



RESEARCH ARTICLE

EVALUATION OF GENETIC VARIABILITY FOR GROWTH AND YIELD CHARACTERS IN TOMATO (*SOLANUM LYCOPERSICUM* L.)

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ARTICLE INFO

Article History:

Received 08th June, 2023
Received in revised form
20th July, 2023
Accepted 16th August, 2023
Published online 19th September, 2023

Key Words:

Heritability, Genetic Variability,
Correlation Coefficient, Genotypes

ABSTRACT

The present investigation entitled "Evaluation of Genetic Variability for Growth and Yield characters in tomato (*Solanum lycopersicum* L.)" involving forty three genotypes including one check varieties of tomato was carried out in Randomized Block Design (RBD) with three replications during 2022-2023 at Faculty of Agriculture Farm, Guru Kashi University, Talwandi Sabo. The observations were recorded for growth, quality and yield characters. The maximum plant height was recorded in the genotype F-2 IDH-1 (207.67cm), days to first flowering (32.80). Maximum value of primary branches was recorded in S-25-1 (17.33), days to last fruit harvest (168.00) and number of fruits per cluster (7.67). Maximum value of days to first fruit set was observed in S-38-1 (57.33) and number of fruits per plant (90.67). Maximum value of days to first fruit harvest was observed in S-31-1 (121.67), and total soluble solids (7.23°Brix). Maximum value for pH was recorded in Sel Marmade-1 (5.17) and equatorial diameter (6.33cm). Maximum value of polar diameter (6.43cm) was observed in S-22-1. Maximum value of pericarp thickness was observed in Punjab Upma (8.00 mm). Maximum value of number of locules was found in S9-2 Cherry-1 (9.67). Maximum value of average fruit weight was recorded in S-17-1 (65.45g) and total yield per plant was recorded in S-17-1 (5.69kg). The genotypic and phenotypic correlation coefficients showed that total yield per plant had positive and significant association with number of fruits per plant, number of fruits per cluster, plant height, days to first fruit harvest, number of primary branches, equatorial diameter and number of locules. The path analysis estimates indicated that plant height has highest positive direct effect on total yield per plant followed by number of primary branches, number of fruits per plant, TSS, average fruit weight, equatorial diameter, number of fruits per cluster, number of locules, pericarp thickness, polar diameter, pH, days to first flowering, days to last fruit harvest, days to first fruit harvest and days to first fruit set.

INTRODUCTION

Solanum lycopersicum L., belongs to Family: Solanaceae is dicotyledonous annual herb, commonly consumed vegetable in worlds (Paduchuri *et al.* 2010; Adeniji *et al.* 2020). China is the major producer followed by India (Nimbrayan *et al.* 2022). Punjab, Andhra Pradesh, Haryana, West Bengal, Bihar, Madhya Pradesh, Maharashtra, Gujarat, Tamil Nadu, Uttar Pradesh, and Chhattisgarh are the major tomato producing states (Gaikward *et al.* 2020). Due to its rich source of minerals, antioxidant and vitamins it is also considered as poor protective food (Imran *et al.* 2020; Ahmed *et al.* 2020). It is also having medicinal values and can able to reduced the risk of cancers, heart diseases, gastric problem, wound healing (Heber and Lu, 2002; Hedau *et al.*, 2008; Rathod *et al.* 2018). This leads to increase in demand of tomato. But supply of this crop in India is far below compare to the global demand (Ara *et al.*, 2009).

Considering the potentiality and requirement of tomato crop, there is a need for improvement and to identify varieties suitable for growing, yield and for processing. A detailed knowledge about the genetic variability present in various characters is important to begin the crop improvement programme ((Tiwari *et al.* 2019). It is the tendency of individual genotype in a population to differ from one another as it is raw material on which selection is done to obtain desirable or suitable genotypes. Heritability and genetic advance help in assessing the influence of environment in expression of characters and the extent of improvement possible after selection (Ogunniyan and Olakojo, 2014). The genotypic and phenotypic coefficients of variation play role in determining the amounts of variability present in the population (Sesay *et al.* 2016; Nalla *et al.* 2016). Genetic advance can be used to predict the efficiency of selection (Terfa and Gurmu 2020). Correlation coefficient is a measure of degree of association between two characters (Bajpai *et al.* 2017). Hence, there is need to develop superior varieties for different agro-ecological conditions. Keeping the above stated points in view the present investigation was undertaken to

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determine to assess the genetic variability, heritability and genetic advance for growth and yield contributing characters in tomato.

MATERIALS AND METHODS

The present study was conducted at Guru Kashi University, Talwandi Sabo, Punjab, India during 2022-2023. Forty three genotypes of tomato including one check were collected from different sources and utilized for the present investigation (Table 1). On the first week of November, seeds of all genotypes were sown in elevated nursery beds. To raise the healthy nursery, suggested cultural practices were adopted. A Randomized Block Design (RBD) was used to set up the experiment, which included 42 genotypes, one check varieties (Punjab Upma), and three replications of each treatment. The plants were transplanted on January 10, 2023. On raised beds, planting was done at a row distance of 1.25 meters by plant distance 30 cm. The experiment was carried out in Vegetable farm. The observations on the selected parameters i.e. Plant height (cm), Number of primary branches, Days to first flowering, Days to first fruit set, Days to first fruit harvest, Number of fruits per plant, Total yield (kg), Average fruit weight, Number of locules, Polar diameter (cm), Equatorial diameter (cm), Pericarp thickness (mm), Days to last fruit harvest, pH, and Total soluble solids (°Brix) were recorded from five randomly selected plants from each plot. The statistical analysis was carried out for each observed character under study using MS-Excel and MVM Statistical software.

