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Research Article

VARIABILITY AND CORRELATION STUDY IN TOMATO (*Solanum lycopersicum* L.)

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Abstract- The present study was carried out with twenty five tomato germplasm during summer season of 2013 at Pantnagar Centre for Plant Genetic Resources (PCPGR), G.B. Pant University of Agriculture and Technology, Pantnagar, (U.S. Nagar) Uttarakhand. The experiment was conducted in Randomized Block Design with three replications. Observations were recorded on ten quantitative and three qualitative traits. The results revealed significant variation among germplasm for all the characters. Among all the genotypes, DARL-62 showed the highest fruit yield per hectare (232.36q/ha). Higher phenotypic and genotypic coefficients of variation (PCV and GCV) were observed for average fruit weight, number of fruits per plant and percentage acidity. High heritability coupled with high genetic advance as per cent of mean were estimated for average fruit weight, number of fruits per plant, percentage acidity, pericarp thickness and number of locules per fruit. The yield per hectare displayed positive correlation with number of fruits per plant, pericarp thickness, number of locules per fruit, average fruit weight, ascorbic acid content and yield per plant. Path analysis indicated that positive direct effect on fruit yield per hectare was exerted by yield per plant, number of flowers per inflorescence, number of locules per fruit, ascorbic acid content, percentage acidity, fruit diameter, plant height and total soluble solids. The findings suggested that average fruit weight, number of fruits per plant, number of locules per fruit and percentage acidity should be considered as important characters for improvement of tomato through selection.

Keywords- Correlation and path coefficient, Tomato, Variability.

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Introduction

Tomato (*Solanum lycopersicum* L., formerly *Lycopersicon esculentum* Mill.), is one of the most economically important and widely grown plants in *Solanaceae* family because of its wider adaptability, high yielding potential and suitability for variety of uses in fresh as well as processed food industries [16]. All the species of tomato are native to Western South America [15]. The popularity of tomato as fresh and processed crop has made it an important source of vitamin A and C in diets. Worldwide tomato ranks first among processed vegetables.

Tomato is one of such crop, which has received wider attention of vegetable breeders in various countries. Improvement of crop depends on the magnitude of genetic variability in economic characters, therefore, the evaluation and utilization of genetic variability in desired direction becomes extremely important in any yield improvement programme [2]. The extent of genetic variability in a specific breeding population depends on the genotypes included in it and its selection history. In this regard, it is necessary to survey the available useful variability and nature of association among the various plant characters. The phenotypic expression of the plant characters is mainly controlled by the genetic makeup of the plant and the environment, in which it is growing. The genetic variance of any quantitative traits is due to of additive variance and non-additive variance and include epitasis (non-allelic interaction) and dominance. It is necessary to partition the observed phenotypic variability into its heritable and non-heritable components with parameters like phenotypic and genotypic coefficient of variation, heritability and genetic advance. Efficiency of selection can be determined by using genetic advance. For any effective selection programme, it would be desirable to consider the relative magnitude of association of various characters with yield. The path coefficient technique helps in estimating the direct and indirect contribution of various traits out of the total correlation towards yield [12]. On the basis of these strategies, present investigation was undertaken to study the variability, heritability, genetic advance, correlation and path analysis in twenty five genotypes of tomato.

Materials and Methods

The experiment was conducted in Randomized Block Design with three replications during the spring summer season of 2013 at Pantnagar Centre for Plant Genetic Resources (PCPGR), G.B. Pant University of Agriculture and Technology, Pantnagar, (U.S. Nagar) Uttarakhand. The experimental material comprised of 25 genotypes, detail of germplasms given in [Table-1]. A spacing of 60 cm × 45 cm was adopted and all the standard practices and plant protection measures were timely adopted to raise the crop successfully. Observations were recorded on five randomly selected competitive plants per replication for each entry on ten quantitative and three qualitative traits *viz*., plant height (cm), number of flowers per inflorescence, number of fruit set per inflorescence, number of fruits per plant, pericarp thickness (mm), number of locules per fruit, fruit diameter (cm), average fruit weight (g), yield per plant (g), fruit yield (q/ha), total soluble solids (^{0}B), ascorbic acid content (mg/100g) and percentage acidity (%). The data regarding above mentioned characters were averaged and subjected to analysis of variance [14]. The genotypic and the phenotypic coefficients of variation were calculated according to the formula given by [5]. Heritability in broad sense and genetic advance as per cent of mean were computed by following the methods of

