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Genetic Associations Analysis in Tomato (*Solanum lycopersicum* L.) Involving Improved Germplasm Lines for Agronomic and Yield Contributing Traits

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ABSTRACT

Keywords

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Correlation and path analysis was carried out in 60 tomato genotypes using growth, earliness, quality and yield characters. Very high (>40%) genotypic coefficient of variation (GCV) and phenotypic coefficient variation (PCV) were observed for fruit volume, average fruit weight and yield plant-1. It indicates existence of broad genetic base, which would be amenable for further selection. Very high heritability (>90%) coupled with very high genetic advance as per cent over mean (>40%) was recorded for the characters viz., polar diameter, fruit volume, average fruit weight, number of fruits plant-1, yield plot-1. Yield per plant was positively and significantly associated with average fruit weight, fruit volume, equatorial diameter, pericarp thickness, polar diameter and number of locules. Yield per plant was negatively and significantly associated with number of branches at 90 DAT, number of branches at 60 DAT, plant height at 90 DAT and plant spread from north to south at 60 DAT. Path analysis revealed that number of fruits per plant followed by plant spread from north to south at 60 DAT, plant spread from east to west at 60 DAT, average fruit weight and fruit volume. Hence, direct selection for these traits is suggested for yield improvement.

Introduction

Tomato is an important member of family Solanaceae. For a systematic breeding program, it is essential to identify the parents as well as crosses to bring the genetic improvement in economic character (Kaushik and Dhaliwal, 2018). The magnitude of heterosis depends on the genetic diversity existing between the parents. In a crop like a

tomato, where there are evidences for polygenic action determining the yield, and the yield components the choice of parents must be based on refined biometrical techniques (Vijeth *et al.*, 2019).

The value of genotypes depends on the ability to produce superior hybrids in combination with other genotypes (Kaushik, 2015). In tomato to exploit the available variability

through the breeding program, the genetic study regarding the yield and quality trait is essential.

The yield in tomato is due to the interaction between many of the correlated characters. Selection of these characters is very important when based on the component characters which will be highly heritable and also positively correlated (Kaushik *et al.*, 2015). The correlation coefficient method of analysis helps to identify the mutual relationship between several characters and it also helps to identify the component traits on which selection can be relied. Correlation studies provides information on all characters which are associated with yield.

A hybrid possessing higher yield, better quality will be an important contribution to farmers. An ideal chilli hybrid should be vigorous, have good branching habit, early flowering, prolonged production of flowers, high fruit weight, good plant height and high yield potential (Kaushik, 2019a and Kaushik, 2019b). It may be difficult to develop a hybrid having all these characters, but it is reasonable to develop one which can have maximum number of desirable characters keeping yield as a primary motto.

Materials and Methods

Sixty genotypes collected from different sources were evaluated during 2014-15 in the Department of Vegetable Science, Kittur Rani Channamma, College of Horticulture, Arabhavi. Arabhavi is situated in Northern dry zone of Karnataka State at 16° 12' North latitude, 74° 54' East longitude and an altitude of 640 meters above the mean sea level. Arabhavi, which comes under the Zone-3 of Region-2 among the agro-climatic zones of Karnataka, has benefits of both the south-west and north-east monsoons. Genotypes used in this experiment with their sources of

collection are listed in Table 1. The crop was grown in a randomized block design with two replications at spacing of 90 x 60 cm. Five randomly chosen plants in each replication of each genotype were labelled and used for recording the observations. Genotypic correlation coefficients were worked out among different traits using *per se* values (n=120). Correlations and path analysis carried out according to procedure given by Dewey and Lu (1959) respectively.

Estimation of genetic variability parameters

Genotypic and phenotypic coefficient of variation

Genotypic and phenotypic coefficients of variance were estimated according to Burton and Devane (1953) based on estimate of genotypic and phenotypic variance.

Genotypic co-efficient of variation (GCV)

$$GCV (\%) = \frac{\sigma_g}{\bar{X}} \times 100$$

Phenotypic co-efficient of variation (PCV)

$$PCV (\%) = \frac{\sigma_p}{\bar{X}} \times 100$$

Where,

$\bar{X}$ = General mean

σ_g = Genotypic standard deviation

σ_p = Phenotypic standard deviation

GCV and PCV were classified as suggested by Burton and Devane (1953)

0-10% : Low

10-20% : Moderate

20% and above: High

Heritability (h^2)

The broad sense heritability (h^2_{bs}) was estimated by following the procedure suggested by Webber and Moorthy (1952) as indicated here below.

$$h^2 = \frac{\sigma^2_g}{\sigma^2_p} \times 100$$

Where, h^2 (%) = Heritability (Broad sense)

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

Expected genetic advance

Genetic advance for each character was predicted by the formula given by Johnson *et al.*, (1955).

$$GA = h^2 \times \sigma_p \times k$$

Where, k = selection differential (2.06) at 5 per cent selection intensity

h^2 = Heritability in broad sense

σ_p = Phenotypic standard deviation

Genetic advance over per cent of mean (GAM)

Genetic advance as percentage over mean was worked out as suggested by Johnson *et al.*, (1955).

$$\text{Genetic advance over mean (GAM)} = \frac{GA}{\bar{X}} \times 100$$

Where, GA = Genetic advance

$\bar{X}$ = General mean

The genetic advance as per cent of mean was categorized as suggested by Johnson *et al.*, (1955) and the same is given below.

