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Genetic variability, heritability and genetic advance in tomato (*Solanum lycopersicum* L.)

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Abstract
Twenty genotypes were used to study genetic variability, heritability and genetic advance in tomato (*Solanum lycopersicon* L.) Analysis of variance revealed highly significant differences among the genotypes for all the characters indicating presence of good amount of genetic variability in the genotypes. High GCV and PCV values were observed for locules per fruit, seed yield, fruit shape index and pericarp thickness indicating the presence of high amount of genetic variability for these characters. Hence, direct selection for these characters would be effective. High heritability along with high genetic advance was observed for total fruit yield per hectare and number of fruit per plant indicating the preponderance of additive gene action in the inheritance of these traits hence simple selection would be rewarding.

Keywords: Genetic variability, heritability, GCV (Genotypic coefficient of variation), PCV (Phenotypic coefficient of variation) and GA (Genetic advance)

Introduction
Tomato, *Solanum lycopersicum* L. (2n=2x=24) belongs to the solanaceae family and its native to Western South America (Rick, 1976) [1]. Tomato word is derived from the Spanish word 'tomate' earlier which was derived from Mexican word 'tomatl' (Peixoto *et al*., 2017) [2]. Globally, India stands at second place in terms of production and area, with 19.01 million tonnes produced by an area of 0.7 million ha (FAO, 2021). Within the genus *Lycopersicon* there are about twelve species. On the basis of fruit colour, all these species have been divided into two subgenera, namely Eriopersicon (Characterised by green fruits with anthocyanin pigmentation) and Eulycopersicon (Characterised by red fruits with carotenoid pigmentation and annual growth habit).

Tomato is one of the most important warm-season self-pollinated vegetables grown for both fresh market and processing (Das *et al*., 2011; Nwosu *et al*., 2014) [4, 5]. Its petals are generally yellow in colour, in full bloom it is less than an inch in diameter. It is chasmogamous, pentamerous, hermaphrodite with pistil enveloped by a solid tube formed by the stamens. The optimum temperature for the growth and development of the tomato is 20-24 °C. Temperatures above 34 °C are considered super-optimal heat stress.

The tomato consists of 93-94% water, vitamins such as thiamine, riboflavin, niacin, vitamin C, vitamin A and carotene (Kaur *et al*., 2013) [6]. Dhaliwal *et al*. (2003) [7] suggested that tomato is helpful against heart and cancer diseases as it is rich in antioxidants, and a greatest source of minerals (Ca, P and Fe). Tomato fruit contain carbohydrate 3.6 g, protein 19 g, fat 0.1 g, water 93.1 g, mineral 0.6 g, iron 0.8 mg, calcium 20 mg, phosphorous 36 mg, thiamine 2.27 mg, nicotinic acid 0.4 mg, carotene (As a vitamin A) 320 IU and ascorbic acid 3.1mg per 100 g of fruit pulp. It also contains biotin, panthonic acid, vitamin K, folic acid and vitamin related inhibitors (E. Aykroyed 1963) [8].

In India, tomato yield is below world averages (Kumar *et al*., 2013) [9]. It is necessary to develop superior varieties/hybrids to increase productivity. Besides, improving fruit quality has also become a major goal in plant breeding. However, the efficiency of selection depends upon the nature and magnitude of genetic variability and heritability of trait of interest. Because yield is a complex character, its direct improvement is difficult. Genotypic and phenotypic coefficients of variation are advantageous in determining the amounts of variability present in genotypes. Heritability and genetic advance aid in establishing the influence of environment in expression of traits and the extent to which improvement is possible after selection (Robinson *et al*., 1955; Kumar *et al*., 2013) [11, 9]. Heritable variation can be effectively studied in association with genetic advance. According to Johanson *et al*. (1955) [11], high heritability alone is ineffective to make efficient selection in segregating generation and needs to be followed by a significant amount of genetic advance.

Materials and Methods

The study was carried out during *Rabi* season 2022-2023 at the Vegetable Research Farm, Department of Horticulture, Institute of Agricultural & Natural Sciences, Deen Dayal Upadhyaya Gorakhpur University, Gorakhpur. Twenty genotypes of tropical and subtropical origin collected from ICAR- Indian Institute of Vegetable Research (IIVR), Varanasi,(U.P), IARI, Pusa New Delhi and BHU Varanasi were taken for investigation. Experiment was laid out in Randomized Block Design (RBD) with three replications. The healthy seedlings were transplanted 28 days after sowing in the experimental field at spacing of 60cm from row to row and 60 cm from plant to plant.

