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PERFORMANCE OF TOMATO (*Solanum lycopersicum* L.) GENOTYPES UNDER NATURALLY VENTILATED POLYHOUSE IN KUMAON HILLS OF UTTARAKHAND (INDIA)

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ABSTRACT

This study was aimed to assess the performance of various tomato genotypes under ventilated poly-house conditions. The study was conducted in Kumaun hills of Uttarakhand (India) during summer 2017. The study revealed the presence of high genotypic and high heritability for most economic traits *viz*., number of fruits plant^{-1}, yield plant^{-1}, ascorbic acid content and total antioxidant activities. The variety 'VL-4' proved superior over other varieties with respect to fruit length (5.43 cm), fruit width (5.27 cm), number of fruits plant^{-1} (51.67), average fruit weight (85.34 g) and fruit yield plant^{-1} (4.42 kg). Highest luminous (L*= 49.96), TSS (6.03°B), reducing sugar (1.99%) and total sugar (3.39%) were estimated in genotype 'H-86'; whereas highest red colour (a*= 42.43) and total antioxidant activity (28.06 mMTE L^{-1}) were found in hybrid 'Dev' and maximum yellow colour (b*= 48.8) in hybrid 'Badshah'. The chroma (C*= 57.16), ascorbic acid (40.22 mg 100 g^{-1}), non-reducing sugar (1.62%) and lowest hue angle (h°=38.83) were found maximum in hybrid 'Shahanshah'. The maximum heritability (broad sense) estimates were noted for total sugar (100%) and non-reducing sugar (100%). The study depicted the scope of further improvement of these traits through selection procedure and these genotypes could be considered for further heterosis breeding programme for future improvement.

Keywords: Correlation coefficient, genotypes, heritability, tomato, variability

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most important edible and nutritious vegetable fruit of the world. In India, it ranks 3rd among the vegetable crops with respect to the area and production and occupies an area of 0.80 million ha with a production of 19.7 million tonnes and productivity of 24.62 t ha^{-1} (NHB, 2016-2017). Tomato is the main supplier of many important nutritional values to the human diet (Willcox *et al.,* 2003). Various qualitative factors of tomato like flavour, colour, total soluble solids and nutrition value, etc. are influenced by cultivar, weather condition, storage, fruit maturity and cultivation methods (Gould, 1983).

Protected cultivation or controlled environment agriculture (CEA) is a total concept of modifying the natural environment for optimum plant growth (Sirohi, 2002). Growing of crops under protection has many advantages but biggest advantage lies with off-seasonality and superior quality of the produce (Kumar *et al.* 2007). Production of vegetables under protected cultivation system

results in effective use of land resources, besides being able to increase the production of quality vegetables by offsetting biotic and abiotic stresses to a great extent that otherwise is prevalent in open cultivation. Production of vegetables under protected conditions involves protection of vegetables at production stage mainly from adverse environment conditions such as temperature, hails, heavy rains, snow and frost (Singh *et al.*, 1999). Hence, the crop genotypes were grown under natural ventilated poly-house to overcome climatic variations for growing the crop successfully. The investigation was aimed to find out the suitable varieties for harnessing higher yield and quality in tomato under protected conditions in Kumaon region of Uttarakhand (India).

MATERIALS AND METHODS

The experiment was conducted in high hills (village Sunkiya, altitude: 1750 m, latitude: 29°N and longitude: 79°E, Nainital) of Kumaon region of Uttarakhand (India) during summer season in 2017 under National Mission for Sustaining Himalayan Ecosystem (Task Force-6) project. The tomato seeds were sown in pro-trays under polyhouse on 8th March and transplanted to polyhouse on 26th April, 2017. The experiment was conducted in a randomized block design with eleven treatments (varieties). Each treatment was replicated three times. The eleven genotypes included were 'H-86', 'Manisha', 'Aman', 'Dev', 'Laxmi', 'Shahanshah', 'Badshah', 'Navin', 'Abhimanyu', 'PS-2225' and 'VL-4' grown under naturally ventilated polyhouse conditions. The seedlings were planted at a spacing of 60×30 cm. The growth attribute *viz.*, plant height, number of fruits plant^{-1}, fruit width, fruit length, fruit weight, fruit yield plant^{-1}, specific gravity of fruit and fruit firmness were estimated. Titratable acidity was measured by titration of 2 mL homogenated juice with added 2 drops of 1% phenolphthalein and titrated by 0.1N NaOH solution till it became light pink in colour. Titratable acidity was calculated as following:

$$\text{Titratable acidity} = \frac{\text{Standardized value of malic acid } x\ 0.67}{2}$$

