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ESTIMATION OF GENETIC VARIATION, HERITABILITY AND GENETIC ADVANCE IN TOMATO (*SOLANUM LYCOPERSICUM* L.) FOR VITAL HORTICULTURAL TRAITS UNDER KASHMIR'S TEMPERATE CLIMATE

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ABSTRACT

In a field experiment, twenty-seven genotypes of tomato were examined in order to determine the genetic variability, heritability and genetic advance for various growth and yield traits. Randomized Block Design (RBD) with 3 replications were used to conduct the experiment. Number of fruits plant-^{1} had the highest phenotypic and genotypic coefficients of variability, followed by lycopene content (mg/100g), fruit yield plot^{-1} (kg), number of locules fruit^{-1} and fruit length and diameter (cm). In contrast, pericarp thickness (cm), ascorbic acid content (mg/100g), plant height (cm) and plant spread (cm) displayed moderate coefficients of variability.All of the traits have been found to possess high heritability (bs). For each attribute, with the exception of days to 50% flowering and days to red ripen fruit stage, a high genetic advance has also been seen. The highest genetic advance (percentage of mean) and highest heritability were demonstrated by the lycopene content (mg/100g), which was followed by fruit yield plot^{-1} (kg), number of fruits plant^{-1}, fruit length and diameter (cm), and number of locules fruit^{-1}. Additive gene action controls attributes exhibiting high genotypic and phenotypic coefficient of variability, high heritability, along with genetic advance. Thus, it will be more beneficial to select the characters based on phenotypic performance.

Key words : Genetic variation, Heritability, Genetic advance, Fruit yield, Tomato.

Introduction

One of the most significant vegetable crops cultivated worldwide is the tomato (*Solanum lycopersicum* L.). Herbaceous plants with short the lifespans that are annuals or perennials make up the genus Lycopersicon. The tomato is a typical day-neutral plant that pollinates primarily by self with a little amount via cross-pollination as well. It is a warm-season crop that can thrive in a variety of soil types and climates and is quite resistant to heat and drought. Because of its nutritious characteristics, which guard the body from several ailments, it is referred to as a protective vegetable. Additionally, it is the vegetable that gets processed the most. When it comes to canned veggies, tomatoes come in first. Ripe fresh tomato fruit is used to make a variety of processed items, including puree, paste, powder, ketchup, sauce, soup and canned whole fruits. It is also eaten raw in salads and after cooking. Chutneys and pickles are made from unripe green fruits. Tomatoes are prized for their color and flavor and are a good source of β-carotene, ascorbic acid and the antioxidant lycopene.

Over time, tomato cultivation has expanded both in area and yield. China is the leader in tomato production and area, with India coming in second. Madhya Pradesh is the top producing state in India, with Karnataka, Andhra Pradesh, Tamil Nadu and Gujarat following closely after. In an area of around 0.81 million hectares, India produced 20.51 million metric tonnes of tomatoes in 2019–20. 16.1 metric tons of productivity is the average (NHB, 2nd Advance estimates, 2019–20).

The degree of genetic diversity in a population is a key factor in crop genetic improvement and germplasm is a useful source of base population with a wide range of genetic variability. The strengthening of plant traits both quantitative and qualitative is the main focus of vegetable breeders. In order to achieve the expected results in the generation, a vegetable breeding program must have a sufficient understanding of the genetics of numerous traits. The amount and quantity of variation present in the germplasm, however, determines the effectiveness of vegetable breeding. Meanwhile, heritable variation enables a possible improvement. Therefore, there is a need to increase tomato yield attributes. Thus, the primary focus should be on comprehensive knowledge about the genetic architecture of fruit yield and its characteristics. Knowledge of the type and extent of genetic variation as well as the frequency of trait transmission is crucial for the success of any crop improvement effort. The range of population variability may be divided into heritable and non-heritable components, such as phenotypic and genotypic coefficients of variation, heritability and genetic advance, on which selection can be used with efficacy. Breeders can choose the best variety for a certain character by considering heritability, which indicates the percentage of phenotypic variation owing to genotypes. Heritability, however, does not show the anticipated genetic advancement in a single selection cycle; rather, it just shows how well a genotype may be selected based on phenotypic performance. Unless information is accompanied by a significant quantity of genetic advance, high heritability alone is insufficient to perform efficient selection in segregating generations (Jhonson *et al*., 1955). Breeders can choose progenies from the earlier generation by using genetic advance, which is defined as an improvement in the mean genotypic values of chosen families over the base population.

