Pak. J. Bot., 51(4): 1341-1347, 2019. DOI: http://dx.doi.org/10.30848/PJB2019-4(28)

RELATIONSHIP OF PATH COEFFICIENT ANALYSIS AND DIFFERENT GENETIC COMPONENTS IN DIVERSE TOMATO (*SOLANUM LYCOPERSICUM* L.) GERMPLASM

SYED M. WAQAS GILLANI[1*], M. YUSSOUF SALEEM[2] AND AMJAD HAMEED[2]

[1]*Pakistan Institute of Engineering and Applied Sciences, Islamabad, Pakistan*
[2]*Nuclear Institute for Agriculture and Biology, Faisalabad, Pakistan*
[*]*Corresponding author's email: Waqasgillani@gmail.com*

Abstract

A study was conducted to estimate heritability, genetic advance correlation between yield and yield components and fruit quality parameters in 50 tomato genotypes to establish the selection criteria in 2015-16 at Nuclear Institute for Agriculture and Biology (NIAB). Analysis of variance showed significant mean square for all that traits indicating scope of improvement in tested genotypes. High heritability and high genetic advance was observed in cluster per plant, plant height, fruit weight, vitamin C and protein contents proposed additive the gene action and early improvement of those traits via selection. Yield per plant was significantly and positively correlated with plant height, fruit weight, fruit width and fruit length suggesting improvement in yield via those traits. Flowers per cluster had highest direct positive effect on yield followed by fruit width, fruit length, plant height, fruit firmness and total carotenoids. So, keeping in view the results of heritability, genetic advance, correlation and path analysis yield can be increased by number of flowers, plant height, fruit width and length, fruit firmness, total carotenoids and vitamin C.

Key words: Path coefficient analysis genetic advance, Heritability, Vitamin C, Lycopene.

Introduction

Tomato (*Solanum lycopersicum* L.) is the rich source of mineral elements (Ca, P and Fe), vitamin (A, C) and bioactive molecules such as lycopene, β carotene and carotenoids a very cheap rate (Dhaliwal *et al.*, 2003; Kavanaugh *et al.*, 2007; Shahidi *et al.*, 2011). Earlier, tomato breeding was focused mainly on the aspect of increasing yield potential and resistance to abiotic and biotic stresses (Martí *et al.*, 2016). But due to human health related concerns owing to cancer and cardiovascular problems, tomato breeding was diverted to nutritional improvement (Causse *et al.*, 2003; Causse *et al.*, 2007). Fruit quality of tomato has become the important selection criterion for any tomato improvement program due to the recently developed concept of optimal nutrition and demands of functional food industries (Chaib *et al.*, 2006; Causse *et al.*, 2007; Dagade *et al.*, 2015) .

Hence, in order to increase yield and nutritive quality of tomato, genetic information to establish selection criteria is indispensable. Most commonly used technique s for this purpose is heritability, genetic advance, correlation and path analysis. Present study was conducted on exotic, wild and introgression lines, diverse in origin and parentage to elucidate those yield related traits along with some important nutritive characteristics which may eventually paid due attention to establish selection criteria. This will definitely help breeders to develop high yielding and nutritivily enrich tomato cultivars.

