield per plot, marketable fruit yield per hectare, marketable fruit yield per plant, fruit borer incidence, lycopene content, pericarp thickness, average fruit weight, shelf-life, number of fruits per cluster, number of fruits per plant, fruit length, number of fruit clusters per plant, fruit breadth and harvest duration, while phenotypic co-efficients of variation were recorded low in magnitude for days to first fruit harvesting and total soluble solids. Earlier workers like Rahaman *et al*. (2012) and Patel *et al*. (2013) had also reported similar genotypic co-efficients of variation trends for different traits under study.

The genotypic co-efficient of variation does not offer full scope to estimate the variations that are heritable and therefore, estimation of heritability becomes necessary. The estimates of heritability (broad sense) varied from 63.90-96.20 per cent for different traits under study (Table 3). Further, genetic gain (expressed as per cent of population mean) was found low to high in nature and ranged from 11.54-56.35 per cent for different horticultural traits (Table 3). In the present studies, high

**Table 1: Analysis of variance for various horticultural traits in tomato**

| Source of variation | Replication | Treatment | Error |
|---|---|---|---|
| Degree of freedom | 2 | 29 | 58 |
| Days to first fruit harvesting (days) | 2.31 | 55.86* | 1.82 |
| Fruit length (cm) | 0.037 | 1.99* | 0.03 |
| Fruit breadth (cm) | 0.18 | 1.64* | 0.04 |
| Average fruit weight (g) | 43.18 | 488.05* | 13.68 |
| Number of fruit clusters per plant | 0.09 | 2.26* | 0.13 |
| Number of fruits per cluster | 0.39 | 1.96* | 0.10 |
| Number of fruits per plant | 7.00 | 61.19* | 2.31 |
| Harvest duration (days) | 2.43 | 92.70* | 1.19 |
| Marketable fruit yield per plant (kg) | 0.07 | 0.40* | 0.01 |
| Marketable fruit yield per plot (kg) | 10.09 | 58.75* | 2.87 |
| Marketable fruit yield per hectare (q) | 6152.45 | 35816.15* | 1333.50 |
| Shelf-life (days) | 1.64 | 41.92* | 1.64 |
| Pericarp thickness (mm) | 0.21 | 5.01* | 0.13 |
| Lycopene content (mg/100g) | 0.01 | 7.74* | 0.20 |
| Total soluble solids ($^{o}$Brix) | 0.19 | 0.72* | 0.11 |
| Buckeye rot incidence (%) | 3.29 | 109.33* | 8.43 |
| Fruit borer incidence (%) | 1.92 | 125.24* | 10.85 |