Materials and Methods

The current study was carried out in the summer of 2021 at the Division of Vegetable Science's Experimental Farm, SKUAST-K, Shalimar, India. The experimental plot is situated at latitude 34° North and longitude 74.89° East. Summers are moderate and the climate is generally temperate. The months of March and April saw the most rainfall. Following Randomized Block Design (RBD), the genotypes were duplicated three times. Table 1 presents the genotype information along with their source. Each replication of the experimental plot includes 27 treatments, for a total of 81 treatments (genotypes). For both plant to plant and row to row, the spacing is 60 × 35 cm. To ensure a healthy crop, standard plant protection and cultural techniques were adhered to. INDOSTAT statistical software was used for all statistical analysis.

Table 1 : List of genotypes of tomato (*Solanum lycopersicum* L.).

S. no.	Genotype/variety	Source
1.	Kashi Hemanth	IIVR (Varanasi)
2.	Kashi Amrit	IIVR (Varanasi)
3.	Kashi Sharad	IIVR (Varanasi)
4.	Kashi Vishesh	IIVR (Varanasi)
5.	Kashi Chayan	IIVR (Varanasi)
6.	Kashi Aman	IIVR (Varanasi)
7.	Kashi Anupam	IIVR (Varanasi)
8.	TOLCV-16	IIVR (Varanasi)
9.	TOLCV-28	IIVR (Varanasi)
10.	TOLCV-32	IIVR (Varanasi)
11.	VRT-01	IIVR (Varanasi)
12.	VRT-19	IIVR (Varanasi)
13.	VRT-13	IIVR (Varanasi)
14.	Sel-7	IIVR (Varanasi)
15.	Jawahar-99	IIVR (Varanasi)
16.	2016/TOVDVAR-12	AICRP, IIVR (Varanasi)
17.	2016/TODVAR-11	AICRP, IIVR (Varanasi)
18.	2016/TODVAR-1	AICRP, IIVR (Varanasi)
19.	2016/TODVAR-3	AICRP, IIVR (Varanasi)
20.	2016/TODVAR-10	AICRP, IIVR (Varanasi)
21.	2016/TODVAR-5	AICRP, IIVR (Varanasi)
22.	2016/TODVAR-2	AICRP, IIVR (Varanasi)
23.	2015/TODHYB-4	AICRP, IIVR (Varanasi)
24.	2015/TODBYB-1	AICRP, IIVR (Varanasi)
25.	Roma	SKUAST-K, Shalimar
26.	Shalimar Hybrid Tomato-1	SKUAST-K, Shalimar
27.	Marglobe	SKUAST-K, Shalimar

Using mean data, the analysis of variance for different traits was performed to evaluate the variability among genotypes as reported by Panse and Sukhatme (1985). Burton's formula (1952) was used to calculate the amount of phenotypic co-efficient of variation (PCV) and genotypic co-efficient of variation (GCV) present in a trait. The Johnson *et al*. (1955) approach is used to calculate the genotypic and phenotypic variances. Broad sense heritability is calculated using the method established by Hanson *et al*. (1956) and Johnson *et al*. (1955). The genetic advance at 5% selection intensity was computed using Lush's (1949) formula.

Quality parameters

Ascorbic acid content (mg/100g) : The ascorbic acid concentration was measured in milligrams per 100 grams of fruits using the 2,6-dichlorophenol indophenol titration technique (A.O.A.C., 1960).

Lycopene content (mg/100g) : With minor adjustments, Lee's (2000) technique was used to

Table 2 : Analysis of variance for twelve characters in tomato (*Solanum lycopersicum* L.).

S. no.	Character	Mean sum of squares		
		Replication	Treatment	Error
	d.f	2	26	52
1.	Plant height (cm)	0.8492	342.5798**	2.3381
2.	Plant spread (cm)	5.9393	552.5597**	8.3681
3.	Days to 50% flowering	0.3144	19.1047**	0.1227
4.	Days to red ripen fruit stage	0.3482	76.3705**	0.2416
5.	Fruit length (cm)	0.0127	3.5471**	0.0677
6.	Fruit diameter (cm)	0.1593	3.4443**	0.0609
7.	No. of locules fruit^{-1}	8.0171	2.4190**	0.0854
8.	Pericarp thickness (cm)	0.0028	0.0202**	0.0007
9.	No. of fruits plant^{-1}	0.5925	444.8461**	4.7079
10.	Fruit yield per plot (kg)	0.0064	20.0112**	0.1162
11.	Lycopene content (mg/100g)	0.0075	29.8218**	0.0400
12.	Ascorbic acid content (mg/100g)	0.0208	35.6402**	0.0365

