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GENETIC VARIATION AND CHARACTER ASSOCIATION STUDY AMONG MORPHOLOGICAL AND BIOCHEMICAL TRAITS OF TOMATO (*Solanum lycopersicum* L.)GENOTYPES

ANKITA DEBNATH[1], RAJESH KUMAR[2]*, SITA KUMARI PRASAD[2] AND NISHA SHARMA[2]
[1] Department of Vegetable and Spice Crops, Uttar Banga Krishi Viswavidyalaya,
Pundibari, Coochbehar, West Bengal
[1,2] Department of Horticulture, Sikkim University, Gangtok, Sikkim – 737 102, INDIA
e-mail: rkumar@cus.ac.in

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***Corresponding author**

ABSTRACT

The present investigation was statistically laid out in Randomized Block Design with three replications during 2017-2018 to study genetic variability for yield and quality traits among thirteen tomato (*Solanum iycopersicum* L.) genotypes. Significant differences were noticed for the twelve quantitative characters and promising genotype ST-102 revealed highest fruit yield per plant (681.32 g) along with maximum ascorbic acid (34.68 mg). Magnitude of phenotypic coefficient of variation was slightly higher than the genotypic coefficient of variation for all the traits. Highest estimate of GCV and PCV was recorded for total phenol content (56.61 % and 56.93 %) respectively. High heritability along with genetic advance as per cent of mean was noticed for total phenol content (99 % and 115.96 %), average fruit weight (91 % and 64.88 %) and fruit yield per plant (90 % and 67.39 %) respectively. Average fruit weight was found to be significantly and positively correlated (0.90 and 0.88) with fruit yield per plant and also produced highest direct effect (0.83 and 0.85) towards fruit yield at both the genotypic and phenotypic levels considering that these traits may be put under selection pressure due to additive gene action towards crop improvement of tomato under organic growing condition.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crop grown widely all over the world. The production of tomato is highly influenced by environmental factors such as temperature, relative humidity, light and CO_2 level in the atmosphere. Being a warm season crop it can be grown in wide range of soil and temperature but the most adequate range of temperature for its record yield is 20 to 24ºC. The mean temperature below 16ºC and above 27ºC is not desirable for its cultivation. Tomato is rich source of several essential and beneficial elements in human diet such as antioxidants, vitamins and minerals. The crop stands unique among vegetables because of its high nutritive values and innumerable uses and considered as 'Protective food' for some antioxidant properties due to the presence of lycopene and flavonoids (Sepat *et al*., 2013). Plant genetic resources enable plant breeders to create novel genetic recombination and select crop cultivars more suited to the diverse systems of agriculture (Glaszmann *et al*., 2010). The State of Sikkim harbours 28% of country's biodiversity and has also become first organic state in the country. There are number of potential horticultural crops having high nutritive and medicinal values found in this region. The various indigenous and locally grown horticultural crops serve as good source of nutrition as well as income for tribal farming community of Sikkim. Tomato has a wide range of variability which provides a tremendous scope for genetic improvement of economic traits under organic growing conditions. However productivity of tomato crop in Sikkim is still far behind because of unavailability of potent cultivars to produce higher yield with good horticultural quality. Morphological screening of germplasm not only helps in the identification of lines with novel characteristics but also in the planning of inheritance research of vegetable crops (Kumar *et al*., 2018). Genetic variability refers to the amount of dissimilarity among the individuals of any plant population. It is always advisable to subject the breeding material to genetic variability analysis since it is a pre-breeding step towards development of a cultivar with high yield potential and quality. Determination of heritability and the genetic parameters that compose heritability estimate is to compare the expected genetic gains from selection based on alternative selection strategies (Bamaniya *et al*., 2018). Effective and trustworthy selection for any trait depends upon the extent of variability to which it will be passing on from one generation to the other, because only heritable variation may be utilized further in effective breeding programme (Maharana *et al*., 2017). It is well proven that for desirable selection, variability in germplasm alongside prior knowledge of genetic association of yield with other associated characters is prerequisite. Therefore, direct selection for yield alone is usually not very effective or may often be misleading (Pandey *et al*., 2016). Hence, selection based on its contributing characters could be more efficient and reliable (Kumar *et al*., 2012). Information on magnitude as well as nature of the associations yielded by correlation coefficient and path coefficient analysis act as an effective measure to find out direct and indirect sources of associations (Sharma *et al*., 2020). By considering all above facts, present study is an attempt to obtain information on the genetic variability present in various genotypes of tomato and the association among the various traits for assessing their utility in developing the promising highly potent cultivar. It can be achieved either through direct selection or by finding out heterotic combinations for commercial utilization under complete organic growing condition in Sikkim Himalayas.