Materials and Methods

Fifty diverse tomato genotypes were collected (Table 1) and grown under field condition during 2014-15 following randomized complete block design plan in triplets. Six to four inches height seedlings were transplanted in field keeping plant × plant distance 50 cm and bed × bed distance 1.5 m, respectively. Each replication consisted of 7 plants per genotype. Nitrogen (N): Phosphorous (P): Potash (K) were applied @ 90:45:75 kg per acre. N was applied in the split farm; one-third dose of the N and full dose of both P and K was applied at transplanting while half of N was applied at flowering and fruiting stage. Plants were irrigated fortnightly during winter and weekly during summer. Crop was protected from insect pest and diseases using recommended insecticide/fungicide. Observations were recorded on five plants for number of clusters per plant, number of flowers per cluster, number of fruits per cluster, plant height(cm), fruit firmness(kg/cm^3), fruit weight (g), fruit length (mm), fruit width(mm) and fruit yield per plant (kg) as per tomato descriptor (Saldarelli *et al.*, 1996). In order to determine the different biochemical parameters, fully matured fruits were collected from the field and their extract was collected in falcon tubes using west point juicer blender grinder model number 7701. The extract was then centrifuged at 15,000 rpm. Supernatant was collected and stored at –20ºC and analyzed. To measure the lycopene (mg/g f.wt) content, the tomato fruits were homogenized by a Bosch Easy Mix crusher (type CNHR6, Robert Bosch GmbH, Stuttgart, Germany). Lycopene was estimated using spectrophotometer following the method of Scott, (2001). Total carotenoids (mg/g f.wt) were also determined by spectrophotometer as described by Metzner *et al.,* (1965). Ascorbic acid/ Vitamin C (µg/g. f.wt) was determined by the method given by Hameed *et al.*, (2005). Total soluble proteins (mg/g f.wt) were measured by Bradford's method (Bradford, 1976). Analysis of variance was done following the method of by Steel *et al.*, (1997) for studied parameters. Broad sense heritability [h^2 (b.s)] and genetic advance (GA%) was estimated following the method described by Lush, (1949). Genotypic(rg) and phenotypic(rp) correlation coefficients were estimated using the method of Johnson *et al*., (1955) . Correlation coefficients were divided into components of indirect and direct effects by path analysis and assessed using method of Dewey & Lu (1959) and Wright (1960).

Table 1. List of tomato genotypes.

Ascension ID.	Line/Cultivar	Pedigree	Traits	Region/country
LA3845	NCEBR-5	*S. lycopersicum* (Mutant)	Early Blight resistant	U.S.A (north Carolina)
LA3846	NCEBR-6	*S. lycopersicum* (Mutant)	Early Blight resistant	Peru
LA1035	CLN2768A	*S. cheesmaniae* (wild type)	Wild specie	Ecuador
	BV 3	*S. esculentum*	Yield	Bulgaria
	BV 4	*S. esculentum*	Yield	Bulgaria
	H-24	*S. esculentum*	Early blight	Pakistan(Faisalabad)
Romaking	V54	*S. esculentum*	Late Blight resistance	Pakistan(Islamabad)
Pak0010576	V48	*S. esculentum*	Late Blight resistance	North korea
	Titano	*S. lycopersicum*	Late Blight resistance	Pakistan (Faisalabad)
	Galia	*S. lycopersicum*	Late Blight resistance	Pakistan(Gujranwala)
LA3475	M-82	*S. lycopersicum* (Mutant)	Late Blight resistance	U.S.A(Califonia
	Lyp-1		Fruit quality	Pakistan(Faisalabad)
LA4347	B-L-35	*L. esculentum* (Mutant)	Disease resistance, Fruit quality	Spain
	Canada Acc-1	S	Fruit quality	
	West Viginia-63		Disease	
LA3847	NC HS-1	*S. lycopersicum* (Mutant)	Disease resistant, Stress tolerant, Fruit quality	Guatemala
LA2938	UC-N28	*S. esculentum* (Mutant)	Fruit quality traits	U.S.A(California)
	Naqeeb	*S. lycopersicum*	Yield	Pakistan(Faisalabad)
	Meijielo	*S. esculentum*	Yield	China
LA3913	TA1258	Introgression line (*S. habrochaites*)	Resistance to Tobacco mosaic virus	Spain
LA3921	TA1105	Introgression line (*S. habrochaites*)	Resistance to Tobacco mosaic virus	U.S.A(California)
LA3925	TA1111	Introgression line (*S. habrochaites*)	Resistance to Tobacco mosaic virus	Spain
LA3930	TA1133	Introgression line (*S. habrochaites*)	Resistance to Tobacco mosaic virus	U.S.A(California)
LA3938	TA1287	Introgression line (*S. habrochaites*)	Resistance to Tobacco mosaic virus	U.S.A(Indiana)
LA3960	TA1550	Introgression line (*S. habrochaites*)	Resistance to Tobacco mosaic virus	Spain(Madrid)
LA3969	TA1121	Introgression line (*S. habrochaites*)	Resistance to Tobacco mosaic virus	U.S.A(New York)

Table 1. (Cont'd.).

