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Multivariate Analysis for Post Harvest Quality and Yield Attributes in Tomato (*Solanum lycopersicum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To study the multivariate analysis, genetic parameters and correlation for post harvest quality and yield traits in tomato.
Study Design: The variability in the twenty genotypes of tomato (*Solanum lycopersicum* L.) was evaluated for 18 yield attributes and post harvest quality traits using randomized block design and analyzed with multivariate methods.
Place and Duration of Study: Twenty genotypes of tomato augmented from Indian Institute of Vegetable Research, Varanasi were sown during *rainy season* at Horticulture Research Farm of Banaras Hindu University.
Methodology: The unweighted pair group method of the average linkage (UPGMA) cluster analysis and principal component analysis (PCA) were used to analyze the data. Canonical discriminant analysis showed the contribution of each trait to the classification of the tomato accessions into different cluster groups.

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Results: The first seven principal components (PC) explained 87.83% of total variation and has eigen values >1. The traits that mainly contributed for this variation in PC1 and PC2 are fruit yield, plant height, number of flower clusters per plant, number of fruits per plant, days to first fruit set, number of fruits per cluster. High (>20%) genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) was observed for number of fruits/cluster, fruit shape index, number of fruits/plant, fruit yield and shelf life. The correlation coefficients of number of primary branches/plant, days to first fruit set, number of flower clusters/plant, number of fruits/cluster, fruit width (cm), number of fruits/plant, fruit weight (g) and lycopene (mg/100 g) were positively and significantly correlated to fruit yield/plant.

Conclusion: Number of flower clusters/plant, fruit weight and number of fruits per plant had contributed for maximum variation. These traits also had high heritability, high genetic gain and significant correlation with fruit yield.

Keywords: Post harvest; yield attributes; multivariate analysis; genetic parameters; tomato.

1. INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most important widely grown vegetable fruit crop in the world in general and India in particular as it is highly nutritive as well as remunerative crop. The estimated annual production of tomato globally is 184.78 million tonnes which is grown in an area of 5.01 million hectares [1]. In India, tomato occupies an area of 0.84 million hectares with a production of 21.18 million tonnes and productivity of 25.07 metric tonnes per hectare. India being the second largest producer of tomato in the world its productivity is 21 t/ha which is far below the productivity of many tomato producing countries. The highest productivity in the world is 502.42 t/ha (Belgium) [1].

Multivariate analysis is based on a statistical principle involving observation and analysis of more than one statistical variable at a time. The genetic improvement of tomato mainly depends upon the amount of genetic variability present in the population. The information on nature of variability together with the magnitude of heritability for any given quantitative character under improvement is of utmost importance to the breeders to proceed towards fruitful hybridization program. The present investigation was done to know the nature and magnitude of genetic divergence, genetic parameters and correlation of twenty genotypes of tomato for yield attributes and post harvest quality traits.

2. MATERIALS AND METHODS

Twenty genotypes (Table 1) of tomato augmented from Indian Institute of Vegetable Research, Varanasi were sown during *rainy season* at Horticulture Research Farm of Banaras Hindu University (BHU), Uttar Pradesh, India. Geographically the station is located at 25˚18' north latitude, 83˚03' east longitude and at an altitude of 75.7 meters above mean sea level. Each genotype was sown in 3m × 4m plot and replicated thrice. Spacing of 60 cm between rows and 50 cm between plants was maintained. The data was recorded on 10 plants for all the characters *i.e*., plant height (cm), number of primary branches/plant, number of flower clusters/plant, number of flowers/cluster, number of fruits/cluster, number of fruits/plant, fruit length (cm), fruit width (cm), fruit shape index, fruit weight (g) except for days to fifty per cent flowering, days to first fruit set and yield per plant, which were recorded on whole plot basis. Shelf life was tested under room temperature, total soluble solids (TSS) (°Brix) was measured using digital hand refract to meter. Lycopene (mg/100g), ascorbic acid (mg/100g) and titrable acidity (%) were analyzed using the procedures of [2]. The mean replicated data on various biometric traits were subjected to analysis of variance of randomized block design as per the standard statistical procedure. Multivariate techniques including factor analysis (FA) were employed using Indostat software.

Table 1. List of genotypes used for the present study

S. No	Genotype name	S. No	Genotype name	S. No	Genotype name	S. No	Genotype name
1.	H-86	6.	Punjab Chhauhara	11.	CO-3 (Marutham)	16.	Avinash-2-2-1
2.	Kashi Amrit	7.	H-24	12.	Fla 7171	17.	DT-2
3.	Kashi Sharad	8.	Pant-T3	13.	H-88-78-4	18.	Angoor Lata
4.	Floradade	9.	Sel-7	14.	Hisar Lalima	19.	Azad-T5
5.	Punjab Upma	10.	BT-120	15.	Ageta-32	20.	NDTVR-60

3. RESULTS AND DISCUSSION

The principal component analysis of the 20 genotypes of tomato for eighteen characters patitionedthe total variation into seven significant principal components (Table 2) with eigen value >1. The first principal component contributed for 28.62% of total variation, was strongly associated positively with fruit yield, plant height, number of flower clusters/plant, ascorbic acid, fruit weight, number of primary branches/plant and titrable acidity. This component was regarded as fruit yield component as it includes several traits which are components of fruit yield. The sign of the loading indicates the direction of the relationship between the component and the variable.