[2,10] respectively. Correlation and path coefficient analysis were worked out as per formulae suggested by [1,7] respectively.

Table-1 *List of genotypes and their sources used for diversity study*

S.No	Genotypes	Source
1.	AC-576	PCPGR, Pantnagar
2.	Sel-816-06	PCPGR, Pantnagar
3.	ARTH-3	PCPGR, Pantnagar
4.	EC-519821`	PCPGR, Pantnagar
5.	Cherry Sutton	PCPGR,Pantnagar
6.	EC-519812	PCPGR, Pantnagar
7.	Cherry Tomato	PCPGR ,Pantnagar
8.	EC-519977	PCPGR, Pantnagar
9.	EC-519769	PCPGR, Pantnagar
10.	CLN-2413	PCPGR, Pantnagar
11.	PT-09-06	PCPGR, Pantnagar
12.	Cherry-2	PCPGR, Pantnagar
13.	EC-519818	PCPGR, Pantnagar
14.	PT-19	PCPGR, Pantnagar
15.	PT-8	PCPGR, Pantnagar
16.	EC-519724	PCPGR, Pantnagar
17.	DARL-67	DRDO, Pithoragarh
18.	ArkaVikas	PCPGR, Pantnagar
19.	DARL-69	DRDO, Pithoragarh
20.	DARL-68	DRDO, Pithoragarh
21.	DARL-66	DRDO, Pithoragarh
22.	DARL-62	DRDO, Pithoragarh
23.	Shalimar	PCPGR, Pantnagar
24.	PantT-3	PCPGR, Pantnagar
25.	CO-3	PCPGR, Pantnagar

Results and Discussion

The success of breeding programme depends upon quantum of variability present in the available germplasm. Analysis of variance showed the difference due to genotypes was significant for all the characters studied. This indicates sufficient genetic variability to be exploited in a breeding programme and was reflected in the broad range observed for each trait [Table-2]. No. of flowers per inflorescence was recorded maximum in the genotype Cherry Sutton (7.83) followed by Cherry Tomato (7.50), EC-519724 (7.33), EC- 519977 (7.23) and EC- 519818 (7.07) whereas minimum no. of flower per inflorescence was recorded in check PT-3 (4.17). Among all the genotypes DARL-62 showed the highest fruit yield per hectare (232.36 q/ha). The maximum fruits per plant were recorded in Cherry Tomato (53.57) followed by Cherry Sutton (53.03), whereas minimum number of fruits per plant were recorded in PT-09-06 (16.62). Maximum average fruit weight was shown by DARL-67 (80.63) followed by PT-09-06 (53.90) and CO-3 (46.60) whereas minimum average fruit weight was shown by Cherry Sutton (12.77). Among all genotypes maximum percent acidity was shown by fruits of CO-3 (0.58) followed by Check Arka Vikas (0.55) whereas minimum percent acidity was shown by ARTH-3(0.15).

The higher phenotypic coefficient of variation than those of genotypic coefficient of variation [Table-3] indicated the predominant role of environment in the expression of traits, which is in confirmation with the result obtained by [3,16]. The results showed that higher phenotypic and genotypic coefficients of variation (PCV and GCV) were observed for average fruit weight (PCV= 51.14%; GCV= 50.46%), number of fruits per plant (PCV= 38.65%; GCV= 37.66%) and percentage acidity (PCV= 38.90%; GCV= 37.06%). Similar findings were also reported by [11,13].