* indicate significance of value at P=0.05

**Table 2: Mean performance of 30 genotypes for different horticultural traits in tomato**

| Genotypes/Traits | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LC-1 | 76.00 | 4.01 | 4.50 | 43.31 | 5.40 | 4.73 | 25.53 | 39.33 | 1.11 | 13.30 | 328.45 | 16.67 | 5.05 | 6.50 | 4.60 | 10.36(18.67)* | 9.38(17.59) |
| LC-2 | 68.67 | 3.10 | 2.74 | 22.98 | 5.93 | 3.21 | 18.87 | 31.67 | 0.43 | 5.20 | 128.48 | 14.00 | 1.67 | 3.41 | 4.77 | 32.15(34.53) | 29.79(33.07) |
| LC-3 | 70.33 | 3.14 | 2.78 | 25.37 | 5.07 | 3.90 | 19.73 | 34.00 | 0.50 | 6.00 | 148.21 | 13.33 | 1.59 | 4.89 | 4.33 | 30.75(33.67) | 28.66(32.35) |
| LC-4 | 73.33 | 3.65 | 5.04 | 44.18 | 5.23 | 5.61 | 29.27 | 42.67 | 1.29 | 15.53 | 383.36 | 16.67 | 5.38 | 7.96 | 3.32 | 11.06(19.32) | 17.10(24.37) |
| LC-5 | 80.00 | 5.03 | 5.36 | 64.69 | 3.53 | 4.23 | 15.10 | 21.33 | 0.98 | 11.72 | 289.30 | 18.00 | 6.21 | 8.15 | 3.17 | 26.95(31.23) | 30.69(33.61) |
| LC-6 | 74.67 | 4.95 | 4.93 | 58.57 | 5.27 | 3.65 | 19.20 | 34.33 | 1.12 | 13.47 | 332.64 | 15.33 | 4.95 | 6.34 | 4.33 | 19.36(25.95) | 26.74(30.99) |
| LC-7 | 68.00 | 4.15 | 5.15 | 51.25 | 5.73 | 4.64 | 26.47 | 40.00 | 1.36 | 16.29 | 402.14 | 14.33 | 4.62 | 4.99 | 4.77 | 15.83(23.40) | 16.80(24.17) |
| LC-8 | 65.33 | 6.08 | 5.11 | 71.41 | 5.90 | 4.70 | 27.70 | 42.00 | 1.98 | 23.74 | 586.11 | 21.67 | 6.37 | 8.63 | 5.60 | 13.67(21.60) | 11.07(19.39) |
| LC-9 | 65.00 | 5.35 | 4.78 | 66.44 | 5.60 | 5.14 | 28.80 | 43.33 | 1.91 | 22.96 | 566.85 | 20.00 | 6.25 | 8.54 | 4.80 | 9.73(18.15) | 15.45(23.02) |
| LC-10 | 77.67 | 3.87 | 5.07 | 47.06 | 5.47 | 3.53 | 19.33 | 34.67 | 0.91 | 10.91 | 269.41 | 15.67 | 4.90 | 5.39 | 4.33 | 22.17(28.07) | 25.46(30.27) |
| Arka Alok | 69.00 | 4.54 | 5.09 | 55.53 | 4.17 | 4.53 | 18.87 | 33.33 | 1.05 | 12.61 | 311.31 | 14.00 | 4.12 | 8.87 | 4.37 | 26.06(30.65) | 22.73(28.46) |
| Arka Abha | 76.67 | 4.17 | 5.18 | 51.80 | 5.53 | 3.69 | 20.27 | 35.00 | 1.05 | 12.63 | 311.77 | 17.33 | 5.10 | 8.27 | 4.87 | 16.33(23.78) | 18.70(25.59) |
| Arka Meghali | 72.33 | 4.16 | 5.04 | 50.42 | 4.50 | 5.61 | 25.20 | 36.67 | 1.26 | 15.18 | 374.69 | 14.67 | 4.31 | 5.42 | 4.73 | 20.88(27.15) | 25.00(29.98) |
| Arka Vikas | 72.00 | 3.96 | 5.16 | 49.10 | 5.27 | 4.99 | 26.27 | 38.67 | 1.29 | 15.47 | 382.05 | 15.67 | 4.61 | 4.66 | 3.87 | 13.11(21.16) | 15.97(23.49) |
| Arka Saurabh | 73.33 | 4.17 | 5.31 | 53.14 | 4.93 | 4.93 | 24.33 | 39.00 | 1.29 | 15.50 | 382.79 | 15.00 | 4.41 | 5.74 | 4.17 | 15.41(23.09) | 22.33(28.19) |
| Punjab Chhuhara | 64.00 | 5.75 | 4.29 | 64.18 | 5.60 | 4.93 | 27.60 | 41.33 | 1.77 | 21.29 | 525.63 | 22.00 | 6.47 | 6.34 | 4.70 | 13.49(21.49) | 17.01(24.30) |