The value 0.335 was multiplied to the titer value of juice. Ascorbic acid content was measured by using 2,6 dichlorophenol indophenols method and reducing sugar was estimated as per Ranganna (2010). Total soluble solids (TSS) was measured by hand refractometer and other quality parameters were determined as per AOAC (1975). Ascorbic acid, reducing sugar, non-reducing sugar and total sugars were estimated as per Ranganna (2010). Total antioxidant activity (mMTE L^{-1}) was recorded as per the method of Apak *et al.* (2004). The colour value of different tomato genotypes were noted in terms of luminous (L*), red colour (a*), yellow colour (b*), chroma (C*) and hue angle (h$^{\circ}$) values using a Lovibond RT series reflectance tintometer. The 'L*' describes luminosity or lightness and varies from zero (black) to 100 (perfect white). The chromaticity dimension 'a*' magnitude redness when positive, grey when zero and greenness when negative. The 'b*' value describes yellowness when positive, grey when zero and blueness when negative. The 'C*' measures the chroma (saturation) of colour, a measure of how far from the great tone the colour is. Hue angle (h$^{\circ}$), the measure of hue colour, depicted the colour tonalities (red, green, yellow etc.) [Kishor *et al.*, 2017].

The phenotypic and genotypic variance and coefficients of variation were estimated as per the formula suggested by Syukur *et al.* (2012). Correlation coefficients were worked out as per the procedure of Al-Jibouri *et al.* (1958). The heritability in broad sense and genetic advance were calculated as per the method of Jonson *et al.* (1955). The total antioxidants activity was estimated by the method of Apak *et al.* (2004). The antioxidants activity was expressed as m mol Trolox (mMTE) L^{-1}. The data were statistically analyzed by using the standard statistical procedure (Gomez and Gomez, 1984). Statistical analysis was computed as ANOVA test to assess significance of treatment means.

RESULTS AND DISCUSSION

Performance of genotypes for quantitative and qualitative parameters

The genotypes under study exhibited significant differences for various growth, yield and quality traits (Table 1 and 2). The maximum plant height was observed in hybrid 'Manisha' (2.59 m), followed by 'VL-4' (2.41 m); while lowest height was recorded in hybrid 'Laxmi' (0.96 m). The optimum temperature, high carbon dioxide concentration and better light distribution are necessary for optimum plant growth and development under polyhouse conditions. The observed variations in plant height might be due to the genetic characteristic of genotypes and adaptability to a particular environment (Khan *et al.,* 2013). Performance of any crop with respect to growth, yield and quality are highly influenced by various factors especially the genetic constitution of a variety, the micro-climate of an area and crop management. The improvement in growth characters is considered a pre-requisite for increasing the crop yield. The wide range of variation obtained may be due to divergent genotypes included in the study. Similar findings have been reported for fruit yield plant^{-1} (Kaushik *et al.,* 2011) and for plant height, yield plant^{-1} and fruit diameter (Patil *et al.,* 2013). The cultivar 'VL-4' yielded maximum fruit length (5.43 cm) and fruit diameter (5.27 cm), followed by cultivar 'Abhimanyu' (5.32 cm) and 'PS-2225' (5.13 cm), respectively). The lowest fruit length (3.92 cm) and fruit diameter (4.10 cm) was observed in 'Laxmi' and 'Shahanshah'. Yellava (2008) recorded higher fruit weight and fruit yield under naturally ventilated polyhouse conditions. It is also influenced by the microclimatic condition surrounding the tomato plant and cultural practices under the polyhouse conditions.

The variety 'VL-4' exhibited maximum number of fruits plant^{-1} (51.67), average fruit weight (85.34 g) and fruit yield plant^{-1} (4.42 kg) while minimum number of fruits plant^{-1} (13.0), average fruit weight (44.37 g) and yield plant^{-1} (0.613 kg) was recorded in hybrid 'Dev', 'Shahanshah' and 'Laxmi', respectively. The highest fruit yield may be attributed to the favorable growth conditions that prevailed under polyhouse and also due to its protective ability against major abiotic stresses, which reduces the effect of excessive rainfall, water logging as well as provide controlled environment. Higher temperature in controlled condition than in open field condition leads to higher vegetative growth which contributes to higher number of flowers, better fruit setting and higher number of fruits (Singh *et al.,* 2010).