0-10% : Low

11-20% : Moderate

21% and above: High

Correlation analysis

The correlation co-efficient among all possible character combinations at phenotypic (rp) and genotypic (rg) level were estimated employing formula (Al-Jibouriet *al.*, 1958).

$$\text{Phenotypic correlation } = r_{xy}(p) = \frac{\text{Cov}_{xy}}{\sqrt{V_x(p) \times V_y(p)}}$$

$$\text{Genotypic correlation } = r_{xy}(g) = \frac{\text{Cov}_{xy}(g)}{\sqrt{V_x(g) \times V_y(g)}}$$

Where,

$\text{Cov}_{xy}(G)$ = Genotypic covariance between x and y

$\text{Cov}_{xy}(P)$ = Phenotypic covariance between x and y

$V_x(G)$ = Genotypic variance of character 'x'

$V_x(P)$ = Phenotypic variance of character 'x'

$V_y(G)$ = Genotypic variance of character 'y'

$V_y(P)$ = Phenotypic variance of character 'y'

The test of significance for association between characters was done by comparing table 'r' values at n-2 error degrees of freedom for phenotypic and genotypic correlations with estimated values, respectively.

Path co-efficient analysis

Path co-efficient analysis suggested by Wright (1921) and Dewey and Lu (1959) was carried out to know the direct and indirect effect of the morphological traits on plant yield. The following set of simultaneous equations were formed and solved for estimating various direct and indirect effects.

$$r_{1y} = a + r_{12}b + r_{13}c + \dots + r_{1li}$$

$$r_{2y} = a + r_{21}a + b + r_{23}c + \dots + r_{2li}$$

$$r_{3y} = r_{31}a + r_{32}b + c + \dots + r_{3i}i$$

$$r_{1y} = r_{11}a + r_{12}b + r_{13}c + \dots + I$$

Where,

r_{1y} to l_{1y} = Co-efficient of correlation between causal factors 1 to I with dependent characters y.

r_{12} to r_{11} = Co-efficient of correlation among causal factors

a, b, c.....i =Direct effects of characters 'a' to 'I' on the dependent character 'y'

Residual effect (R) was computed as follows.

$$\text{Residual effect (R)} = 1 - \sqrt{a^2 + b^2 + c^2 + \dots + i^2 + 2abr_{12} + 2acr_{13} + \dots}$$

Results and Discussion

Very high (> 40%) genotypic coefficient of variation (GCV) and phenotypic coefficient variation (PCV) were observed for fruit volume, average fruit weight and yield per plant. It indicates existence of broad genetic base, which would be amenable for further selection.

Fruit yield per plant exhibited high positive significant correlation with polar diameter, equatorial diameter, pericarp thickness, number of locules, average fruit weight and fruit volume at both genotypic and phenotypic level. The positive association of these suggests that selection of these traits would result in increased yield. Whereas, Fruit yield per plant exhibited high negative significant correlation with plant height at 60 and 90 DAT, number of branches at 60 and 90 DAT and plant spread from north to south at 60 and 90 DAT. Increased vegetative growth increases the number of fruits per plant but reduced individual fruit size because of increased competition among fruits for photosynthates which ultimately reduced the fruit yield per plant and fruit yield per plant.

Positive association of yield per plant with average fruit weight, polar diameter and equatorial diameter are in confirmation with findings of Singh(2007) and Prashanth *et al.*, (2008). Positive association of yield per plant with number of locules as also reported by Mahapatra *et al.*, (2013) and pericarp thickness is in accordance with earlier reports of Kumari and Sharma (2013) and Mahapatra *et al.*, (2013). Positive association of yield per plant with fruit volume (Prashanth *et al.*, 2008). Equatorial diameter was positively and significantly associated with polar diameter of the fruit (Singh *et al.*, 2008). Pericarp thickness was negatively and significantly associated with plant height at 60 DAT and number of branches at 90 DAT (Fageria and Kohli (1996) and Prashanth *et al.*, (2008) indicating inverse relationship between pericarp thickness and vegetative parameters.

Polar diameter was negatively and significantly associated with plant height 60 DAT (Krishnaprasad and Mathurarai, 1999 and Prashanth *et al.*, 2008), number of branches 90 DAT (Prashanth *et al.*, 2008). Number of locules positively and significantly associated with equatorial diameter (Singh *et al.*, 1974). It was also positively and significantly associated with plant spread from east to west at 60 DAT.

Average fruit weight was inversely associated with plant height at 60 DAT (Fageria and Kohli, 1996), number of branches at 90 DAT (Reddy and Gulshanlal, 1987), plant spread from east to west 90 DAT, plant spread from north to south at 90 DAT and plant canopy at 90 DAT. This is attributed to its (average fruit weight) inverse relation with number of fruits, where more competition for photosynthates resulted into reduced fruit size. Fruit volume was positively and significantly associated with polar diameter, equatorial diameter, pericarp thickness and number of locules per

fruit since all these traits increase the fruit size which in turn increases the fruit volume. But fruit volume was inversely correlated with plant height, number of branches and plant canopy due to increased vegetative growth resulting in decreased fruit size which ultimately reduces fruit volume (Prashanth *et al.*, 2008).

Number of fruits per plant was negatively and significantly associated with polar and equatorial diameter of the fruit, fruit volume and average fruit weight, pericarp thickness, days to first flowering and days to 50 per cent flowering (Sharma *et al.*, 2010) indicates inverse relationship.

Number of seeds per fruit was positively but non significantly associated with plant height at 60 and 90 DAT, number of locules per fruit (Prashanth *et al.*, 2008), days to first flowering and days to 50 per cent flowering. Negative and significant association of plant height and number of branches per plant with polar diameter of the fruit, equatorial diameter of the fruit and average fruit weight could be justified by low mean yield of indeterminate genotypes due to high number of fruits/plant although they possessed smaller fruits and more number of branches/plant. This substantiated that determinate types were high yielder because of higher average fruit weight they furnished. The correlation coefficient between plant canopy with plant height, number of branches, plant spread from east to west and plant spread from north to south were positively significant at both phenotypic and genotypic level suggesting the interdependence of these traits on each other (Manivannan *et al.*, 2005).

In the present study, path coefficient analysis between the components of yield per plot in tomato was worked out. As the genotypic associations are inherent, the path analysis is discussed only at genotypic level.