MATERIALS AND METHODS

The present investigation was carried out at Main Experiment Station, Department of Horticulture, Sikkim University located at 27º14´20½ N latitude and 88º18´15½ E longitude with an altitude of 1230 m above mean sea level during warm season, 2017-2018. The total rainfall during the growing season was 1625 mm with a temperature ranging from 10-30ºC. Thirteen tomato genotypes from different geographic location of West Bengal covering Kalimpong, Kolkata, Coochbehar and few genotypes maintained in department itself (Pusa Ruby, IIHR-2623, H-86, Arka Abha and Arka Vikas) were collected and utilized for present study. The seeds were sown in nursery and all the essential cares were taken to ensure proper growth of seedlings. The seedlings became ready for transplanting after four weeks of germination. The genotypes were statistically laid out in randomized block design (RBD) with three replications. Transplanting was done in evening at 60 cm x 45 cm spacing followed by light irrigation. All other recommended package of practices such as organic fertilization, eco-friendly plant protection and other intercultural practices were followed for raising a healthy crop according to organic standards. The data was recorded for three growth characters *viz*., plant height (cm), number of primary branches per plant, days taken to 50% flowering, five yield characters *viz*., equatorial diameter (cm), polar diameter (cm), number of fruits per plant, average fruit weight (g), fruit yield per plant (g) and four quality characters *viz*., total soluble solids (ºBrix), ascorbic acid content (mg/100 g), protein content (g/100 g) and total phenol content (mg/100 g). Morphological parameters were recorded by using guidelines mentioned in NBPGR descriptors on vegetable crops at their respective growth and reproductive phase. Quality attributes were estimated by the standard methodology suggested by the previous workers *viz*., T.S.S. (ºBrix) was estimated using a digital refractometer. Ascorbic acid (mg/100 g) was measured by using the protocol suggested by Rangana, 1976. Protein content was determined by the method given by Lowry *et al*., 1951 and polyphenol content (mg/100 g) extraction was based on the method by Thimmaiah, 1999. The data thus obtained were analyzed statistically through OPSTAT statistical package to draw the valid conclusion. Genotypic and phenotypic coefficients of variation were calculated as per Burton and Devane (1953). However the range of genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) were validated by Sivasubramanian and Menon (1973) method. Broad sense heritability was calculated by using the formulae of Lush (1949) and genetic advance estimated as per the method of Johnson *et al*. (1955). Genetic advance is the improvement of selected individuals over the base population that can potentially be made from selection for a characteristic. The range of heritability and genetic advance (GA) categorized as by Johnson *et al*. (1955). Correlation coefficient is the degree and direction of the relationship between independent variables. Correlation coefficient was calculated by using formula given by Johnson *et al*. (1955) and Al Jibouri *et al*. (1958) while Path coefficient analysis was estimated by formula suggested by Wright (1921) and elaborated by Dewey and Lu (1959) considering fruit yield/plant as dependant variable.

RESULTS AND DISCUSSION

Mean performance

Significant differences among the genotypes with all the characters were found indicating sufficient variability among the genotype ($p < 0.05$). The data presented in the Table 1 showed that the maximum plant height was recorded in ST-102 (187 cm) may be due to the genetic makeup and morphological differentiation which results in apical dominance through better cell division and better enzymatic activities. The result was in accordance with Golani *et al*. (2007), who indicated that plant height is an important trait for the selection of superior genotypes. It was also clear from Table 1 that that the maximum number of primary branches per plant was found in genotype ST-82 (9.33) and the minimum was recorded in genotype Arka Vikas (4.33). The number of primary branches were increased due to the genetic makeup