Table-2 *Mean performance of different genotypes of tomato*

Germplasm	Plant height (cm)	No. of flowers per inflore-scence	No. of fruit set per inflore-scence	No. of fruits per plant	Pericarp thickness (mm)	No. of locules per fruit	Fruit diameter (cm)	Average fruit weight (g)	T.S.S (⁰B)	Ascorbic acid content (mg)	Percent Acidity	Yield per plant (g)	Fruit yield (q/ha)
AC-576	92.07	6.13	5.16	29.80	2.71	3.33	3.79	21.87	4.67	28.23	0.46	488.83	180.87
Sel-816-06	102.20	6.20	5.10	36.07	3.09	2.73	2.93	15.53	6.27	29.93	0.34	561.46	207.74
ARTH-3	108.00	5.13	4.33	28.40	2.87	3.13	3.37	22.90	6.93	28.60	0.15	492.00	182.04
EC-519821`	133.27	6.87	6.83	25.10	2.59	2.00	2.85	19.60	5.69	15.63	0.25	433.50	135.07
Cherry Sutton	115.74	7.83	5.87	53.03	2.16	2.00	2.70	12.77	5.73	17.30	0.29	471.59	174.49
EC-519812	114.09	6.33	5.40	23.57	2.23	4.00	3.69	25.50	4.74	22.33	0.22	485.83	179.70
Cherry Tomato	116.62	7.50	5.93	53.57	2.18	3.00	2.79	18.27	5.23	27.73	0.24	547.00	202.39
EC-519977	115.00	7.23	5.17	41.83	2.25	3.33	3.10	17.90	5.35	28.80	0.18	568.67	210.41
EC-519769	121.60	6.73	5.47	49.23	2.11	2.63	3.06	21.60	4.91	28.17	0.29	567.33	209.91
CLN-2413	127.33	7.00	5.97	28.80	1.93	2.80	2.86	15.53	4.82	29.33	0.30	562.50	208.13
PT-09-06	110.00	6.27	4.23	16.62	3.71	3.20	3.22	53.90	4.76	21.97	0.27	525.67	194.50
Cherry-2	111.47	6.20	4.73	32.87	2.65	2.00	2.48	16.70	5.10	30.10	0.29	544.83	201.59
EC-519818	102.38	7.07	5.33	21.03	3.26	3.17	4.13	36.30	4.72	23.97	0.25	492.50	182.23
PT-19	99.33	6.40	5.23	20.58	3.45	2.43	3.21	36.61	4.30	33.63	0.28	545.08	201.68
PT-8	106.93	6.57	4.63	19.78	4.01	2.00	4.43	40.00	4.13	30.23	0.19	487.50	180.35
EC-519724	108.99	7.33	4.90	33.30	2.70	2.00	2.99	16.63	4.99	27.90	0.16	485.29	179.55
DARL-67	73.50	6.37	4.67	18.00	4.78	4.53	5.47	80.63	5.21	17.27	0.47	572.00	211.64
Arka Vikas	132.33	4.80	4.00	27.89	3.50	3.25	3.30	34.17	3.73	26.87	0.55	533.90	197.54
DARL-69	74.97	5.40	4.77	20.00	3.27	3.67	3.27	24.65	5.19	27.83	0.36	522.08	193.17
DARL-68	80.83	6.27	4.37	18.50	4.37	2.80	3.45	38.03	4.34	24.90	0.21	624.14	230.90
DARL-66	71.27	6.50	4.60	19.67	4.74	2.77	4.99	31.97	5.05	28.77	0.25	462.27	171.04
DARL-62	65.47	4.43	3.53	23.33	3.44	4.67	4.21	42.87	5.07	37.70	0.41	628.00	232.36
Shalimar	71.80	4.47	3.80	20.67	2.77	4.37	4.57	27.83	4.30	34.83	0.55	372.00	137.38
PT-3	125.26	4.17	3.23	24.43	3.76	3.40	4.22	43.67	4.67	29.50	0.35	557.63	206.32
CO-3	70.07	6.63	5.23	24.03	4.12	4.10	4.47	46.60	3.90	27.90	0.58	456.33	168.84
GM	102.0	6.2	4.9	28.4	3.1	3.1	3.6	30.5	4.9	27.2	0.32	519.5	191.2
SEM	6.0	0.40	0.3	1.4	0.12	0.15	0.17	1.4	0.29	1.1	0.02	33.7	12.4
CD (1%)	22.8	1.5	1.2	5.4	0.45	0.56	0.63	5.5	1.1	4.3	0.08	127.9	47.0
CD (5%)	17.1	1.1	0.87	4.1	0.34	0.42	0.47	4.1	0.84	3.3	0.06	95.9	35.2
CV	10.2	11.2	10.8	8.7	6.5	8.2	8.0	8.3	10.4	7.3	11.8	11.2	11.2