** significant at 1%.

determine the total lycopene concentration of tomatoes. Five grams of tomato pulp were crushed in acetone until colorless using a mortor and pestle. The extracted solution was then transferred into a funnel for separation. Next came petroleum ether and a tiny bit of sodium sulphate, which were added and vigorously shaken to ensure thorough mixing. The lycopene pigment was then separated from the acetone to petroleum ether layer by leaving the separating funnel undisturbed. Subsequently, the colored solution was separated into a 500 ml volumetric flask and petroleum ether was used to regulate the volume. Lastly, using petroleum as a blank, the sample absorbance was measured in a spectrophotometer at 503 nm. The results were expressed as 100 g^{-1}FW (fresh weight) basis.

$$\text{Lycopene content (mg/100g)} = \frac{3.1206 \times \text{vol. made up} \times \text{dilution}}{\text{Weight of sample}} \times 100$$

Results and Discussion

Genetic variability

Table 3 indicate the mean performance as well as additional genetic data for each of the twelve traits, including heritability (h^2_{bs}), genetic advance (GA), genetic advance as a percentage of mean (GAM) and phenotypic and genotypic co-efficients of variability (PCV, GCV). The mean performance of different genotypes for the twelve attributes in the research showed that there was a significant variation in the genotypes. This suggested that the genetic material under investigation had enough diversity and was suitable for further investigation.

The mean value of the plant height was 72.95 cm, with a range of 47.66 cm (VRT-01) to 90.90 cm (Kashi Amrit). With a mean value of 81.22 cm, the plant spread varied from 49.66 cm (VRT-01) to 102.66 cm (Kashi Amrit). With a mean value of 48.80, the data collected for days to 50% flowering varied from 46.40 days (Shalimar Hybrid Tomato-1) to 55.00 days (2016/TODVAR-10). Days to red ripe fruit stag had a mean value of 72.98 and ranged from 63.50 days (Jawahar-99) to 84.36 days (2015/TODVAR-1). Fruit lengths of 8.50 cm at the maximum and 3.60 cm at the minimum were measured in Roma and Kashi Amrit, respectively, with a mean value of 4.93 cm overall.The fruit's diameter varied between 3.53 cm (TOLCV-16, TOLCV-28) and 8.40 cm (Roma), with a mean value of 4.94 cm. The genotype Kashi Anupam (5.70) had the highest number of locule fruit$^{-1,}$ which was considerably greater than the average (3.71). The Roma genotype had the lowest number of locules. The results in Table 1 showed that the genotype Sel.7 had the highest number of fruits (65.33). The genotype 2016/TODVAR-12 has the lowest value for this attribute, which is 13.66. For this attribute, the average was 41.33 overall. The data collected revealed that the average fruit yield per plot was 9.63 kg, with variation ranging from 5.36 kg (2016/TODVAR-12) to 16.13 kg (Kashi Sharad). With a mean of 12.13 mg/100g, the lycopene concentration varied from 6.80 mg/100g (2016/TODVAR-12) to 18.50 mg/100g (Kashi Aman). With a mean value of 22.91 mg/100g, the ascorbic acid concentration varies from 18.73 mg/100g (Marglobe) to 29.30 mg/100g (Kashi Chayan).

Higher phenotypic coefficients of variability than

Table 3 : Estimates of mean, range, genotypic and phenotypic coefficients of variability,genotypic and phenotypic coefficients of variance, heritability and genetic advance (as percent of mean) for different characters in tomato (*Solanum lycopersicum* L.).

S. no.	Characters	Mean	Range	Genotypic coefficient of variation (GCV)	Phenotypic coefficient of variation (PCV)	Genotypic variance (gv)(σg^2)	Phenotypic variance (pv) (σg^2)	Heritability (bs)%	Genetic advance (as percent of mean)
1	Plant height (cm)	72.95	47.66-90.90	14.59	14.74	113.41	115.75	98.00	29.76
2	Plant spread (cm)	81.22	49.66-102.66	16.58	16.96	181.39	189.76	95.60	33.39
3	Days to 50% flowering	48.80	46.40-55.00	5.15	5.20	6.32	6.45	98.10	10.51
4	Days to red ripen fruit stage	72.98	63.50-84.36	6.90	6.93	25.37	25.61	99.10	14.15
5	Fruit length (cm)	4.93	3.60-8.50	21.80	22.43	1.16	1.22	94.50	43.66
6	Fruit diameter (cm)	4.94	3.53-8.40	21.48	22.05	1.12	1.18	94.90	43.10
7	Number of locules fruit^{-1}	3.71	1.73-5.70	23.75	25.02	0.77	0.86	90.10	46.43
8	Pericarp thickness (cm)	0.51	0.36-0.72	15.58	16.46	0.006	0.007	89.50	30.36
9	Number of fruits plant^{-1}	41.33	13.66-65.33	29.30	29.77	146.71	151.42	96.90	59.42
10	Fruit yield plot^{-1} (kg)	9.64	5.36-16.13	26.71	26.94	6.63	6.74	98.30	54.55
11	Lycopene content (mg/100g)	12.13	6.80-18.50	28.38	28.43	11.86	11.90	99.70	58.38
12	Ascorbic acid content (mg/100g)	22.91	18.73-29.30	13.75	13.77	9.92	9.96	99.60	28.27

