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Orignal Article

DECIPHERING THE GENETIC VARIABILITY FOR FRUIT QUALITY TRAITS IN TOMATO (*SOLANUM LYCOPERSICUM L.*)

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Abstract: Advances in basic biology on fruit development and ripening serve as important information to improve fruit and produce quality in tomato (Solanum Lycopersicum L.) Deciphering the diversity of germplasm collection through characterization for fruit quality traits is therefore a key component of germplasm management and their effective exploitation in crop breeding. In the present study, a diverse collection of 260 tomato germplasm was analyzed during kharif and rabi season for fruit quality traits viz; fruit firmness, shelf life, total soluble solids, lycopene content, ascorbic acid and locule numbers. Analysis of coefficient of variation unraveled more of phenotypic coefficient of variation than the genotypic coefficient of variation for all the studied traits. Variability for major traits at P<0.001 indicated that traits could be exploited for improvement through conventional and molecular aided breeding strategy. Correlation study gave insights into link among quality traits thereby it may assist the improvement of independent or combined traits through a breeding programme.

Keywords : Tomato, Germplasm, Fruit quality traits

INTRODUCTION

Tomato (***Solanum Lycopersicum* L.**), an important and most widely grown vegetable crop of the world, belonging to the family ***Solanaceae*** covers >3000 species [1,2]. ***Solanum Lycopersicum*** is only domesticated and cultivated species constitutes major horticulture industry and it stands second in position concerning wide consumption after potato [3]. Keeping farmers and consumer preference as prior breeding objective wide-ranging varieties/hybrids have been bred focusing on yield, fleshy fruit development with better quality and for sustainability in extreme stress conditions [4]. In the world, 4.76 million ha

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area produced 182.26 million tons of fresh fruits. In India, 0.81 million ha of tomatoes were cultivated during 2020, with an annual production of 20.57 million tons (FAO STAT, 2020).

In the recent market era, the quality standard of consumers highlights more on fruit flavor, appearance, color and nutritional value etc. Tomato as model species for fleshy fruit has generated greater scope to create variability through the execution of conventional and modern breeding tools thereby improving agronomically important traits. The straight forwardness of crossing, high self-pollination of tomato has advanced the fleshy fruit breeding concerning nutritionally important traits such as high sugars, firmness, shelf life, pigments and vitamins [5-7]. Total soluble solids contribute to fruit quality by providing sweetness. Cell expansion is promoted by maintaining turgor pressure with the involvement of sugars [8]. Antioxidant compounds such as ascorbic acid and carotenoids have greater potential diet value which could be associated with a reduced risk of cancer (prostate, lung, mouth, and colon), inflammation and cardiovascular diseases. Beyond their critical role in human nutrition, prevention of oxidative stress, hormonal signaling, cell cycle, cell expansion, responses to biotic and abiotic stresses is also regulated by these antioxidants [9-11]. Fruit firmness and shelf life contribute positively to ease of transportation thereby reduce post-harvest losses [12]. These versatile nutritional benefits of fleshy fruit have provided a greater platform for breeders and researchers to exploit germplasm variation and investigate the complexity of traits for improvement of cultivars/hybrids with better fruit quality traits [13].

The heterogeneous germplasm represents a greater source of variation thus helpful for exploitation in breeding schemes. Since tomato is domesticated, considerable diversity levels have been observed and recorded through selection. However, the traits where complex genetics is involved could not be studied extensively in the exotic collection, landraces due to the positive impact of an environment which limits breeding for fruit quality traits. Deciphering the diversity of germplasm collection through characterization for complex quality traits is therefore a key component of germplasm management and their effective exploitation in crop breeding [14,15). Besides, the value of association mapping has gained more importance due to its ability to get insights into genotype-phenotype correlations [16]. Further, being a self-pollinated crop, the extent of LD over the tomato genome is relatively high, it is possible to conduct genome-wide association-mapping analysis, using fewer markers than with many others cross-pollinated species having low LD [17]. Therefore, the combination of large germplasm collections, their variability studies for fruit quality traits provides a framework to apply GWAS, which is a promising genetic method for the dissection of complex traits.

In the present study, to investigate variation in tomato association mapping panel, 260 accessions were analyzed during ***kharif*** and ***rabi*** season for fruit quality traits viz; fruit firmness, shelf life, total soluble solids, lycopene content, ascorbic acid and locule numbers. The main goal of our work was to characterize accessions with special emphasis on fruit quality traits for the establishment of a superior structured population for wide genome association mapping.

