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

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Abstract
Forty one genotypes were used to study genetic variability, heritability and genetic advance in tomato (*Solanum lycopersicum* L.). The analysis of variance revealed highly significant variation among the genotypes for all the characters studied indicating considerable amount of variability among the genotypes. High genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were observed for average fruit weight, fruit volume, number of fruits per plant, number of locules per fruit**,** yield per plant, yield per plot, yield per hectare, ascorbic acid, pericarp thickness and titratable acidity. This indicates the existence of broad genetic base, which would be amenable for further selection. High heritability coupled with high genetic advance over mean were observed for fruit length, fruit diameter, average fruit weight, fruit volume, number of locules per fruit, number of fruits per cluster, number of fruits per plant, yield per plant, yield per plot, yield per hectare, TSS, ascorbic acid content of fruit, lycopene content, titratable acidity, pericarp thickness and firmness.

Keywords: Genetic variability, heritability, GCV, PCV and genetic advance over mean

Introduction
Tomato (*Solanum lycopersicum* L.) is one of the most important solanaceous vegetable crops grown world-wide due to its acclimatization to a wide variety of environments as well as its high nutritive value. It is originated from Peru-Eucador-Bolivia region of Andes (South America). It remains in the focus of the horticultural industry ever since the mid nineteenth century. It is a tropical annual herb which can be cultivated under wide range of soil and climatic conditions. It is eulogised as wolf apple, love apple or poor man's orange. It is universally treated as 'protective food' due to its nutritive value and rich in beta-carotene and lycopene. It is considered as a major source of carotenoids in the human diet and also it is regarded as number one processing vegetable in the world. Tomato fruits are directly used as raw vegetable in sandwiches and salad or as processed items like paste, puree, syrup, juice, sauce and ketchup. The fruits are used for preparation of chutney, sambar, pickles *etc.* The tomato products having great export demand are puree and paste.

Tomato plants are generally much branched, spreading 60–180 cm and somewhat trailing when fruiting, some plants are determinate and semi-determinate. The determinate types of tomato are the one in which inflorescence occurs more frequently in almost every internodes until terminal ones are formed and elongation ceases at this point. It may be referred as self-topping and the main axis terminates with a flower cluster. In indeterminate type of tomato flower cluster occurs at every third internodes and the main axis continues growing indefinitely. Indeterminate types are commonly grown in greenhouse condition.

Tomato is a good source of minerals, vitamins A, C, E, niacin, folic acid, biotin and other compounds, including lycopene that has antioxidant activity and prevent cancer and other chronic diseases. It plays a vital role in human nutrition, fruit contains water 93.1 per cent, protein 1.9 per cent, fat 0.3 g, fibre 0.7 per cent, carbohydrates 3.6 per cent, vitamin A 320 I.U., vitamin B_1 0.07 mg, vitamin B_2 0.01 mg, vitamin C 31 mg, calcium 20 mg, phosphorus 36 mg and iron 0.8 mg. It has valuable vitamins which help in lowering cholesterol. Approximately 20 to 50 mg of lycopene per 100 g of fruit weight can be obtained from tomato (Thamburaj and Singh, 2016) [14]. Lycopene is the pigment principally responsible for the characteristic deep red colour of ripe tomato fruits and tomato products. The plants are resistant to heat and drought and can be grown on a wide range soils from sandy loam to loamy soils. The soil should be well drained with optimum range of 6.0-6.5 pH. The highest fruit quality and maximum yields are obtainable in the dry season with supplementary water.

Temperatures above 32 °C adversely affect the fruit set and development. Tomato is the major vegetable in the tropics. The plants cannot withstand frost and high humidity. Because of its physicochemical and biological properties, the crop has attracted attention particularly related to its effects as a natural antioxidant.

Yield is a complex character which is highly influenced by environmental fluctuations and the selection on the basis of observed phenotypic variability is not effective. However, the expected improvement chiefly relies on the nature and magnitude of the heritable variation. Selection based on the highly heritable characters is too effective than those which are poorly heritable.

