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Assessment of Genetic Variability, Heritability and Genetic Advance among Different Characters in Tomato [*Solanum lycopersicum* (Mill.) Wettsd]

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Authors' contributions

This work was carried out in collaboration among all authors. Author DSM performed the experiment, analyzed the data, prepared figures and/or tables, authored or reviewed drafts of the article and approved it. Author SK supervised the study, conceived and designed the experiment, analyzed the data, prepared figures and/or tables, authored or reviewed drafts of the article and approved it. Author SY reviewed drafts of the article and approved it. Author SV performed experiment, analyzed data, authored or reviewed drafts and approved the final draft. Author LY analyzed data, authored or reviewed drafts and approved the final draft. All authors read and approved the final manuscript.

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ABSTRACT

The field experiment was carried out at Horticulture Research Farm No.1, Babasaheb Bhimrao Ambedkar University, Lucknow during Rabi season 2021-22. In this, twenty genotypes including check cultivars were evaluated to estimate the genetic variability, heritability and genetic advance for different characters. The experiment was laid out in Randomized Block Design (RBD) with three replications. Characters viz., days to 50% flowering, plant height, number of primary branches per plant, polar diameter of fruit, equatorial diameter of fruit, total soluble solids, number of fruits per cluster, average fruit weight, number of fruits per plant, marketable fruit yield per plant, unmarketable fruit yield per plant and total fruit yield per plant were studied during the experiment. Analysis of variance showed significant differences among genotypes for all the characters under study during the investigation. The Phenotypic coefficient of variance (PCV) was higher than the genotypic coefficient of the variation (GCV) for the characters studied. The highest genotypic coefficient of variation (GCV) was observed for unmarketable fruit yield per plant. The moderate GCV was reported for total fruit yield per plant followed by plant height and average fruit weight, polar diameter of fruit, no. of primary branches per plant, marketable fruit yield per plant and equatorial diameter of fruit whereas it was least for TSS followed by days to 50% flowering and number of fruits per cluster. Therefore these characters exhibited high heritability coupled with genetic advance thus show some scope for improvement through selection.

Keywords: Tomato; RBD; traits, genotypes; heritability; PCV; GCV.

1. INTRODUCTION

Tomato (*Solanum lycopersicum* (Mill.) Wettsd.) belongs to the Solanaceae family. Tomatoes are one of the world's most frequently produced crops because of its global acclimatization to wide variety of environment. It is widely utilised in the processing business as well as in fresh marketplaces [1,2]. Alternative names for it comprise poor man's orange, love apple, and wolf apple. It is universally treated as protective food due to its nutritive value. Several minerals and vitamins like A, C, and E, niacin, folic acid, biotin, and other chemicals, such as antioxidant-rich lycopene that guards against cancer and other chronic illnesses, are all found in tomatoes. Fruit, which is essential to human nutrition, is composed of 93.1% water. It contains Iron 0.8 mg, calcium 20 mg, phosphorus 36 mg, vitamin A 320 LU, vitamin B 0.07 mg, vitamin B 0.01 mg, vitamin C 31 mg, protein 1.9%, fat 0.3 g, fibre 0.7%, and carbs 3.6%. It contains important vitamins that aid in cholesterol reduction. Tomato contain about 20 to 50 mg of lycopene per 100 g of fruit weight [3]. Tomato is mostly grown in open fields, green houses, and net homes. It ranks third in total vegetable output, after only potatoes and sweet potatoes, but first in processed vegetables. China is the world's largest tomato producer, followed by India, the United States, Spain, and Egypt. The global tomato output is 38.82 million metric tonnes. India has a total area of 27.77 million hectares and a total production of 22.28 million tonnes, with a productivity of 25.74 tonnes per hectare that is much lower than the global average. According to an APEDA Agri Exchange (2021-2022) study, the major states involved in tomato production in India are Madhya Pradesh, Andhra Pradesh, Karnataka, Tamil Nadu, and Orissa, with 14.63%, 10.92%, 10.23%, and 7.34%, respectively.