Table 1: Vegetative growth performance of tomato genotypes under protected condition

Tomato varieties	Plant height (m)	No. of fruits (plant^{-1})	Fruit length (cm)	Fruit diameter (cm)	Av. fruit weight (g)	Fruit yield (kg plant^{-1})	Fruit firmness (kg cm^{-2})
H-86	1.01	21.67	4.50	4.62	53.32	1.18	1.19
Manisha	2.59	47.33	5.16	4.84	69.24	3.46	0.58
Aman	1.53	29.33	5.06	4.91	62.26	1.85	0.98
Dev	1.28	13.00	5.06	4.69	57.35	0.73	0.86
Laxmi	0.96	13.33	3.92	4.63	46.38	0.61	0.60
Shahansha	1.46	21.33	4.69	4.10	44.37	0.94	0.85
Badshah	1.72	26.00	4.72	4.42	54.84	1.40	1.00
Navin	1.08	37.33	4.93	4.75	56.96	2.09	0.64
Abhimanyu	1.62	17.33	5.32	4.34	59.11	0.97	1.22
PS-2225	1.62	28.33	5.15	5.13	80.02	2.29	0.73
VL-4	2.41	51.67	5.43	5.27	85.34	4.42	0.34
Mean	1.57	27.88	4.91	4.70	60.84	1.81	0.82
SE(m)±	17.12	4.11	0.21	0.21	8.65	0.474	1.16
$CD_{0.05}$	0.35	8.64	0.63	0.62	18.17	1.00	0.34

Table 2: Biochemical and fruit colour traits of tomato genotypes under protected condition

Tomato variety	TSS (°B)	AA (mg 100 g^{-1})	Acidity (%)	NRS (%)	RS (%)	Total sugar (%)	TAA (mMTE L^{-1})	SGF (g cc^{-1})	L*	a*	b*	C*	hº
H-86	6.03	23.92	0.70	1.33	1.99	3.39	16.32	0.97	49.96	+18.96	+44.61	49.35	67.32
Manisha	5.03	36.02	0.62	1.57	1.56	3.21	16.28	1.18	49.00	+17.46	+33.94	38.27	62.94
Aman	4.27	34.96	0.52	1.00	1.56	2.61	15.91	0.98	45.58	+31.17	+33.87	43.63	43.61
Dev	4.60	30.72	2.03	1.41	1.49	2.97	28.06	0.82	44.55	+42.43	+35.73	55.45	40.00
Laxmi	6.00	38.34	0.36	1.59	1.56	3.23	11.52	0.89	47.10	+35.85	+43.27	56.22	50.02
Shahansha	5.50	40.22	0.54	1.62	1.54	3.24	18.12	0.86	45.16	+34.41	+32.89	57.16	38.83
Badshah	4.97	36.22	0.74	1.09	1.69	2.84	16.61	1.01	49.84	+28.85	+48.8	57.12	59.19
Navin	5.13	34.22	2.17	1.05	1.87	2.98	14.44	0.92	41.68	+29.3	+33.31	44.32	48.60
Abhimanyu	4.33	33.64	0.51	0.83	1.62	2.49	13.50	0.98	39.41	+29.23	+42.65	52.27	57.47
PS-2225	5.47	38.51	4.44	1.32	1.76	3.15	15.95	0.9	45.85	+23.7	+31.84	39.72	53.53
VL-4	5.77	25.38	0.55	1.29	1.90	3.26	15.83	0.88	42.16	+27.19	+37.28	46.01	53.68
Mean	5.19	33.83	1.20	1.28	1.69	3.03	16.59	0.94	45.48	+28.96	+38.02	49.05	52.29
SE(m)±	0.21	1.30	0.83	0.03	0.02	0.02	1.26	0.05	1.94	2.16	2.69	3.94	2.57
$CD_{0.05}$	0.62	3.85	NA	0.08	0.07	0.04	3.75	0.16	5.76	6.42	7.98	11.71	7.62

*AA = Ascorbic acid; NRS = Non-reducing sugars; RS = Reducing sugars; TAA = Total antioxidant activity; SGF = Specific gravity of fruit