In the present investigation, among 21 characters chosen for path analysis number of fruits per plant, average fruit weight, fruit volume, pericarp thickness, equatorial diameter, plant height at 90 DAT, plant spread from north to south at 60 DAT, plant spread from east to west at 60 DAT and days to first flowering had high positive direct effects and positive correlation with total yield. This indicates the true positive association of these traits with total yield. Therefore, direct selection for these traits would reward for improvement of yield.

Number of fruits per plant and average fruit weight had high positive direct effects on total yield (Kumari and Sharma, 2013 and Mahapatra *et al.*, 2013). Number of primary branches per plant and equatorial diameter of the fruit also had high positive direct effects on total yield (Singh and Singh, 2008 and Mahapatra *et al.*, 2013). Plant height (Singh and Singh, 2008) and days to first flowering (Kumari and Sharma, 2013) also had high positive direct effect on total yield. Number of seeds per fruit (Sengupta *et al.*, 2009), yield per plant, polar diameter (Mahapatra *et al.*, 2013), plant canopy at 90 DAT, plant spread from north to south at 60 DAT, number of branches 90 DAT, plant canopy at 60 DAT, plant height at 90 DAT and days to 50 per cent flowering (Sharma *et al.*, 2010). had negative direct effects on total yield.

Plant canopy had high negative direct effects as well as negative association with fruit yield indicating that, this character were highly influenced by the environmental factors (Manivannan *et al.*, 2005). Number of branches at 90 DAT was negatively and significantly correlated ($r_g = -0.454$) with total yield and it had negative and high direct effects (-0.300) on total yield, but it had high indirect and negative effects through average fruit weight (-0.699), plant canopy at 60 DAT (-1.550) and plant height at 60 DAT (-0.544)

and high indirect and positive effects through number of fruits per plant (0.637), Plant height 90 DAT (0.430), Plant spread from north to south 60 DAT (1.041) and Plant

spread from east to west 60 DAT (0.580). Under these circumstances, the indirect causal factors also need to be considered simultaneously for selection (Kaushik 2019c).

Table.1 List of genotypes with their codes and sources of collection

Sl. No.	Genotype	Source	Sl. No.	Genotype	Source
1.	EC 361959	NBPGR, New Delhi	18.	EC 630512	NBPGR, New Delhi
2.	EC 399667	NBPGR, New Delhi	19.	EC 631962	NBPGR, New Delhi
3.	EC 570022	NBPGR, New Delhi	20.	EC 654725	NBPGR, New Delhi
4.	EC 608246	NBPGR, New Delhi	21.	EC 654724	NBPGR, New Delhi
5.	EC 608250	NBPGR, New Delhi	22.	EC 654719	NBPGR, New Delhi
6.	EC 608271	NBPGR, New Delhi	23.	EC 654699	NBPGR, New Delhi
7.	EC 608358	NBPGR, New Delhi	24.	EC 638577	NBPGR, New Delhi
8.	EC 608362	NBPGR, New Delhi	25.	EC 638573	NBPGR, New Delhi
9.	EC 608368	NBPGR, New Delhi	26.	EC 608288	NBPGR, New Delhi
10.	EC 608389	NBPGR, New Delhi	27.	EC 686554	NBPGR, New Delhi
11.	EC 610652	NBPGR, New Delhi	28.	EC 686550	NBPGR, New Delhi
12.	EC 608465	NBPGR, New Delhi	29.	EC 677111	NBPGR, New Delhi
13.	EC 610654	NBPGR, New Delhi	30.	EC 608348	NBPGR, New Delhi
14.	EC 610655	NBPGR, New Delhi	31.	EC 608320	NBPGR, New Delhi
15.	EC 610661	NBPGR, New Delhi	32.	EC 686548	NBPGR, New Delhi
16.	EC 632944	NBPGR, New Delhi	33.	EC 638519	NBPGR, New Delhi
17.	EC 634394	NBPGR, New Delhi	34.	EC 686544	NBPGR, New Delhi

NBPGR - National Bureau of Plant Genetic Resources, New Delhi

Table.1 Contd...

Sl. No.	Genotype	Source	Sl. No.	Genotype	Source
35.	EC 686543	NBPGR, New Delhi	48.	ArkaAbha	IIHR, Bengaluru
36.	EC 677044	NBPGR, New Delhi	49.	T-26	KRCCH, Arabhavi
37.	EC 608269	NBPGR, New Delhi	50.	DMT-2	UAS, Dharwad
38.	EC 686553	NBPGR, New Delhi	51.	ARS A-10	ARS, Arabhavi
39.	Kashi Hemanth	IIVR, Varanasi	52.	ARS A-06	ARS, Arabhavi
40.	Kashi Anupam	IIVR, Varanasi	53.	ARS A-11	ARS, Arabhavi
41.	Sel-12	IARI, New Delhi	54.	ARS A-05	ARS, Arabhavi
42.	Hissar Arun	HAU, Hissar	55.	ARS A-07	ARS, Arabhavi
43.	Swarna Lalima	HARP, Ranchi	56.	ARS A-04	ARS, Arabhavi
44.	Pusa 120	IARI, New Delhi	57.	ARS A-09	ARS, Arabhavi
45.	Pusa Gaurav	IARI, New Delhi	58.	ARS A-12	ARS, Arabhavi
46.	HUB 18	KRCCH, Arabhavi	59.	ARS A-08	ARS, Arabhavi
47.	Megha	UAS, Dharwad	60.	ARS A-13	ARS, Arabhavi

KRCCH - Kittur Rani Channamma College of Horticulture, Arabhavi, IIHR - Indian Institute of Horticulture Research, Bengaluru

ARS – Agricultural Research Station, Arabhavi (Karnataka)

UAS - University of Agricultural Sciences, Dharwad

IIVR - Indian Institute of Vegetable Research, Varanasi

HARP - Horticulture and Agro forestry Research Programme, Ranchi

HAU – Hissar Agricultural University, Hissar

Table.2 Genotypic correlation coefficients among growth, earliness, yield and quality parameters in tomato