| Pant T-3 | 75.33 | 3.74 | 4.74 | 42.50 | 5.93 | 4.25 | 25.07 | 39.00 | 1.07 | 12.79 | 315.70 | 15.33 | 4.51 | 4.81 | 4.67 | 21.81(27.80) | 18.48(25.41) |
| Roma | 70.00 | 6.22 | 4.19 | 62.55 | 6.10 | 4.05 | 24.71 | 38.67 | 1.55 | 18.58 | 458.72 | 20.00 | 5.88 | 6.39 | 4.17 | 13.92(21.80) | 24.10(29.35) |
| Sioux | 79.67 | 4.98 | 6.35 | 75.90 | 4.53 | 3.75 | 17.00 | 25.67 | 1.29 | 15.49 | 382.39 | 17.33 | 5.10 | 9.02 | 3.70 | 18.86(25.68) | 21.54(27.61) |
| AVTO0201 | 68.33 | 5.32 | 5.42 | 69.11 | 6.40 | 3.89 | 24.86 | 39.00 | 1.72 | 20.62 | 509.13 | 23.00 | 6.76 | 5.18 | 4.90 | 15.39(23.06) | 13.51(21.47) |
| AVTO9803 | 67.67 | 3.36 | 3.34 | 29.41 | 6.20 | 5.58 | 34.61 | 49.33 | 1.02 | 12.27 | 302.95 | 31.00 | 7.05 | 4.54 | 5.00 | 20.50(26.90) | 17.46(24.66) |
| AVTO9001 | 68.33 | 5.23 | 5.20 | 65.27 | 7.50 | 3.95 | 29.65 | 43.00 | 1.94 | 23.23 | 573.47 | 22.33 | 6.57 | 4.43 | 4.50 | 14.35(22.22) | 15.37(23.07) |
| AVTO0101 | 77.33 | 4.72 | 4.69 | 53.10 | 5.53 | 3.34 | 18.37 | 32.67 | 0.98 | 11.71 | 289.11 | 19.67 | 5.78 | 4.71 | 4.60 | 30.32(33.37) | 29.27(32.71) |
| AVTO1173 | 73.67 | 5.16 | 5.18 | 64.11 | 6.03 | 3.26 | 19.63 | 34.33 | 1.26 | 15.11 | 373.01 | 21.00 | 6.18 | 4.76 | 4.33 | 20.18(26.65) | 28.92(32.37) |
| AVTO1002 | 75.00 | 5.06 | 4.66 | 56.66 | 6.73 | 3.03 | 20.42 | 31.00 | 1.16 | 13.91 | 343.49 | 20.67 | 6.08 | 6.36 | 4.50 | 23.78(29.17) | 28.45(32.20) |
| AVTO1130 | 75.33 | 5.05 | 4.61 | 55.97 | 5.53 | 3.89 | 21.38 | 33.00 | 1.20 | 14.35 | 354.27 | 20.33 | 6.16 | 7.58 | 4.73 | 18.87(25.69) | 19.93(26.50) |
| AVTO1219 | 73.67 | 5.12 | 5.10 | 62.89 | 5.33 | 3.72 | 19.76 | 32.00 | 1.25 | 14.99 | 370.00 | 19.67 | 5.96 | 5.94 | 4.17 | 22.28(28.08) | 27.21(31.38) |
| AVTO1314 | 68.67 | 4.59 | 5.08 | 57.39 | 7.07 | 3.17 | 22.37 | 35.67 | 1.29 | 15.44 | 381.15 | 19.00 | 5.76 | 5.36 | 4.50 | 19.84(26.43) | 27.14(31.38) |
| AVTO1315 | 74.33 | 5.00 | 4.55 | 54.59 | 7.33 | 2.74 | 20.05 | 33.33 | 1.09 | 13.14 | 324.36 | 21.33 | 6.34 | 5.25 | 4.77 | 20.85(27.06) | 30.75(33.63) |
| Solan Lalima (Check) | 69.00 | 5.25 | 5.02 | 63.17 | 5.20 | 5.07 | 26.35 | 40.00 | 1.67 | 19.99 | 493.53 | 20.67 | 6.26 | 8.55 | 4.83 | 13.15(21.16) | 11.20(19.51) |
| Mean | 72.09 | 4.63 | 4.79 | 54.40 | 5.62 | 4.19 | 23.23 | 36.47 | 1.26 | 15.11 | 373.15 | 18.52 | 5.35 | 6.23 | 4.47 | 19.05(25.57) | 21.54(27.34) |
| S.E. ± | 1.11 | 0.15 | 0.18 | 3.02 | 0.30 | 0.27 | 1.24 | 0.89 | 0.10 | 1.21 | 29.82 | 1.05 | 0.30 | 0.37 | 0.28 | 1.78 | 1.88 |
| C.D. (P=0.05) | 2.22 | 0.30 | 0.36 | 6.05 | 0.61 | 0.53 | 2.49 | 1.78 | 0.20 | 2.42 | 59.69 | 2.10 | 0.60 | 0.74 | 0.55 | 3.57 | 3.76 |