MATERIAL AND METHODS

Experimental material: For the study, 260 tomato association-mapping panel and four commercial check varieties were evaluated for fruit quality traits. Seeds were sown in June 2017 and December 2017 and 25-day-old seedlings were transplanted to open field. Each accession was transplanted in a ridge of three meter length spaced 45 cm apart with an intra row spacing of 60 cm. All recommended package of practices for tomato cultivation were followed and crop was raised in a field for 2 seasons. Precise phenotyping and biochemical tests were carried out for fruit related- traits. The tomato accessions constituting the mini-core used in the study are provided in supplementary file.

Fruit quality traits measurement and estimation

1. Fruit firmness (N): Fruit firmness was measured using stable microsystems texture analyzer. A 2-mm stainless probe was applied on the fruit equator, the force applied by the probe was recorded using exponent connect software, and the average of the three fruits was used.

2. Evaluation of shelf life: Shelf life in days was assessed similar to the procedure described by Yogendra and Gowda [18]. Five tomato fruits per accession were harvested at breaker stage and stored at room temperature. The days between harvesting

Tavle 1: List of Tomato mini-core collections to be used in present study

UHS Code	Accession	UHS Code	Accession	UHS Code	Accession	UHS Code	Accession
1	Ageta-32	30	CLN-2026	59	EC-520059	88	EC-605694
2	Angoor lata	31	CLN-2116	60	EC-520061	89	EC-605695
3	Arka abha	32	CLN-1621	61	EC-520071	90	EC-605696
4	Arka alok	33	CLN-2366	62	EC-3957165690	91	Ec-620362
5	Arka Meghalli	34	D-1-1	63	EC-520075	92	EC-620366
6	Arka vikas	35	D-2-2-1	64	Ec-520078	93	EC-620370
7	Avinash-2-2-1	36	D-3-2	65	Ec-521039	94	EC-620373
8	Azad T-2	37	D-5-1	66	Ec-521056	95	EC-620374
9	Azad T-5	38	DARL-66	67	Ec-521078	96	EC-620375
10	B-4-1	39	Dhrubya	68	Ec-526139	97	EC-620383
11	B-7-2	40	DT-10	69	EC-528372	98	EC-620386
12	Bhillai	41	DVRT-1	70	EC-528374	99	EC-620398
13	BL-1208	42	DVRT-2	71	Ec-529080	100	EC-620401
14	BTH-9 Male	43	E-4-3	72	Ec-529083	101	EC-620403
15	C-1-4	44	EC-2791	73	EC-538138	102	EC-620406
16	C-3-2	45	EC-13904	74	Ec-538155	103	EC-620409
17	C-4-1	46	EC-317-6-1	75	EC-538380	104	EC-620410
18	C-8-1	47	EC-273966	76	Ec-538404	105	EC-620411
19	C-9-2	48	EC-381263	77	EC-538405	106	EC-620413
20	C-10-2	49	EC-381554	78	EC-538408	107	EC-620419
21	C-11-1	50	EC-501574	79	EC-538419	108	EC-620421
22	C-11-2	51	EC-501575	80	EC-538423	109	EC-620438
23	C-11-3	52	EC-501576	81	EC-538439	110	EC-620444
24	C-20-1	53	EC-501577	82	EC-538440	111	EC-620446
25	C-20-2	54	EC-501580	83	EC-538441	112	EC-620455
26	C-26-1	55	EC-501582	84	EC-538455	113	EC-620456
27	CHRT-4	56	EC-501583	85	EC-552141	114	EC-620464
28	CH-155	57	EC-519730	86	EC-560340	115	EC-620469
29	C0-3	58	EC-520046	87	Ec-570028	116	EC-620470
UHS Code	**Accession**	**UHS Code**	**Accession**	**UHS Code**	**Accession**	**UHS Code**	**Accession**
117	EC-620474	149	FLA-7421	181	jawahar-99	213	Persia Bed
118	EC-620476	150	FLORA-DADE	182	kashiHemant	214	PDT-3-1
119	EC-620480	151	G-4-5	183	KashiSharad	215	PDVT-14
120	EC-620486	152	G-5-4	184	K. Vishesh	216	PKM-1
121	EC-620500	153	G-6-3	185	Kashi amrit	217	PS-1
122	EC-620502	154	GT-1	186	K. Anupam	218	Prestige
123	EC-620514	155	GT-2	187	Kajla	219	PusaGaurav
124	EC-620519	156	GT-3	188	Kalyanpur 1	220	Pusa Ruby
125	Ec-620530	157	H-88-78-1	189	Kashmiriya	221	Pusa-120
126	Ec-620533	158	H-88-78-2	190	LA-3772	222	Pjb Barkha Bahar-2
127	Ec-620540	159	H-88-78-3	191	LA-3957	223	Pusa Hybrid-2
128	Ec-620556	160	H-88-78-4	192	LA-3997	224	Roma
129	Ec-620568	161	H-88-78-5	193	M-1-4	225	sanjeevani
130	Ec-620575	162	Hawai	193	M-3-2	226	Sankranti
131	Ec-620598	163	HiasrAnmol	195	MUKTHI	227	Sel-18
132	Ec-625644	164	HisarArun (Sel-7)	196	MoneyMaker	228	Sioux
133	Ec-625645	165	Hisar lalit	197	Monte Favet	229	SolanGola
134	Ec-625651	166	I-4-4	198	N-2-2	230	Solanvajr
135	Ec-625652	167	IC-373378	199	N-2-3	231	Sun-cherry
136	Ec-625660	168	IC-427766	200	Nandhi	232	Swarna Naveen
137	EC-6202041	169	IC-447708	201	NDT-1	233	Swarnavaibhav
138	F-5020	170	IC-469626	202	NDT-8	234	TLBR-6
139	F-6022	171	IIHR-01	203	NDT-4	235	TLH-17
140	F-6050-1	172	IIHR-2202	204	NDTVR-60	236	TLH-27
141	F-6059	173	INDAM-2102	205	NDTVR-73	237	TLH-30
142	F-7012	174	INDAM-2103	206	NF37SB-8	238	Tripura local
143	F-7025	175	INDAM-2103-1	207	Palam Pink	239	UtkalPragyan
144	F-7028	176	INDAM-2103-1-1	208	Pant T-3	240	Utkal raja
145	F-6009	177	Indam-2103-4	209	pant T-5	241	VRT-32-1
146	FEB.-02	178	INDAM-2103-6	210	Parul	242	VRT-101A
147	FEB.-04	179	INDAM-2103-6-1	211	Pb-Chhuhara	243	WIR-3957
148	FLA-7171	180	INDAM-2103-6-4	212	Pb.Upma	244	WIR-5032
245	WIR-13706	250	15 SB	255	WIR-13717	260	DMT3