Ascension ID.	Line/Cultivar	Pedigree	Traits	Region/country
LA4043	IL 3-1	Introgression line (*S. pennellii*)	Drought tolerant, Fruit development & quality	Israel(Jerusalem)
LA4054	IL 5-1	Introgression line (*S. pennellii*)	Drought tolerant, Fruit development & quality	Israel(Jerusalem)
LA4071	IL 8-1	Introgression line (*S. pennellii*)	Drought tolerant, Fruit development & quality	Israel(Jerusalem)
LA4078	IL 9-1	Introgression line (*S. pennellii*)	Drought tolerant, Fruit development & quality	Israel(Jerusalem)
LA4087	IL 10-1	Introgression line (*S. pennellii*)	Drought tolerant, Fruit development & quality	Israel(Jerusalem)
LA4097	IL 12-1	Introgression line (*S. pennellii*)	Drought tolerant, Fruit development & quality	Israel(Jerusalem)
LA4099	IL 12-2	Introgression line (*S. pennellii*)	Drought tolerant, Fruit development & quality	Israel(Jerusalem)
LA4139	TA2874	Inbred line of *S. pimpinellifolium*	Biotic & abiotic stresses, fruit quality	Turkey
LA4141	TA2876	Inbred line of *S. pimpinellifolium*	Biotic & abiotic stresses, fruit quality	Turkey
LA4142	TA2877	Inbred line of *S. pimpinellifolium*	Biotic & abiotic stresses, fruit quality	Peru
LA4145	TA2880	Inbred line of *S. pimpinellifolium*	Biotic & abiotic stresses, fruit quality	Peru
LA4146	TA2881	Inbred line of *S. pimpinellifolium*	Biotic & abiotic stresses, fruit quality	Peru
LA4147	TA2882	Inbred line of *S. pimpinellifolium*	Biotic & abiotic stresses, fruit quality	Peru
LA4149	TA2884	Inbred line of *S. pimpinellifolium*	Biotic & abiotic stresses, fruit quality	U.S.A (New York)
LA4151	TA2886	Inbred line of *S. pimpinellifolium*	Biotic & abiotic stresses, fruit quality	Peru
LA4153	TA2888	Inbred line of *S. pimpinellifolium*	Biotic & abiotic stresses, fruit quality	Turkey
LA4154	TA2890	Inbred line of *S. pimpinellifolium*	Biotic & abiotic stresses, fruit quality	Ecuador
LA4157	TA2893	Inbred line of *S. pimpinellifolium*	Biotic & abiotic stresses, fruit quality	Ecuador
LA4158	TA2894	Inbred line of *S. pimpinellifolium*	Biotic & abiotic stresses, fruit quality	Ecuador
LA4159	TA2895	Inbred line of *S. pimpinellifolium*	Biotic & abiotic stresses, fruit quality	Ecuador
LA4160	TA2896	Inbred line of *S. pimpinellifolium*	Biotic & abiotic stresses, fruit quality	U.S.A (New York)
	21354		Fruit quality	Mexico
	21396		Disease resistance and yield	Guatemala
	Islamabad 4-2		Yield	
	RioMutant-400		Yield	

Table 2. Analysis of variance and estimates of genetic parameters of different yield parameters and fruit quality traits in tomato (*Solanum lycopersicum*) genotypes.