RESULTS AND DISCUSSION

The result revealed that the mean plant height recorded was 162.59cm. It ranged from 147.00cm to 207.67cm. The maximum plant height was recorded in the genotype F-2 IDH-1 (207.67cm) and the minimum plant height was recorded in Late87-1 (147.00cm). Ganesan (2001) revealed that Pusa Ruby attained maximum plant height (2.11m) under greenhouse conditions.

Table 1. List of genotypes used in the research

Genotypes			
S 31-1	SEL 69 OVAL	ISRAEL SEL-1	S9-2 CHERRY-1
LATE 47-1	S-10-1	S-17-1	S-25-1
S-55-1	S-9-1	SEL 110-1	M MARMAD-2
LATE 87-1	S-22-1	F-2 PR-1	ISRAEL SEL-2
LATE 109-1	W-1 181-1	S -17-2	S9-2 CHERRY-1
LATE 167-1	HERA-120-1	F-2 IDH-1	S-Deep Red Marmade
LATE 165-1	S-22-1	S-39-1	F-2 VPR-1
S9-2 CHERRY-1	S-168-1	BAPRO (F1)	VP-1510-1
S-5-1	S-4-3 PIRI	S-105-1	S-38-1
HERO 120-1	SEL 1 MST-1	HERO 100-1	SEL 21 CHERRY ROUND
SEL 109-1	SEL MARMAD-1	Punjab Upma	

However, as per the studies of Cheema *et al.* (2013), tomato hybrids grown in open field conditions show ranges in between the 81 to 181cm. Maximum value of primary branches was recorded in 17.33It was statistically at par with genotypes viz. F-2 IDH-1 (16.67). The minimum value was observed in Late 167-1 (9.33). Maximum value of days to first flowering was observed in F-2 IDH-1 (32.80). Maximum value of days to first fruit set was observed in S-38-1 (57.33) and minimum value was recorded in Israel sel-2 (49.67).

Maximum value of days to first fruit harvest was observed in S-31-1 (121.67) and it was statistically at par with S-38-1 (120.00). Minimum value was recorded in S-110-1 (103.33). Maximum value of days to last fruit harvest was observed in S-25-1 (168.00) and minimum value was recorded in F-2IDH-1 (162.67). Significant differences were obtained among all the genotypes for pH and TSS. It ranged from 4.10 to 5.17 and 4.03 to 7.23°Brix. This is in consonance with the experiment conducted by Cheema *et al.*, (2013). An additional advantage of improved fruit appearance was noticed under the polyhouse tomato fruits. Fruits under shade were uniformly red coloured with very good appearance. Maximum value of polar diameter (6.43cm) was observed in S-22-1. Minimum value of polar diameter of fruit was recorded in F-2IDH-1 (2.03cm).

Maximum value of equatorial diameter was observed in Sel Marmade-1(6.33cm). Minimum value of equatorial diameter was recorded in F-2IDH-1 (1.73cm). Arora *et al.* (2006) and Cheema *et al.* (2013) reported similar variations for fruit characters under protected cultivation. Significant variation for pericarp thickness was obtained among all the genotypes studied. Maximum value of pericarp thickness was observed in Punjab Upma (8.00 mm). Maximum value of number of fruits per cluster was found in S-25-1 (7.67), S-9-1 (7.67) and Minimum value of number of fruits per cluster was observed in Hero120-1. Tomato crop grown under polyhouse conditions produced higher number of fruits per cluster than in the open field conditions because, better environmental conditions under polyhouse helped in better pollination which leads to more fruit setting as revealed by Cheema *et al.* (2013). Maximum value of average fruit weight was recorded in S-17-1 (65.45g) it was statistically at par with genotypes F-2 IDH-1 (61.46g). The minimum was recorded in Hero120-1 (11.67g). Maximum value of total yield per plant weight was recorded in S-17-1 (5.69kg) and at par with F-2IDH-1 (4.30. Minimum value was recorded in S-14 (1.18kg) (Table 2). Increased fruit yield per plant under polyhouse condition compared to open field condition due to minimum incidence of pest and insects under polyhouse was reported by Singh and Kumar (2017).

Genetic variability, heritability and genetic advance: The parameters of variability viz., coefficients of variation (genotypic and phenotypic), heritability (broad sense), genetic advance and genetic gain were worked out for various characters and are presented in Table 3. Phenotypic coefficient of variation (Table 3) was high for characters like number of fruits per plant (57.66%), number of locules (50.48%) and average fruit weight (32.39%). Moderate values were recorded in pericarp thickness (26.50%), polar diameter (24.62%).

Low values of phenotypic coefficient of variation were observed in plant height (10.61%), pH (7.35%), days to first flowering (5.35%), days to first fruit set (4.29%), days to first fruit harvest (3.54%) and days to last fruit harvest (1.44%). Genotypic coefficient of variation (Table 3) was high for characters like number of fruits per plant (57.38%), number of locules (46.70%) and average fruit weight (31.71%). Moderate values were recorded in pericarp thickness (24.52%), polar diameter (24.16%). Low values of phenotypic coefficient of variation were observed in number of fruits per cluster (10.40%), plant height (10.39%), pH (5.77%), days to first fruit harvest (2.54%), days to first flowering (1.86%), days to first fruit set (0.79%) and days to last fruit harvest (0.15%). The estimates of heritability varied from 1.16 to 99.03% for different characters under study (Table 3).