The observations were recorded in all randomly tagged five plants in each replication for different traits *viz*., Days to 50% flowering, plant height (cm), number of primary branches per plant, number of fruits per cluster, number of fruits per plant, average fruit weight (g), fruit length(cm), fruit width (cm), fruit shape index(mm), pericarp thickness(mm), number of locules per fruit, number of seeds per fruit, seed yield (q/ha), total fruit yield per hectare (q/ha), total soluble solid (Brix), ascorbic acid (mg/100ml). The average values were computed as treatment means under each replication.

The analysis of variance for design of experiment was done by partitioning the variance into treatments and replications by Analysis of variance for the design of experiment. Phenotypic and genotypic coefficients variations were calculated by using the following formula suggested by Coefficient of variability. Heritability in broad sense by (Kempthorne and Curnow, 1961; Hanson, 1961) [20, 21] and genetic advance by (Johnson *et al*., 1955) [11].

Results and Discussion

Genetic variability

The mean performance of 20 genotypes for 16 characters exhibited a wide range of variations and the mean performance were observed for all the traits is presented in (Table 1), Analysis of variance was carried out on various yield and yield contributing traits for studding the variation and the results showed that there are significant differences among all genotypes in respect of all the 16 traits indicating the presence of sufficient variability among the genotypes for all the traits taken for present investigation. The estimation of these variance showed that genotypic variations contributed maximum to the phenotypic variances for all the traits studied (Table 2). The variation in the genotypes would be helpful in the development of superior varieties in further breeding programme.

The investigation revealed that the phenotypic variation was high as compared to genotypic variation for all the traits studied indicating the influence of environment and it was found maximum for locules per fruit (23.03%) followed by seed yield (19.48), fruit shape index (17.31), pericarp thickness (16.68), plant height (16.61),total soluble solid (15.17), number of primary branches per plant (15.19), number of fruits per plant (10.19), fruit width (10.01) and days to 50% flowering (9.20).

The highest GCV were observed for number of locules per fruit (21.90) followed by seed yield (17.96) and pericarp thickness (16.17). Whereas, moderate GCV was recorded for total soluble solid (14.67) and number of primary branches per plant (13.05). The lower values of genotypic coefficient of variation were seen in ascorbic acid (12.78) and fruit shape index (12.70).These findings were similar to results obtained by Kumar *et al.* (2013) [9], Kumari *et al.* (2020) [12], Sinha *et al*. (2020) [13], Mishra *et al*. (2022) [14], Madhavi *et al*. (2022) [15] and Eppakayala *et al.* (2021) [16].

High GCV and PCV values were observed for locules per fruit, seed yield, fruit shape index and pericarp thickness indicating the presence of high amount of genetic variability for these characters. Hence, direct selection for these characters would be effective.

Heritability and genetic advance

Genetic variability may be due to due to additive, dominance and epistatic gene action. In the present study, the broad sense heritability for characters are categorized as high (>80%), moderate (50-80%) and low (<50%) as previously suggested by Warshamana (2005) [22].

The highest heritability was recorded for Ascorbic acid (95%) followed by pericarp thickness, total soluble solid (94%), number of locules per fruit (90%), seed yield (85%) and plant height (82%). While, moderate heritability was observed for fruit shape index and total fruit yield per hectare (54%) and lowest was found in days to 50% flowering (52%) which comes under moderate range, (Table 2). Such high values of heritability for ascorbic acid, pericarp thickness, total soluble soilds number of locules per fruit, plant height, total fruit yield per hectare implies that it may be due to environment influence and selection based on phenotypic performance would be reliable. In traits with high heritability, genotypic variance is more than environmental variance and these characters could be considered and exploited for selection in earlier generations. Whereas, in the traits with low heritability, influence of environmental factor is strong for their expression and genotype selection based on these characters may be postponed to the later generations.

The variation in range for genetic advance as percent of mean varies from 10.03 (days to 50% flowering) to 42.92 (number of locules per fruit). The maximum genetic advance was observed for number of locules per fruit (42.92) followed by seed yield (34.12) and pericarp thickness (32.32), while minimum value of genetic advance was recorded for fruit weight (12.65) followed by days to 50% flowering (10.03).These results are in agreement with the finding of Dutta *et al*. (2018) [17], Singh *et al.* (2018) [18], Reddy *et al.* (2019) [23], Madhavi *et al*. (2022) [15] and Yadav *et al*. (2022) [19] for pericarp thickness and ascorbic acid. These character possessing high values of heritability accompanied with high genetic advance emerge as ideal trait for improvement through selection due to high variability and transmissibility. Thus, the characters mentioned above are likely to show very high response to selection practiced in breeding population.