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	1.000	0.897**	0.698**	0.677**	0.452**	0.503**	0.611**	0.487**	0.602**	0.575**	0.007	-0.094	-	-	-	-0.150	-	-	0.480**	0.053	-0.017	-
2		1.000	0.671**	0.633**	0.319**	0.347**	0.493**	0.394**	0.454**	0.423**	-0.130	-0.009	0.450**	0.464**	0.325**	-0.083	0.411**	0.454**	0.451**	0.043	-0.023	-
3			1.000	0.997**	0.444**	0.420**	0.823**	0.578**	0.695**	0.567**	0.039	-0.019	0.440**	0.460**	0.350**	-0.102	0.475**	0.511**	0.469**	-0.050	0.137	-
4				1.000	0.409**	0.390**	0.790**	0.609**	0.659**	0.558**	0.051	-0.007	0.602**	0.576**	0.523**	-0.102	0.536**	0.611**	0.440**	-0.093	0.044	-
5					1.000	0.957**	0.567**	0.407**	0.906**	0.822**	-0.072	-0.155	0.627**	0.573**	0.542**	-0.051	0.570**	0.602**	0.448**	-0.020	0.176	-0.088
6						1.000	0.575**	0.495**	0.890**	0.916**	-0.033	-0.146	0.507**	0.333**	0.344**	0.127	0.289**	0.329**	0.415**	0.089	0.135	-0.101
7							1.000	0.995**	0.860**	0.873**	-0.073	-0.131	0.469**	0.280**	0.286**	0.094	0.278**	0.306**	0.535**	-0.086	0.119	-
8								1.000	0.741**	0.811**	-0.043	-0.089	0.692**	0.499**	0.377**	-0.156	0.489**	0.495**	0.258**	-0.133	0.043	-0.214*
9									1.000	0.947**	-0.067	-0.167	0.461**	0.275**	-	0.137	0.354**	0.281**	0.555	-0.043	0.165	-0.201*
10										1.000	-0.044	-0.148	0.669**	0.475**	0.422**	0.169	0.427**	0.468**	0.409**	0.001	0.099	-0.168
11											1.000	0.676**	0.544**	0.334**	0.274**	-0.196*	0.360**	0.346**	-	0.408**	0.142	-0.192*
12												1.000	0.274**	0.099	0.105	-0.006	0.132	0.119	0.372**	0.214*	0.091	-0.168
13													1.000	0.721**	0.750**	-0.183*	0.687**	0.751**	-	0.105	0.106	0.441**
14														1.000	0.781**	0.380**	0.788**	0.906**	0.613**	0.137	0.081	0.635**
15															1.000	-0.009	0.619**	0.760**	-	0.129	0.113	0.549**
16																1.000	0.253**	0.289**	0.508**	0.008	0.112	0.339**
17																	1.000	0.900**	0.501**	0.165	0.083	0.688**
18																		1.000	-	0.077	0.062	0.750**
19																			1.000	-0.115	0.217*	0.143
20																				1.000	0.050	0.052
21																					1.000	0.143
22																						1.000

Critical r_g value at 5% =0.179*Significant at $p=0.05$ Critical r_g value at 1% =0.234**Significant at $p=0.01$

1. Plant height 60 DAT (cm)
2. Plant height 90 DAT (cm)
3. Number of branches 60 DAT (cm)
4. Number of branches 90 DAT (cm)
5. Plant spread from east to west 60 DAT (cm)
6. Plant spread from east to west 90 DAT (cm)

7. Plant spread from north to south 60 DAT (cm)
8. Plant spread from north to south 90 DAT (cm)
9. Plant canopy 60 DAT (cm²)
10. Plant canopy 90 DAT (cm²)
11. Days to first flowering
12. Days to 50 per cent flowering

13. Polar diameter (mm)
14. Equatorial diameter (mm)
15. Pericarp thickness (mm)
16. Number of locules
17. Fruit volume (cc)
18. Average fruit weight (g)

19. Number of fruits per plant
20. Number of seeds per fruit
21. Thousand seed weight (g)
22. Yield per plant (kg)

Table.2a Phenotypic correlation coefficients among growth, earliness, yield and quality parameters in tomato