*Figures in the parenthesis are arc sine transformed

Whereas, 1=Days to first fruit harvesting (days), 2= Fruit length (cm) , 3=Fruit breadth (cm), 4= Average fruit weight (g), 5= Number of fruit clusters per plant, 6= Number of fruits per cluster, 7= Number of fruits per plant, 8= Harvest duration (days), 9= Marketable fruit yield per plant (kg), 10= Marketable fruit yield per plot (kg), 11= Marketable fruit yield per hectare (q), 12= Shelf life (days), 13= Pericarp thickness (mm), 14= Lycopene content (mg/100g), 15= Total soluble solids (°Brix), 16= Buckeye rot incidence (%) and 17= Fruit borer incidence (%)

heritability estimates coupled with high genetic gain were observed for marketable fruit yield, lycopene content and buckeye rot incidence, which indicated that these traits are under additive gene effects and are more reliable for effective selection (Panse, 1957). Similar results were also reported by Ghosh *et al*. (2010); Vyas *et al*. (2011); Al-Aysh *et al*. (2012); Buckseth *et al*. (2012); Kumar *et al*. (2013a); Patel *et al*. (2013) and Reddy *et al*. (2013) for these traits under study. High heritability coupled with moderate genetic gain observed for shelf- life, pericarp thickness, fruit length, fruit breadth, average fruit weight, number of fruit clusters per plant, number of fruits per

**Table 3: Estimates of phenotypic and genotypic co-efficients of variation, heritability, genetic advance and genetic gain for different traits in tomato**

| Sr. No. | Characters | Range | Mean ± SE(d) | Co-efficients of variation (%) | | Heritability (%) | Genetic advance | Genetic gain (%) |
|---|---|---|---|---|---|---|---|---|
| | | | | Phenotypic | Genotypic | | | |
| 1. | Days to first fruit harvesting (days) | 64.00-80.00 | 72.09±1.11 | 6.18 | 5.89 | 90.70 | 8.32 | 11.54 |
| 2. | Fruit length (cm) | 3.10-6.22 | 4.63±0.15 | 17.89 | 17.44 | 95.10 | 1.62 | 34.99 |
| 3. | Fruit breadth (cm) | 2.74-6.35 | 4.79±0.18 | 15.92 | 15.24 | 91.60 | 1.44 | 30.06 |
| 4. | Average fruit weight (g) | 22.98-75.90 | 54.40±3.02 | 24.09 | 23.12 | 92.00 | 24.84 | 45.66 |
| 5. | Number of fruit clusters per plant | 3.53-7.50 | 5.62±0.30 | 16.37 | 15.01 | 83.60 | 1.58 | 28.11 |
| 6. | Number of fruits per cluster | 2.74-5.61 | 4.19±0.27 | 20.36 | 18.81 | 85.40 | 1.50 | 35.80 |
| 7. | Number of fruits per plant | 15.10-34.61 | 23.23±1.24 | 20.16 | 19.07 | 89.40 | 8.63 | 37.15 |
| 8. | Harvest duration (days) | 21.33-49.33 | 36.47±0.89 | 15.44 | 15.14 | 96.20 | 11.16 | 30.60 |
| 9. | Marketable fruit yield per plant (kg) | 0.43-1.98 | 1.26±0.10 | 30.34 | 28.72 | 89.60 | 0.71 | 56.35 |
| 10. | Marketable fruit yield per plot (kg) | 5.20-23.74 | 15.11±1.21 | 30.36 | 28.74 | 89.60 | 8.47 | 56.06 |
| 11. | Marketable fruit yield per hectare (q) | 128.48-586.11 | 373.15±29.82 | 30.35 | 28.73 | 89.60 | 209.05 | 56.02 |
| 12. | Shelf-life (days) | 13.33-31.00 | 18.52±1.05 | 20.96 | 19.79 | 89.10 | 7.13 | 38.50 |
| 13. | Pericarp thickness (mm) | 1.59-7.05 | 5.35±0.30 | 24.81 | 23.83 | 92.30 | 2.52 | 47.10 |
| 14. | Lycopene content (mg/100g) | 3.41-9.02 | 6.23±0.37 | 26.47 | 25.45 | 92.40 | 3.14 | 50.40 |
| 15. | Total soluble solids ($^{o}$Brix) | 3.17-5.60 | 4.47±0.28 | 12.63 | 10.09 | 63.90 | 0.74 | 16.55 |
| 16. | Buckeye rot incidence (%) | 9.73-32.15 | 19.05±1.78 | 34.05 | 30.44 | 80.00 | 10.69 | 56.12 |
| 17. | Fruit borer incidence (%) | 9.38-30.75 | 21.54±1.88 | 32.49 | 28.67 | 77.80 | 11.22 | 52.09 |

