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ESTIMATION OF VARIABILITY PARAMETERS, CORRELATION AND PATH COEFFICIENT ANALYSIS IN F_2 POPULATION OF TOMATO IN THE CROSS BETWEEN LINE 33-1 × LA-1

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Abstract– Genetic variability, correlation and path coefficient analysis were the important parameters which aid in the selection. For this study 300 F_2 plants were used from the cross between Line 33-1 × LA-1. The study showed that existence of large amount of genetic variability for all the characters studied viz., Plant height, primary branches per plant, number of clusters, number of fruits per clusters, number of fruits per plant, average fruit weight, number of locules and fruit yield per plant exhibited higher values of genotypic and phenotypic coefficient of variation. Whereas, high heritability was exhibited by all characters except number of fruits per plant, while high genetic advance as per cent mean was exhibited by plant height, primary branches per plant, number of clusters, number of fruits per clusters, number of fruits per plant, average fruit weight, rind thickness, number of locules and fruit yield per plant. These characters can be effectively improved through selection. Correlation indicated that yield was significantly and positively associated with plant height, primary branches per plant, number of clusters, number of fruits per cluster, number of fruits per plant and average fruit weight. The number of clusters, average fruit weight, number of fruits per cluster and number of fruits per plant had the most positive direct influence in path coefficient analysis. To decrease the indirect influence of other traits during the creation of a high yielding tomato variety, direct selection can be performed with these qualities as the primary selection criteria.

INTRODUCTION

Tomato (*Solanum lycopersicon* Mill.) is third most important *Solanaceous* vegetable crop after potato and onion in India. It is originated from Peru region which is grown widely across the world. It is one of the most significant "Protective foods" because of its exceptional nutritional content. Because of its excellent standard and nutritional benefits, it is known as the "poor man's orange" in many nations. Lycopene, the red pigment in tomatoes, is currently regarded as the "world's most effective natural antioxidant." The F_2 generation, which results from the selfing of an F_1 hybrid, has all potential variants. So, selection with specific goals in F_2 generation is quite successful and selfing of those selected genotypes generation after generation aids in the development of inbred lines. To increase the genetic yield potential, the maximum utilization of the desirable characters for synthesizing of any ideal genotypes is essential. Variability in tomato is expected to be immense as the fruits vary greatly in shape and size (Dixit and Dubey, 1985; Bhardwaj and Sharma, 2005).

Studies on genetic parameters and character associations aid in the selection and development of the best breeding procedure. Many scientists (Kamruzzahan *et al*., 2000) have reported various genetic parameters in tomato based on a few traits. Even though yield is the primary goal of a breeder, it is critical to understand the relationship between various characters that have a direct and indirect effect on yield. Correlation studies can determine the degree of relationship or association of these characteristics with yield. This would aid in the development of an effective breeding programme for increasing yield potential through its components (Frageria and Kokli, 1997). Path analysis makes it easier to categorise the correlation coefficient's effects on yield and other variables as direct or indirect effects (Kumar *et al*., 2013). Path coefficient analysis can also be used to develop breeding strategies for elite genotype development through selection in advanced generations. As a result, the current study was conducted to assess the performance of several economic features in tomato, as well as to quantify the level of variability, heritability, predicted genetic progress, correlation, and path coefficient analysis components.

MATERIALS AND METHODS

During Rabi 2020-21, the material was sown in an unreplicated trial at Botany Garden, Department of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad. During the 2020-2021 planting season, 300 F_2 tomato plants resulting from the cross Line 33-1 × LA-1, along with parents and F_1'S, were evaluated for yield and yield contributing characters. The F_2 offspring of the F_1 cross that were produced by selfing were developed. Each plant in the cross was labelled for recording 14 quantitative and qualitative characters, which includes days to first harvest, plant height (cm), number of primary branches, number of cluster, number of fruits per cluster, number of fruits per plant, average fruit weight, fruit length (mm), fruit diameter (mm), rind thickness (mm), number of locules per fruit, TSS (°Brix), pH of fruit juice and fruit yield per plant (kg). The Singh and Chaudhary (1985) suggested method was used to calculate the genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability in the broad sense (h^2), genetic advance (GA), and genetic advance as a percentage over mean. The correlation coefficient was calculated using the Johnson *et al*. (1955) formula. Dewey and Lu's (1959) technique was used to determine the direct and indirect pathways.