Tomato, being a self-pollinated crop, have a remarkable potential for heterosis breeding and are employed in many breeding programmes. The variability in tomato is expected to be immense as the fruit vary greatly in shape and size [4]. The variability available in the population can be portioned into heritable and non-heritable components viz., phenotypic and genotypic coefficients of variation, heritability and genetic advance on which the selection can be effectively carried out [5]. The genetic improvement of any crop plant needs to have knowledge on the nature and the magnitude of variability in the base population [6]. Tomato variability is predicted to be considerable, as the fruits vary significantly in shape and size [4]. To boost tomato output, the primary focus should be on crop genetic improvement and the development of superior varieties through cross- and within-population selection using available genetic diversity. As yield is a breeder's primary aim, it is vital to understand the relationship between various qualities that contribute to output. Variability may be detected using genetic factors such as genotypic and phenotypic

coefficients of variation (GCV and PCV). Heritability and genetic advancement aid in assessing the effect of environment on character expression and the extent to which improvement is feasible following selection [7]. As a result, the study was conducted in tomato with the goal of estimating the phenotypic coefficient of variation, genotypic coefficient of variation, heritability, and genetic progress. The genotypic and phenotypic coefficients of variation were computed using the Burton and De Vane technique [8]. Heritability (in the broad sense) and genetic gain was calculated as per suggestion by Johnson et al. [9].

2. MATERIALS AND METHODS

This experiment was examined out at the Horticultural Research Farm No.1 of the Department of Horticulture of Babasaheb Bhimrao Ambedkar University, Lucknow, on a well-leveled field with appropriate drainage facilities during the Rabi Season 2021-22. The experimental material included 20 genotypes with two check cultivars NDT-4© and NDT- 7©. Geographically, Babasaheb Bhimrao Ambedkar University (A Central University), Vidya- Vihar, Rae Bareli Road, Lucknow, is located at 80.52' east longitude; 26.56' north latitude and 111 metres above mean sea level (MSL), lies is in upper Gangetic Alluvial Plain and it has a humid subtropical climate.

2.1 Experimental Details

In this experiment there are 20 genotypes of tomato including two checks which were maintain by ANDUAT, Kumarganj, Ayodhya were collected for the examination. The list of genotypes used in this experiment are mentioned in Table 1. The experiment used randomized block design (RBD), with three replications for each treatment. On November 15, 2021, the plants were transplanted. The spacing between rows and between plants was set at 60cm and 45cm, respectively. Each plot is 2.00 m × 2.00 m in size and accommodated 16 seedlings.

2.2 Parameter Recorded

In this study, 12 characters were studied from 16 sample plants in each net plot and the results were expressed as mean values. List of characters for experimental analysis during the trial are Days to 50% flowering, Plant height (cm), Number of primary branches per plant, Polar diameter of fruit (cm), Equatorial diameter of fruit (cm), TSS (ºBrix), Number of fruits per cluster, Average fruit weight (g), Number of fruits per plant, Marketable fruit yield per plant (g), Unmarketable fruit yield per plant (g), Total fruit yield per plant (g). All the data represent per plant observation except for marketable fruit yield and unmarketable fruit yield which are computed from net plot observation and days to flowering and maturity were computed on the basis of harvestable rows in each net plot.