Continue on next page

246	WIR-13708	251	Rio Grande	256	Pallavi		
247	97/384	252	S.Lalima	257	Pnjb Keshri		
248	97/753	253	Swezerland	258	V. Pragyan		
249	97/754 (Kewalo)	254	UtkalUrvashi	259	DMT1		

and excessive softening were considered as the shelf life of each accession in days.

3. Lycopene content: Lycopene content was estimated using spectrometric method described by [19]. Total 100µL of homogenized tomato paste sample was taken into a brown color tube.

a) 8.0 ml of Hexane: Ethanol: Acetone (2:1:1) mixture was added into sample and tubes were vortexed immediately, followed by incubated in dark light for 10 minutes.
b) After incubation 1.0 ml water was added to each sample and vortexed again. Kept for 10 minutes to allow phases to separate and all air bubbles to disappear.
c) Absorbance of the upper layers of lycopene samples was recorded at 503 nm. Lycopene levels in the hexane extracts were calculated using the formula:

Lycopene (mg/kg fresh wt.) = (A503×537×8×0.55)/(0.10×172). where, 537 g/mole is the molecular weight of lycopene, 8 mL is the volume of mixed solvent, 0.55 is the volume ratio of the upper layer to the mixed solvents, 0.10 g is the weight of tomato added, and 172 m M-1 is the extinction co-efficient for lycopene in hexane

4. Total soluble solids (°Brix): The total soluble solid (TSS) was determined by following the procedure described by (20). 2-3 drops of juice aliquot extracted from fruit pulp was placed on the prism of digital refractometer (0 to 32 °Brix). Brix value was recorded for five tomato fruits per accession and finally average value was used for data interpretation.