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	1.000	0.773**	0.617**	0.571**	0.376**	0.444**	0.507**	0.418**	0.524**	0.527**	-0.007	-0.079	-0.408**	-0.422**	-0.296**	-0.104	-0.384**	-0.431**	0.422**	0.054	-0.019	0.168	0.269**	0.001	0.195*	-0.243**	-0.252**
2		1.000	0.591**	0.554**	0.281**	0.293**	0.359**	0.295**	0.382**	0.357**	-0.090	-0.018	-0.411**	-0.435**	-0.308**	-0.101	-0.450**	-0.467**	0.433**	0.036	-0.022	0.194*	0.273**	0.002	0.224*	-0.269**	-0.281**
3			1.000	0.885**	0.390**	0.383**	0.613**	0.488**	0.593**	0.516**	0.014	-0.021	-0.558**	-0.530**	-0.438**	-0.073	-0.495**	-0.563**	0.432**	-0.038	0.104	0.274**	0.289**	-0.017	0.210*	-0.385**	-0.402**
4				1.000	0.346**	0.337**	0.626**	0.488**	0.570**	0.490**	0.062	-0.015	-0.554**	-0.521**	-0.446**	-0.030	-0.511**	-0.539**	0.387**	-0.061	0.040	0.298**	0.212*	-0.005	0.232*	-0.388**	-0.403**
5					1.000	0.811**	0.448**	0.356**	0.869**	0.728**	-0.069	-0.126	-0.462**	-0.296**	-0.325**	0.137	-0.260**	-0.293**	0.408**	-0.024	0.153	0.192*	-0.098	-0.086	0.097	-0.053	-0.069
6						1.000	0.452**	0.389**	0.748**	0.867**	-0.005	-0.088	-0.419**	-0.256**	-0.233*	0.119	-0.238**	-0.245**	0.353**	0.097	0.110	0.141	0.031	-0.056	0.107	-0.046	-0.063
7							1.000	0.699**	0.829**	0.679**	-0.046	-0.079	-0.542**	-0.401**	-0.323**	0.097	-0.368**	-0.393**	0.396**	-0.062	0.048	0.207*	0.049	0.035	0.167	-0.218*	-0.236**
8								1.000	0.607**	0.787**	-0.069	-0.061	-0.408**	-0.242**	-0.139	0.068	-0.311**	-0.252**	0.225*	-0.116	0.035	0.165	0.038	0.136	0.116	-0.179*	-0.204*
9									1.000	0.825**	-0.060	-0.126	-0.594**	-0.423**	-0.397**	0.120	-0.370**	-0.414**	0.481**	-0.039	0.119	0.229*	-0.025	-0.026	0.158	-0.164	-0.185*
10										1.000	-0.035	-0.102	-0.507**	-0.312**	-0.247**	0.108	-0.330**	-0.312**	0.365**	0.013	0.091	0.178	0.042	0.032	0.136	-0.137	-0.158
11											1.000	0.612**	0.238**	0.082	0.086	-0.174	0.115	0.108	-0.328**	0.385**	-0.140	-0.103	-0.122	0.023	0.064	-0.159	-0.163
12												1.000	0.154	0.154	0.078	-0.066	0.108	0.078	-0.264**	0.198*	-0.093	-0.277**	0.161	0.199*	-0.042	-0.141	-0.138
13													1.000	0.697**	0.696**	-0.144	0.670**	0.726**	-0.590**	0.103	-0.085	-0.339	-0.133	0.007	-0.161	0.404**	0.418**
14														1.000	0.721**	0.300**	0.772**	0.867**	-0.585	0.134	-0.076	-0.169	-0.095	0.040	-0.218	0.545**	0.570**

																		**						*				
15															1.00 0	0.016	0.569 **	0.719 **	- 0.459 **	0.134	0.099	- 0.138	- 0.149	0.155	- 0.168	0.490 **	0.501 **	
16																1.000	0.208 *	0.236 **	- 0.030	0.007	- 0.060	0.236 **	- 0.083	- 0.173	- 0.068	0.280 **	0.269 **	
17																	1.000	0.871 **	- 0.483 **	0.163	- 0.080	- 0.230 *	- 0.025	0.055	- 0.138	0.607 **	0.633 **	
18																		1.000	- 0.528 **	0.073	- 0.055	- 0.185 *	- 0.175	0.054	- 0.170	0.707 **	0.716 **	
19																			1.000	- 0.115	0.198 *	0.101	0.204 *	0.092	0.319 **	0.131	0.130	
20																				1.000	0.042	0.093	0.020	0.106	0.164	0.030	0.034	
21																					1.000	0.133	0.029	0.088	0.226 *	0.138	0.147	
22																							1.000	- 0.191	- 0.239 **	0.031	- 0.136	- 0.137
23																								1.000	0.243 **	0.166	- 0.068	- 0.064
24																									1.000	0.233 *	0.119	0.117
25																												
26																											1.000	0.949 **
27																												1.000

Critical r_p value at 5% = 0.179

*Significant at $p=0.05$

Critical r_p value at 1% = 0.234

**Significant at $p=0.01$

Plant height 60 DAT (cm)	7. Plant spread from north to south 60 DAT (cm)	13. Polar diameter (mm)	19. Number of fruits per plant	25. Total soluble solids ($^{\circ}$ Brix)
Plant height 90 DAT (cm)	8. Plant spread from north to south 90 DAT (cm)	14. Equatorial diameter (mm)	20. Number of seeds per fruit	26. Yield per plant (kg)
Number of branches 60 DAT (cm)	9. Plant canopy 60 DAT (cm ²)	15. Pericarp thickness (mm)	21. Thousand seed weight (g)	27. Yield per plot (kg)
Number of branches 90 DAT (cm)	10. Plant canopy 90 DAT (cm ²)	16. Number of locules	22. Lycopene content (mg/100g)	
Plant spread from east to west 60 DAT (cm)	11. Days to first flowering	17. Fruit volume (cc)	23. β - carotene (mg/100g)	
Plant spread from east to west 90 DAT (cm)	12. Days to 50 per cent flowering	18. Average fruit weight (g)	24. Ascorbic acid (mg/100g)	

Table2b Estimates of mean, range, components of variance, heritability and genetic advance for growth and earliness parameters in tomato

Sl. No.	Character	Mean $\pm$ S. Em	Range	GV	PV	GCV (%)	PCV (%)	h^2	GA	GAM
A. Growth parameters										
1.	Plant height 60 DAT (cm)	67.17 $\pm$ 3.18	52.40-116.90	136.53	156.79	17.39	18.64	87.08	22.46	33.43
2.	Plant height 90 DAT (cm)	80.84 $\pm$ 2.91	64.07-129.62	135.29	152.30	14.38	15.26	88.82	22.58	27.93
3.	Number of primary branches 60 DAT	5.34 $\pm$ 0.34	3.10-9.90	1.61	1.85	23.80	25.51	87.01	2.44	45.73
4.	Number of primary branches 90 DAT	8.64 $\pm$ 0.38	6.26-13.05	1.61	1.92	14.70	16.02	84.22	2.40	27.80
5.	Plant spread from east to west 60 DAT (cm)	50.07 $\pm$ 2.27	36.90-90.80	70.50	80.88	16.76	17.95	87.16	16.14	32.24
6.	Plant spread from east to west 90 DAT (cm)	64.78 $\pm$ 2.41	49.65-102.65	88.14	99.77	14.49	15.41	88.33	18.17	28.05
7.	Plant spread from north to south 60 DAT (cm)	49.94 $\pm$ 3.06	39.80-65.50	30.72	49.56	11.09	14.09	61.98	8.98	17.99
8.	Plant spread from north to south 90 DAT (cm)	65.20 $\pm$ 2.49	53.61-85.62	43.06	55.51	10.06	11.42	77.57	11.90	18.26
9.	Plant canopy 60 DAT (cm ²)	49.84 $\pm$ 2.04	38.43-64.77	36.52	44.88	12.12	13.44	81.38	11.23	22.53
10.	Plant canopy 90 DAT (cm ²)	64.99 $\pm$ 1.72	54.61-82.37	46.34	52.26	10.50	11.15	88.67	13.20	20.37
B. Earliness parameters										
1.	Days to first flowering	34.07 $\pm$ 0.61	29.70-39.00	4.04	4.78	5.90	6.42	84.42	3.80	11.16
2.	Days to 50 per cent flowering	37.99 $\pm$ 0.58	34.00-43.40	4.31	5.01	5.46	5.89	86.18	3.97	10.45
GV = Genotypic variance	GCV = Genotypic coefficient of variance					h^2 = Heritability (broad sense)			GAM = Genetic advance (per cent mean)	
PV = Phenotypic variance	PCV = Phenotypic coefficient of variance					GA = Expected genetic advance			DAT = Days after transplanting	