Table 2. Mean performance of tomato genotypes for different characters

Characters	Plant height (cm)	No. of primary branches	Days to first flowering	Days to first fruit set	Days to first fruit harvest	Days to last fruit harvest	pH	TSS (°Brix)	Polar diameter (cm)	Equatorial diameter (cm)	Pericarp thickness (mm)	No. of locules	No. of fruits per cluster	Average fruit weight (g)	No. of fruits per plant	Total yield per plant (kg)	
Genotypes																	
1	S 31-1	147.67	10.33	30.67	55.00	121.67	163.00	4.37	7.23	2.97	3.20	3.67	2.67	5.67	37.88	44.67	1.69
2	LATE 47-1	152.33	9.67	31.33	54.00	117.33	165.00	4.40	5.37	3.20	3.53	6.33	2.33	5.33	40.47	37.67	1.55
3	S-55-1	154.33	9.67	31.00	52.00	116.67	165.67	5.20	4.10	4.30	4.70	5.67	8.67	5.33	46.69	39.67	1.85
4	LATE 87-1	147.67	11.00	32.67	55.33	118.00	165.00	4.43	5.43	2.53	3.50	5.67	3.00	4.67	47.65	39.00	1.85
5	LATE 109-1	154.33	10.67	32.33	56.00	114.67	165.00	4.53	4.27	3.93	2.83	6.33	2.33	5.67	37.64	65.67	2.48
6	LATE 167-1	147.67	9.33	31.67	55.67	112.33	164.30	4.63	5.03	3.77	3.43	4.00	2.67	5.33	40.60	40.00	1.62
7	LATE 165-1	164.33	12.33	30.67	56.00	113.33	167.67	4.47	6.27	4.00	4.23	5.67	2.33	5.67	24.38	82.33	2.01
8	S9-2 CHERRY-1	159.33	10.67	32.67	54.67	116.67	166.00	4.80	5.03	4.47	5.03	5.33	9.67	5.33	54.61	32.00	1.75
9	S-5-1	160.00	9.67	31.67	53.67	117.67	164.33	4.47	4.67	5.07	5.93	5.67	3.67	5.33	52.65	61.67	3.25
10	HERO 120-1	147.00	9.33	32.33	52.33	115.67	164.00	4.27	4.77	4.30	4.43	4.67	3.67	4.67	12.10	82.00	2.39
11	SEL 109-1	152.67	10.33	31.33	53.00	115.33	167.33	5.10	5.43	5.97	4.80	7.67	3.33	5.00	42.10	28.00	1.18
12	ISRAEL SEL-1	157.33	10.67	31.00	55.00	116.00	164.00	4.70	4.37	4.73	3.97	7.67	3.33	5.67	42.66	42.33	1.91
13	S-17-1	159.00	10.67	32.67	53.33	106.67	166.00	4.43	4.43	4.53	4.87	6.67	3.67	5.67	65.45	87.00	5.69
14	SEL 110-1	152.33	9.33	30.00	55.33	103.33	164.00	4.57	5.13	4.23	3.97	7.67	3.33	6.00	49.23	32.33	1.59
15	F-2 PR-1	152.00	9.33	31.67	53.67	109.33	162.67	4.53	4.43	3.90	3.37	6.67	3.67	5.33	38.87	62.33	2.42
16	S -17-2	158.33	11.00	31.00	54.33	117.33	163.67	4.70	4.37	4.27	5.60	4.67	3.33	5.67	35.08	72.00	2.53
17	F-2 IDH-1	207.67	16.67	32.80	55.00	116.67	164.33	4.77	7.17	2.03	1.73	2.00	3.00	7.33	61.46	70.33	4.33
18	S-39-1	156.67	11.00	30.80	55.33	117.33	164.67	4.57	4.20	4.43	7.03	5.67	6.67	5.67	53.14	42.67	2.32
19	BAPRO (F1)	155.67	10.33	30.33	55.00	115.00	166.00	4.53	6.00	3.77	3.37	6.67	2.67	5.33	24.84	69.67	1.73
20	F-2 VPR-1	156.00	10.33	32.67	53.00	114.00	165.00	4.40	5.63	4.10	4.43	6.33	3.67	5.67	35.30	60.00	2.12
21	VP-1510-1	162.33	10.33	30.33	54.00	111.00	165.33	4.40	4.27	4.33	5.33	5.33	5.33	5.33	45.06	51.33	2.31
22	S-105-1	166.33	11.67	32.33	55.67	114.33	167.00	4.90	5.37	4.37	5.00	4.67	4.67	5.67	17.57	124.67	2.19
23	HERO 100-1	170.00	11.67	32.33	53.67	105.67	165.67	4.60	4.17	5.70	6.23	4.67	5.67	5.67	48.88	49.00	2.39
24	S-38-1	160.00	11.00	30.00	57.33	120.00	162.67	4.67	4.23	4.17	5.13	8.00	6.00	6.67	39.22	90.67	3.50
25	SEL 21 CHERRY ROUND	157.67	10.67	31.33	53.33	116.33	165.33	4.53	4.37	3.47	4.73	5.67	6.67	5.67	32.64	52.33	1.71
26	SEL 69 OVAL	165.67	11.67	29.67	54.00	116.33	163.00	4.70	4.20	5.27	4.30	6.67	2.67	5.67	38.60	46.00	1.77
27	S-10-1	200.00	15.67	30.00	56.33	112.67	165.67	4.73	4.60	3.10	3.17	5.33	2.33	5.67	36.37	51.00	1.85
28	S-9-1	201.67	14.00	31.00	55.33	111.00	165.33	4.40	6.23	2.47	2.50	3.67	2.60	7.67	23.37	88.33	2.06
28	S-22-1	153.67	10.00	28.00	55.00	111.67	168.00	4.05	4.60	6.43	5.00	5.67	2.33	6.33	40.32	51.00	2.05
30	W-1 181-1	147.67	9.67	31.00	53.67	116.33	165.33	4.57	5.10	3.77	4.10	6.67	3.33	5.00	52.56	31.67	1.66
31	HERA-120-1	152.33	10.33	31.33	55.67	116.33	165.33	4.33	5.03	4.77	4.23	6.67	3.67	6.33	36.00	52.33	1.88
32	S-22-1	153.67	11.33	31.67	53.00	115.33	165.67	5.17	4.30	4.90	4.53	7.67	2.20	6.33	37.58	60.00	2.26
33	S-168-1	155.00	10.67	31.67	54.67	115.67	165.33	4.30	4.27	3.70	4.13	5.00	7.67	6.00	31.83	73.33	2.35
34	S-4-3 PIR1	159.33	11.33	32.33	57.00	115.67	165.33	4.97	4.47	3.27	4.53	4.33	7.33	6.00	50.46	35.00	1.76
35	SEL 1 MST-1	158.67	10.00	31.00	55.67	117.67	165.67	4.93	4.77	4.53	4.20	6.33	2.67	7.00	50.22	39.67	1.98
36	SEL MARMAD-1	162.67	11.67	32.00	56.33	114.00	162.67	5.17	4.43	5.90	6.34	6.33	6.33	5.67	40.37	60.00	2.42
37	S9-2 CHERRY-1	201.67	16.00	30.33	53.67	115.67	167.67	4.10	7.20	3.47	3.80	4.67	2.33	7.00	28.72	71.00	2.04
38	S-25-1	206.67	17.33	30.00	54.67	116.67	168.00	4.57	6.27	2.53	3.43	4.00	3.33	7.67	16.28	132.33	2.16
39	M MARMAD-2	159.00	10.33	30.33	54.00	115.33	164.33	4.30	4.03	5.13	5.63	6.67	3.33	5.67	21.95	80.00	1.76
40	ISRAEL SEL-2	161.67	11.33	31.67	49.67	116.00	164.67	5.60	4.83	3.63	4.7	4.33	3.00	5.33	28.77	65.67	1.89
41	S9-2 CHERRY-1	161.00	10.33	31.67	55.33	115.00	164.67	4.53	5.27	5.40	4.33	7.67	3.33	6.67	37.23	54.00	2.02
42	S-Deep Red Marmad	155.67	11.33	32.67	54.67	118.00	165.67	4.60	4.17	3.50	3.67	5.67	3.33	5.67	39.50	55.67	2.21
43	Punjab Upma	155.33	10.00	32.33	54.67	115.67	164.67	4.43	4.13	4.47	5.03	8.00	3.00	5.33	34.43	55.67	1.92
Mean		162.59	11.33	31.35	54.5	114.93	165.21	4.63	4.99	4.16	4.35	5.79	3.85	5.87	38.24	62.53	2.04
CD _(0.05)		4.02	1.05	0.80	3.72	1.08	1.82	0.34	0.53	0.32	0.36	0.94	1.2	1.05	4.02	3.25	1.41
Range		147-207.67	9.33-16.67	28-32.80	49.67-57.33	103.33-121.67	162.67-168	4.1-5.17	4.03-7.23	2.03-6.43	1.73-6.33	2-8.00	2.20-9.67	4.67-7.67	11.67-65.45	28-90.67	1.18-5.69