3. RESULTS AND DISCUSSION

Analysis of variance for 12 characters revealed that mean squares due to treatments were highly significant for all the traits showing the existence of sufficient variability in the genotypes. Mean performance for the character days to 50% flowering ranged from 25.93 - 38.03. The genotype NDT-5-1-1(25.93 days) took minimum days to reach 50% flowering whereas NCT-1(38.03 days) recorded the maximum days for 50% flowering. Comparison to genotypes for plant height, the mean ranged from 70.53-171.87. Maximum plant height was recorded in NDT-52 (171.87 cm) and the minimum was recorded in NDT-5-1-1 (70.53 cm). Data recorded for the no. of primary branches per plant ranged from 3.43 - 7.67. NDT-P (3.43) and NDT-38 (7.67) had minimum and maximum no. of primary branches per plant respectively. The mean range for polar diameter of fruit was recorded from 3.33-8.37. NDT-27 (8.37 cm) had the maximum polar diameter of the fruit which was superior over other genotypes and NDT-P (3.33 cm) showed the minimum polar diameter of the fruit. Data recorded for equatorial diameter of the fruit ranged from 3.53-7.83. Among all the genotype studied, NCT-2 (3.53 cm) recorded for minimum equatorial fruit diameter and NDT-P (7.83 cm) showed maximum equatorial diameter of the fruit. The TSS among all genotypes varied from 4.53-6.67. In which the highest TSS was recorded for NDT-47 (6.67 ºB) and the minimum content was found in NDT-38 (4.53 ºB). Data recorded for the number of fruits per cluster ranged from 2.70 - 4.77. Among all genotypes, the maximum fruit per cluster was recorded in NDT-5 (4.77) and the minimum was recorded in NDT-38 (2.70). Average fruit weight ranged from 33.37 - 83.23 among all the studied genotypes. In which NDT-27 (33.37 g) possesed minimum average fruit weight and NDT-5-1-1 (83.23 g) possesed maximum average fruit weight. The mean values for number of fruits per plant ranged from 35.27-61.73. The minimum no. of fruit per plant was observed in NDT-5-1-1 (35.27)

and the maximum no. of fruits per plant was recorded in NDT-38 (61.73). Marketable fruit yield per plant among all genotypes varied from 1594.37 - 3947.97. Highest marketable fruit yield per plant was recorded in NDT-45 (3947.97 g) and the least marketable fruit yield per plant was observed in check variety i.e., NDT-4© (1594.37 g). Similarly, observation on the unmarketable fruit yield per plant showed the maximum in NDT-15 (120.23 g) whereas the minimum unmarketable fruit yield per plant was recorded in NDT-P (31.53 g). Maximum and minimum total fruit yield per plant was seen in NDT-45 (4516.80 g) & NDT-15 (1610.23 g) respectively.

Parameters of variability: The parameters of variability i.e., mean range, coefficients of variation (genotypic and phenotypic), heritability (broad sense), genetic advance and genetic gain were worked out for various characters (Table 4).

3.1 Genetic Variability

Genetic variability in plants is key for selection of plants with desirable characterstics [10]. The mean sums of squares associated with treatments were significantly significant for all characters. In other words, the genotypes' performance on these variables was statistically significant demonstrating that there is plenty of potential for selection in a variety of tomato features. However, in order to determine the absolute magnitude of the variability, the phenotypic and genotypic coefficients of variance were determined. It indicates only the extent of variability present in the genotypes for different traits. The genotypic coefficient of variation (G.C.V.) was lower than the phenotypic coefficient of variation (P.C.V.), indicating that the environment has less impact and influence in the expression of the observed traits. As a consequence, the differences in P.C.V. and G.C.V values for all characters are small. The differences in P.C.V and G.C.V values observed for different morphological traits suggest that characters will demonstrate notable genetic advancement. As a result of the additive gene effects, it is obvious that selection based on phenotypic values for these qualities may be useful in improving these characters. The highest phenotypic coefficient of variation (PCV) was recorded in unmarketable fruit yield per plant i.e., 30.37% which was followed by total fruit yield per plant 30.24%. The least PCV was observed in TSS (9.08%) which was followed by days to 50% flowering (9.67%). The genotypic coefficient of variation (G.C.V.) results showed that the unmarketable fruits yield per plant had the highest genotypic coefficient of variation (30.23%) and was followed by total fruit yield per plant, which was 29.52% whereas the least genotypic coefficient of variation was observed in TSS (7.76%) followed by the days to 50% flowering (8.46%) and Number of fruits per cluster (13.11%). The moderate to low variation observed for these attributes suggested that there is substantial room for improvement. Madhurina (2012) found similar results in their research.