Source	d.f.	Clusters /Plant	Flowers /Clusters	Fruits/ Clusters	Plant height (cm)	Fruit firmness (Kg/cm^2)	Single fruit weight (g)	Single fruit width (mm)	Single fruit length (mm)	Lycopene (mg/g f.wt)	Total Carotenoids (mg/g f.wt)	Vitman C (µg/g. f.wt)	Protein contents (mg/g f. wt)	Yield/plant (kg)
Replications	2	10.01	0.180	0.607	15.89	0.09647	106.52	12.990	11.203	0.00685	0.1994	4454	168.84	0.02
Genotypes	49	453.4 **	5.021 **	5.56 **	1324.6 **	3.77 **	1676.6 **	120.62 **	221.47 **	5.38 **	19.09 **	141268 **	3575.8**	0.64 **
Error	98	9.76	0.337	0.566	15.31	0.09558	96.33	18.247	14.962	0.02244	1.0789	4699	132.85	0.02
Mean± S.E		78.17± 2.5510	5.38± 0.4736	4.77± 0.6142	65.43± 3.1946	5.41± 0.2524	58.55± 8.0136	45.17± 3.4878	50.03± 3.1583	6.48± 0.1223	14.04± 0.8481	4139.2± 55.970	223.2± 9.4111	1.16± 0.1084
C.V %		4.00	10.78	15.78	5.98	5.71	16.76	9.46	7.73	2.31	7.40	1.66	5.16	11.47
σ^2g		3704.70	33.187	33.813	891.038	29.213	1075.47	69.673	140.541	29.469	24.929	92942.9	2343.1	55.94
σ^2p		3711.35	34.358	40.938	901.456	29.591	1141.03	82.091	150.724	29.530	25.665	96140.9	2433.5	56.74
GCOV		77.86	3.188	3.188	45.619	2.498	56.011	18.477	23.696	3.644	12.255	7.365	21.69	0.42
PCOV		77.93	3.417	3.417	45.885	2.563	57.69	20.057	24.540	3.659	12.898	7.491	22.11	0.43
h^2(b.s) in % age		99.8	93.3	89.9	99.8	97.5	94.3	84.9	93.2	99.6	94.3	96.7	96.0	97.0
G.A% of mean		85.14	2.41	2.46	41.55	2.19	44.57	10.77	16.03	2.67	4.76	419.65	66.50	0.89

[1] *, ** = Significant at 0.05 and highly significant 0.01 level of probability

Table 3. Genotypic and phenotypic correlation coefficients of different yield parameters and fruit quality traits in tomato (*Solanum persicum*) genotypes.