The contribution of second principal component towards total variation was 14.53%. The traits number of fruits/plant, days to first fruitset and number of fruits/cluster contributed positively to the maximum variation of second principal component. Third principal component contributed to 12.28% of total variation for which the traits fruit shape index, fruit width, plant height and fruit weight contributed for maximum variation. Fourth principal component contributed for 10.85% of total variation for which maximum variation was positively contributed by fruit length and TSS. The contribution of fifth principal component towards total variation was 8.69% for which TSS mainly contributed positively. First seven principal components have the eigen value >1. These seven principal components contributed for the 87.83% of the cumulative variance. Similar findings were reported by [3-5].

The genetic parameters corresponding to the genotypes were presented in Table 3. It is evident from the data that number of fruits/cluster, fruit shape index, number of fruits/plant, fruit yield and shelf life recorded high (>20%) genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) whereas plant height, number of primary branches/plant, number of flower clusters/plant, number of flowers/cluster, fruit length, fruit width, fruit weight, TSS, titrable acidity and lycopene exhibited moderate (10-20%) GCV and PCV. All the traits under study had PCV higher than GCV. Similar findings were also presented by [6-10].

Genotypic Coefficient of Variation represents the total genetic variation in the genotypes whereas heritability measures the proportion of trait variation transferred to the offspring. Heritability would provide information only on magnitude of interference of quantitative characters, while genetic advance will be helpful in formulating selection procedure to be adopted. Very high heritability and genetic gain for the trait suggested the possibility of selecting high yielding genotypes. All the traits under study

Table 2. Principal components (PC), Eigen values, Cumulative variance for 18 post harvest quality and yield attributes in tomato

Characters	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
Plant height (cm)	0.318	0.019	0.356	0.134	0.049	0.196	0.109	0.073
Number of primary branches/plant	0.259	0.238	-0.099	-0.072	-0.221	0.480	0.001	-0.225
Days to 50% flowering	0.032	-0.075	0.073	0.198	-0.632	-0.265	0.251	0.091
Days to first fruit Set	-0.158	0.376	0.143	-0.039	-0.106	-0.335	0.112	-0.576
Number of flower clusters/plant	0.306	-0.131	0.064	0.069	-0.120	0.042	0.514	0.335
Number of flowers/cluster	0.098	0.242	-0.099	0.107	-0.491	-0.056	-0.521	0.081
Number of fruits/cluster	0.251	0.310	0.179	-0.031	0.104	0.394	-0.139	0.206
Fruit length (cm)	-0.162	0.020	-0.013	0.609	-0.104	0.052	-0.218	0.161
Fruit width (cm)	0.009	0.115	0.411	-0.453	-0.224	-0.073	-0.099	-0.002
Fruit shape index	-0.252	0.123	-0.443	-0.018	0.033	0.277	0.068	-0.105
Number of fruits/plant	-0.182	0.431	0.218	0.161	0.065	-0.014	0.251	0.275
Fruit weight (g)	0.278	-0.142	0.345	0.244	0.014	0.239	-0.232	-0.135
Fruit yield (kg/plant)	0.332	-0.196	0.248	-0.097	-0.042	0.042	-0.241	0.109
Shelf life (days)	0.156	-0.211	0.173	0.100	0.031	-0.024	-0.030	-0.070
TSS (°Brix)	0.185	0.245	-0.164	0.386	0.239	-0.268	-0.024	-0.088
Titrable acidity (%)	0.260	0.192	-0.303	-0.228	-0.237	0.086	0.061	0.339
Ascorbic acid (mg/100 g)	0.283	0.099	0.138	0.185	-0.160	0.359	0.338	-0.342
Lycopene (mg/100 g)	0.146	-0.347	-0.173	0.052	-0.253	0.190	0.036	-0.235
Eigene Value	**5.152**	**2.616**	**2.210**	**1.954**	**1.564**	**1.216**	**1.097**	**0.642**
% Variance contribution	**28.62**	**14.53**	**12.28**	**10.85**	**8.69**	**6.76**	**6.09**	**3.57**
% Cumulative variance	**28.62**	**43.15**	**55.43**	**66.28**	**74.98**	**81.73**	**87.83**	**91.40**