Table 1. List of tomato genotypes used in the present study

Sl. No.	Name of genotypes	Source of origin
1.	NDT-2	A.N.D.U.A.&T, Ayodhya
2.	NDT-p	A.N.D.U.A.&T, Ayodhya
3.	NDT-5	A.N.D.U.A.&T, Ayodhya
4.	NDT-6	A.N.D.U.A.&T, Ayodhya
5.	NDT-8	A.N.D.U.A.&T, Ayodhya
6.	NDT-5-1-1	A.N.D.U.A.&T, Ayodhya
7.	NDT-67	A.N.D.U.A.&T, Ayodhya
8.	NDT-45	A.N.D.U.A.&T, Ayodhya
9.	NDT-27	A.N.D.U.A.&T, Ayodhya
10	NCT-2	A.N.D.U.A.&T, Ayodhya
11	NCT-1	A.N.D.U.A.&T, Ayodhya
12	NDT-56	A.N.D.U.A.&T, Ayodhya
13	NDT-17	A.N.D.U.A.&T, Ayodhya
14	NDT-15	A.N.D.U.A.&T, Ayodhya
15	NDT-52	A.N.D.U.A.&T, Ayodhya
16	NDT-25	A.N.D.U.A.&T, Ayodhya
17	NDT-47	A.N.D.U.A.&T, Ayodhya
18	NDT-38	A.N.D.U.A.&T, Ayodhya
19	NDT-4 ©	A.N.D.U.A.&T, Ayodhya
20	NDT-7 ©	A.N.D.U.A.&T, Ayodhya

Table 2. Mean performance of different tomato genotypes with respect to the various traits

Source of variation	DF	Days to 50% flowering	Plant height (cm)	No. of primary branches per plant	Polar diameter of fruit (cm)	Equatorial diameter of fruit (cm)	TSS (ºB)	No. of fruits per cluster	Average fruit weight (g)	No. of fruits per plant	Marketable fruit yield per plant (g)	Unmarketable fruit yield per plant(g)	Total fruit yield per plant(g)
Replication	2	8.76	193.69	0.41	0.47	0.13	0.58	0.02	7.12	9.11	2064.12	9.24	5473.40
Treatment	19	28.71**	3955.18**	4.74**	5.74**	4.59**	0.73**	0.88**	593.41**	204.10**	1062542.1**	1456.8**	1739825.4**
Error	38	2.66	51.60	0.22	0.21	0.12	0.08	0.07	5.18	13.97	1197.22	4.51	28152.29
Total	59	11.26	1350.79	1.68	2.00	1.56	0.31	0.33	194.67	75.03	346405.46	473.38	580270.07

DF: Degree of freedom, TSS: Total Soluble Solids
**, ** significant at 5% and 1% level, respectively*

Table 3. Mean performance of different tomato genotypes with respect to the various traits