Material and Methods

The study was conducted at Regional Horticultural Research and Extension Centre (RHREC), Kumbapur, Dharwad, University of Horticultural Sciences (UHS), Bagalkot (Karnataka), during *rabi* season 2020-2021. Twenty nine genotypes collected from RHREC, Dharwad, four from IIHR, Bangalore, one from TNAU, Coimbatore, two from IARI, New Delhi, one from IIVR, Varanasi and four from UAS, Dharwad were taken for investigation.

Experiment was laid out in randomized complete block design (RCBD) with three replications. The healthy seedlings were transplanted 30 days after sowing in the experimental field at spacing of 60 cm from row to row and 50 cm from plant to plant.

The observations were recorded in all randomly tagged five plants in each replication for different traits *viz*., plant height, number of branches per plant, plant spread, days to first flower initiation, days to 50 per cent flowering, number of fruits per cluster, average fruit weight, number of fruits per plant, number of locules per fruit, TSS, pH, ascorbic acid content, pericarp thickness of fruit, firmness, lycopene content, titratable acidity, fruit length, fruit diameter, fruit volume, yield per plant, yield per plot and yield per hectare. The average values were computed as treatment means under each replication.

The analysis of variance for design of experiment was done for partitioning the variance into treatments and replications. Phenotypic and genotypic coefficients of variation were calculated by using the following formulae suggested by Burton and Devane (1953) [5]. The broad sense heritability (h^2) was calculated using the method proposed by Webber and Moorthy (1952) [15]. Genetic advance and genetic advance as per cent over mean for each character was predicted by the formula given by Johnson *et al*. (1955) [7].

Results and Discussion

The results of the analysis of variance for different quantitative and qualitative traits of 41 genotypes of tomato were presented in Table 1. The results revealed that differences due to various genotypes were highly significant for characters studied.

For all the traits studied, PCV was slightly higher than GCV, this indicates that these characters were not much influenced by environmental factors. Hence, selection based on phenotypic performance will be more reliable. These results were in accordance with the findings of Reddy *et al*. (2013) [10] and Taiana *et al*. (2015) [13] in tomato.

High (>20%) GCV and PCV were observed for plant spread at 60 DAT, number of branches per plant, average fruit weight, fruit volume, yield per plant, yield per plot, yield per hectare, number of fruits per plant, number of locules per fruit**,** ascorbic acid, pericarp thickness and titratable acidity (Table 2). This indicates the existence of broad genetic base, which would be amenable for further selection. Estimates of GCV and PCV were moderate (10-20%) for traits like plant height at 60 DAT, fruit length, fruit diameter, number of fruits per cluster, TSS and firmness which indicates presence of limited amount of variation for these traits. Low (0-10%) GCV and PCV were recorded for traits like days to first flower initiation, days to 50 per cent flowering and pH of the fruit. This indicates the lack of sufficient variability in the genotypes. Hence, variability has to be generated in these traits either through introduction or hybridizing divergent genotypes to recover transgressive segregants or by mutation breeding. Similar results were also reported by Mohamed *et al*. (2012) [8] and Rahaman *et al*. (2012) [9].

Coefficient of variation indicates only the extent of variability present in the genotypes for different traits, but for the prediction of response to selection, heritability estimates are useful. Considering heritability in broad sense along with genetic advance may reveal the prevalence of specific components (additive or non-additive) of genetic variance and thus, help in judging the effectiveness of selection for the trait more accurately (Johnson *et al*. 1955) [7].