Table 1: Analysis of variance for yield and its attributing traits in tomato genotypes

S. N	Source of Variations	DF	Plant height	Days to 50% flowering	Number of primary branches	Number of fruits per plant	Number of fruits per cluster	Fruit weight (gm)	Fruit Length (cm)	Fruit width (cm)
1	Replication	2	7.38	32.71	0.02	3.38	0.64	177.97	0.01	0.04
2	Treatments	19	538.47**	22.17**	1.37**	13.43**	0.77**	179.86**	0.67**	0.71**
3	Error	38	35.72	5.06	0.14	1.69	0.09	36.46	0.05	0.09

S. N	Source of Variations	DF	Pericarp thickness (mm)	Fruit shape Index	Number of locules per fruit	Number of seed per fruit	Seed yield	TSS	Ascorbic Acid	Total fruit yield
1	Replication	2	0.09	0.002	0.01	36.08	0.05	0.11	0.39	17747.54
2	Treatments	19	2.31**	0.05**	2.20**	286.11**	0.31**	1.88**	26.44**	11645.15**
3	Error	38	0.04	0.01	0.07	23.39	0.01	0.04	0.39	2523.86

*, ** Significant at 5 and 1 per cent level, respectively

Table 2: Estimation of genotypic and phenotypic coefficient of variation, heritability, genetic advance for different characters in tomato

	Plant height	Days to 50% Flowering	Number of primary branches per plant	Number of fruits per plant	Number of fruits per cluster	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)
GCV %	15.08	6.69	13.05	8.51	11.09	8.15	8.73	8.27
PCV %	16.61	9.20	15.19	10.19	13.24	10.83	9.90	10.01
h^2 (Broad Sense)	0.82	0.52	0.73	0.69	0.70	0.56	0.77	0.68
Genetic Advance5%	24.21	3.57	1.13	3.40	0.82	10.72	0.82	0.77
Gen. Adv. As % of Mean 5%	28.21	10.03	23.10	14.65	19.15	12.65	15.88	14.07
Minimum Range	56.28	28.00	3.73	18.44	3.02	63.200	4.02	4.34
Maximum Range	126.30	41.00	6.98	31.60	5.81	104.00	6.44	6.83

	Pericarp thickness (mm)	Fruit shape Index	Number of locules per fruit	Number of seeds per fruit	Seed yield (q/ha)	TSS (Brix)	Ascorbic acid (mg/100ml)	Total fruit yield per hectare (q/ha)
GCV %	16.17	12.69	21.90	11.15	17.96	14.67	12.78	10.09
PCV %	16.68	17.08	23.03	12.55	19.48	15.17	13.06	13.65
h^2 (Broad Sense)	0.94	0.55	0.90	0.78	0.85	0.93	0.95	0.54
Genetic Advance 5%	1.73	0.186	1.70	17.12	0.59	1.55	5.93	83.96
Gen. Adv. As % of Mean 5%	32.32	19.43	42.92	20.40	34.12	29.21	25.75	15.36
Minimum Range	3.94	0.63	2.00	68.14	1.21	3.78	17.11	375.23
Maximum Range	7.14	1.66	5.77	108.72	2.80	6.81	27.11	714.27

Conclusion

The results obtained from this study can be exploited for further breeding programme in tomato. Analysis of variance revealed highly significant differences among the genotypes for all the characters indicating presence of good amount of genetic variability in the genotypes. The PCV values were higher than GCV values for all the characters studied indicating the effect of the environment on character's expression. High GCV and PCV values were observed for locules per fruit, seed yield, fruit shape index and pericarp thickness indicating the presence of high amount of genetic variability for these characters. Hence, direct selection for these characters would be effective.

Heritability estimates were high for ascorbic acid followed by pericarp thickness, total soluble solid, number of locules per fruit, seed yield and plant height indicating thereby important role of these characters in tomato improvement. Genetic advance as per cent of mean was high for total fruit yield per hectare followed by number of locules per fruit and seed yield. It was medium for pericarp thickness, fruit weight and days to 50% flowering. High heritability along with high genetic advance was observed for total fruit yield per hectare and number of fruit per plant indicating the preponderance of additive gene action in the inheritance of these traits hence simple selection would be rewarding.

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