Table 1: Mean performance of twelve characters of tomato genotypes

S. N.	Genotypes	Plant height (cm)	No. of primary branches / Plant	Days to 50% flowering	Equatorial diameter (cm)	No. of fruits/ Plant	Average fruit weight (g)	Polar diameter (cm)	Fruit yield/ plant (g)	Total soluble solid (°BRIX)	Ascorbic acid content (mg/100 g)	Protein content (g/100 g)	Total phenol content (mg/100g)
1	ST-42	186.66	7.33	27.33	4.68	16.66	36.82	5.35	614.87	5.33	23.81	0.12	110.03
2	ST-52	164.33	7.33	34	4.47	16	29.91	4.86	477.15	4.23	15.73	0.24	75.23
3	ST-62	117.33	5.33	33.66	4.8	17	24.65	5.3	418.82	4.73	18.22	0.24	199.76
4	ST-72	119.33	5	34.33	4.96	13.66	17.19	5.26	234.42	3.8	19.41	0.14	171.26
5	ST-82	80.33	9.33	30	4.92	18.33	33.39	5.17	612.61	4.43	27.36	0.16	189.63
6	ST-92	111.66	5.33	31.33	5.46	16.33	40.35	4.4	657.86	4.76	26.78	0.27	283.26
7	ST-102	187	8.66	41.33	4.98	14.33	47.67	4.82	681.32	5.26	34.68	0.32	287.8
8	ST-112	123.33	5	32.33	1.86	16	15.25	1.9	245.55	6.4	19.41	0.18	57.2
9	IIHR-2623	136.66	6.33	30.66	5.14	11.66	16.94	4.27	198.54	4.33	19.15	0.16	98.46
10	Pusa Ruby	186.66	8	35.33	5.07	14	34.07	4.92	472.33	3.8	22.17	0.2	65.63
11	H-86	128	5.33	42.33	4.1	12	42.98	4.37	517.87	4.8	20.33	0.19	169.53
12	Arka Abha	177	6.33	27.33	5.11	12.66	42.56	4.36	539.16	4.76	21.58	0.2	61.5
13	Arka Vikas	115	4.33	39.66	5.14	11.66	31.46	4.8	366.54	5.46	20.21	0.12	85.03
	GM	141.02	6.43	33.82	4.67	14.64	31.79	4.6	464.39	4.77	22.21	0.19	142.64
	SE(m)	6.86	0.62	2.04	0.11	0.71	1.88	0.17	31.5	0.09	0.75	0.01	4.98
	C.D at 5%	20.03	1.81	5.96	0.33	2.08	5.49	0.51	91.96	0.27	2.21	0.05	14.54

Table 2: Genetic parameters

S. No.	Characters	Co-efficient of variation (%)			Heritability % (broad sense)	Genetic advance as % of mean
		GCV	PCV	ECV		
1	Plant height (cm)	24.49	25.9	8.43	89	47.69
2	No. of primary branches/ Plant	22.44	27.97	16.69	64	37.09
3	Days to 50% flowering	13.02	16.7	10.47	61	20.91
4	Equatorial diameter (cm)	19.32	19.77	4.2	95	38.9
5	No. of fruits/plant	14.46	16.74	8.44	75	25.72
6	Average fruit weight (g)	32.98	34.54	10.25	91	64.88
7	Polar diameter (cm)	19.09	20.2	6.6	89	37.16
8	Fruit yield/ plant (g)	34.55	36.5	11.75	90	67.39
9	Total soluble solid (°BRIX)	14.89	15.26	3.36	95	29.92
10	Ascorbic acid content (mg/100 g)	22.14	22.92	5.92	93	44.06
11	Protein content (g/100 g)	28.18	32.82	16.82	74	49.85
12	Total phenol content (mg/100 g)	56.61	56.93	6.05	99	115.96

Table 3: Genotypic and phenotypic correlation co-efficient among different traits