RESULTS AND DISCUSSION

Variability plays a pivotal role in vegetable breeding, because it increases the likelihood of producing desirable crop plants. Table 1 displays the results of the range, mean, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (h^2), and genetic advance as a percent mean (GAM percent) in the F_2 population of the cross Line 33-1 × LA-1. The traits with the highest PCV and GCV were viz. Plant height (24.31; 25.25), primary branches per plant (30.85; 25.36), number of clusters (36.23; 28.76), number of fruits per cluster (26.42; 21.96), number of fruits per plant (42.11; 32.48), average fruit weight (55.63; 50.68), number of locules (24.67; 22.46) and fruit yield per plant (36.74; 26.15) indicating higher magnitude of variability for these characters. Whereas, days to 1st harvest showed low PCV and GCV (4.08; 3.73), while fruit length (12.63; 11.15), fruit diameter (13.98; 11.31) and rind thickness (19.42; 16.99) had shown moderate PCV and GCV. Total soluble solids and pH of fruit juice had shown moderate PCV (11; 10.78) and low GCV (8.96; 8.66). For all traits, the phenotypic coefficient of variation was higher than the genotypic coefficient of variation, but the difference was narrow, indicating that environmental variation had less influence. These findings were similar to those reported in tomato by Khan *et al*. (2017); Begum *et al.* (2022) and Islam *et al*.

Table 1. Genetic parameters in F_2 population of the cross Line 33-1 × LA-1

Characters	MEAN	MAX	MIN	Vp	Ve	Vg	PCV	GCV	h^2bs	GA	GAM
Days to 1st harvest	89.35	96.00	86.00	13.31	2.21	11.10	4.08	3.73	83.39	5.72	6.41
Plant height (cm)	75.97	130.00	25.00	367.94	26.83	341.11	25.25	24.31	92.71	35.27	46.43
Primary branches per plant	1.15	2.00	1.00	0.13	0.04	0.08	30.85	25.36	67.54	0.40	35.28
Number of clusters	13.81	29.00	4.00	25.03	9.25	15.78	36.23	28.76	63.03	5.16	37.34
Number of fruits per clusters	2.86	5.00	2.00	0.57	0.18	0.39	26.42	21.96	69.12	0.89	31.27
Number of fruits per plant	31.61	81.00	7.00	177.17	71.76	105.41	42.11	32.48	59.49	12.58	39.81
Average fruit weight (g)	61.68	329.00	28.93	1177.36	200.32	977.04	55.63	50.68	82.99	53.43	86.64
Fruit length (mm)	40.13	55.29	3.60	25.67	5.64	20.03	12.63	11.15	78.04	7.20	17.93
Fruit daimeter (mm)	42.16	57.62	26.70	34.73	12.01	22.72	13.98	11.31	65.42	6.42	15.24
Rind thickness (mm)	3.71	5.20	0.40	0.52	0.12	0.40	19.42	16.99	76.49	0.99	26.76
Number of locules	4.76	9.00	2.00	1.38	0.24	1.14	24.67	22.46	82.85	1.82	38.33
TSS (^{0} brix)	4.65	6.50	3.40	0.26	0.09	0.17	11.00	8.96	66.40	0.57	12.26
pH of fruit juice	4.52	5.94	3.94	0.24	0.08	0.15	10.78	8.66	64.47	0.52	11.50
Yield per plant (Kg)	1.74	4.11	0.44	0.41	0.20	0.21	36.74	26.15	50.68	0.47	27.30