Table 3. Genetic variability, heritability and genetic advance

Characters	Heritability (%)	Genetic Advance	% Genetic Gain	Coefficient of Variability		Coefficient of Variation
				Phenotypic	Genotypic	
Plant height(cm)	95.95	34.1	20.97	10.61	10.39	2.14
No. of primary branches	68.83	3.21	28.34	19.99	16.58	11.16
Days to first flowering	12.07	0.42	1.33	5.35	1.86	5.01
Days to first fruit set	3.4	0.16	0.3	4.29	0.79	4.21
Days to first fruit harvest	51.54	4.32	3.76	3.54	2.54	2.46
Days to last fruit harvest	1.16	0.06	0.03	1.44	0.15	1.43
pH	61.74	0.43	9.35	7.35	5.77	4.54
TSS(°Brix)	89.53	1.88	37.6	20.39	19.29	6.6
Polar diameter(cm)	96.28	2.03	48.83	24.62	24.16	4.75
Equatorial diameter(cm)	95.65	2.09	48.03	24.37	23.84	5.08
Pericarp thickness(mm)	85.65	2.71	46.75	26.5	24.52	10.04
No. of locules	85.57	3.43	88.99	50.48	46.7	19.18
No. of fruits per cluster	46.95	0.86	14.68	15.18	10.4	11.06
Average fruit weight(g)	95.86	24.46	63.96	32.39	31.71	6.59
No. of fruits per plant	99.03	73.55	117.63	57.66	57.38	5.68
Total yield per plant(kg)	78.06	0.63	30.89	19.01	16.88	8.74