Characters		No. of primary branches / Plant	Days to 50% flowering	Equatorial diameter (cm)	No. of fruits/ Plant	Average fruit weight (g)	Polar diameter (cm)	Total soluble solid (°BRIX)	Ascorbic acid content (mg/100g)	Protein content (g/100g)	Total phenol content (mg/100g)	Fruit yield /plant (g)
Plant height (cm)	G	0.37	-0.01	0.1	-0.24	0.4	0.12	-0.02	0.16	0.27	-0.27	0.27
	P	0.34	-0.01	0.09	-0.14	0.36	0.1	-0.05	0.13	0.24	-0.24	0.24
No. of primary branches/ Plant	G	-	-0.17	0.23	0.39	0.43*	0.34	-0.29	0.62**	0.29	0.14	0.60*
	P	-	-0.13	0.24	0.40*	0.32	0.34	-0.24	0.45*	0.21	0.13	0.49*
Days to 50% flowering	G		-	-0.06	-0.49*	0.27	0.01	0.07	0.14	0.3	0.31	0.02
	P		-	-0.01	-0.32	0.19	0.06	0.04	0.13	0.23	0.24	-0.01
Equatorial diameter	G			-	-0.2	0.41*	0.82**	-0.64**	0.28	0.09	0.35	0.36*
(cm)	P			-	-0.13	0.36	0.79**	-0.61**	0.26	0.07	0.33	0.33*
No. of fruits/plant	G				-	-0.02	0.08	0.1	0.23	0.27	0.31	0.40*
	P				-	-0.04	0.09	0.07	0.16	0.1	0.27	0.37*
Average fruit weight (g)	G					-	0.32	0.03	0.64**	0.47*	0.39	0.90**
	P					-	0.3	0.02	0.60**	0.35	0.38	0.88**
Polar diameter (cm)	G						-	-0.64**	0.15	-0.05	0.31	0.38*
	P						-	-0.60**	0.15	-0.04	0.29	0.35*
Total soluble solid (°BRIX)	G							-	0.17	-0.02	-0.05	0.03
	P							-	0.15	-0.02	-0.06	0.02
Ascorbic acid content	G								-	0.46*	0.68**	0.72**
(mg/100g)	P								-	0.36	0.65**	0.66**
Protein content (g/100g)	G									-	0.60**	0.52*
	P									-	0.50*	0.37*
Total phenol content	G										-	0.52*
(mg/100g)	P										-	0.49*

** - Significant at 1 % level, *- significant at 5 % level

and morphological differentiation of the genotypes studied. It is a general conception that if less time is taken for 50% flowering; it would be economical because day taken to 50% flowering is directly correlated to early yield. It is indicated from Table 1 that the genotype of ST-42 and Arka Abha were earliest (27.33 days) in producing 50% flowering followed by ST-82 (30.00) days whereas H-86 took maximum time (42.33 days). The results might be due to the genetic makeup of genotypes which results in early formation of floral primordia through early transformation from vegetative phase to reproductive phase. Similar study was done by Bhandari *et al*. (2017) who concluded in their study that the variation was due to the varietal characteristics. The average fruit weight of all genotypes was recorded which range from 15.25 g to 47.67 g. The maximum average fruit weight was recorded in genotype ST-102 (47.67 g) and minimum was in genotype ST-112 (15.25 g). This might be due to the varietal differences, genetic makeup and morphological differentiation of genotypes studied which results in better nutrition diversion towards fruit development. The data presented in Table 1 indicates that maximum value regarding number of fruits per plant was recorded in genotype of ST-82 (18.33) followed by ST-62 with the value of 17.00 and minimum value was recorded in genotypes IIHR-2623 and Arka Vikas (11.66). The results might be due to the varietal differentiation, geographical distributions, morphological differentiation and genetic makeup of genotypes studied. Similar observation was recorded by Sarma *et al*. (2000). The data presented in Table 1 clearly showed significant variation among all the materials studied regarding diameter of fruit. The minimum value for polar diameter was obtained from the genotype ST-112 *i.e.*, 1.90 cm and maximum value was for ST-42 (5.35 cm). In case of equatorial diameter of individual fruits of all genotypes were ranging from 1.86 cm (ST-112) to 5.46 cm (ST-92). This might be due to the varietal differences, genetic makeup and morphological differentiation of genotypes studied which results in better nutrition diversion towards fruit development. Sarma *et al*. (2000) also reported in their study that fruit circumference and average fruit weight were the main characters affecting grouping of genotypes. In case of fruit yield per plant the maximum value was recorded in genotype ST-102 (681.32 g) and the minimum value recorded in genotype IIHR-2623 (198.54 g). Meena *et al*.

Table 4: Direct and indirect effect of various traits on fruit yield per plant at genotypic and phenotypic level (Path analysis)