Table.2c Estimates of mean, range, components of variance, heritability and genetic advance for yield parameters in tomato

Sl. No.	Character	Mean $\pm$ S. Em	Range	GV	PV	GCV (%)	PCV (%)	h^2	GA	GAM
C. Yield parameters										
1.	Polar diameter (mm)	44.34 $\pm$ 1.42	19.67-59.73	91.07	95.12	21.52	21.99	95.74	19.23	43.37
2.	Equatorial diameter(mm)	44.21 $\pm$ 1.07	19.00-58.67	69.54	71.85	18.86	19.17	96.79	16.90	38.22
3.	Pericarp thickness(mm)	4.66 $\pm$ 0.45	2.13-8.10	1.00	1.41	21.45	25.47	70.93	1.73	37.22
4.	Number of locules	2.62 $\pm$ 0.28	2.00-4.67	0.37	0.53	23.28	27.80	70.10	1.05	40.16
5.	Fruit volume (cc)	35.16 $\pm$ 1.32	2.94-69.21	241.02	244.52	44.15	44.47	98.56	31.75	90.30
6.	Average fruit weight (g)	45.87 $\pm$ 3.02	4.44-88.57	356.34	374.67	41.14	42.19	95.10	37.92	82.66
7.	Number of fruits per plant	32.67 $\pm$ 2.08	13.86-59.40	142.82	151.49	36.57	37.66	94.27	23.90	73.14
8.	Yield per plant (kg)	2.04 $\pm$ 0.24	0.35 - 4.75	0.82	0.94	44.43	47.47	87.59	1.75	85.66
9.	Yield per plot(kg)	31.91 $\pm$ 1.28	5.20-68.25	160.31	163.61	39.67	40.08	97.97	25.81	80.89
10.	Yield per hectare (t)	39.39 $\pm$ 1.58	6.42 - 84.25	244.34	249.38	39.67	40.08	97.97	31.87	80.89
GV = Genotypic variance		GCV = Genotypic coefficient of variance		h^2 = Heritability (broad sense)			GAM = Genetic advance (per cent mean)			
PV = Phenotypic variance		PCV = Phenotypic coefficient of variance		GA = Expected genetic advance						