Table 4 Genotypic and Phenotypic Correlation of different characters of tomato

Characters		Plant height (cm)	No. of primary branches	Days to first flowering	Days to first fruit set	Days to first fruit harvest	Days to last fruit harvest	pH	TSS (°Brix)	Polar diameter (cm)	Equatorial diameter (cm)	Pericarp thickness(mm)	No. of locules	No. of fruits/ cluster	Average fruit weight(g)	No. of fruits/ plant	Total yield/ plant(kg)
Plant height(cm)	G		0.9922	-0.3271	0.6528	-0.0087	1.4096*	-0.0511	0.5995	-0.4929	-0.4517	-0.5669**	-0.2285	0.8574	-0.5445	0.6969	0.1852
	P		0.8558*	-0.1696	0.1079	-0.0297	0.1221	-0.0345	0.5633	-0.4746	-0.4337	-0.5142	-0.2084	0.5687	-0.5214**	0.6892	0.1925
No. of primary branches	G			-0.1973	0.6358	0.1784	1.7721*	-0.0255	0.6524	-0.5757	-0.4568	-0.6021**	-0.2821	0.8467	-0.5464	0.6877	0.0746
	P			-0.1747	0.0558	0.0282	0.116	-0.0288	0.5213	-0.4626**	-0.3722	-0.4562	-0.1654	0.4397	-0.4437	0.6124*	0.2253
Days to first flowering	G				-2.1861**	-0.0558	-2.0361	0.3113	-0.3549	-0.0858	0.0599	0.1507	0.3425	-0.5154	0.3786*	-0.2339	-0.0572
	P				-0.0424	0.0075	0.0687	-0.0557	-0.1346	-0.0375	0.0088	0.0326	0.1206	-0.1684**	0.1359*	-0.1002	-0.0565
Days to first fruit set	G					0.0878	1.0208*	0.7385	0.6571	-0.3948	-0.5616	-0.2847	-0.2462	0.5865	-0.6482**	0.4514	-0.0159
	P					0.0165	-0.1081	0.0465	0.0704	-0.071	-0.0868	-0.0834	-0.0778	0.1364*	-0.1141**	0.0709	-0.0404
Days to first fruit harvest	G						-1.0412**	0.0735	0.2153*	-0.3067	-0.0563	-0.3781	0.0942	0.0399	-0.1883	0.1792	0.1385
	P						-0.0395	0.1007	0.1549*	-0.2238	-0.0398	-0.2307**	0.0280	0.0257	-0.1464	0.1156	0.0049
Days to last fruit harvest	G							-0.2192	1.1679	0.3260	-0.1234	-0.0589	-1.0042	1.5082*	-1.2066**	0.6676	-1.1336
	P							0.1239	0.1368*	0.0566	0.0017	0.0351	-0.0475	0.1117	-0.1343**	0.0641	-0.1202
pH	G								-0.2163**	0.2446*	0.1303	0.0470	0.1545	-0.0391	-0.0093	-0.0144	-0.1103
	P								-0.1075**	0.1977*	0.1100	0.0338	0.1116	-0.0092	-0.0022	-0.0123	-0.0862
TSS(°Brix)	G									-0.5822	-0.6118**	-0.5753	-0.4297	0.5328	-0.5528	0.6269*	-0.0249
	P									-0.5384	-0.5659**	-0.4975	-0.3698	0.3695	-0.5123	0.5909*	-0.0158

Continue

Polar diameter(cm)	G																		0.5777	0.7049*	0.1545	-0.3113	0.3833	-0.4715**	-0.0212	
	P																			0.5862	0.6554*	0.1343	-0.1928	0.3666	-0.4593**	-0.0142
Equatorial diameter(cm)	G																				0.3916	0.5301*	-0.4523	0.4961	-0.4879**	0.0642
	P																				0.3688	0.4692	-0.2816	0.4746*	-0.4756**	0.0547
Pericarp thickness(mm)	G																					0.0451	-0.4413	0.5002	-0.6413	-0.2554
	P																					0.0116	-0.2665	0.4430*	-0.5906**	-0.2197
No. of locules	G																						-0.2418	0.3976*	-0.2735**	0.0488
	P																						-0.1797	0.3646*	-0.2479**	0.0630
No. of fruits/cluster	G																							-0.5101**	0.6525*	0.2242
	P																							-0.3502**	0.4431*	0.1282
Average fruit weight(g)	G																								-0.8192**	-0.2236
	P																								-0.7996**	-0.1508
No. of fruits/plant	G																									0.4618
	P																									0.4426

*= Positive correlation **= Negative correlation

Table 5. Path analysis: Direct and indirect effects at genotypic and phenotypic levels in tomato