(2022). Plant height (92.71 %) had the highest heritability, followed by days to first harvest (83.39 %), average fruit weight (82.99 %), number of locules (82.85 %), fruit length (78.04 %), rind thickness (76.49 %), primary branches per plant (67.54 %), rind thickness (76.49 %), number of fruits per cluster (69.12 %), fruit diameter (65.42 %), pH of fruit juice (64.87 %) and number of clusters (63.03%). The number of fruits per plant (59.49 %) and fruit yield per plant, on the other hand, showed moderate heritability (50.68%). Gopinath and Vethamoni (2017) also observed similar results for number of fruits per plant.

Plant height (46.43 %), primary branches per plant (35.28 %), number of clusters (37.34 %), number of fruits per cluster (31.27 %), number of fruits per plant (39.81 %), average fruit weight (86.64 %), rind thickness (26.76 %), number of locules (38.33 %) and fruit yield per plant (27.30 %) all had high genetic advance as a percent of mean. The days to first harvest had the lowest genetic advance as a percentage of the mean (6.41 %). Fruit length (17.93 %), fruit diameter (15.24 %), TSS (12.26 %) and pH fruit juice showed moderate genetic advance as a percentage of the mean (11.50 %). Plant height, number of clusters, number of fruits per cluster, average fruit weight, rind thickness, and number of locules all had high estimates of heritability with high genetic advance as a percent over mean. These findings are consistent with those of Khan *et al*. (2017) and Islam *et al*. (2022). It could be assigned to be controlled by additive genes and phenotypic selection for their improvement could be accomplished through simple breeding methods.

Correlation studies

Table 2 shows the relationship between fruit yield per plant and various yield attributes. The correlation coefficient between different characteristics revealed that yield per plant was significantly and positively associated with the number of clusters (0.34), number of fruits per cluster (0.2), number of fruits per plant (0.62) and average fruit weight (0.26). These findings in tomato are consistent with those of Ballat and Araby (2020); Nevani and Sridevi (2021); Akhtar and Nojnine (2022) and Sanam *et al.* (2022). Days to 1^{st} harvest has showed positive and significant association with primary branches per plant (0.15), number of fruits per clusters (0.17), fruit length (0.13), fruit diameter (0.11), number of locules (0.13) and pH of fruit juice (0.2). Begum *et al.* (2022) obtained comparable results. There was a negative significant correlation between the number of clusters and the number of primary branches (-0.13), fruit length (-0.12), and TSS (-0.15). Plant height had a positive and significant correlation with the number of fruits per plant (0.14). The number of clusters had a positive and significant correlation with the number of fruits per plant (0.45), fruit length (0.17), number of locules (0.19) and TSS (0.15), but a negative significant correlation with average fruit weight (-

Table 2. Correlation coefficient between fruit yield and yield components traits in F_2 generation of Line 33-1 × LA-1