Table.3 Genotypic path coefficient analysis for total yield per plot in tomato

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	rg
1	0.011	-0.003	-0.079	0.313	-0.071	-0.027	0.025	-0.022	0.012	-0.010	-0.005	0.016	-0.013	-0.015	-0.388	0.157	0.249	0.017	0.013	0.041	-0.076	0.144
2	0.000	-0.078	-0.030	-0.066	0.089	0.054	0.028	0.039	-0.012	-0.000	0.017	0.011	0.027	0.029	0.099	-0.113	-0.027	-0.006	-0.042	-0.097	0.221	0.043
3	0.001	-0.004	-0.568	0.200	0.859	0.219	0.122	0.175	-0.052	0.017	0.014	-0.010	0.139	-0.210	0.456	-0.350	-0.115	-0.055	0.208	0.056	-0.105	0.998**
4	0.002	0.009	-0.078	1.447	-0.640	-0.163	-0.114	-0.174	0.076	-0.042	-0.033	0.051	-0.132	0.306	-1.304	0.704	0.635	0.060	-0.385	0.126	-0.202	0.146
5	-0.000	-0.006	-0.420	-0.798	1.161	0.294	0.170	0.257	-0.090	0.036	0.036	-0.038	0.180	-0.348	1.100	-0.652	-0.466	-0.078	0.364	-0.036	0.064	0.731**
6	-0.000	-0.013	-0.381	-0.724	1.045	0.326	0.138	0.224	-0.082	0.037	0.046	-0.034	0.171	-0.323	1.004	-0.644	-0.410	-0.069	0.330	-0.050	0.071	0.663**
7	0.001	-0.010	-0.310	-0.734	0.882	0.202	0.224	0.222	-0.090	0.028	0.020	-0.035	0.162	-0.238	0.991	-0.497	-0.486	-0.067	0.261	-0.051	0.057	0.532**
8	-0.000	-0.010	-0.350	-0.887	1.051	0.257	0.175	0.284	-0.086	0.034	0.036	-0.034	0.172	-0.312	1.117	-0.657	-0.471	-0.074	0.372	-0.074	0.053	0.594**
9	-0.001	-0.008	-0.246	-0.913	0.872	0.224	0.168	0.205	-0.120	0.056	0.060	-0.058	0.188	-0.299	1.573	-0.911	-0.718	-0.077	0.361	-0.075	0.149	0.429**
10	0.001	-0.000	0.093	0.592	-0.402	-0.117	-0.061	-0.095	0.065	-0.104	-0.106	0.114	-0.167	0.287	-2.226	1.150	1.164	0.073	-0.462	0.067	-0.024	-0.160
11	0.000	0.010	0.122	0.372	-0.326	-0.115	-0.035	-0.078	0.055	-0.084	-0.131	0.061	-0.183	0.268	-1.742	1.323	0.576	0.074	-0.391	0.040	-0.023	-0.205*
12	0.001	-0.007	0.048	0.601	-0.355	-0.090	-0.064	-0.079	0.056	-0.095	-0.065	0.124	-0.117	0.236	-2.092	0.758	1.356	0.054	-0.404	0.066	-0.018	-0.087
13	0.000	0.007	0.263	0.637	-0.699	-0.186	-0.121	-0.163	0.075	-0.058	-0.080	0.048	-0.300	0.430	-1.550	1.041	0.580	0.134	-0.544	0.003	0.027	-0.454**
14	-0.000	-0.003	0.175	0.652	-0.593	-0.155	-0.078	-0.130	0.053	-0.044	-0.051	0.043	-0.190	0.680	-1.066	0.650	0.451	0.086	-0.721	0.004	-0.070	-0.309**
15	0.001	0.003	0.110	0.802	-0.543	-0.139	-0.094	-0.135	0.080	-0.098	-0.097	0.110	-0.198	0.308	-2.351	1.134	1.284	0.089	-0.483	0.076	-0.036	-0.176
16	0.001	0.006	0.151	0.773	-0.575	-0.159	-0.084	-0.142	0.083	-0.091	-0.132	0.071	-0.237	0.335	-2.023	1.317	0.803	0.106	-0.491	0.059	-0.039	-0.266**
17	0.001	0.001	0.046	0.648	-0.382	-0.094	-0.077	-0.094	0.061	-0.085	-0.053	0.119	-0.122	0.217	-2.130	0.746	1.417	0.057	-0.363	0.070	-0.039	-0.056
18	0.001	0.003	0.245	0.678	-0.710	-0.175	-0.117	-0.164	0.072	-0.059	-0.076	0.052	-0.313	0.456	-1.633	1.084	0.629	0.129	-0.561	0.008	0.021	-0.427**
19	-0.000	-0.004	0.147	0.694	-0.527	-0.134	-0.073	-0.132	0.054	-0.060	-0.064	0.062	-0.203	0.611	-1.414	0.805	0.640	0.090	-0.803	0.043	0.004	-0.265**
20	-0.001	-0.016	0.095	-0.399	0.092	0.036	0.025	0.046	-0.019	0.015	0.011	-0.018	0.002	-0.006	0.393	-0.172	-0.219	-0.002	0.075	-0.457	0.367	-0.151
21	-0.001	-0.032	0.110	-0.538	0.138	0.043	0.023	0.028	-0.033	0.004	0.005	-0.004	-0.015	-0.088	0.156	-0.095	-0.101	0.005	-0.005	-0.309	0.543	-0.167

rggenotypic correlation coefficients with total yield per plot.

Diagonal values indicate direct effects.

Residual = 0.049

*Significant at p=0.05

**Significant at p=0.01

1	Thousand seed weight(g)	7	Pericarp thickness(mm)	13	Number of branches 90 DAT	19	Plant height 60 DAT (cm)
2	Number of seeds per fruit	8	Equatorial diameter(mm)	14	Plant height 90 DAT(cm)	20	Days to 50 per cent flowering
3	Yield per plant(kg)	9	Polar diameter(mm)	15	Plant canopy 60 DAT(cm ²)	21	Days to first flowering
4	Number of fruits per plant	10	Plant canopy 90 DAT (cm ²)	16	Plant spread from north to south 60 DAT (cm)		
5	Average fruit weight (gm)	11	Plant spread from north to south 90 DAT (cm)	17	Plant spread from east to west 60 DAT (cm)		
6	Fruit volume(cc)	12	Plant spread from east to west 90 DAT(cm)	18	Number of branches 60 DAT		

Plant spread from north to south at 60 DAT was negatively and significantly correlated ($r_g = -0.266$) with total yield and it had positive and very high direct effects (1.317) on total yield and it had high indirect and negative effects through average fruit weight (-0.575), plant height at 60 DAT (-0.491) and plant canopy at 60 DAT (-2.023) on total yield. Plant height at 90 DAT was negatively and significantly correlated ($r_g = -0.309$) with total yield and it had positive and high direct effects (0.680) on total yield and it had high indirect and negative effects through average fruit weight (-0.593), plant height at 60 DAT (-0.721) and plant canopy at 60 DAT (-1.066) on total yield. Under these circumstances also, a restricted simultaneous selection model (Singh and Kolkar, 1977) can be followed to nullify the undesirable indirect effects through average fruit weight, plant canopy at 60 DAT and plant height at 60 DAT in order to make use of direct effects of plant height at 90 DAT on total yield.

Polar ($r_g = 0.429$) and equatorial ($r_g = 0.594$) diameter of the fruit were positively and significantly correlated with yield, and these characters had moderate (+) and negligible (-) direct effects on total yield respectively, but both of these traits had high indirect and positive effects through average fruit weight (Prashant *et al.*, 2008), plant canopy at 60 DAT and plant height at 60 DAT. Hence, the indirect causal factors also need to be considered for selection.

Fruit volume, number of fruits per plant, average fruit weight, yield per plot and yield per plant can be improved through direct selection from the existing germplasm, as there is high degree of additive components of variance and high to very high GCV and PCV for these traits.

Yield per plot was positively and significantly associated with yield per plant, polar diameter of the fruit, equatorial diameter of the fruit,

number of locules per fruit, pericarp thickness, fruit volume and average fruit weight. Since, these association characters are in desirable direction, selection for these traits may improve the yield per plot. Whereas, yield per plot was negatively and significantly associated with plant height at 60 DAT, plant height at 90 DAT, number of branches at 60 DAT, number of branches at 90 DAT, plant spread from north to south 60 DAT and plant spread from north to south at 90 DAT. It was also negatively and significantly associated with plant spread from east to west at 60 DAT at phenotypic level only.