The highest fruit firmness (1.22 kg cm^{-2}) was found in hybrid 'Abhimanyu' and it was at par with 'H-86' (1.19 kg cm^{-2}) and 'Badshah' (1.00 kg cm^{-2}) whereas minimum firmness was found in genotype 'VL-4' (0.34 kg cm^{-2}). The hybrid 'Manisha' exhibited highest values for specific gravity (1.18 g cc^{-1}), followed by 'Badshah' (1.01 g cc^{-1}) while lowest value was observed in 'Dev' (0.82 g cc^{-1}). The maximum ascorbic acid was observed in 'Shahanshah' (40.22 mg 100 g^{-1}) which was at par with 'PS-2225' (38.51 mg 100 g^{-1}) and 'Laxmi' (38.34 mg 100 g^{-1}) and minimum value was found in hybrid 'H-86' (23.92 mg 100 g^{-1}). The variation in ascorbic acid content may be due to the varietal characteristics of fruit. The maximum TSS was found in 'H-86' (6.03 °B), followed by 'Laxmi' (6.00 °B); whereas lowest TSS was in 'Aman' (4.27 °B). Quality characters are very important in any crop especially in vegetables like tomato because they impart nutritional quality of produce as well as processing quality. The difference among the genotypeswith respect to vitamin C and total soluble solids contents of fruits might be due to the genetic constitution of the genotypes. These results are in conformity with Manna and Paul (2012). The lowest acidity was found in 'Laxmi' (0.36%), followed by 'Abhimanyu' (0.51%), 'Aman' (0.52%), 'Shahanshah' (0.54%) and 'VL-4' (0.55%); and maximum acidity was in variety 'PS-2225' (4.44 %). These findings are in agreement with Caliman *et al.,* 2010). Maximum reducing sugars (1.99%) and total sugars (3.39%) was recorded in 'H-86', followed by 1.90% and 3.26%, respectively, in 'VL-10'. The varieties 'Dev' (1.49%) and 'Abhimanyu' (2.49%) showed lowest values for reducing and total sugars, respectively. The genotype 'Shahanshah' recorded highest non-reducing sugars (1.62%) which was at par with 'Laxmi' (1.59%) and 'Manisha' (1.57%). The lowest non-reducing sugars was recorded in genotype 'Aman' (1.00%). Highest total antioxidant activity (28.06 mMTE L^{-1}) was found in hybrid 'Dev', followed by 'Shahanshah' (18.12 mMTE L^{-1}), whereas minimum values were noted in 'Laxmi' (11.52 mMTE L^{-1}).

Colour parameters of fruit

The ground colour and blush depend on sunlight during ripening. Low value of 'L*' indicates dark fruit skin. The genotypes 'H-86' (L* = 49.96) was found the most luminous, followed by 'Badshah' (L* = 49.84) and 'Manisha' (L* = 49.00); while the lowest values were observed in 'Abhimanyu' (L* = 39.41). The 'a*' or red-green values showed significant difference in the germplasms studied. The highest red colour was rfound in 'Dev' (a* = +42.43), followed by 'Laxmi' (a* = +35.85) and 'Shahanshah' (a* = +34.41). The lowest red colour values were noted in 'Manisha' (a* = +17.46). The

Table 3: Mean, range, variance and coefficient of variations, heritability, genetic advance and genetic advance as percent of mean for tomato genotypes