Characters		Plant height (cm)	No. of primary branches	Days to first flowering	Days to first fruit set	Days to first fruit harvest	Days to last fruit harvest	pH	TSS (°Brix)	Polar diameter (cm)	Equatorial diameter (cm)	Pericarp thickness (mm)	No. of locules	No. of fruits per cluster	Average fruit weight (g)	No. of fruits per plant	Total yield per plant (kg)
Plant height (cm)	G	-10.2600	9.6606	0.2912	0.2733	0.0064	1.2246	0.0460	-1.7890	-0.4886	1.1759	0.5689	-0.3491	-1.8728	-1.5998	3.2976	105.2669
	P	-0.2699	0.1669	0.0092	-0.0020	-0.0003	-0.0076	0.0049	-0.1793	-0.0743	-0.0518	0.0552	0.0065	0.0047	-0.2545	0.7848	0.0728
No. of primary branches	G	-10.1797	9.7367	0.1756	0.2662	-0.1309	1.5395	0.0230	-1.9470	-0.5707	1.1891	0.6043	-0.4309	-1.8494	-1.6053	3.2541	94.8043
	P	-0.2310	0.1951	0.0095	-0.0010	0.0002	-0.0072	0.0041	-0.1659	-0.0724	-0.0445	0.0489	0.0051	0.0037	-0.2166	0.6973	0.0380
Days to first flowering	G	3.3558	-1.9207	-0.8902	-0.9153	0.0410	-1.7688	-0.2805	1.0591	-0.0851	-0.1561	-0.1512	0.5231	1.1259	1.1123	-1.1066	0.7924
	P	0.0458	-0.0341	-0.0543	0.0008	0.0001	-0.0042	0.0079	0.0429	-0.0059	0.0010	-0.0035	-0.0038	-0.0014	0.0663	-0.1141	0.0029
Days to first fruit set	G	-6.6978	6.1906	1.9460	0.4187	-0.0644	0.8868	-0.6654	-1.9609	-0.3914	1.4620	0.2857	-0.376	-1.2811	-1.9046	2.1358	0.1753
	P	-0.0291	0.0109	0.0023	-0.0184	0.0001	0.0067	-0.0066	-0.0224	-0.0111	-0.0104	0.0089	0.0024	0.0011	-0.0557	0.0808	0.0003
Days to first fruit harvest	G	0.0890	1.7371	0.0497	0.0367	-0.7339	-0.9046	-0.0662	-0.6426	-0.3040	0.1466	0.3795	0.1439	-0.0872	-0.5533	0.8479	0.5385
	P	0.0080	0.0055	-0.0004	-0.0003	0.0087	0.0024	-0.0142	-0.0493	-0.0350	-0.0048	-0.0248	-0.0009	0.0002	-0.0715	0.1317	0.0001
Days to last fruit harvest	G	-14.4624	17.2548	1.8125	0.4274	0.7641	0.8687	0.1975	-3.4855	0.3232	0.3213	0.0591	-1.5338	-3.2943	-3.5451	3.1590	0.7547
	P	-0.0330	0.0226	-0.0037	0.0020	-0.0003	-0.0619	-0.0175	-0.0435	0.0089	0.0002	-0.0038	0.0015	0.0009	-0.0655	0.0730	0.0038
pH	G	0.5240	-0.2485	-0.2771	0.3092	-0.0539	-0.1904	-0.9010	0.6455	0.2425	-0.3391	-0.0472	0.2359	0.0853	-0.0273	-0.0682	0.8117
	P	0.0093	-0.0056	0.0030	-0.0009	0.0009	-0.0077	-0.1414	0.0342	0.0310	0.0131	-0.0036	-0.0035	-0.0001	-0.0011	-0.0140	0.0200
TSS (°Brix)	G	-6.1506	6.3522	0.3159	0.2751	-0.1580	1.0146	0.1949	-2.9843	-0.5771	1.5929	0.5774	-0.6563	-1.1638	-1.6241	2.9663	8.9062
	P	-0.1520	0.1017	0.0073	-0.0013	0.0013	-0.0085	0.0152	-0.3183	-0.0843	-0.0677	0.0534	0.0115	0.0031	-0.2501	0.6728	0.1013
Polar diameter (cm)	G	5.0567	-5.6055	0.0764	-0.1653	0.2251	0.2832	-0.2204	1.7374	0.9913	-1.5040	-0.7075	0.236	0.6800	1.1263	-2.2308	0.9827
	P	0.1281	-0.0902	0.0020	0.0013	-0.0019	-0.0035	-0.0279	0.1714	0.1566	0.0701	-0.0703	-0.0042	-0.0016	0.1789	-0.5229	0.0245
Equatorial diameter (cm)	G	4.6343	-4.4473	-0.0534	-0.2351	0.0413	-0.1072	-0.1174	1.8259	0.5727	-2.6034	-0.3930	0.8097	0.9879	1.4577	-2.3086	6.7775
	P	0.1170	-0.0726	-0.0005	0.0016	-0.0003	-0.0001	-0.0155	0.1801	0.0918	0.1196	-0.0396	-0.0146	-0.0023	0.2317	-0.5416	0.0143
Pericarp thickness (mm)	G	5.8162	-5.8627	-0.1341	-0.1192	0.2775	-0.0512	-0.0424	1.7170	0.6988	1.4698	-1.0036	0.0688	0.9639	1.4696	-3.0346	1.0072
	P	0.1388	-0.0890	-0.0018	0.0015	-0.0020	-0.0022	-0.0048	0.1584	0.1026	0.0441	-0.1073	-0.0004	-0.0022	0.2169	-0.6725	0.0115
No. of locules	G	2.3448	-2.7471	-0.3049	-0.1031	-0.0692	-0.8724	-0.1392	1.2823	0.1532	-1.3801	-0.0452	1.5274	0.5281	1.1683	-1.2941	2.3328
	P	0.0562	-0.0323	-0.0065	0.0014	0.0002	0.0029	-0.0158	0.1177	0.0210	0.0561	-0.0012	-0.0311	-0.0015	0.1780	-0.2822	0.0010
No. of fruits per cluster (no.)	G	-8.7970	8.2439	0.4588	0.2456	-0.0293	1.3102	0.0352	-1.5901	-0.3086	1.1774	0.4429	-0.3693	-2.1843	-1.4987	3.0875	4.7711
	P	-0.1535	0.0858	0.0091	-0.0025	0.0002	-0.0069	0.0013	-0.1176	-0.0302	-0.0337	0.0286	0.0056	0.0083	-0.1710	0.5045	0.0001
Average fruit weight (g)	G	5.5867	-5.3199	-0.3370	-0.2714	0.1382	-1.0482	0.0084	1.6496	0.3800	-1.2917	-0.5020	0.6074	1.1142	2.9381	-3.8759	8.6324
	P	0.1407	-0.0865	-0.0074	0.0021	-0.0013	0.0083	0.0003	0.1631	0.0574	0.0567	-0.0477	-0.0113	-0.0029	0.4882	-0.9105	0.2383
No. of fruits per plant (no.)	G	-7.1505	6.6962	0.2082	0.1890	-0.1315	0.5800	0.0130	-1.8709	-0.4674	1.2702	0.6437	-0.4178	-1.4253	-2.4068	4.7316	22.3882
	P	-0.1860	0.1194	0.0054	-0.0013	0.0010	-0.0040	0.0017	-0.1881	-0.0719	-0.0569	0.0634	0.0077	0.0037	-0.3903	1.1387	1.2966