Heritability is used in predicting the expected progress to be achieved through selection [6,10]. In the present study, the high heritability was noticed for average fruit weight (97.37%), number of fruits per plant (94.93%), pericarp thickness (94.15%), percentage acidity (90.77%), number of locules per fruit (90.63%), fruit diameter (87.63%) and ascorbic acid content (86.72%). High heritability can be attributed to the greater role of additive gene and additive x additive gene action, which can be exploited by following simple selection. Genetic advance is the improvement over the base population that can potentially be made from selection for a character. High genetic advance as per cent of mean was observed for average fruit weight (102.5%), percentage acidity (76.67%), number of fruits per

plant (75.60%), pericarp thickness (53.23%), number of locules per fruit (50.3%), fruit diameter (40.8%), plant height (36.47%) and ascorbic acid content (35.85%). This is in conformity with the findings of [17]. Estimating the real effects of selection, heritability alone is not sufficient and genetic advance along with heritability is more useful [10]. High heritability coupled with high genetic advance as per cent of mean were estimated for average fruit weight, number of fruits per plant, percentage acidity, pericarp thickness and number of locules per fruit. Similar observations were obtained by [8,9]. It suggested that these traits could be considered as reliable indices for selection and higher response of these traits could be expected from selection.

A perusal of the data revealed that genotypic correlation coefficients were higher than phenotypic correlation coefficients for most of the pairs of characters [Table-4]. This might be due to the masking effect of environment in the total expression of the genotypes resulting in the reduced phenotypic association [4]. The yield per hectare displayed positive correlation with number of fruits per plant, pericarp thickness, number of locules per fruit, average fruit weight, ascorbic acid content and yield per plant. Similar correlation of yield per plant with yield per hectare was also reported by [17]. Positive correlation of fruit yield with number of fruits per plant, pericarp thickness and average fruit weight was also noted by [12]. However, yield per hectare was negatively correlated with plant height, number of fruit set per inflorescence, fruit diameter and percentage acidity both at phenotypic and genotypic level.

Table-3 *Range, general mean, standard error mean and variability parameters in tomato.*