		Clusters /Plant	Flowers /Clusters	Fruits/ Clusters	Plant height (cm)	Fruit firmness (Kg/f)	Single fruit weight (g)	Single fruit width (mm)	Single fruit length (mm)	Lycopene (mg/g f.wt)	Total carotenoids (mg/g f.wt)	Vitman C (ug/g. f.wt)	Protein contents (mg/g f. wt)	Yield/Plant (kg)
Clusters/Plant	G	1.000	0.3473*	0.1155*	0.4593*	-0.3887*	-0.2622*	-0.2252*	-0.4170*	0.1482*	0.2433*	0.0904*	-0.4437*	0.0587*
	P	1.000	0.3345**	0.1098	0.4560**	-0.3835**	-0.2537*	-0.2038	-0.3992**	0.1480	0.2356*	0.0885	-0.4342**	0.0578
Flowers/Clusters	G		1.000	0.889*	-0.1089*	0.3117*	-0.2074*	-0.1092*	-0.2673*	0.118	0.1438*	0.1215*	-0.4280*	-0.2558*
	P		1.000	0.862**	-0.1087	0.2995**	-0.2072	-0.0976	0.2571*	0.1053	0.1389	0.1242	-0.4021**	-0.2397*
Fruits/Clusters	G			1.000	-0.2419*	0.4564*	-0.1260*	0.0237	-0.1305*	-0.0433	0.0694	0.0864*	-0.2477*	-0.4173*
	P			1.000	-0.2337*	0.422**	-0.1284	0.0273	-0.1245	-0.0404	0.0607	0.0877	-0.2348*	-0.3794**
Plant height (cm)	G				1.000	-0.4541*	0.2147*	-0.0457*	0.2023*	-0.1387*	-0.1703*	0.0283*	-0.0451*	0.4006*
	P				1.000	-0.4464**	0.2091	-0.0424	0.1939	-0.1383	-0.1710	0.0257	-0.0458	0.3912**
Fruit firmness (Kg/f)	G					1.000	-0.2526*	-0.1799*	-0.1287*	0.2212*	0.2391*	-0.1573*	0.0168	-0.3187*
	P					1.000	-0.2447*	-0.1615	-0.1228	0.2175	0.2351*	-0.1555	0.0132	-0.3049**
Single fruit weight (g)	G						1.000	0.8902*	0.7076*	-0.4263*	-0.4560*	-0.1047*	0.3196*	0.4493*
	P						1.000	0.8126**	0.6800*	-0.4116**	-0.4371*	-0.0976	0.3052**	0.4240**
Single fruit width (mm)	G							1.000	0.4171*	-0.2843*	-0.2107*	-0.0645*	0.3239*	0.2739*
	P							1.000	0.3920**	-0.2645*	-0.1959	-0.0581	0.2974**	0.2459*
Single fruit length (mm	G								1.000	-0.4164*	-0.4853*	0.0082*	0.1960*	0.4049*
	P								1.000	-0.4031**	-0.4548**	0.0018	0.1945	0.3785**
Lycopene (mg/g f.wt)	G									1.000	0.9255*	-0.0047	-0.4524*	-0.1191
	P									1.000	0.8943**	-0.0048	-0.4429**	-0.1173
Total Carotenoids (mg/g f.wt	G										1.000	0.0055	-0.5340*	-0.1364
	P										1.000	0.0001	-0.5108**	0.1266
Vitman C (ug/g. f.wt	G											1.000	-0.2870*	-0.0065
	P											1.000	-0.2813*	-0.0043
Protein contents (mg/g f. wt)	G												1.000	0.0026
	P												1.000	0.0058
Yield kg/Plant	G													1.000
	P													1.000

[1] ..* Significant at 5% level : [2] ** Significant at 1% level

Table 4. Genotypic path coefficient of different yield parameters and fruit quality traits on fruit yield in tomato (*Solanum persicum*) genotypes.

	Clusters /Plant	Flowers /Clusters	Fruits/ Clusters	Plant height (cm)	Fruit firmness (Kg/f)	Single fruit weight (g)	Single fruit width (mm)	Single fruit length (mm)	Lycopene (mg/g f.wt)	Total Carotenoids (mg/g f.wt)	Vitman C (ug/g. f.wt)	Protein contents (mg/g f. wt)	Yield/Plant (kg) G. Cor
Clusters/Plant	**-0.0687**	0.5055	-0.2181	0.1822	-0.1130	0.3063	-0.2665	-0.3226	-0.1022	0.1156	-0.0061	0.0462	0.0587*
Flowers/ Cluster	-0.0239	**1.4554**	-1.6686	-0.0432	0.0906	0.2423	-0.1292	-0.2068	-0.0771	0.0683	-0.0082	0.0445	-0.2558*
Fruits /cluster	-0.0079	1.2857	**-1.8888**	-0.0959	0.1326	0.1472	0.0280	-0.1010	0.0299	0.0330	-0.0058	0.0258	-0.4173*
Plant height (cm)	-0.0315	-0.1585	0.4568	**0.3966**	-0.1320	-0.2508	-0.0540	0.1565	0.0956	-0.0809	-0.0019	0.0047	0.4006*
Fruit firmness (Kg/f)	0.0267	0.4536	-0.8621	-0.1801	**0.2906**	0.2951	-0.2129	-0.0996	-0.1525	0.1136	0.0106	-0.0017	-0.3187*
Single fruit weight (g)	0.0180	-0.3019	0.2381	0.0851	-0.0734	**-1.1682**	1.0533	0.5473	0.2939	-0.2167	0.0071	-0.0332	0.4493*
Single fruit width(mm)	0.0155	-0.1589	-0.0447	-0.0181	-0.0523	-1.0400	**1.1831**	0.3226	0.1960	-0.1001	0.0044	-0.0337	0.2739*
Single fruit length(mm)	0.0286	-0.3891	0.2466	0.0802	-0.0374	-0.8266	0.4934	**0.7735**	0.2871	-0.2306	-0.0006	-0.0204	0.4049*
Lycopene (mg/g f.wt)	-0.0102	0.1628	0.0818	-0.0550	0.0643	0.4980	-0.3364	-0.3221	**-0.6894**	0.4398	0.0003	0.0471	-0.1191
Total Carotenoids (mg/g f.wt)	-0.0167	0.2093	-0.1312	-0.0676	0.0695	0.5327	-0.2492	-0.3754	-0.6381	**0.4751**	-0.0004	0.0555	-0.1364
Vitman C (ug/g. f.wt)	-0.0062	0.1769	-0.1633	0.0112	-0.0457	0.1223	-0.0763	0.0063	0.0033	0.0026	**-0.0675**	0.0298	-0.0065
Protein contents (mg/g f. wt)	0.0305	-0.6229	0.4678	-0.0179	0.0049	-0.3733	0.3832	0.1516	0.3119	-0.2537	0.0194	**-0.1040**	0.0026