Characters		Plant height (cm)	No. of primary branches / plant	Days to 50% flowering	Equatorial diameter (cm)	No. of fruits/ Plant	Average fruit weight (g)	Polar diameter (cm)	Total soluble solid (°BRIX)	Ascorbic acid content (mg/100g)	Protein content (g/100g)	Total phenol content (mg/100g)
Plant height (cm)	G	-0.049	-0.018	0	-0.005	0.0122	-0.02	-0.006	0.001	-0.008	-0.013	0.013
	P	-0.053	-0.018	0	-0.005	0.007	-0.019	-0.005	0.002	-0.007	-0.013	0.012
No. of primary branches/ plant	G	-0.069	-0.183	0.031	-0.042	-0.071	-0.079	-0.063	0.054	-0.115	-0.053	-0.027
	P	-0.003	-0.01	0.001	-0.002	-0.004	-0.003	-0.003	0.002	-0.004	-0.002	-0.001
Days to 50% flowering	G	0.001	0.01	-0.062	0.003	0.031	-0.017	0	-0.004	-0.009	-0.019	-0.019
	P	0.001	0.01	-0.082	0.001	0.026	-0.016	-0.005	-0.003	-0.011	-0.019	-0.02
Equatorial diameter (cm)	G	-0.011	-0.024	0.006	-0.105	0.021	-0.043	-0.086	0.067	-0.03	-0.009	-0.037
	P	0	-0.001	0	-0.007	0	-0.002	-0.005	0.004	-0.001	0	-0.002
No. of fruits/plant	G	-0.096	0.151	-0.193	-0.078	0.388	-0.008	0.034	0.042	0.091	0.107	0.12
	P	-0.054	0.149	-0.119	-0.048	0.369	-0.017	0.035	0.028	0.061	0.039	0.1
Average fruit weight (g)	G	0.342	0.365	0.231	0.345	-0.019	0.837	0.274	0.03	0.544	0.394	0.333
	P	0.309	0.276	0.168	0.312	-0.039	0.855	0.258	0.022	0.516	0.303	0.327
Polar diameter (cm)	G	0.022	0.062	0.002	0.149	0.015	0.059	0.181	-0.117	0.028	-0.009	0.057
	P	0.008	0.027	0.005	0.063	0.007	0.024	0.079	-0.048	0.012	-0.003	0.023
Total soluble solid (°BRIX)	G	0.003	0.031	-0.007	0.068	-0.011	-0.003	0.069	-0.106	-0.019	0.002	0.006
	P	0	0.001	0	0.004	0	0	0.004	-0.006	-0.001	0	0
Ascorbic acid content	G	0.055	0.212	0.048	0.095	0.079	0.218	0.051	0.06	0.336	0.157	0.229
(mg/100g)	P	0.015	0.053	0.016	0.031	0.019	0.071	0.018	0.018	0.117	0.043	0.077
Protein content (g/100g)	G	0.024	0.026	0.028	0.008	0.025	0.043	-0.004	-0.002	0.042	0.091	0.054
	P	0.011	0.01	0.011	0.003	0.005	0.016	-0.002	-0.001	0.017	0.046	0.023
Total phenol content	G	0.056	-0.03	-0.065	-0.073	-0.064	-0.082	-0.066	0.011	-0.141	-0.124	-0.207
(mg/100g)	P	0.011	-0.006	-0.011	-0.016	-0.013	-0.018	-0.014	0.002	-0.032	-0.024	-0.048
Fruit yield per plant (g)	G	0.273	0.603	0.027	0.362	0.409	0.903	0.381	0.033	0.721	0.528	0.527
	P	0.246	0.492	-0.011	0.335	0.379	0.889	0.359	0.022	0.666	0.37	0.492

Residual effect = 0.04 (genotypic level), 0.13 (phenotypic level)

(2015) also reported high estimates of range for fruit yield/ plant and plant height. The result might be due to the geographical location, morphological differentiation, genetic makeup, environmental interaction of genotypes and combined effect of various yield contributing traits which are directly correlated with fruit yield per plant; it is quite obvious that the genotype ST-102 responded well to organic growing conditions. Rai *et al.* (2016) obtained similar results while carrying out an experiment to investigate yield and quality traits in tomato in order to generate information regarding the extent of genetic variability, heritability and genetic gain.

Finding related with TSS of different genotypes of tomato have been presented in Table 1. The maximum TSS was recorded in genotype ST-112 (6.40 ºB) followed by Arka Vikas (5.46 °B) and ST-102 (5.26 °B) while minimum TSS was recorded in ST-72 (3.80 ºB). Similar results were also reported by Kerketta and Bahadur (2019). Ascorbic acid content of the fruit was estimated highest in ST-102 (34.68 mg) and minimum in ST-52 (15.73 mg). Similar findings were also reported by Kumar *et al.* (2016) and Reddy *et al.* (2013). The reason behind dissimilarity in result might be the genetic makeup of the genotypes and the location of experiment and strong correlation of ascorbic acid with the environmental condition. The data pertaining to the protein content has been presented in Table 1 clearly showed significant variation among all the treatments studied with highest value in ST-102 (0.32 g). Total phenol content of the fruit was estimated highest in ST-102 (287.80 mg) and minimum was estimated in ST-112 (57.20 mg). These results are similar with the study of Ravali *et al.* (2017). Patel *et al.* (2013) in tomato. The reason behind dissimilarity in result might be the genetic makeup of the genotypes and the location of experiment as strong correlation of polyphenol is reported with the environmental condition.