S.No.	Character	Range	General Mean (GM)	Standard error mean (SEM)	Coefficient of variation (%)		Heritability in broad sense h^2 (%)	Genetic advance GA	Genetic Advance as per cent of mean (%)
					PCV (%)	GCV (%)			
1	Plant height (cm)	65.47- 133.27	102.0	6.0	22.35	19.89	79.17	37.20	36.47
2	No. of flowers per inflorescence	4.17-7.83	6.2	0.40	18.29	14.40	61.99	1.46	23.55
3	No. of fruit set per inflorescence	3.23- 6.83	4.9	0.3	18.85	15.46	67.21	1.28	26.12
4	No. of fruits per plant	16.62- 53.57	28.4	1.4	38.65	37.66	94.93	21.47	75.6
5	Pericarp thickness (mm)	1.93- 4.78	3.1	0.12	27.03	26.23	94.15	1.65	53.23
6	No. of locules per fruit	2.00- 4.67	3.1	0.15	26.94	25.65	90.63	1.56	50.3
7	Fruit diameter (cm)	2.48- 5.47	3.6	0.17	22.75	21.30	87.63	1.47	40.8
8	Average fruit weight (gm)	12.77- 80.63	30.5	1.4	51.14	50.46	97.37	31.27	102.5
9	T.S.S (^{0}B)	3.73- 6.93	4.9	0.29	16.60	12.96	60.98	1.03	21.02
10	Ascorbic acid content (mg)	15.63- 37.70	27.2	1.1	20.10	18.71	86.72	9.75	35.85
11	Percentage Acidity (%)	0.15- 0.58	0.32	0.02	38.90	37.06	90.77	0.23	71.8
12	Yield per plant (g)	372.0- 628.0	519.5	33.7	14.52	9.2	40.06	62.25	11.98
13	Fruit yield (q/ha)	135.07-232.36	191.2	12.4	15.41	10.56	46.98	28.53	14.92

Table-4 *Phenotypic and genotypic correlations coefficients for 13 characters in tomato*

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}
X_1	1	0.29	0.41*	0.49*	-0.61**	-0.59**	-0.68**	-0.45*	0.15	-0.32	-0.39*	0.076	-0.0039
X_2		1	0.88**	0.51**	-0.34	-0.60**	-0.38	-0.32	0.15	-0.54**	-0.51**	-0.21	-0.18
X_3			1	0.48*	-0.57**	-0.49*	-0.49*	-0.51**	0.26	-0.54**	-0.30	-0.26	-0.34
X_4				1	-0.71**	-0.37	-0.60**	-0.62**	0.39*	-0.079	-0.14	0.13	0.15
X_5					1	0.27	0.74**	0.80**	-0.38	-0.007	0.23	0.12	0.16
X_6						1	0.63**	0.54**	-0.21	0.19	0.64**	0.098	0.16
X_7							1	0.75**	-0.35	0.086	0.40*	-0.24	-0.16
X_8								1	-0.39*	-0.16	0.34	0.24	0.24
X_9									1	-0.25	-0.41*	0.029	0.018
X_{10}										1	0.18	0.21	0.32
X_{11}											1	-0.14	-0.11
X_{12}												1	0.01
X_{13}													1

Where X_1=Plant height (cm), X_2= No of flowers per inflorescence, X_3= No. of fruit set per inflorescence, X_4 = No. of fruit per plant, X_5 = Pericarp thickness, X_6= No. of locules per fruit, X_7= Fruit diameter (cm), X_8= Average fruit weight, X_9= T.S.S.(^{0}B), X_{10}= Ascorbic acid content (mg/100gm),X_{11}= percent acidity, X_{12}=Yield per plant (g), X_{13}= Fruit yield (q/ha).

**= Significant at 1 % level

*= Significant at 5 % level

Table-5 *Estimates of phenotypic direct and indirect effect on yield for 13 character in tomato.*