It was high for characters like plant height (95.95%), total soluble solid (89.53%), polar diameter (96.28%), equatorial diameter (95.65%), pericarp thickness (85.65%), number of locules (85.57%), average fruit weight (95.86%) and number of fruits per plant (99.03%). Low heritability was observed for number of fruits per cluster (46.95%), days to first flowering (12.07), days to first fruit set (3.4%) and days to last fruit harvest (1.16%). According to Mohamed *et al.* (2012), highest heritability was recorded on plant height (97%), while the lowest was for fruit yield per plant (43%). The genetic gain was low to high in nature and ranged from 0.03 to 117.63% (Table 3). High genetic gain was recorded for number of fruits per plant (117.63 %), number of locules (88.99%) and average fruit weight (63.96%), while moderate for number of primary branches (28.34%), total soluble solids (37.60%), polar diameter (48.83%), equatorial diameter (48.03%), pericarp thickness (46.75%) and total yield per plant (30.89%). Low values of genetic gain were observed for plant height (20.97%), days to first flowering (1.33%), days to first fruit set (0.30%), days to first fruit harvest (3.76%), days to last fruit harvest (0.03%), pH (9.35%) and number of fruits per cluster (14.68%).

Genotypic Correlation Coefficients: The genotypic correlation coefficients among 16 characters (Table 4) showed that total yield per plant had positive and significant association with number of fruits per plant (0.4618), number of fruits per cluster (0.2242) and plant height (0.1852), days to first fruit harvest (0.1385), number of primary branches (0.0746), equatorial diameter (0.0642) and number of locules (0.0488). Plant height had positive correlation with days to last fruit harvest (1.4096), number of primary branches (0.9922) and number of fruits per cluster (0.8574). It showed negative correlation with pericarp thickness (-0.5669), average fruit weight (-0.5445) and polar diameter (-0.4929). Number of primary branches had positive correlation with days to last fruit harvest (1.7721), number of fruits per cluster (0.8467), number of fruits per plant (0.6877) and negative correlation with pericarp thickness (-0.6021), polar diameter (-0.5757) and average fruit weight (-0.5464). Days to first flowering had positive correlation with average fruit weight (0.3786), number of locules (0.3425), pH (0.3113) and negative correlation with days to first fruit set (-2.1861), days to last fruit harvest (-2.0361) and number of fruits per cluster (-0.5154). Fruit pH had positive correlation with polar diameter (0.2446), number of locules (0.1545), equatorial diameter (0.1303) and negative correlation with TSS (-0.2163), number of fruits per cluster (-0.0391) and number of fruits per plant (-0.0144). TSS had positive correlation with number of fruits per plant (0.6269), number of fruits per cluster (0.5328) and negative correlation with equatorial diameter (-0.6118), polar diameter (-0.5822) and pericarp thickness (-0.5753). Number of locules had positive correlation with average fruit weight (0.3976) and negative correlation with number of fruits per plant (-0.2735) and number of fruits per cluster (-0.2418). Number of fruits per cluster had positive correlation with number of fruits per plant (0.6525) and negative correlation with average fruit weight (-0.5101). Average fruit weight had negative correlation with number of fruits per plant (-0.8192).

Phenotypic correlation coefficients: The phenotypic correlation coefficients among 16 characters (Table 4) showed that total yield per plant had positive and significant association with number of fruits per plant (0.4426), number of primary branches (0.2253), plant height (0.1925), number of

fruits per cluster (0.1282) and equatorial diameter (0.0547). Plant height had positive correlation with number of primary branches (0.8558), number of fruits per plant (0.6892) and number of fruits per cluster (0.5687). It showed negative correlation with average fruit weight (-0.5214), pericarp thickness (-0.5142) and polar diameter (-0.4746). Number of primary branches had positive correlation with number of fruits per plant (0.6124), TSS (0.5213), number of fruits per cluster (0.4397) and negative correlation with polar diameter (-0.4626), pericarp thickness (-0.4562) and average fruit weight (-0.4437). Days to first flowering had positive correlation with average fruit weight (0.1359), number of locules (0.1206), days to last fruit harvest (0.0687) and negative correlation with number of fruits per cluster (-0.1684), TSS (-0.1346) and number of fruits per plant (-0.1002). Days to first fruit set had positive correlation with number of fruits per cluster (0.1364), number of fruits per plant (0.0709), TSS (0.0704) and negative correlation with average fruit weight (-0.1141), days to last fruit harvest (-0.1081) and equatorial diameter (-0.0868). Days to first fruit harvest had positive correlation with TSS (0.1549), number of fruits per plant (0.1156), pH (0.1007) and negative correlation with pericarp thickness (-0.2307) and polar diameter (-0.2238) and average fruit weight (-0.1464). Days to last fruit harvest had positive correlation with TSS (0.1368), pH (0.1239), number of fruits per cluster (0.1117) and negative correlation with average fruit weight (-0.1343) and number of locules (-0.0475). Fruit pH had positive correlation with polar diameter (0.1977), number of locules (0.1116), equatorial diameter (0.1100) and negative correlation with TSS (-0.1075), number of fruits per plant (-0.0123) and number of fruits per cluster (-0.0092). TSS had positive correlation with number of fruits per plant (0.5909), number of fruits per cluster (0.3695) and negative correlation with equatorial diameter (-0.5659), polar diameter (-0.5384) and average fruit weight (-0.5123). Pericarp thickness had positive correlation with average fruit weight (0.4430), number of locules (0.0116) and negative correlation with number of fruits per plant (-0.5906) and number of fruits per cluster (-0.2665). Number of locules had positive correlation with average fruit weight (0.3646) and negative correlation with number of fruits per plant (-0.2479) and number of fruits per cluster (-0.1797). Number of fruits per cluster had positive correlation with number of fruits per plant (0.4431) and negative correlation with average fruit weight (-0.3502). Average fruit weight had negative correlation with number of fruits per plant (-0.7996).