**Table 4: Clustering pattern of 30 genotypes of tomato on the basis of genetic divergence**

| Cluster | Number of genotypes | Genotypes along with their sources |
|---|---|---|
| I | 2 | LC-2 (Kotdwara) and LC-3 (Uttarakashi) |
| II | 7 | LC-1 (Nainital), LC-4 (Tehri Garhwal), LC-7 (Sirmour), Arka Meghali (IIHR), Arka Vikas (IIHR), Arka Saurabh (IIHR) and Pant T-3 (GBPUAT) |
| III | 8 | LC-8 (Shimla), LC-9 (Bilaspur), Punjab Chhuhara (PAU), Roma (IARI), AVTO0201 (AVRDC), AVTO9803 (AVRDC), AVTO9001 (AVRDC) and Solan Lalima (UHF) |
| IV | 13 | LC-5 (Almora), LC-6 (Solan), LC-10 (Kangra), Arka Alok (IIHR), Arka Abha (IIHR), Sioux (IARI), AVTO0101 (AVRDC), AVTO1173 (AVRDC), AVTO1002 (AVRDC), AVTO1130 (AVRDC), AVTO1219 (AVRDC), AVTO1314 (AVRDC) and AVTO1315 (AVRDC) |

**Table 5: Average intra and inter cluster distance ($D^2$)**

| Cluster | I | II | III | IV |
|---|---|---|---|---|
| I | 0.986 | | | |
| II | 6.508 | 2.018 | | |
| III | 8.789 | 3.961 | 2.928 | |
| IV | 6.491 | 3.617 | 4.730 | 2.660 |

cluster, number of fruits per plant and harvest duration, indicated that these characters are under non-additive gene effects and selection for these characters will be less effective. Such traits are more under the influence of environment and do not respond to selection. Similar results for different traits under study were also reported by Joshi *et al*. (2004) and Mahesha *et al*. (2006).

**Genetic divergence analysis:**

Information on genetic diversity is used to identify the promising diverse genotypes, which may be used in further breeding programmes. Based on the Mahalanobis $D^2$ statistics, 30 genotypes of tomato were grouped into four clusters (Table 4). Maximum number of genotypes were accommodated in the cluster-IV (13) followed by cluster-III (8), cluster-II (7) and I (2). It is interesting to notice that genotypes from the same place of collection were placed in separate clusters, indicating wide genetic diversity among them. This may be due to frequent exchange of germplasm between different geographical regions. The intra cluster distance was found maximum in cluster III (2.928) and minimum in cluster I (0.986). Whereas, highest inter cluster distance (8.789) was recorded between cluster I and III and lowest (3.617) was observed between cluster II and IV (Table 5). Theoretically, crossing of genotypes belonging to same cluster will not expect to yield superior hybrids or segregants. But diverse genotypes characterized by maximum inter cluster distance will differ in phenotypic performance and therefore, chances to obtain favourable transgressive seggregants are more on the basis of results obtained.

The existence of diversity among the genotypes was also assessed by the considerable amount of variations observed in cluster means for different traits (Table 6). Cluster-III exhibited most desirable means for days to first fruit harvesting, fruit length, average fruit weight, number of fruit clusters per plant, number of fruits per plant, harvest duration, shelf- life, pericarp thickness, total soluble solids, buckeye rot incidence, fruit borer incidence, marketable fruit yield per plant, whereas cluster-IV exhibited higher means for lycopene content and fruit breadth, while cluster-II was found superior for number of fruits per cluster. Crossing between the genotypes of two clusters appeared to be most promising to combine the desirable characters. In the present investigations, cluster I and III were found more divergent and there will be more chances of getting better segregants in $F_2$ and subsequent generations from the crossing genotypes from cluster I and III. Earlier workers like Kumar *et al*. (2013a); Reddy *et al*. (2013); Iqbal *et al*. (2013); Nalla *et al*. (2014); Srivastava *et al*. (2014); Bernousi *et al*. (2011) and Thapa *et al*. (2014) have also indicated the significance of genetic divergence in tomato.