genotypic coefficients of variability often suggest that the environment has an impact on characters. However, as those characteristics are less impacted by the environment, there are lower differences between PCV and GCV values for every character in the sample, suggesting that selection based on these traits is reliable. Number of fruits plant^{-1} (29.77%) had the highest phenotypic and genotypic coefficients of variability, followed by lycopene content (28.43%), fruit yield plot^{-1} (26.94%), number of locules fruit^{-1} (25.02%), fruit length (22.43%) and diameter (22.05%). These findings suggest that a higher degree of genetic variability is present for these characters, offering more opportunities for selection. Moderate coefficients of variability were found for plant spread (16.96%), pericarp thickness (16.46%), plant height (14.74%) and ascorbic acid content (13.77%), suggesting that these features have a moderate degree of genetic variability. Low PCV and GCV values were observed in the days to 50% blooming (5.20%) and days to red mature fruit stage (6.93%), suggesting that there is little scope for improvement along this path of improvement. The current investigation's results are consistent with those of Dar and Sharma (2011), Venkadeswaran *et al.* (2020).

Heritability and Genetic advance

The lycopene content (99.70%), ascorbic acid content (99.60%), days to red ripen fruit stage (99.10%), fruit yield plot^{-1} (98.30%), days to 50% flowering (98.10%), plant height (98.00%), number of fruits plant^{-1} (96.1%), plant spread (95.60%), fruit diameter (94.90%), fruit length (94.50%), number of locules fruit^{-1} (90.10%) and pericarp thickness (89.50%) all showed high broad sense heritability values, indicating that it would be more successful to select based on the phenotypic performance of these traits. The characters number of fruits per plant (59.42%), lycopene content (58.38%), fruit yield per plot (54.55%), number of locules per fruit (46.43%), fruit length (43.66%), fruit diameter (43.10%), plant spread (33.39%), pericarp thickness (30.36%), plant height (29.76%) and ascorbic acid content (28.77%) were found to have high genetic advance as a percentage of mean (GAM). Days to 50% flowering (10.51%) and days to red ripen fruit stage (14.15%) are two traits that show a modest amount of genetic advance, respectively. Previous reports by Mohammad *et al.* (2012), Mehta and Asati (2008), Ahirwar *et al.* (2013) and Arup *et al.* (2014) corroborate these findings. For traits such as lycopene content (mg/100g), fruit yield plot^{-1} (kg), number of fruits plant^{-1}, fruit length and diameter (cm) and number of locules fruit^{-1}, high heritability in conjunction with high genetic advance as a percent of mean is observed. This suggests that these traits are strongly influenced by additive gene action and that simple selection based on phenotypic performance of these traits would be more effective. Days to 50% flowering and days to red fruit stage have high heritability and moderate GAM values, respectively, suggesting that non-additive gene action and the environment have a significant impact on these characters expression. This could be taken advantage by establishing dominance and using heterosis to produce epistatic components.

Conclusion

Fruit length and diameter (cm), lycopene content (mg/ 100g), fruit yield plot^{-1} (kg), number of locules fruit^{-1} and number of fruits plant^{-1} had the highest phenotypic and genotypic coefficients of variability. These findings suggest that there is a high level of genetic variability present, which increases the potential for selection. For every trait, a high heritability (bs) value is reported. All the characteristics, with the exception of the days to 50% flowering and the days to red ripen fruit stage, likewise show high genetic advances. Lycopene content (mg/ 100g) demonstrated high heritability along with the maximum genetic advance (percent of mean). Fruit yield plot^{-1} (kg), number of fruits plant^{-1}, fruit length and diameter (cm) and number of locules fruit^{-1} were next. These traits suggest that additive gene action controls these characters, so simple selection based on phenotypic performance of these traits would be more effective.

Conflict of interest

The authors declare that there is no conflict of interest.

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