Characters	Mean	Range		Coefficient of variation		Heritability (bs) (%)	Genetic advance	G.A. as percentage of mean
		Min.	Max.	Phenotypic	Genotypic			
Plant height (m)	1.57	0.96	2.59	422.76	411.60	94.70	106.36	67.52
No. of fruit plant^{-1}	27.88	13.00	51.67	244.38	238.10	94.90	25.89	97.77
Fruit length (cm)	4.91	3.92	5.43	19.15	16.88	78.00	0.77	15.72
Fruit diameter (cm)	4.70	4.10	5.27	15.30	12.20	63.63	0.26	5.64
Avg. fruit weight (g)	60.84	44.37	85.34	164.35	144.45	77.25	23.21	38.15
Fruit yield (kg plant^{-1})	1.81	0.73	4.42	89.19	85.72	92.30	2.37	131.21
Specific gravity of fruit (g cc^{-1})	0.94	0.82	1.18	9.78	7.99	66.66	0.16	16.91
Fruit firmness (kg cm^{-2})	0.82	0.34	1.22	112.44	107.24	90.96	27.49	234.35
L*	45.48	39.41	49.96	50.82	41.91	68.00	5.82	12.80
+a*	28.96	17.46	42.43	134.87	128.75	91.10	14.27	49.27
+b*	38.02	31.84	48.80	93.83	83.10	78.43	10.53	27.69
C*	49.05	38.27	57.16	100.76	83.53	68.70	12.05	24.58
h^{o}	52.29	40.00	67.32	126.99	121.98	92.26	18.14	34.70
TSS ($^{\circ}$B)	5.19	4.27	6.03	27.05	25.50	89.47	1.19	301.82
Ascorbic acid (mg 100 g^{-1})	33.83	23.92	40.22	90.06	87.26	93.87	10.46	30.91
Acidity (%)	1.20	0.36	4.44	113.65	71.67	55.48	1.91	126.16
Non-reducing sugar (%)	1.28	0.83	1.62	23.38	23.38	100.00	0.54	42.58
Reducing sugar (%)	1.68	1.49	1.99	15.43	13.36	75.00	0.08	4.76
Total sugar (%)	3.03	2.49	3.39	16.24	16.24	100.00	0.58	19.22
Total antioxidant activity (mMTE L^{-1})	16.59	11.52	28.06	102.82	98.05	90.93	8.23	49.60

'b*' or yellow-blue component values were highest (b*= +48.8) in hybrid 'Badshah' which was at par with 'H-86' (b* = +44.61), 'Laxmi' (b* = +43.27) and 'Avimanyu' (b* = +42.65) and the lowest values were in 'PS-2225' (b* = +31.84). The croma (C*) values measure colour saturation intensity, a measure of how far from the great tone the colour is. The hybrid 'Shahanshah' (C* = 57.16) depicted maximum chroma, followed by 'Badshah' (C* = 57.12), 'Laxmi' (C* = 56.22), 'Dev' (C* = 55.45), 'Abhimanyu' (C* = 52.27), 'VL-4' (C* = 46.01) and 'H-86' (C* = 49.35), whereas minimum values of chroma was noticed in 'Manisha' (C* = 38.27). The hue angle (h$^{\circ}$) correlates with 'a*' and 'b*' values. It is a good factor to assess the changes of characteristics colour in these genotypes. Lowest h$^{\circ}$ values indicates a redder colour as exemplified by 'Shahanshah' (h$^{\circ}$ = 38.83) which was at par with 'Dev' (h$^{\circ}$ = 40.0) and 'Aman' (h$^{\circ}$ = 43.61); whereas 'H-86' (h$^{\circ}$ = 67.32) showed the highest h$^{\circ}$ value.

Estimation of coefficient of variations, heritability and genetic advance

The extent of variability among the genotypes was estimated in term of lowest and highest mean values for all characters, Phenotypic coefficient of variations (PCV), genotypic coefficient of variations (GCV), heritability, genetic advance and genetic advance as percentage of mean (Table 2). A wide variation was observed in plant height (0.96 - 2.59), followed by average fruit weight (44.37 - 85.34), hue angle (h^{o} = 40.0 - 67.32), chroma (C* = 38.27 - 57.16), luminous (L* = 39.41 - 49.96), yellow-blue colour (b* = 31.84 - 48.80), red-green colour (a* = 17.46 - 42.43), ascorbic acid (23.92 - 40.22), number of fruit plant^{-1} (13.00 - 51.67), total antioxidant activity (11.52 - 28.06), fruit firmness (0.34 - 1.22), total soluble solids (4.27 - 6.03), fruit length (3.92 - 5.43), fruit diameter (4.10 - 5.27), total sugar percent (2.49 - 3.39), fruit yield plant^{-1} (0.73 - 4.42), reducing sugar per cent (1.49 - 1.99), non-reducing sugar percent (0.83 - 1.62), acidity percent (0.36 - 4.44) and specific gravity percent (0.82 - 1.18), indicating their maximum contribution to the total variability observed among the tomato genotypes. The high estimated GCV and PCV were exhibited by the traits namely plant height (411.60 & 422.76), number of fruits plant^{-1} (238.10 & 244.38), average fruit weight (144.45