**Table 6: Cluster means for different characters in 30 genotypes of tomato**

| Sr. No. | Characters | Clusters | | | |
|---|---|---|---|---|---|
| | | I | II | III | IV |
| 1. | Days to first fruit harvesting (days) | 69.50 | 72.90 | 67.21 | 75.05 |
| 2. | Fruit length (cm) | 3.12 | 3.98 | 5.32 | 4.80 |
| 3. | Fruit breadth (cm) | 2.76 | 4.99 | 4.67 | 5.07 |
| 4. | Average fruit weight (g) | 24.18 | 47.70 | 61.44 | 58.33 |
| 5. | Number of fruit clusters per plant | 5.50 | 5.29 | 6.06 | 5.54 |
| 6. | Number of fruits per cluster | 3.56 | 4.97 | 4.66 | 3.58 |
| 7. | Number of fruits per plant | 19.30 | 26.02 | 28.03 | 19.37 |
| 8. | Harvest duration (days) | 32.83 | 39.33 | 42.08 | 32.03 |
| 9. | Shelf-life (days) | 13.67 | 15.48 | 22.58 | 18.41 |
| 10. | Pericarp thickness (mm) | 1.63 | 4.70 | 6.45 | 5.59 |
| 11. | Lycopene content (mg/100g) | 4.15 | 5.73 | 6.57 | 6.61 |
| 12. | Total soluble solids ($^o$Brix) | 4.55 | 4.30 | 4.81 | 4.34 |
| 13. | Buckeye rot incidence (%) | 31.45 | 15.49 | 14.28 | 21.99 |
| 14. | Fruit borer incidence (%) | 29.23 | 17.87 | 15.65 | 25.97 |
| 15. | Marketable fruit yield per plant (kg) | 0.47 | 1.24 | 1.69 | 1.13 |

## Conclusion:

From the present investigation, it can be concluded that five genotypes *viz.*, LC-8, AVTO9001, LC-9, Punjab Chhuhara and AVTO0201 belonging to cluster-III performed better for most of the horticultural traits except number of fruits per cluster, fruit breadth and lycopene content. These genotypes need further testing to be released as a substitute of already existing tomato varieties or these can be crossed with other genotypes of cluster-II (superior for number of fruits per cluster) and cluster-IV (superior for fruit breadth and lycopene content) for the development of superior varieties or hybrids in tomato.

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## REFERENCES

**Al-Aysh, F., Al-Serhan, M., Al-Shareef, A., Al-Nasser, M. and Kutma, H. (2012).** Study of genetic parameters and character interrelationship of yield and some yield components in tomato (*Solanum lycopersicum* L.). *Internat. J. Genet.*, **2**: 29-33.

**Allard, W. (1960).** *Principles of plant breeding*. John Willey and Sons. Inc. London, pp. 83-108.

**Bernousi, I., Emami, A., Tajbakhsh, M., Darvishzadeh, R. and Henareh, M. (2011).** Studies on genetic variability and correlation among the different traits in *Solanum lycopersicum* L. *Not. Bot. Horti. Agrobo.*, **39** (1):152-158.

**Bisht, A.S. and Sharma, K.D. (2014).** Plant utilization by the communities of Bharsar and adjoing area of Pauri Garhwal District, Uttarakhand, India. *Biodiversitas*, **15** : 94-100.

**Buckseth, T., Sharma, M.K. and Thakur, K.S. (2012).** Genetic diversity and path analysis in tomato (*Solanum lycopersicum* L.). *Veg. Sci.*, **39** (2): 221-223.

**Burton, G.W. and De Vane, E.H. (1953).** Estimating heritability in tall fescue (*Festuca arundinacea*) from replicated clonal material. *Agron. J.*, **45**: 478-481.

**Ghosh, K.P., Islam, A.K.M.A., Milan, M.A.K. and Hossian, M.M. (2010).** Variability and character association in $F_2$ segregating population of different commercial hybrids of tomato (*Solanum lycopersicum* L.). *J. Appl. Sci. Environ. Manage*, **41**(2): 91-95.

**Gomez, K.A. and Gomez, A.A. (1983).** *Statistical procedures for agricultural research*. John Wiley and Sons Inc., New York. pp. 357-427.