5. **Ascorbic acid estimation**: Ascorbic acid standard: 100 mg of L-ascorbic acid was dissolved to 100 ml of 3% metaphosphoric acid. 5 to 50 ml dilutions were made with metaphosphoric acid solution (1 ml = 0.1 mg of ascorbic acid)

Dye solution: 50 mg of 2,6-dichlorophenol indophenols was dissolved in 150 ml of hot distilled water containing 42 mg of sodium bicarbonate. After cooling, solution was diluted to 200 ml and stored in refrigerator until further use.

Standardization of Dye: 5 ml of the standard ascorbic acid solution added into a 100 ml conical flask and added 5 ml of the 3% HPO_3 solution. Microburette was filled with the dye solution. Ascorbic acid solution was titrated with the dye solution to a pink colour. Titre value was used to calculate the dye factor.

Volume of ascorbic acid solution taken for titration = 5 ml
Volume of dye solution required (titre) = v = ml
Dye factor = mg of ascorbic acid per ml of the dye
Since 5ml of the standard ascorbic acid solution contains 0.5 mg ascorbic acid.
Dye factor = 0.5/titre = 0.5/V = mg ascorbic acid per ml dye

Total 10-20 g sample was blended with 3% HPO_3 solution and made up to 100ml with 3% HPO, solution. Solution was filtered through a Whatman No. 1 filter paper. 2-10 ml of the sample extract was pipette out into a 100 ml conical flask and titrated against the dye solution.

Observations:
Weight of sample taken for extraction with HPO_3 (W) ----gm
Volume of the sample made up with HPO_3 solution ---------gm
Volume of sample extract taken for dye titration V1 -------gm
Volume of dye required (titre) V2 ----------gm

Calculations:
Ascorbic acid in V, ml of the sample extract= dye factor x V2= m

$$\text{Therefore, AC in 100 ml of the extract} = \frac{\text{Dye factor} \times V2 \times 100}{V1}$$

Since W (g) sample was made upto 100 ml, ascorbic acid content of the sample (mg/100 g)

$$\frac{\text{Dye factor} \times V2 \times 100 \times 100}{V1 \times W}$$

Numbers of locules per fruit: The number of locules was counted after cutting the fruit transversely and counted the locules isolated by septae. The data was recorded on five randomly selected fruits was averaged.

Statistical analysis: Analysis of variance (ANOVA)

The data of first experiment was subjected to Fischer's method of analysis of variance given by [21] for analysis and interpretation of data. The Critical differences (CD) were worked out whenever 'F' test was significant.

Components of variance: The genotypic and phenoty pic components of variance were computed according to given formulae [22,23] for the observ-ed characters.

Coefficient of variability : Genotypic and phenotypic coefficient of variability was computed according to [24].

$$\text{Genotypic coefficient of variability (GCV)} = \frac{\text{“Vg}}{\bar{X}} \times 100$$

$$\text{Phenotypic coefficient of variability (PCV)} = \frac{\text{“Vp}}{\bar{X}} \times 100$$

Vg = Genotypic variance
Vp = Phenotypic variance
$\bar{X}$ = General mean of character

Heritability: Broad sense heritability was estimated based on the ratio of genotypic variance to the phenotypic variance and was expressed in percentage [25].

Where,
Vg = Genotypic variance
Vp = Phenotypic variance

Genetic advance : Genetic advance (GA) was computed according to the formula given by Johnson et al. [26].

Genetic advance (GA) = ih^2"Vp

$$h^2 = \frac{Vg}{Vp} \times 100$$

Where,
i = Selection differential (2.06) at 5 per cent selection intensity
h^2 = Broad sense heritability
“Vp = Phenotypic standard deviation

Genetic advance as per cent of mean (GAM) : Genetic advance as per cent of mean (GAM) expressed in percentage was computed by using the following formula;

$$\text{GAM} = \frac{\text{GA}}{\bar{X}} \times 100$$

Where, $\bar{X}$ = Mean of the population.