[1] * Significant at 5% level; [2] ** Significant at 1% level, [3] Diagonal values (Bold) indicate direct effects

Results

Analysis of variance: Analysis of variance showed highly significant mean square of genotypes for all traits (Table 2). Coefficient of variation (C.V) for quality and agronomic traits ranged 10-20% respectively. Phenotypic coefficient of variation (PCOV) was high as compared to genotypic coefficient of variation (GCOV) in all traits (Table 2). Cluster per plant, plant height, fruit weight, vitamin C and protein contents had high heritability and high genetic advance. While, flowers per clusters, fruits per clusters, fruit firmness, lycopene, total careteniods and yield per plant had high heritability and low genetic advance. In this investigation high heritability with moderated genetic advance was observed for fruit weight and fruit length.

Genotypic and phenotypic correlations: Genotypic and phenotypic correlation is presented in Table 3. Yield per plant had significant and positive genotypic and phenotypic correlation with plant height (0.4006, 0.3912), fruit weight (0.4493, 0.4240), fruit width (0.2739, 0.2459) and fruit length (0.4049, 0.3785) while, positive but non-significant correlation of yield per plant for both rg and rp coefficients was observed with protein contents. On the other hand characters like flowers per cluster, fruit per cluster and fruit firmness had significant and negative correlation rg and rp with yield per plant. Clusters per plant had positive and significant rg but positive non-significant rp with yield per plant. Negative but non-significant correlation of both rg and rp were observed with lycopene and vitamin C contents with yield per plant, however rg correlation coefficient was negative and non-significant while rp coefficient of correlation was positive for total careteniods with yield per plant.

Path analysis: Path analysis (Table 4) results indicated that number of flowers per cluster had highest direct positive effect on yield per plant followed by fruit width, fruit length plant height, fruit firmness and total carotenoids. While, there were certain traits which contributed indirectly towards yield per plant these traits were clusters per plant via plant height, fruit per clusters via fruit firmness and fruit width. Lycopene also contributed indirectly through flowers/ clusters and fruit firmness and vitman C through flowers per clusters, plant height and fruit length towards yield kg per plant.

Discussion

Significant mean square (Table 2) emphases considerable scope of improvements in tested traits moreover the C.V being in proper limits validate the data set as described earlier elsewhere (Fozia *et al.*, 2010; Jilani *et al.*, 2013). Higher PCOV value in comparison to GCOV showed the sensitivity of the material to the environment this might be due to genetically diverse material in our investigation. High broad sense heritability associated with genetic advance for cluster per plant, plant height, fruit weight, vitamin C and protein contents showed additive genetic control in the inheritance of these traits, therefore early selection for those traits would be rewarding to improve yield. However, fruit weight and fruit length showed high heritability along with moderate genetic advance were equally important and improvement in yield could also be brought via those traits (Agong *et al.,* 2000).