**Iqbal, M., Ahmad, W., Shafi, J., Ayub, C.M., Atiq, M., Shahid, M. and Saleem, M. (2013)**. Comparative genetic variability and heritability in some tomato varieties against fruit borer, shape disorders and their correlation. *J. Biosci. Bioeng.*, **1**(2): 17-23.

**Johnson, H.W., Robinson, H.F. and Comstock, R.E. (1955).** Estimates of genetic and environmental variability in soybean. *Agron. J.*, **47** (7): 314-318.

**Joshi, A., Vikram, A. and Thakur, M.C. (2004).** Studies on genetic variability, correlation and path analysis for yield and physico-chemical traits in tomato (*Lycopersicon esculentum* Mill.). *Prog. Horti.*, **36** (1) : 51-58.

**Kumar, D., Kumar, R., Kumar, S., Bhardwaj, M.L., Thakur, M.C., Kumar, R. Thakur, K., Dogra, B.S., Vikram, A., Thakur, A. and Kumar, P. (2013a).** Genetic variability, correlation and path co-efficient analysis in tomato. *Int. J. Veg. Sci.*, **19**(4): 313-323.

**Kumar, S., Kumar, D., Kumar, R., Thakur, K.S. and Dogra, B.S. (2013b)**. Estimation of genetic variability and divergence for fruit yield and quality traits in cucumber (*Cucumis sativus* L.) in North-Western Himalays. *Univ. J. Plant Sci.*, **1**(2): 27-36.

**Kumari, N., Srivastava, J.P., Shekhavat, A.K.S., Yadav, J.R. and Singh, B. (2007).** Genetic variability and heritability of various traits in tomato (*Lycopersicon esculentum* Mill.). *Prog. Agri.*, **7**(1/2): 80-83.

**Mahalanobis, P.C. (1936).** On the generalized distance in statistics. *Proceedings of National Academic Science (India)* **2**: 79-85.

**Mahesha, D.K., Apte, U.B. and Jadhav, B.B. (2006).** Genetic variability in tomato (*Lycopersicon esculentum* Mill.). *Res. Crops*, **7**(3): 771-773.

**Nalla, M.K., Rana, M.K., Singh, S.J., Sinha, A.K., Reddy, P.K., and Mohapatra, P.P. (2014).** Assessment of genetic diversity through $D^2$ analysis in tomato *(Solanum lycopersicon* L.*). Intl. J. Innovation & App. Stud.*, **6**(3): 431-438.

**Patel, S.A., Kshirsagar, D.B., Attar, A.V. and Bhalekar, M.N. (2013).** Study on genetic variability, heritability and genetic advance in tomato. *Internat. J. Plant Sci.*, **8**(1): 45-47.

**Rahaman, S., Lakshman, S.S. and Maitra, N.J. (2012).** Genetic variability and heritability studies in tomato (*Lycopersicon esculentum* Mill.). *Internat. J. Plant Sci.*, **7**(1): 58-62.

**Rao, R. (1952).** *Advanced statistical methods in biometrical research.* John Willey and sons Inc., New York, pp. 357-363.

**Reddy, B.R., Reddy, D.S., Reddaiah, K. and Sunil, N. (2013).** Studies on genetic variability, heritability and genetic advance for yield and quality traits in tomato (*Solanum lycopersicum* L.). *Int. J. Curr. Microbiol. App. Sci.*, **2**(9): 238-244.

**Singh, S.P. and Ramanujam, S. (1981).** Genetic divergence and hybrid performance in *Cicer arietinum. Indian J. Genet.*, **41**: 268-276.

**Srivastava, M.K., Vishal, K., Agrawal and Agrawa, R.K. (2014).** Estimation of genetic divergence among indigenous and exotic accessions of tomato (*Solanum lycopersicum* L.). *Asian J. Bio. Sci.*, **9**(1): 30-34.

**Thapa, R.P., Jha, A.K., Deka, B.C., Reddy, A.N., Verma, V.K. and Yadav, R.K. (2014)**. Genetic divergence in tomato grown in subtropical mid-hills of Meghalaya. *Indian J. Hort.*, **71**(4): 581-583.

**Vyas, M., Singh, A.K., Rai, V.K. and Mishra, R. (2011).** Genetic variability, correlation and path co-efficient analysis of tomato (*L.esculentum esculentum* Mill.). *Environ. Ecol.*, **29**(3): 1076-1081.