Correlation studies for yield and its component traits Correlation coefficient:

Simple correlation coefficients were worked out among different growth, yield and quality parameters [27]. Significance of correlation was tested by comparing with critical ‘r’ value which was obtained by using formula given below;

$$r = \frac{\sqrt{t^2}}{t^2 + n - 2}$$

Where,
r = Critical coefficient value
t = Table value at 5 or 1 per cent
n = Number of observations used for analysis

RESULTS

The present study involved systematic evaluation of tomato association mapping panel (TAMP) for the fruit quality traits which is key component for germplasm management and utilisation in crop breeding. Analysis of variance revealed significant differences among treatments in both seasons for fruit quality traits (Table 1). All mean square estimates of traits were significant at $P < 0.001$. The wide range of variation during both seasons was deciphered by studying genetic parameters. The genetic variability parameters for all fruit quality traits have been furnished in Table 2. All the fruit quality traits showed greater phenotypic and genotypic variability. Fruit firmness, shelf life and Lycopene content exhibited high genotypic and phenotypic coefficients of variation. Ascorbic acid and locule numbers exhibited moderate GCV and PCV. Higher variability indicated that germplasm can be exploited for improvement for the trait of interest through conventional and molecular aided selection. The genetic advance expressed as percent of population mean recorded high estimates in fruit quality traits except for total soluble solids.

ANOVA and variability in morphometric traits:

Fruit firmness (N): For fruit firmness great extent of variation was observed as a mean value for each accession ranged from 0.13 N to 2.86 N during *kharif*

Table 1: Analysis of variance (ANOVA) from two seasons for quality traits in germplasm accessions

	Df	Firmness		Shelf life		TSS		Lycopene		Ascorbic acid		Locule No.	
		Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
Block	3	1.014***	1.015***	1185.65***	1181.18	0.96 ***	0.19 ***	7.75 ***	17.42 ***	122.34***	129.19***	1.364***	1.55***
Treatments	263	0.143***	0.143***	207.04***	217.11***	0.89***	1.46***	17.39 ***	18.86***	35.67***	43.17***	0.802***	0.79***
Checks	3	0.44***	0.45 ***	77.83***	73.12***	3.49 ***	3.45***	81.01***	80.90***	40.79***	40.83***	5.18***	5.25***
Checks+Var Vs Var.	260	0.13***	0.13***	208.53***	211.37***	0.86 ***	1.44 ***	16.65 ***	18.14 ***	35.614***	43.20***	0.75***	0.74 ***
Error	9	0.01	0.01	0.49	0.494	0.002	0.002	0.03	0.04	0.113	0.115	0.01	0.018

Table 2: Genetic variability parameters for quality traits in germplasm accession field evaluated during kharif and Rabi 2017-2018

Trait	Mean		Range		Coefficient of variability (%)				H (BS) (%)		GA (5%)		GAM(5%)	
					GCV		PCV							
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
Firmness (N)	0.65	0.66	0.13 - 2.86	0.13 - 2.92	55.08	55.04	58.45	58.37	88.82	88.92	0.69	0.69	106.93	106.93
Shelf life	23.45	23.96	3.25 - 97.25	3.00 – 99.25	60.30	60.58	60.38	61.13	99.00	99.45	29.69	31.16	124.08	126.52
TSS (Brix)	5.01	5.70	3.1 - 7.74	3.04 – 9.24	18.00	19.69	18.27	19.70	99.76	99.87	1.86	2.34	37.04	40.54
Lycopene (mg/100g)	8.08	8.19	0.96 - 20.33	0.96 – 21.43	49.47	50.99	50.53	51.5	99.7	99.77	8.22	8.60	101.79	104.92
Ascorbic acid (mg/100g)	16.14	16.27	4.08 - 36.67	3.33 – 35.83	36.96	40.01	37.02	40.6	99.68	99.73	12.20	13.42	76.02	82.31
Locule No.	3.05	3.04	1.90 - 6.05	1.90-6.03	27.1	27.58	28.74	27.94	97.84	97.45	1.71	1.70	56.47	56.09

Table 3a. Correlation coefficient among fruit quality traits in germplasm accession evaluated during *kharif*

	Firmness	TSS	Ascorbic acid	Lycopene	Locule No.	Shelf life
Firmness	1.000	0.099***	-0.009	0.041***	0.1286***	0.502***
TSS		1.000	0.045***	0.010	-0.276	0.042***
Ascorbic acid			1.000	-0.038	-0.023	-0.141
Lycopene				1.000	-0.149	0.003
Locule No.					1.000	-0.192
Shelf life						1.000

Table 3b. Correlation coefficient among fruit quality traits in germplasm accession evaluated during *rabi*