S.No	Genotypes	Days to 50% flowering	Plant height (cm)	No. of primary branches per plant	Polar diameter of fruit (cm)	Equatorial diameter of fruit (cm)	TSS (ºB)	No. of fruits per cluster	Average fruit weight (g)	No. of fruits per plant	Marketable fruit yield per plant (g)	Unmarketable fruit yield per plant(g)	Total fruit yield per plant(g)
1	**NDT-2**	36.67	84.43	3.87	4.40	4.77	6.43	4.17	35.13	55.67	1793.67	45.83	1897.13
2	**NDT-P**	35.33	157.87	3.43	8.37	7.83	5.87	3.50	63.53	59.43	3391.53	31.53	3709.47
3	**NDT-5**	35.27	140.70	5.87	4.63	5.57	5.83	4.77	56.83	54.87	2778.47	73.47	2023.17
4	**NDT-6**	35.00	121.83	4.57	4.13	4.77	6.53	3.93	44.13	61.13	2477.97	76.83	2547.87
5	**NDT-8**	35.57	164.90	3.73	3.73	3.53	5.77	3.73	34.03	59.47	1861.23	74.90	1999.60
6	**NDT-5-1-1**	25.93	70.53	5.57	7.43	7.67	6.33	4.63	83.23	35.27	2215.83	66.43	2630.73
7	**NDT-67**	34.37	79.87	3.57	4.67	4.57	5.67	4.37	38.33	57.47	2011.47	77.33	2430.43
8	**NDT-45**	35.67	80.77	6.83	7.87	7.53	6.13	4.70	78.13	58.83	3947.97	34.07	4516.80
9	**NDT-27**	37.37	166.63	7.27	3.33	4.53	6.57	4.50	33.37	53.47	1670.17	115.27	1677.23
10	**NCT-2**	37.67	77.07	5.43	5.40	3.53	5.73	3.70	57.07	55.37	2839.27	66.90	3316.10
11	**NCT-1**	38.03	90.53	3.97	6.50	4.47	5.77	3.30	70.17	44.43	2464.33	85.20	2805.80
12	**NDT-56**	35.07	157.10	5.67	4.53	5.57	5.83	4.10	55.43	36.93	1742.17	66.23	2185.83
13	**NDT-17**	35.37	162.53	5.13	4.57	5.83	5.80	3.60	56.53	46.07	2261.83	55.27	2675.50
14	**NDT-15**	37.03	150.73	4.73	5.27	6.03	6.57	3.70	45.77	56.03	2230.93	120.23	1610.23
15	**NDT-52**	32.20	171.87	5.57	4.93	5.63	5.87	3.87	57.11	59.47	2928.43	81.70	3295.63
16	**NDT-25**	36.37	151.87	3.93	4.97	6.37	6.53	3.60	46.47	56.13	2329.53	90.47	1664.03
17	**NDT-47**	31.93	101.40	4.73	5.90	6.57	6.67	4.40	65.63	44.07	2461.07	71.43	2605.30
18	**NDT-38**	37.13	123.03	7.67	4.63	5.53	4.53	2.70	56.10	61.73	2844.13	63.87	3249.97
19	**NDT-4©**	28.33	134.20	3.51	3.57	5.27	5.77	4.63	43.17	41.97	1594.37	84.93	1845.60
20	**NDT-7 ©**	36.33	84.13	4.53	5.13	4.63	5.83	3.67	48.03	59.37	2545.47	73.93	2483.67
	Mean	**34.83**	**123.60**	**4.98**	**5.20**	**5.51**	**6.00**	**3.98**	**53.41**	**52.86**	**2419.49**	**72.79**	**2558.51**
	Min	25.93	70.53	3.43	3.33	3.53	4.53	2.70	33.37	35.27	1594.37	31.53	1610.23
	max	38.03	171.87	7.67	8.37	7.83	6.67	4.77	83.23	61.73	3947.97	120.23	4516.80
	SE(d)	1.33	5.87	0.38	0.38	0.29	0.23	0.21	1.86	3.05	28.25	1.73	137.00
	C.D.	2.71	11.92	0.78	0.77	0.59	0.47	0.43	3.78	6.20	57.41	3.52	278.41
	C.V.	4.68	5.81	9.39	8.90	6.41	4.73	6.49	4.26	7.07	1.43	2.92	6.56

Table 4. Mean, range, genotypic and phenotypic coefficient of variance, heritability, and genetic advance in percentage of mean of different traits of tomato