Correlation study revealed that, yield can be improved by selecting genotypes having more polar and equatorial diameter, number of locules per fruit, pericarp thickness, fruit volume and average fruit weight.

Highest positive direct effects on total yield per plant was shown by number of fruits per plant followed by average fruit weight, fruit volume, pericarp thickness, equatorial diameter, plant height at 90 DAT, plant spread from north to south at 60 DAT, plant spread from east to west at 60 DAT and days to first flowering.

Highest negative direct effects on total yield was shown by plant canopy at 60 DAT followed by plant height at 90 DAT, days to 50 per cent flowering, number of seeds per fruit, polar diameter and plant canopy at 90 DAT had negative direct effects on total yield. Characters having high positive direct effects along with positive significant correlation with yield per plant can be directly selected, and simultaneously the characters which show high positive indirect effects can also be selected for the improvement of yield.

References

- Dewey, D.H., and Lu, K.H., 1959, A correlation and path analysis of

- components of crested wheat grass production. *Agron. J.*, 51: 515-518.
- Fageria, M.S. and Kohli, U.K. (1996), Correlation studies in tomato – A note. *Haryana J. Hort. Sci.*, 25(3): 158-160.
- Kaushik, P., Dhaliwal, S. M., Jindal, K. S., Srivastava, A., Tyagi, V., Brar, S. N., Rana, K. M., 2015. Heterosis and leaf curl virus resistance in rainy season tomato under North Indian conditions. *African Journal of Agricultural Research* 10: 2763-2772. <https://doi.org/10.5897/AJAR2014.9133>.
- Kaushik, P., 2015. Tomato Leaf Curl Virus Resistance in Tomato (*Solanum lycopersicum*) Hybrids Grown in the Rainy Season under Punjab Conditions. *Trends in Biosciences* 8(23), Print : ISSN 0974-8431, 6721-6722.
- Kaushik, P., Dhaliwal, M., Kaushik, P., Dhaliwal, M.S., 2018. Diallel Analysis for Morphological and Biochemical Traits in Tomato Cultivated under the Influence of Tomato Leaf Curl Virus. *Agronomy* 8, 153. <https://doi.org/10.3390/agronomy8080153>
- Kaushik, P., 2019. Line $\times$ Tester Analysis for Morphological and Fruit Biochemical Traits in Eggplant (*Solanum melongena* L.) Using Wild Relatives as Testers. *Agronomy* 9, 185. <https://doi.org/10.3390/agronomy9040185>
- Kaushik, P., 2019b. Genetic Analysis for Fruit Phenolics Content, Flesh Color, and Browning Related Traits in Eggplant (*Solanum melongena*). *International Journal of Molecular Sciences* 20, 2990. <https://doi.org/10.3390/ijms20122990>
- Kaushik, P., 2019c. Application of Conventional, Biotechnological and Genomics Approaches for Eggplant (*Solanum melongena* L.). Breeding with a Focus on Bioactive Phenolics. <https://doi.org/10.4995/Thesis/10251/122295>
- Vijeth, S., Dhaliwal, M. S., Jindal, S. K., Garg, N., Kaushik, P., Sharma, A., 2019. Diallel Analysis of Elite tomato Lines Comprising Leaf Curl Virus Resistance Genes. *Applied Ecology and Environmental Research* 17(3): 6457-6471.
- Krishnaprasad, V.S.R., and Mathurai, 1999, Genetic variation, component association and direct and indirect selections in some exotic tomato germplasm. *Indian J. Hort.*, 59 (3): 262-266.
- Kumari, S., and Sharma, M.K., 2013, Genetic variability studies in tomato (*Solanum lycopersicum* L.). *Veg. Sci.*, 40 (1): 83-86.
- Mahapatra, A.S., Singh, A. K., Vani, V.M., Mishra, R., Kumar, H. and Rajkumar, B.V., 2013, Inter-relationship for various components and path coefficient analysis in tomato (*Lycopersicon esculentum* Mill.). *Int. J. Curr. Microbiol. App. Sci.*, 2 (9): 147-152.
- Manivannan, M.I., Prasad, D. and Mir, D.P.M., (2005), Correlation and path coefficient analysis in cherry tomato (*Lycopersicon esculentum* var. *Cerasiforme*). *New Agriculturist*, 16 (2): 151-154.
- Prashanth, S.J., Jaiprakashnarayan, R.P., Mulge, R. and Madalageri, M.B., 2008, Correlation and path analysis in tomato (*Lycopersicon esculentum* Mill.). *Asian J. Hort.*, 3 (2): 403-408.
- Reddy, M.L.N. and Gulshanal, 1987, Genetic variability and path coefficient analysis in tomato (*Lycopersicon esculentum* Mill.) under summer season. *Prog. Hort.*, 19 (3-4): 284-288.
- Sengupta, S.K., Mehta, A. K. and Naidu, A.K., 2009, Genetic studies for fruit yield and its components in tomato

- (*Lycopersicon esculentum* Mill.). *Haryana J. Hort. Sci.*, 38 (1-2): 112-114.
- Sharma, J.P., Singh, A.K. and Tiwari, S.P., 2010, Selection parameters for productive plant type in tomato (*Lycopersicon esculentum* Mill.). *J. Hill Agric.*, 1 (1): 52-55.
- Singh, A.K., 2007, Correlation and path coefficient studies in tomato under cold arid conditions of Ladakh. *Haryana J. Hort. Sci.*, 36 (3-4): 346-347.
- Singh, A.K., 2009, Genetic variability, heritability and genetic advance studies in tomato under cold arid region of Ladakh. *Indian J. Hort.*, 66 (3): 400-403.

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