Yield is complex character controlled by many factors with negative and positive effects (Mohamed *et al.*, 2012). To understand the extent of association of yield with other characters, one should measure the extent of association of these characters (Manna & Paul, 2012). Yield per plant have significant and positive correlation with plant height, fruit weight, fruit width and fruit length while, positive but non-significant correlation was observed with protein contents. Clusters per plant had significant positive genotypic correlation with yield per plant. Negative but non-significant correlation of both rg and rp were with lycopene and vitamin c contents with yield per plant, however rg correlation coefficient was negative and non-significant while rp coefficient of correlation was positive for total carotenoids with yield per plant. These findings were validated by the earlier findings of Fozia *et al.* (2010) and Jilani *et al*., (2013)

Independent characters viz via number of flowers per cluster, fruit width, fruit length, plant height, fruit firmness and total Carotenoids had direct positive effect on the yield per plant. A number of workers pointed out the greater role for the improvement in dependent factor yield maintaining the adequate amount of fruit quality (Hannan *et al.*, 2007; Al-Aysh *et al.*, 2012). While indirect effects of certain traits (yield and quality) can contribute towards better/ higher yield in F_1 hybrids without compromising the fruit quality and antioxidant potential of the hybrids. Those traits include clusters/plant via plant height, fruit per clusters via fruit firmness and fruit width, Lycopene via flowers per clusters and fruit firmness kg/f, vitman C through flowers per clusters, plant height and fruit length, towards yield kg per plant. It is therefore advocated that due attention should be given to these traits while doing selection. These finding are in accordance with the earlier investigation (Rani *et al.*, 2010; Narolia *et al.*, 2012).

Conclusion

In order to establish a selection criterion for introgression lines, backcross population, modern and vintage cultivars and wild accession, number of flowers, plant height, fruit width and length and fruit firmness are the yield related parameters on which the selection can be made. However, total carotenoids and vitamin C might be selected as the potential fruit quality parameters to design a judicious hybridization scheme.

Acknowledgment

We would like to acknowledge Pakistan Science Foundation (PSF) for provision the resources and funds for carrying out the research out of the project No. PSF/NSLP/P-NIAB (164).

References

Agong, S., S. Schittenhelm and W. Friedt. 2000. Genotypic variation of Kenyan tomato (*Lycopersicon esculentum* L.) germplasm. *Noticiário de Recursos Genéticos*, 123(67): 61.

Al-Aysh, F., H. Kutma, M. Serhan, A. Al-Zoubai, M.A. Al-Naseer and D.A.G. Village. 2012. Genetic analysis and correlation studies of yield and fruit quality traits in tomato (*Solanum lycopersicum* L.). *New York Sci. J.,* 5: 142-145.

Bradford, M.M. 1976. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. *Anal. Biochem.*, 72: 248-254.

Causse, M., M. Buret, K. Robini and P. Verschave. 2003. Inheritance of nutritional and sensory quality traits in fresh market tomato and relation to consumer preferences. *J. Food Sci.*, 68: 2342-2350.

Causse, M., J. Chaïb, L. Lecomte and M. Buret. 2007. Both additivity and epistasis control the genetic variation for fruit quality traits in tomato. *Theor. Appl. Genet.*, 115: 429-442.

Chaib, J., L. Lecomte, M. Buret and M. Causse. 2006. Stability over genetic backgrounds, generations and years of quantitative trait locus (QTLs) for organoleptic quality in tomato. *Theor. Appl. Genet.*, 112: 934-944.

Dagade, S., A. Barad and K. Dhaduk LKand Hariprasanna. 2015. Estimates of hybrid vigour and inbreeding depression for fruit nutritional characters in tomato. *Int. J. Sci. Environ. & Technol.*, 4: 114-124.

Dewey, D.R. and K. Lu. 1959. A Correlation and Path-Coefficient Analysis of Components of Crested Wheatgrass Seed Production 1. *Agron. J.*, 51: 515-518.