& 164.35), yield plant^{-1} (85.72 & 89.19), fruit firmness (107.24 & 112.44), red colour (a* = 128.75 & 134.87), yellow colour (b* = 83.10 & 93.83), chroma (C* = 83.53 & 100.76), hue angle (h^o = 121.98 & 126.99), ascorbic acid (87.26 & 90.06), acidity (71.67 & 113.65) and total antioxidant activity (98.05 & 102.82). Most of the trait under study depicted very good scope for improvement through selection as indicative of the presence of sufficient coefficients of genotypic and phenotypic variations. Similar findings were also reported by Senapati and Kumar (2015). Knowledge of PCV and GCV is much helpful in predicting the amount of variation present in a given genetic stock. The traits like plant height, number of fruits plant^{-1} and average fruit weight recorded maximum result of GCV and PCV indicating the presence of wide range of genetic variability for these traits and chances for improvement of these traits though selection to be fairly high. Genotypic coefficients of variation do not estimate the variations that are heritable (Falconer, 1960), hence estimation of heritability becomes necessary. Heritability in broad sense is a parameter of tremendous significance to the breeders as its magnitude indicates the reliability with which a genotype can be recognized by its phenotypic expression. Data revealed that the estimates of heritability were high for maximum traits and ranged from 75 to 100%, except for acidity (55.48), fruit diameter (63.63), luminous (68.00) and chroma (68.70) which showed moderate heritability. The heritability estimates worked out in present study are in consonance with earlier reports by (Mohamed *et al.*, 2012) for plant height, fruit weight, number of branches plant^{-1} and days to flowering in different genotypes of tomato; Kumar (2010) for days to flowering, polar diameter, TSS, plant height, fruits plant^{-1}, average fruit weight and yield plant^{-1}. The highest heritability for vegetative and yield traits were found for traits like plant height (94.70%), number of fruits plant^{-1} (94.9%) and fruit yield plant^{-1} (92.3%). Likewise, the qualitative attributes *viz*., total sugars (100%), non-reducing sugar (100%), ascorbic acid contents (93.87%) and total anti-oxidant activity (90.93%) also exhibited highest values for heritability.

The estimate of heritability along with genetic advance is more reliable than heritability alone for predicting the effect of selection (Johnson *et al.* 1955). Maximum genetic advance was exhibited in plant height (106.36), followed by fruit firmness (27.49), number of fruits plant^{-1} (25.89) and fruit

Table 4: Correlation coefficient of quantitative and qualitative traits

Char-acters	PH	FPP	FL	FD	AFW	FYP	SG	FF	L*	+ a*	+ b*	C*	h^o	TSS	AA	Aci-dity	NRS	RS	TS	TAA
PH	×	0.98*	0.93*	0.89*	0.93*	0.93*	0.81*	0.88*	0.89*	0.91*	0.96*	0.87*	0.52	0.68*	0.64*	0.66*	0.82*	0.86*	0.78*	0.72*
FPP	×	×	0.94*	0.92*	0.93*	0.94*	0.87*	0.90*	0.92*	0.94*	0.96*	0.86*	0.48	0.63*	0.61*	0.64*	0.80*	0.84*	0.74*	0.68*
FL	×	×	×	0.78*	0.82*	0.85*	0.92*	0.97*	0.95*	0.97*	0.91*	0.97*	0.30	0.48	0.42	0.46	0.63*	0.64*	0.56	0.46
FD	×	×	×	×	0.98*	0.97*	0.74*	0.79*	0.84*	0.81*	0.94*	0.68*	0.46	0.59	0.63*	0.68*	0.83*	0.92*	0.86*	0.82*
AFW	×	×	×	×	×	0.99*	0.78*	0.84*	0.89*	0.85*	0.97*	0.74*	0.43	0.58	0.62*	0.67*	0.82*	0.91*	0.86*	0.82*
YPP	×	×	×	×	×	×	0.84*	0.88*	0.93*	0.90*	0.98*	0.79*	0.39	0.55	0.59	0.65*	0.79*	0.87*	0.82*	0.77*
SG	×	×	×	×	×	×	×	0.96*	0.96*	0.96*	0.86*	0.90*	0.11	0.290	0.29	0.33	0.48	0.54	0.45	0.39
FF	×	×	×	×	×	×	×	×	0.99*	0.97*	0.92*	0.96*	0.15	0.34	0.32	0.38	0.54	0.60	0.55	0.46
L*	×	×	×	×	×	×	×	×	×	0.97*	0.94*	0.93*	0.18	0.37	0.37	0.43	0.58	0.66*	0.63*	0.55
+a*	×	×	×	×	×	×	×	×	×	×	0.93*	0.94*	0.34	0.51	0.48	0.52	0.67*	0.68*	0.56	0.48
+b*	×	×	×	×	×	×	×	×	×	×	×	0.87*	0.45	0.62*	0.63*	0.65*	0.80*	0.86*	0.81*	0.74*
C*	×	×	×	×	×	×	×	×	×	×	×	×	0.22	0.42	0.34	0.35	0.52	0.55	0.50	0.39
h^o	×	×	×	×	×	×	×	×	×	×	×	×	×	0.97*	0.95*	0.86*	0.86*	0.72*	0.54	0.54
TSS	×	×	×	×	×	×	×	×	×	×	×	×	×	×	0.97*	0.87*	0.92*	0.81*	0.67*	0.65
AA	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	0.91*	0.93*	0.85*	0.71*	0.71*
Acidity (%)	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	0.94*	0.81*	0.66*	0.63*
NRS	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	0.95*	0.79*	0.76*
RS	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	0.92*	0.91*
TS	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	0.98*