Path analysis estimates indicated that plant height (105.2669) has highest positive direct effect on total yield per plant followed by number of primary branches (94.8043), number of fruits per plant (22.3882), TSS (8.9062), average fruit weight (8.6324), equatorial diameter (6.7775), number of fruits per cluster (4.7711), number of locules (2.3328), pericarp thickness (1.0072), polar diameter (0.9827), pH (0.8117), days to first flowering (0.7924), days to last fruit harvest (0.7547), days to first fruit harvest (0.5385) and days to first fruit set (0.1753) (Table 5). Plant height had negative direct effect on total yield per plant (-10.2600) and positive indirect effect by number of primary branches (9.6606), number of fruits per plant (3.2976), equatorial diameter (1.1759), days to last fruit harvest (1.2246), pericarp thickness (0.5689), days to first flowering (0.2912), days to first fruit set (0.2733), pH (0.0460) and days to first fruit harvest (0.0064). However, negative indirect effects by average fruit weight (-1.8728), TSS (-1.7890), number of fruits per cluster (-1.5998), polar diameter (-0.4886) and number of locules (-0.3491) (Table 5).

Days to first flowering had negative direct effect on total yield per plant (-0.8902) and positive indirect effect by plant height (3.3558), number of fruits per cluster (1.1259), average fruit weight (1.1123), TSS (1.0591), number of locules (0.5231), days to first fruit harvest (0.0410) and negative indirect effect by number of primary branches (-1.9207), days to last fruit harvest (-1.7688), number of fruits per plant (-1.1066), days to first fruit set (-0.9153), pH (-0.2805), equatorial diameter (-0.1561), pericarp thickness (0.1512) and polar diameter (-0.0851). Days to last fruit harvest had positive direct effect on total yield per plant (0.8687) and positive indirect effect by number of primary branches (17.2548), number of fruits per plant (3.1590), days to first flowering (1.8125), days to first fruit harvest (0.7641), days to first fruit set (0.4274), polar diameter (0.3232), equatorial diameter (0.3213), pH (0.1975), pericarp thickness (0.0591) and negative indirect effect by plant height (-14.4624), average fruit weight (-3.5451), TSS (-3.4855), number of fruits per cluster (-3.2943) and number of locules (-1.5338). TSS had negative direct effect on total yield per plant (-2.9843) and positive indirect effect by number of primary branches (6.3522), number of fruits per plant (2.9663), equatorial diameter (1.5929), days to last fruit harvest (1.0146), pericarp thickness (0.5774), days to first flowering (0.3159), days to first fruit set (0.2751), pH (0.1949) and negative indirect effect by plant height (-6.1506), average fruit weight (-1.6241), number of fruits per cluster (-1.1638), number of locules (-0.6563), polar diameter (-0.5771) and days to first fruit harvest (-0.1580). Polar diameter had positive direct effect on total yield per plant (0.9913) and positive indirect effect by plant height (5.0567), TSS (1.7374), average fruit weight (1.1263), number of fruits per cluster (0.6800), days to last fruit harvest (0.2832), number of locules (0.2360), days to first fruit harvest (0.2251), days to first flowering (0.0764) and negative indirect effect by number of primary branches (-5.6055), number of fruits per plant (-2.2308), equatorial diameter (-1.5040), pericarp thickness (-0.7075), pH (-0.2204) and days to first fruit set (-0.1653). Pericarp thickness had negative direct effect on total yield per plant (-1.0036) and positive indirect effect by plant height (5.8162), TSS (1.7170), average fruit weight (1.4696), number of fruits per cluster (0.9639), polar diameter (0.6988), days to first fruit harvest (0.2775), number of locules (0.0688) and negative indirect effect by number of primary branches (-5.8627), number of fruits per plant (-3.0346), equatorial diameter (-1.0194), days to first flowering (-0.1341), days to first fruit set (-0.1192), days to last fruit harvest (-0.0512) and pH (-0.0424). Number of fruits per cluster had negative direct effect on total yield per plant (-2.1843) and positive indirect effect by number of primary branches (8.2439), number of fruits per plant (3.0875), days to last fruit harvest (1.3102), equatorial diameter (1.1774), days to first flowering (0.4588), pericarp thickness (0.4429), days to first fruit set (0.2456), pH (0.0352) and negative indirect effect by plant height (-8.7970), TSS (-1.5901), average fruit weight (-1.4987), number of locules (-0.3693), polar diameter (-0.3086) and days to first fruit harvest (-0.0293). Number of fruits per plant had positive effect on total yield per plant (4.7316) and positive indirect effect by number of primary branches (6.6962), equatorial diameter (1.2702), pericarp thickness (0.6437), days to last fruit harvest (0.5800), days to first flowering (0.2082), days to first fruit set (0.1890), pH (0.0130) and negative indirect effect by plant height (-7.1505), average fruit weight (-2.4068), TSS (-1.8709), number of fruits per cluster (-1.4253), polar diameter (-0.4674), number of locules (-0.4178) and days to first fruit harvest (-0.1315) (Table 5).

CONCLUSION

It was concluded from the present investigation that the genotypes S-17-1 was found to have maximum fruit weight (65.45g) and exhibited maximum value (5.69kg) of total yield per plant. S-38-1, S-25-1 and F-2 IDH-1 were the promising genotypes for yield and fruit traits. The genotypes S-31-1 and Sel Marmade-1 exhibited maximum value of TSS and pH respectively. These genotypes can be used for processing. Therefore these genotypes can be commercially exploited or can be used in breeding programme for development.

Acknowledgments: The author expresses gratitude to the Dean, Guru Kashi University for providing the facilities and encouragement for carrying out this work.

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