Dhaliwal, M., S. Singh and D. Cheema. 2003. Line x tester analysis for yield and processing attributes in tomato. *J. Res.*, 40: 49-53.

Fozia, N., M.S. Jilani, W. Kashif and K. Mehwish. 2010. Performance of tomato hybrids under hydroponic culture. *Pak. J. Agri. Sci.*, 47: 19-25.

Hameed, A., N. Iqbal, S.A. Malik, H. Syed and M. Ahsanul-Haq. 2005. Age and organ specific accumulation of ascorbate in wheat (*Triticum aestivum* L.) seedlings grown under etiolation alone and in combination with oxidative stress.

Hannan, M., M. Ahmed, M. Razvy, R. Karim, M. Khatun, A. Haydar, M. Hossain and U. Roy. 2007. Heterosis and correlation of yield and yield components in tomato (*Lycopersicon esulentum* Mill.). *Amer. Eurasian J. Scientific Res.*, 2: 146-150.

Jilani, M.S., K. Waseem, K. Ameer, T.A. Jilani, M. Kiran, A. Alizia and A. Parveen. 2013. Evaluation of elite tomato cultivars under agroclimatic conditions of Dera Ismail Khan. *Pak. J. Agri. Sci*., 50: 17-21.

Johnson, H.W., H. Robinson and R. Comstock. 1955. Estimates of genetic and environmental variability in soybeans 1. *Agron. J.*, 47: 314-318.

Kavanaugh, C.J., P.R. Trumbo and K.C. Ellwood. 2007. The US Food and Drug Administration's evidence-based review for qualified health claims: tomatoes, lycopene, and cancer. *J. Nat. Cancer Inst.*, 99: 1074-1085.

Lush, J.L. 1949. Heritability of quantitative characters in farm animals. *Hereditas*, 35: 356-375.

Manna, M. and A. Paul. 2012. Path analysis between fruit yield and some yield components in tomato (*Lycopersicon esculeutum* Mill). *Hort. Flora Res. Spectrum*., 1: 215-219.

Martí, R., S. Roselló and J. Cebolla-Cornejo. 2016. Tomato as a source of carotenoids and polyphenols targeted to cancer prevention. *Cancers*, 8: 58.

Metzner, H., H. Rau and H. Senger. 1965. Untersuchungen zur synchronisierbarkeit einzelner pigmentmangel-mutanten von Chlorella. *Planta*, 65: 186-194.

Mohamed, S., E. Ali and T. Mohamed. 2012. Study of heritability and genetic variability among different plant and fruit characters of tomato (*Solanum lycopersicum* L.). *Int. J. Scientific & Technol. Res.*, 1: 55-58.

Narolia, R.K., R. Reddy and M. Sujatha. 2012. Genetic architecture of yield and quality in tomato (*Solanum lycopersicum*). *Agric. Sci. Digest*., 32.

Rani, C.I., I. Muthuvel and D. Veeraragavathatham. 2010. Correlation and path coefficient for yield components and quality traits in tomato (*Lycopersicon esculentum* Mill.). *Agri. Sci. Digest,* 30.

Saldarelli, P., L. Barbarossa, F. Grieco and D. Gallitelli. 1996. Digoxigenin-labelled riboprobes applied to phytosanitary certification of tomato in Italy. *Plant Disease*, 80: 1343-1346.

Scott, K.J. 2001. Detection and measurement of carotenoids by UV/VIS spectrophotometry. *Curr. Protocols in Food Anal. Chem.,* 1: 215-219.

Shahidi, F., A. Chandrasekara and Y. Zhong. 2011. Bioactive phytochemicals in vegetables. *Handbook of Vegetables & Vegetable Process.,* 125-158.

Steel, R.G. and J.H. Dickey. 1997. *Pinciples and procedures of statistics a biometrical approach*. Mcgrawhill, New York, 3: 666

Wright, S. 1960. Path coefficients and path regressions: alternative or complementary concepts *Biometrics*, 16: 189-202.

(Received for publication 14 March 2018)