Table 3. Genetic Parameters for post harvest quality and yield attributes in tomato

Character	Mean	Range	GCV (%)	PCV (%)	h^2 (Broad Sense) (%)	Genetic Advance	Genetic advance as percent mean (%)
Plant height (cm)	85.40	52.47-116.72	19.48	19.76	97.00	33.78	39.55
Number of primary branches/plant	6.72	5.43-8.50	11.95	12.59	90.00	1.57	23.36
Days to 50% flowering	75.17	63.67-84.00	6.22	6.59	89.00	9.09	12.10
Days to first fruit Set	86.37	75.33-97.00	5.46	5.77	89.00	9.18	10.63
Number of flower clusters/plant	15.39	11.11-21.26	18.23	18.93	93.00	5.57	36.18
Number of flowers/cluster	4.86	3.53-6.50	14.42	16.47	77.00	1.26	26.01
Number of fruits/cluster	3.01	2.17-4.40	21.05	23.22	82.00	1.18	39.32
Fruit length (cm)	4.11	3.13-6.77	19.66	19.97	97.00	1.64	39.87
Fruit width (cm)	4.38	3.13-5.23	13.37	14.02	91.00	1.15	26.25
Fruit shape index	0.86	0.60-1.82	28.82	35.07	68.00	0.42	48.79
Number of fruits/plant	27.89	17.03-42.55	23.53	24.01	96.00	13.25	47.49
Fruit weight (g)	60.12	36.83-73.63	16.75	16.93	98.00	20.53	34.14
Fruit yield (kg/plant)	1.70	0.99-2.98	34.75	35.20	97.00	1.20	70.66
Shelf life (days)	6.41	4.00-10.00	26.06	27.37	91.00	3.27	51.11
TSS (°Brix)	4.23	3.23-5.13	13.61	13.88	96.00	1.16	27.49
Titrable acidity (%)	0.54	0.45-0.65	10.35	10.68	94.00	0.11	20.67
Ascorbic acid (mg/100 g)	24.81	20.40-27.14	6.26	6.72	87.00	2.98	12.00
Lycopene (mg/100 g)	3.33	2.40-4.10	13.17	13.37	97.00	0.89	26.73

Table 4. Phenotypic correlation coefficients between 18 post harvest quality and yield attributes in twenty genotypes of tomato

S. No	Character	Plant Height (cm)	Number of primary branches/plant	Days to 50% Flowering	Days to First Fruit Set	Number of flower clusters/plant	Number of flowers/cluster	Number of fruits/cluster	Fruit Length (cm)	Fruit Width (cm)	Fruit Shape Index
	Plant height (cm)	1.000	-0.117	-0.187	0.001	-0.334 *	0.500**	0.227	-0.025	-0.303*	-0.012
	Number of primary branches/plant	-0.117	1.000	0.137	0.395 **	0.369 **	-0.290*	0.334*	0.052	0.489**	0.041
	Days to 50% flowering	-0.187	0.137	1.000	0.764**	0.226	0.110	-0.387**	0.218	0.030	-0.031
	Days to first fruit Set	0.000	0.395 **	0.764 **	1.000	0.098	0.067	-0.072	0.015	0.302*	-0.119
	Number of flower clusters/plant	-0.334*	0.369 **	0.226	0.098	1.000	-0.372**	-0.019	0.124	0.223	0.118
	Number of flowers/cluster	0.500 **	-0.290 *	0.110	0.067	-0.372 **	1.000	0.005	0.306*	-0.256	0.156
	Number of fruits/cluster	0.227	0.334 *	-0.387 **	-0.072	-0.019	0.005	1.000	-0.029	0.321*	0.141
	Fruit length (cm)	-0.025	0.052	0.218	0.015	0.124	0.306*	-0.029	1.000	-0.243	0.706**
	Fruit width (cm)	-0.303 *	0.489 **	0.030	0.302 *	0.223	-0.256	0.321*	-0.243	1.000	-0.373**
	Fruit shape index	-0.012	0.041	-0.031	-0.119	0.118	0.156	0.141	0.706**	-0.373**	1.000
	Number of fruits/plant	0.120	0.471 **	-0.104	0.270 *	0.394 **	-0.164	0.536**	-0.020	0.457**	0.084
	Fruit weight (g)	0.218	0.313 *	-0.019	0.171	0.345 *	-0.014	0.329*	0.275*	0.392**	0.083
	Fruit yield (kg/plant)	0.158	0.477 **	-0.059	0.275 *	0.448 **	-0.124	0.519**	0.122	0.533**	0.080
	Shelf life (days)	0.181	-0.291 *	0.144	-0.067	-0.331 *	0.162	-0.127	0.268*	-0.362**	0.268
	TSS (°Brix)	0.644 **	0.124	-0.330 *	-0.023	-0.334 *	0.331*	0.533**	0.118	-0.143	0.244
	Titrable acidity (%)	-0.008	0.368 **	0.154	0.267	0.044	-0.013	0.468**	-0.127	0.052	0.188
	Ascorbic acid (mg/100 g)	0.125	0.208	0.222	0.24	-0.051	-0.129	0.013	-0.159	-0.238	0.146
	Lycopene (mg/100 g)	0.176	-0.244	0.161	-0.031	-0.137	0.303*	-0.299*	-0.075	-0.512**	0.012