High heritability (>60%) coupled with high GAM (>20%) was observed for plant height at 90 DAT, plant spread, number of branches per plant, fruit length, fruit diameter, average fruit weight, fruit volume, number of locules per fruit, number of fruits per cluster, number of fruits per plant, yield per plant, yield per plot, yield per hectare, TSS, ascorbic acid content of fruit, lycopene content, titratable acidity, pericarp thickness and firmness. This indicates that these characters are controlled by additive gene effect and are less influenced by environmental factors. Therefore, these characters can be improved by simple selection. Similar results were also reported by Amarjeet *et al.* (2016) [1], Arya *et al.* (2018) [3], Anuradha *et al*. (2020) [2] and Cholin *et al.* (2021) [6]. High heritability coupled with moderate GAM was noticed for days to 50 per cent flowering and pH. This indicates the prevalence of non-additive components and there can be little response to selection and these characters can be exploited through heterosis breeding. High heritability coupled with low GAM was observed for the trait like days to first flower initiation. The results were in agreement with the findings of Bhandari *et al*. (2017) [4], Singh and Singh (2019) [11] and Sushma *et al*. (2020) [12].

Table 1: Analysis of variance (mean squares) for various quantitative and qualitative traits in tomato genotypes

Sl. No.	Characters	Replication	Treatments (Genotypes)	Error	SE.m ±	CD (5%)	CD (1%)
	Degrees of freedom	2	40	80			
1	Plant height at 60 DAT	52.17	192.66**	50.87	4.06	8.09	10.73
2	Plant height at 90 DAT	108.99	639.99**	63.39	4.54	9.03	11.98
3	Plant spread (N-S) at 60 DAT	2.29	342.76**	2.81	0.95	1.90	2.52
4	Plant spread (N-S) at 90 DAT	7.91	368.70**	3.37	1.04	2.08	2.76

5	Plant spread (E-W) at 60 DAT	12.59	391.14**	5.96	1.39	2.77	3.67
6	Plant spread (E-W) at 90 DAT	9-87	390.50**	5.96	1.11	2.21	2,94
7	Number of branches per plant	0.07	1.93**	0.13	0.20	0.41	0.55
8	Days to first flowering	0.83	8.43**	1.33	0.65	1.30	1.73
9	Days to 50% flowering	3.03	24.34**	1.28	0.64	1.28	1.70
10	Fruit length	0.06	1.61**	0.044	0.12	0.23	0.31
11	Fruit diameter	0.13	1.23**	0.063	0.14	0.28	0.37
12	Average fruit weight	14.48	1079.61**	14.25	2.15	4.28	5.68
13	Fruit volume	3.95	854.17**	24.04	2.79	5.56	7.37
14	Number of locules per fruit	0.016	1.80**	0.031	0.10	0.20	0.26
15	Number of fruits per cluster	0.112	0.76**	0.037	0.11	0.21	0.29
16	Number of fruits per plant	21.79	172.47**	7.63	1.57	3.13	4.15
17	Yield per plant	0.06	0.38**	0.02	0.08	0.16	0.22
18	Yield per plot	6.78	32.88**	2.30	0.86	1.72	2.28
19	Yield per hectare	37.53	258.12**	21.50	2.64	5.26	6.97
20	TSS	0.013	0.86**	0.02	0.08	0.16	0.21
21	pH	0.029	0.49**	0.014	0.06	0.13	0.17
22	Ascorbic acid content	1.99	100.04**	0.92	0.54	1.09	1.44
23	Lycopene content	0.0013	1.83**	0.006	0.04	0.08	0.12
24	Titratable acidity	0.00048	0.037**	0.00016	0.01	0.01	0.02
25	Pericarp thickness of fruit	0.013	2.98**	0.04	0.11	0.23	0.30
26	Firmness	0.012	0.37**	0.0126	0.06	0.13	0.16