* = Significant value at 5 % level;

PH, Plant height (cm); FPP = Number of fruit per plant; FL = Fruit length (cm); FD = Fruit diameter (cm); AFW = Average fruit weight (g); FF = Fruit firmness (Ib/in^2); YPP = Yield plant^{-1} (kg); SG = Specific gravity (g cc^{-1}); TSS = Total soluble solids (^{o}B); AA = Ascorbic acid (mg 100 g^{-1}); NRS = Non-reducing sugar (%); RS = Reducing sugar (%); TS = Total sugar (%); TAA = Total ascorbic acid (mMTE L^{-1})

weight (23.21) whereas genetic advance as parentage of mean was highest for total soluble solid (301.82), followed by fruit firmness (234.35), fruit yield plant^{-1} (131.21) and acidity content (126.16). Heritability, genetic advance as percent of mean and genotypic coefficient of variation together could provide best image of the amount of advance to be expected from selection (Johnson *et al.*, 1955). Therefore, this observation indicated that these characters are under additive gene effects and more reliable for effective selection. In present study, high GCV and heritability estimates associated with greater genetic advance was observed for plant height, number of fruits plant^{-1}, average fruit weight, fruit yield plant^{-1}, fruit firmness, +a (red colour), C* (chroma), h^{o} (hue angle) and total anti-oxidant activity which indicated that these traits had additive gene effect and, therefore, are more relative for effective selection. Similar results were reported by Singh and Narayan (2004) in a study on 10 tomato varieties. Burton and De Vane (1953) suggested that genetic coefficients of variability along with heritability estimates would provide a reliable indication of expected degree of improvement through selection.

Estimation of correlation coefficients of quantitative and quality traits

The correlation coefficients between twenty quantitative and qualitative traits were calculated to find out relationship of each other (Table 3). The plant characters *viz*., number of fruits plant^{-1}, fruit length, fruit diameter, average fruit weight, fruit yield plant^{-1}, specific gravity of fruit, fruit firmness, colour, L*, a*, b*, C*, acidity, non-reducing sugar, reducing sugar, total sugars and total antioxidant activity exhibited positive significant correlations with each other. The fruit yield plant^{-1} had significant positive association with the number of fruits plant^{-1} (0.935*), fruit length (0.853*) and fruit diameter (0.970*). A significantly positive association of total antioxidant activity was found with plant height, number of fruit plant^{-1}, fruit diameter, fruit weight, fruit yield plant^{-1}, b*, total soluble solid, ascorbic acid, acidity, non-reducing sugar and total sugars. However, it exhibited a positive but non-significant association with fruit length, specific gravity, firmness, L*, a*, C* and h^{o}. The most important economic trait *viz*, fruit yield plant^{-1} exhibited significant positive correlation coefficient with most of the growth, yield and quality traits studied which indicated that bringing improvement in one trait will improve other linked trait(s). TSS exhibited significant positive relations with plant height, number of fruits plant^{-1} and h^{o}, hence improvement in fruit yield would improve other specified traits. Finally, the fruit yield was positive significantly associated with fruits plant^{-1}, fruit weight, fruit diameter and locule number fruit^{-1}. Similar results have been reported by Ullah *et al.* (2015). The study revealed that genotype 'VL-4' was superior over other varieties with respect to yield in Kumaun hills of Uttarakhand.

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