Sl. No.	Characters	Mean	Min	Max	GV	PV	GCV (%)	PCV (%)	h^2	GA	GAM (%)
1.	**Days to 50% flowering**	34.83	25.93	38.03	8.68	11.34	8.46	9.67	76.54	5.31	15.25
2.	**Plant height (cm)**	123.60	70.53	171.87	1301.20	1352.79	29.18	29.76	96.19	72.88	58.96
3.	**No. of primary branches per plant**	4.98	3.43	7.67	1.51	1.73	24.66	26.39	87.33	2.36	47.47
4.	**Polar diameter of fruit (cm)**	5.20	3.33	8.37	1.84	2.06	26.10	27.58	89.57	2.65	50.89
5.	**Equatorial diameter of fruit (cm)**	5.51	3.53	7.83	1.49	1.61	22.14	23.05	92.27	2.41	43.82
6.	**TSS (ºB)**	6.00	4.53	6.67	0.22	0.30	7.76	9.08	72.89	0.82	13.64
7.	**No. of fruits per cluster**	3.98	2.70	4.77	0.27	0.34	13.11	14.63	80.29	0.96	24.19
8.	**Average fruit weight (g)**	53.41	33.37	83.23	196.08	201.26	26.22	26.56	97.43	28.47	53.31
9.	**No. of fruits per plant**	52.86	35.27	61.73	63.38	77.34	15.06	16.64	81.94	14.85	28.08
10.	**Marketable fruit yield per plant (g)**	2419.49	1594.37	3947.97	353781.6	354978.8	24.58	24.63	99.66	1223.21	50.56
11.	**Unmarketable fruit yield per plant (g)**	72.79	31.53	120.23	484.11	488.62	30.23	30.37	99.08	45.12	61.98
12.	**Total fruit yield per plant (g)**	2558.51	1610.23	4516.80	570557.7	598710.0	29.52	30.24	95.30	1519.00	59.37

Abbreviations used in table 2:

GV-Genotypic variance; PCV- Phenotypic coefficient of variation; h^2 – Heritability in broad sense; PV- Phenotypic variance; GCV- Genotypic coefficient of variation; MIN- Minimum range; GA- Genetic advance; GAM- Genetic advance as percentage over mean; MAX- Maximum range

3.2 Heritability

For the prediction of the response to selection, heritability estimates are very useful. Considering the heritability in broad sense (h^2) along with genetic advance may reveal the prevalence of specific components (additive and non additive) of genetic variance and thus helps in judging the effectiveness of selection for the trait more accurately [9]. The present investigation revealed that low to high heritability estimates represent in almost all the characters. The heritability estimates for characters ranged from 72.89 to 99.66 per cent. High heritability recorded for marketable fruit yield per plant (99.66%) followed by unmarketable fruit yield per plant (99.08%), average fruit weight (97.43%), plant height (96.19%), total fruit yield per plant (95.30%), equatorial diameter of fruit (92.27%), polar diameter of fruit (89.57%) and number of primary branches per plant (87.33%) followed by number of fruits per cluster (80.29%). The TSS showed to have least heritability i.e., 72.89% followed by days to 50% flowering (76.54%). This result was found in accordance with Sushma et al, [11]. It was evident that improving characters with high heritability would be more effective if regular selection processes were used, but improving those with low heritability would necessitate the use of other suitable breeding approaches, such as a population improvement programme.

3.3 Genetic Advance and Genetic Gain

The genetic gain (genetic advance expressed in the percentage of the population mean) was ranged from 13.64 to 61.98%. The highest genetic gain was found for unmarketable fruit yield per plant (61.98%), total fruit yield per plant (59.37%), plant height (58.96%), average fruit weight (53.31%), polar diameter of fruit (50.89%) and marketable fruit yield per plant (50.56%). It was in accordance with the findings of Singh and Singh [12]. Moderate heritability with high genetic advance was recorded for number of primary branches per plant (47.47%), equatorial diameter of fruit (43.82%) and number of fruits per plant (28.08%). While least heritability was observed in total soluble solids (TSS) (13.64%) which was followed by days to 50% flowering (15.25%). Unmarketable fruit production per plant had the most genetic diversity, followed by total fruit yield per plant and plant height. Prema et al., [12] found similar results in their research [14].

4. CONCLUSION

The primary purpose of the study was to find significant variation, heritability, and genetic advances in the numerous genotype traits studied. The outcomes of the study can be utilized to guide future tomato breeding initiatives. We identified significant genetic variety in the variables studied. Except for TSS (72.89%), all characteristics had high heritability along with high genetic progress. As an outcome of the high heritability and genetic advancement of these features, selection may successfully improve the attributes to increase tomato yield. The data presented above confirmed that additive gene activity and the suggested parameters would be beneficial for future enhancement.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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