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14
X1	1	-0.02	0.15**	0.11	0.17**	0.04	-0.02	0.13*	0.11*	0.05	0.13*	0.05	0.2**	0.07
X2	-0.02	1	0.05	-0.13*	0.03	0.02	0.02	-0.12*	-0.11	-0.03	-0.03	-0.15**	-0.05	0.04
X3	0.15	0.05	1	0.08	-0.03	0.14*	-0.06	0.08	0.09	0.01	0.08	-0.04	0.06	0.08
X4	0.11	-0.13	0.08	1	0.07	0.45**	-0.17**	0.17**	0.06	-0.04	0.19**	0.15**	0.09	0.34**
X5	0.17	0.03	-0.03	0.07	1	0.37**	-0.22**	-0.07	-0.07	0.01	0.01	0.03	0.15**	0.2**
X6	0.04	0.02	0.14	0.45	0.37	1	-0.46**	0.08	0.01	-0.04	0.02	0.07	0.03	0.62**
X7	-0.02	0.02	-0.06	-0.17	-0.22	-0.46	1	0.04	0.09	-0.01	0.04	0.01	-0.03	0.26**
X8	0.13	-0.12	0.08	0.17	-0.07	0.08	0.04	1	0.48	0.1	0.08	0.03	0.08	0.1
X9	0.11	-0.11	0.09	0.06	-0.07	0.01	0.09	0.48	1	0.16**	0.27**	0	0.03	0.08
X10	0.05	-0.03	0.01	-0.04	0.01	-0.04	-0.01	0.1	0.16	1	0.03	-0.02	-0.01	-0.04
X11	0.13	-0.03	0.08	0.19	0.01	0.02	0.04	0.08	0.27	0.03	1	0.05	0.11	0.06
X12	0.05	-0.15	-0.04	0.15	0.03	0.07	0.01	0.03	0	-0.02	0.05	1	0.03	0.07
X13	0.2	-0.05	0.06	0.09	0.15	0.03	-0.03	0.08	0.03	-0.01	0.11	0.03	1	0.01
X14	0.07	0.04	0.08	0.34	0.2	0.62	0.26	0.1	0.08	-0.04	0.06	0.07	0.01	1

X_1= Days to 1^{st} harvest
X_2= Plant height (cm)
X_3= Number of Primary branches
X_4= Number of clusters per plant
X_5= Number of fruits per cluster
X_6= Number of fruits per plant
X_7= Average fruit weight (g)
X_8= Fruit length (mm)
X_9=Fruit Diameter (mm)
X_{10}= Rind thickness (mm)
X_{11}= Number of locules
X_{12}= Total soluble solids (TSS) (^{0} brix)
X_{13}=pH of fruit juice
X_{14}=Fruit yield per plant (kg)

0.17). These outcomes are in conformity with the findings of Hussain *et al.* (2021) and Nevani and Sridevi (2021). The number of fruits per cluster had a significant positive correlation with the number of fruits per plant (0.37) negative correlation with average fruit weight (-0.22) and pH of fruit juice (0.15). The findings are consistent with those of Akhtar and Najnine (2022) and Sanam *et al*. (2022). The number of fruits per plant had a positive and significant correlation with the average fruit weight. Fruit diameter had a significant positive correlation with rind thickness (0.16) and number of locules (0.27). Other studies reported by Hussain *et al.* (2021) and Begum *et al*. (2022) support these findings.

Path coefficient analysis

Although correlation studies are useful in determining yield components, the indirect association becomes more complex as more variables are included in correlation studies. Two characters may show a correlation because they share a common third character. In such cases, path analysis assists in the division of correlation coefficients into direct and indirect effects, allowing for a critical examination of the relative importance of each trait. The path coefficient analysis in (Table 3) revealed that the number of fruits per plant (0.9191), average fruit weight (0.6897) and number of clusters (0.0458) had a significant positive direct effect on fruit yield per plant. Primary branches per plant had the greatest negative direct effect on fruit yield per plant (-0.0183). The number of locules had the smallest positive direct effect on fruit yield, with a value of 0.0003. The pH of fruit juice had the least negative direct effect on fruit yield per plant (-0.0075). The characters with a high direct effect on yield per plant suggested that direct selection for these traits could be effective and that there is a possibility of increasing yield per plant through selection based on these characters. Ballat and Araby (2020), Nevani and Sridevi (2021) and Zhang *et al*. (2022) all reported similar results of direct positive effects for those traits. On the other hand, there were positive indirect effects of days to first harvest, plant height, primary branches per plant, number of clusters, number of fruits per plant, fruit length through number of fruits per cluster to yield per plant. Sanam *et al*. (2022) and

Table 3. Path co-efficient analysis on fruit yield per plant in F_2 generation of the cross Line 33-1 × LA-1