Characters	Plant height (cm)	No. of flowers per inflorescence	No. of fruit set per inflorescence	No. of fruits per plant	Pericarp thickness (mm)	No. of locules per fruit	Fruit diameter (cm)	Average fruit weight (gm)	T.S.S (^{0}B)	Ascorbic acid content (mg)	Percent Acidity	Yield per plant (g)
Plant height (cm)	**0.011**	0.068	-0.103	-0.002	0.018	-0.036	-0.010	0.023	0.001	-0.016	-0.019	0.034
No. of flowers per inflorescence	0.003	**0.258**	-0.220	-0.002	0.009	-0.034	-0.005	0.015	0.001	-0.026	-0.023	-0.065
No. of fruit set per inflorescence	0.004	0.209	**-0.272**	0.004	0.209	-0.220	-0.002	0.016	-0.029	-0.007	0.024	0.0001
No. of fruits per plant	0.005	0.121	-0.122	**-0.004**	0.021	-0.023	-0.009	0.032	0.002	-0.004	-0.009	0.104
Pericarp thickness (mm)	-0.006	-0.077	0.141	0.003	**-0.031**	0.016	0.011	-0.041	-0.001	-0.0003	0.012	0.107
No. of locules per fruit	-0.006	-0.138	0.123	0.002	-0.008	**0.064**	0.009	-0.028	-0.000	0.010	0.029	0.076
Fruit diameter (cm)	-0.007	-0.089	0.125	0.003	-0.022	0.038	**0.016**	-0.038	-0.001	0.004	0.020	-0.172
Average fruit weight (gm)	-0.005	-0.074	0.124	0.002	-0.024	0.033	0.011	**-0.052**	-0.001	-0.008	0.018	0.190
T.S.S (^{0} B)	0.001	0.034	-0.065	-0.002	0.010	-0.011	-0.005	0.019	**0.004**	-0.011	-0.021	0.042
Ascorbic acid content (mg)	-0.003	-0.123	0.134	0.0003	0.0001	0.012	0.001	0.008	-0.001	**0.054**	0.007	0.166
Percent Acidity	-0.004	-0.121	0.079	0.001	-0.008	0.038	0.006	-0.019	-0.002	0.008	**0.049**	-0.139
Yield per plant (g)	0.0004	-0.018	0.056	-0.0005	-0.003	0.005	-0.003	-0.010	0.0001	0.009	-0.007	**0.950**

Residual factor **0.0145**

Note: Bold letter indicate direct effect characters, and unbold letter indicate indirect effect of characters on fruit yield

Path coefficient analysis is used to make partition of the correlation coefficient of the different characters to know direct and indirect effects on yield. The information obtained helps in giving proper weightage to the various characters during selection or other breeding programme. Path coefficient analysis [Table-5] indicated that positive direct effect on fruit yield per hectare was extended by yield per plant (0.950), number of flowers per inflorescence (0.258), number of locules per fruit (0.064), ascorbic acid content (0.054), percentage acidity (0.049), fruit diameter (0.016), plant height (0.011) and total soluble solids (0.004). Positive direct effect of fruit diameter and plant height on yield was also observed by [12]. The negative direct effect on fruit yield per hectare was showed by number of flowers per inflorescence (-0.272), average fruit weight (-0.052), pericarp thickness (-0.031) and number of fruits per plant (-0.004). The highest positive indirect contribution towards yield per hectare was observed by number of fruit set per inflorescence (0.209) via number of flowers per inflorescence and number of fruit set per inflorescence (0.209) via pericarp thickness.

Conclusion

Thus based on the finding of present investigation it can be concluded that diversity and variability was present among the genotypes for all the characters indicating that considerable scope existed for the improvement of tomato cultivars through selections. Out of 23 germplasm and 2 checks, seven genotypes were found superior for different characters namely, EC-519821, Cherry Sutton, Cherry Tomato, DARL-67, ARTH-3, DARL-62, and CO-3. These superior genotypes can be used for future breeding programme. In present finding, most of the characters were not significantly correlated with yield due to most divers genotypes

Abbreviations

PCV: Phenotypic coefficients of variation
GCV: Genotypic coefficients of variation

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Author contributions

Ashish Kaushal -conception and design of the work, data collection, data analysis and interpretation, drafting the article, critical revision of the article, final approval of the version to be published and acted as corresponding author Ashish Kaushal -conception and design of the work, critical revision of the article, final approval of the version to be published.
Anita Singh -critical revision of the article.
Akshay Chittora, Lalit Nagar, and Rajeev Kumar Yadav and Mahesh Kumar Kumawat -critical revision of the article, final approval of the version to be published.

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