	Firmness	TSS	Ascorbic acid	Lycopene	Locule No.	Shelf life
Firmness	1.000	0.046***	0.016	0.068***	0.065***	0.248***
TSS		1.000	0.100***	0.016	-0.212	0.076***
Ascorbic acid			1.000	-0.051	-0.036	-0.159
Lycopene				1.000	-0.136	-0.002
Locule No.					1.000	-0.173
Shelf life						1.000

season while in ***rabi*** season range was 0.13 N to 2.92. Genetic parameters for ***kharif*** and ***rabi*** indicated that high GCV (55.08 and 55.04%), PCV (58.45 and 58.37%), heritability (88.82 and 88.92%) for this trait. EC-501574 was recorded lower firmness during both seasons while EC-620514 was more firm in both seasons. Along with EC-620514, EC-620421, EC-538441, EC-620373 and EC-620568 were highest in fruit firmness.

Shelf life: The readings were recorded in days. The shelf life during ***kharif*** season ranged from 3.25 to 97.25 days with mean value of 23.45, while in ***rabi*** season we could observe the range from 3 days to 99.25 days with mean value of 23.96 days. The trait exhibited high genotypic coefficient of variation (60.30%), phenotypic coefficient of variation (60.38%) with broad sense heritability of 99%. Whereas in ***rabi*** season, genotypic and phenotypic coefficient of variation was 60.58 and 61.13% respectively with heritability value of 99.45%. EC-620514, EC-620421, EC-538441, EC-620373 and EC-620568 lines were recorded for highest shelf life.

Total soluble solids (^{0}Brix): The total soluble solids during ***kharif*** season ranged from lowest in CLN-1621 (3.1) and highest in B-7-2 (7.74) with a grand mean 5.01. Moderate estimate of GCV (18.00%), PCV (18.27%) along with higher heritability (99.76%) and GAM (37.04%) were observed for this trait . During, Rabi season this trait value which ranged from 3.04 (EC-521078) to 9.24 (Kalyanpur Type-1) with a grand mean 5.70. Moderate GCV (19.69%), PCV (19.70%) along with higher heritability (99.87%) and GAM (40.54%) were observed for this trait. In the present study, total soluble solids differed moderately over the seasons. Rabi season evaluation recorded a slight increase in TSS over ***kharif*** season.

Lycopene content (mg/100 gm): The lycopene content ranged from 0.96 to 20.33 mg/100 gm of fresh weight in ***kharif*** season with mean value of 8.08 mg/ 100 gm. whereas in ***rabi*** season lycopene content recorded between 0.96 to 21.43 mg/100 gm with mean value of 8.19. However great extent of variability was observed during both seasons for the same trait with GCV (49.47 and 50.99%), PCV (50.53% and 51.5%) coupled with high heritability (99.7%) was recorded.

Ascorbic acid (mg/100 gm): A wider variability was observed for ascorbic acid content as the mean values of accessions ranged from 4.08 (IC-373378) to 36.67 mg (EC -625660) with a grand mean 16.14 mg. High per cent PCV (37.02%) and high per cent GCV (36.96%) along with high heritability (99.68%) and expected genetic advance (76.02%) were observed for this trait. During ***rabi*** season this trait variation mean value which ranged from 3.33 mg to 35.83 mg with a grand mean of 16.27 mg. High per cent PCV (40.6%) and high per cent GCV (40.01%) along with high heritability (97.73%) and expected genetic advance mean (82.31%) were observed for this trait.

Number of locules per fruit: During ***kharif*****,** great variation was observed for locule numbers per fruit as the mean value for each accession ranged from 1.90 to 6.05 with a grand mean 3.05. High per cent PCV (28.74%) and high per cent GCV (27.1%) alongwith high heritability (97.84%) and expected genetic advance (56.47%) were observed for this trait. During ***rabi*** season, this trait variation mean value ranged from 1.90 to 6.03 with a grand mean 3.04. High per cent PCV (27.94) and high per cent GCV (27.58%) along with high heritability (97.45%) and expected genetic advance (56.09%) were observed for this trait.