,: Significant at 5% and 1% level of significance*

Cont:

Table 4. Phenotypic correlation coefficients between 18 post harvest quality and yield attributes in twenty genotypes of tomato

S. No	Character	Fruits/ Plant	Fruit Weight (g)	Fruit Yield (kg/Plant)	Shelf Life (days)	TSS (°brix)	Titrable Acidity (%)	Ascorbic Acid (mg/100 G)	Lycopene (mg/100 G)
	Plant height (cm)	0.1203	0.218	0.158	0.181	0.644**	-0.008	0.125	0.176
	Number of primary branches/plant	0.471**	0.312*	0.477**	-0.291 *	0.124	0.368**	0.208	-0.244
	Days to 50% flowering	-0.1045	-0.019	-0.059	0.144	-0.3302*	0.154	0.222	0.161
	Days to first fruit Set	0.270*	0.172	0.275 *	-0.067	-0.023	0.267	0.240	-0.031
	Number of flower clusters/plant	0.394**	0.345*	0.448**	-0.331 *	-0.334 *	0.044	-0.051	-0.137
	Number of flowers/cluster	-0.1639	-0.014	-0.124	0.162	0.331 *	-0.013	-0.129	0.303 *
	Number of fruits/cluster	0.536**	0.329*	0.518**	-0.127	0.533**	0.468**	0.013	-0.299 *
	Fruit length (cm)	-0.0198	0.275*	0.122	0.268 *	0.118	-0.127	-0.158	-0.075
	Fruit width (cm)	0.457**	0.392**	0.533**	-0.362	-0.143	0.052	-0.238	-0.512**
	Fruit shape index	0.0842	0.083	0.080	0.268	0.244	0.188	0.146	0.012
	Number of fruits/plant	1.0000	0.415**	0.895**	-0.343 *	0.360**	0.273 *	-0.053	-0.569**
	Fruit weight (g)	0.415**	1.000	0.771**	0.082	0.111	-0.203	-0.147	-0.376**
	Fruit yield (kg/plant)	0.895**	0.771**	1.000	-0.209	0.261	0.086	-0.142	-0.596**
	Shelf life (days)	0.343*	0.082	-0.209	1.000	0.171	-0.139	0.237	0.102
	TSS (°Brix)	0.360**	0.111	0.261	0.171	1.000	0.237	0.194	-0.094
	Titrable acidity (%)	0.273*	-0.203	0.086	-0.139	0.237	1.000	0.230	-0.030
	Ascorbic acid (mg/100 g)	-0.0530	-0.147	-0.142	0.237	0.194	0.230	1.000	0.486**
	Lycopene (mg/100 g)	0.569**	-0.376**	-0.596	0.102	-0.094	-0.030	0.486**	1.000

,: Significant at 5% and 1% level of significance*

exhibited high heritability (>60%) coupled with high genetic gain (>20%) except days to 50% flowering, days to first fruit set and ascorbic acid. Although these heritability estimates have been estimated in broad sense represent the maximum heritability, yet it may be suggested that selection for characters having high heritability may be effective due to the fact that in self- pollinated crop additive genetic variation is likely to be much greater than the non-additive genetic variation. The traits with high heritability and genetic gain can be improved by simple selection. These results confounded with the findings of [11-13].

The correlation coefficients (Table 4) of number of primary branches/plant, days to first fruit set, number of flower clusters/plant, number of fruits/cluster, fruit width (cm), number of fruits/plant, fruit weight (g) and lycopene (mg/100 g) were positively and significantly correlated to fruit yield/plant whereas, days to 50% flowering, shelf life, ascorbic acid and lycopene were negatively and significantly correlated to fruit yield. The results are in accordance with the findings of [7,14].

Genetic parameters helps to give information on traits with high heritability and genetic gain. Correlation analysis helps to determine effective traits in order to indirectly select superior genotypes. On the other hand, principal component analysis is suitable multivariate technique to identify and determine independent principal components that are effective on plant traits separately.

4. CONCLUSION

Number of flower clusters/plant, fruit weight and number of fruits per plant had contributed for maximum variation for the tomato genotypes under study. These traits also had high heritability, high genetic gain and significant correlation with fruit yield. So, these traits can be improved by simple selection. By selecting for these traits fruit yield can also be improved as they have strong correlation with fruit yield.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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