** Significant at 1 per cent * Significant at 5 per cent level DAT: Days after transplanting

Table 2: Estimates of genetic parameters in tomato genotypes

Sl. No.	Characters	Range	Mean	GV	PV	GCV (%)	PCV (%)	h^2 (%)	GA	GAM (%)
1	Plant height at 60 DAT (cm)	43.33- 79.13	60.32	47.26	98.13	11.39	16.42	48.16	9.82	16.29
2	Plant height at 90 DAT (cm)	51.13-110.60	72.22	192.19	255.59	19.19	22.13	75.20	24.76	34.29
3	Plant spread (N-S) at 60 DAT (cm)	30.00 - 68.40	46.47	113.31	116.13	22.90	23.19	97.57	21.66	46.61
4	Plant spread (N-S) at 90 DAT (cm)	34.40- 73.93	53.44	121.77	125.14	20.64	20.93	97.31	22.42	41.95
5	Plant spread (E-W) at 60 DAT (cm)	28.13- 72.67	50.02	128.39	134.35	22.65	23.17	95.56	22.81	45.61
6	Plant spread (E-W) at 90 DAT (cm)	35.80-78.00	57.33	128.89	132.71	19.80	20.09	97.12	23.04	40.19
7	Number of branches per plant	1.60- 5.47	3.73	0.60	0.73	20.77	22.99	81.60	1.44	38.67
8	Days to first flowering	30.87- 39.07	33.92	2.36	3.69	4.53	5.66	63.99	2.53	7.47
9	Days to 50% flowering	32-45.33	38.69	7.68	8.96	7.16	7.74	85.70	5.28	13.66
10	Fruit length (cm)	3.31-6.52	4.74	0.52	0.56	15.25	15.89	92.20	1.43	30.18
11	Fruit diameter (cm)	3.36-5.93	4.79	0.39	0.45	13.03	14.04	86.09	1.19	24.90
12	Average fruit weight (g)	35.44-107.44	68.37	355.12	369.37	27.56	28.11	96.14	55.67	38.06
13	Fruit volume (cc)	16.22-81.00	47.19	276.71	300.75	35.25	36.75	92.01	32.86	69.65
14	Number of locules per fruit	2.40-5.07	3.47	0.59	0.62	22.11	22.69	94.92	1.54	44.38
15	Number of fruits per cluster	2.27-4.60	2.98	0.24	0.28	16.53	17.76	86.70	0.94	31.72
16	Number of fruits per plant	12.50-38.39	23.80	54.94	62.58	31.14	33.23	87.70	14.30	60.11
17	Yield per plant (g)	0.84-2.17	1.41	0.12	0.14	24.48	26.61	84.68	0.65	46.41
18	Yield per plot (kg)	10.41-21.17	15.21	10.19	12.49	20.98	23.23	81.58	5.94	39.05
19	Yield per hectare (t/ha)	29.67-58.79	42.45	78.87	100.37	20.92	23.60	78.58	16.21	38.20
20	TSS (°Brix)	2.80-5.52	3.85	0.27	0.30	13.74	14.23	93.10	1.05	27.33
21	pH	3.56-5.13	4.22	0.16	0.17	9.52	9.92	91.97	0.79	18.80
22	Ascorbic acid content (mg/100g)	12.53-41.47	20.12	33.03	33.96	28.56	28.96	97.27	11.67	58.02
23	Lycopene content (mg/100g)	3.33-6.42	4.56	0.60	0.61	17.08	17.17	98.90	1.59	35.02
24	Titratable acidity (%)	0.11-0.77	0.19	0.01	0.01	60.05	60.45	98.67	0.22	122.88
25	Pericarp thickness of fruit (mm)	2.76-7.51	4.83	0.98	1.02	20.49	20.91	96.08	2.00	41.38
26	Firmness (N)	1.21-2.71	1.84	0.12	0.13	18.92	19.88	90.53	0.68	37.08

GV- Genotypic variance **PCV**- Phenotypic coefficient of variation **h^2** - broad sense heritability
PV - Phenotypic variance **GCV**- Genotypic coefficient of variation **DAT**- Days after transplanting
GA- Genetic advance **GAM**- Genetic advance as per cent over mean

Conclusion

The analysis of variance indicated highly significant variation among the genotypes for all the characters studied. High GCV and PCV indicate the existence of broad genetic base, which would be amenable for further selection. High heritability coupled with high GAM indicates that these characters are controlled by additive gene effect and are less influenced by environmental factors. Therefore, these characters can be improved by simple selection.

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