Correlation among the fruit quality traits: The simple correlation study was carried out to know the extent of relationship existing among quality parameters of tomato. The simple correlation coefficients were worked out for all fruit quality traits are presented in Table 3 a and b. During ***kharif*** and ***rabi*** season, fruit firmness was positively correlated with total soluble solids (0.099 and 0.046), lycopene content (0.041 and 0.068). However firmness exhibited strong positive correlation with locule numbers (0.128 and 0.065) and with shelf life (0.50 and 0.24), while it was negatively correlated with ascorbic acid. The Total soluble solid was positively correlated with ascorbic acid (0.045), lycopene (0.010) and shelf life (0.042). While there was a negative correlation between total soluble solids and locule number. Ascorbic acid was negatively correlated with all the traits except total soluble solids, Similarly locule number was negatively associated with all the quality traits except fruit firmness.

DISCUSSION

The experimental finding suggested that accessions which were more firm also having more shelf life.

According to previous studies, genes encoding polygalacturonase and pectin methylesterase actively involved in determining fruit firmness and longer shelf life, so due to low pectolytic activity fruit firmness is directly proportional to shelf life [30,31]. In the present study, we could observe some lines which were having higher firmness and shelf life shown low to moderate ascorbic acid levels. This finding was supported by [32], where transcriptome analysis of the introgressed line for ascorbic acid levels revealed an increase in ascorbic acid levels associated with pectin degradation. The pectin degradation genes were upregulated therefore releasing intermediates for the L-galactonic acid pathway, which is involved in ascorbic acid synthesis through cell wall polymers. In another study phenotypic and genetic variability was unraveled through the development of segregating population. Extended shelf-life tomato hybrids were developed using ripening mutants. alc x Vaibhav derived hybrid progeny shown shelf life upto 40 days. Segregating population of superior hybrid recorded a wide range of genetic variability observed in shelf life (5-106 days) and fruit firmness (0.55-10.65 lbs/cm2) [18]. In the present study, total soluble solids differed moderately over the seasons. Rabi season evaluation recorded a slight increase in TSS over ***kharif*** season. Fleshy fruit development generally determined by osmotic compounds. Water scarcity may have a positive impact on nutritional value with less reduction in yield [28,33]. Rabi season harvested tomatoes were evaluated during march-april month therefore moisture loss might be more in our accessions. Hydrolysis of carbohydrates due to moisture loss increases in the concentration of sugars [34,35]. The effect of drought stress on genotypes derived from the multi-parent advanced generation inter-cross population has been well studies and large fruited tomatoes shown a remarkable increase in sucrose content under moderate water scarcity [36].

The present investigation on variability study was consistent with many previous findings for other fruit quality traits. Variability was investigated for nutritional quality traits by evaluating thirty five genotypes of tomato, where for all quality traits phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) [37]. Fruit firmness, ascorbic acid traits shown high heritability coupled with a high genetic advance which could facilitate selection based on phenotype. With the aim of selection and development of new cultivars with nutritional quality traits by breeders, A total of 119 tomato genotypes were evaluated for studying variations in carotenoids, especially lycopene, and other antioxidants. Significant genotypic differences were observed among all genotypes which were comprised of commercial cultivars and germplasm lines. Carotenoid, ascorbic acid, and flavonoid content showed higher genotypic variation. Lycopene contributed significantly to variation in carotenoid which was ranging from 386.8 – 2067.1 mg/kg. The highest ascorbic acid found in TG-106 (388 mg·kg-1) [38].

The studies on correlation supported by various studies, where the positive correlation was there between TSS and ascorbic acid, but the same traits were negatively correlated with lycopene. Improvement of lycopene content independently through conventional and molecular aided breeding could be better as the biosynthetic pathway is independent from TSS and ascorbic acid metabolism [40,41]. Fruit texture and shelf life is interrelated where texture influence post- harvest performance by the ease of transportation and improving shelf life. Firm fruit maintains cell wall rigidity by reducing pectin degradation activity [29]. Researchers investigated insights of firmness by studying its link with anatomical and biochemical fruit traits. Puncture test unraveled the significant link of firmness with cell volume, total soluble solids and locule number [42].

CONCLUSION

The tomato accessions evaluated in this study exhibited considerable diversity for targeted fruit quality traits. In present study, the majority of top accessions for firmness and shelf life were exotic collections which could be novel for exploiting through advanced breeding methods. The other promising accessions for various fruit quality traits could be exploited as basic breeding material for improvement with special emphasis on independent or combined fruit quality traits. The majority of quality traits are under complex gene control, therefore present phenotypic evaluation of accessions could be used as a structured population for wide genome association mapping.

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