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14
X1	**0.04761**	-0.00027	-0.00276	0.00504	0.00007	0.03677	-0.01380	-0.00223	0.00129	0.00016	0.00005	-0.00042	-0.00151	0.07
X2	-0.00095	**0.01334**	-0.00092	-0.00596	0.00001	0.01838	0.01380	0.00205	-0.00129	-0.00010	-0.00001	0.00127	0.00038	0.04
X3	0.00714	0.00067	**-0.01838**	0.00366	-0.00001	0.12868	-0.04139	-0.00137	0.00105	0.00003	0.00003	0.00034	-0.00045	0.08
X4	0.00524	-0.00173	-0.00147	**0.04581**	0.00003	0.41361	-0.11726	-0.00291	0.00070	-0.00013	0.00007	-0.00127	-0.00068	0.34**
X5	0.00809	0.00040	0.00055	0.00321	**0.00039**	0.34008	-0.15175	0.00120	-0.00082	0.00003	0.00000	-0.00025	-0.00113	0.2**
X6	0.00190	0.00027	-0.00257	0.02061	0.00014	**0.91913**	-0.31729	-0.00137	0.00012	-0.00013	0.00001	-0.00059	-0.00023	0.62**
X7	-0.00095	0.00027	0.00110	-0.00779	-0.00009	-0.42280	**0.68976**	-0.00068	0.00105	-0.00003	0.00001	-0.00008	0.00023	0.26**
X8	0.00619	-0.00160	-0.00147	0.00779	-0.00003	0.07353	0.02759	**-0.01712**	0.00562	0.00033	0.00003	-0.00025	-0.00060	0.1
X9	0.00524	-0.00147	-0.00165	0.00275	-0.00003	0.00919	0.06208	-0.00822	**0.01172**	0.00052	0.00010	0.00000	-0.00023	0.08
X10	0.00238	-0.00040	-0.00018	-0.00183	0.00000	-0.03677	-0.00690	-0.00171	0.00187	**0.00328**	0.00001	0.00017	0.00008	-0.04
X11	0.00619	-0.00040	-0.00147	0.00870	0.00000	0.01838	0.02759	-0.00137	0.00316	0.00010	**0.00036**	-0.00042	-0.00083	0.06
X12	0.00238	-0.00200	0.00074	0.00687	0.00001	0.06434	0.00690	-0.00051	0.00000	-0.00007	0.00002	**-0.00845**	-0.00023	0.07
X13	0.00952	-0.00067	-0.00110	0.00412	0.00006	0.02757	-0.02069	-0.00137	0.00035	-0.00003	0.00004	-0.00025	**-0.00755**	0.01

Residual error: 0.2343

X_1= Days to 1[st] harvest
X_2= Plant height (cm)
X_3= Number of Primary branches
X_4= Number of clusters per plant
X_5= Number of fruits per cluster
X_6= Number of fruits per plant
X_7= Average fruit weight (g)
X_8= Fruit length (mm)
X_9=Fruit Diameter (mm)
X_{10}= Rind thickness (mm)
X_{11}= Number of locules
X_{12}= Total soluble solids (TSS) (^{0} brix)
X_{13}=pH of fruit juice

Akhtar and Najnine (2022) found similar results for indirect effects. A lower residual error of 0.2343 was observed, indicating that a sufficient number of characters are taken into account when calculating direct and indirect effects.

CONCLUSION

High heritability combined with high genetic advance was the important parameter in terms of fruit yield, which is the most important characteristic in any crop improvement programme. The yield per plant was positively and significantly correlated with plant height, primary branches per plant, number of clusters, number of fruits per cluster, number of fruits per plant and average fruit weight in the F_2 population of the cross Line 33-1 × LA-1. Path coefficient analysis revealed that the number of clusters, average fruit weight, number of fruits per cluster and number of fruits per plant had the greatest positive direct effect. As a result, these traits can be further exploited through direct selection for genetic improvement in tomato to improve yield.

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