Genetic parameters

It is apparent from the data presented in Table 2 that total phenol content produced the high range of genotypic coefficient of variation (56.61%) among all the traits studied. The characters *viz*. protein content (28.18 %), ascorbic acid (22.14 %), fruit yield per plant (34.55 %), average fruit weight (32.98 %), no. of primary branches per plant (22.44 %) and plant height (24.49 %) also showed high range of genotypic coefficient of variation. The data also depicted a wide range of phenotypic coefficient of variation for majority of characters under study. The high phenotypic variance (>20%) was recorded in case of total phenol content (56.93 %) followed by fruit yield per plant (36.50 %), average fruit weight (34.54 %), protein content (32.82 %), no. of primary branches per plant (27.97 %), plant height (25.90 %), ascorbic acid content (22.92 %) and polar diameter (20.20 %) whereas equatorial diameter (19.77 %), no. of fruits per plant (16.74 %), days to 50% flowering (16.70%) and TSS (15.26%) showed moderate phenotypic coefficient variation. Similar results were also reported by Ara *et al.* (2009), Buckseth *et al.* (2012), and Chadha and Bhusan (2013) for no. of fruits per plant, average fruit weight and fruit yield per plant.

The term heritability in broad sense defined as the ratio of genetic variance to the total phenotypic variance is presented in Table 2. Almost all the characters under study showed a high value of heritability. Genetic advance, when considered along with heritability gives reasonable assessment of resultant effects of selection in breeding populations. The magnitude of genetic advance as percentage of mean categorized as high (>20 %), moderate (10-20 %) and low (<10%) as suggested by Johnson *et al.* (1955).

The data presented in Table 2 and showed that the heritability in broad sense ranged from 61% (days to 50% flowering) to 99% (total phenol content). High heritability (>60%) is found in all the characters *viz*. plant height (89%), no. of primary branches/plant (64%), equatorial diameter and TSS (95%), no. of fruits per plant (75%), average fruit weight (91%), polar diameter (89%), fruit yield per plant (90%), ascorbic acid content (93%) and protein content (74%) including days taken for 50% flowering and total phenol content (61% and 99% respectively). The data also reveals that the genetic advance as percent of mean was high in almost all the traits like equatorial diameter (38.90 %), average fruit weight (64.88 %), polar diameter (37.16 %), TSS content (29.92 %), ascorbic acid content (44.06 %), protein content (49.85 %), plant height (47.69 %), fruit yield per plant (67.39 %) and total phenol content (115.45%). Rahaman *et al*. (2012) and Manna and Paul (2012) found similar results in the traits like no. of fruits per plant, average fruit weight and fruit yield per plant. The results of the present investigation are also in agreement with previous studies carried out on tomato genotypes by several workers (Singh *et al*., 2000, Ahmed *et al*., 2006, Mehta and Asati, 2008 and Ghosh *et al*., 2010). Sharma (2020) revealed high heritability coupled with high genetic advance as per cent of mean for plant height, fruit yield per plant, no. of fruits per plant, average fruit weight, polyphenol, ascorbic acid, T.S.S. and total protein in brinjal crop under organic growing condition in Sikkim Himalayas.

Character association

Correlation analysis

Correlation studies provide information on the nature and extent of association between a pairs of characters. From this, it would be possible to bring about genetic up gradation in one character by the selection of other character. Hence, an attempt has been made to study the character association in tomato accessions at both genotypic and phenotypic levels. It was quite apparent from Table 3 that the genotypic correlation was higher than the phenotypic correlation in the present study, indicating high heritable nature of the characters under the investigation. The character, average fruit weight produced positive and highly significant correlation with fruit yield per plant at both genotypic and phenotypic levels (0.90 and 0.88 respectively), no. of primary branches per plant also produced the significant and positive value regarding correlation to fruit yield per plant at both genotypic and phenotypic level (0.60 and 0.49 respectively), however biochemical traits like total phenol content (0.52 and 0.49) and ascorbic acid content (0.72 and 0.66) also found to be positively and significantly correlated to fruit yield per plant. Therefore, selection for these significantly associated characters with fruit yield per plant will indirectly increase the effectiveness of selection of plants with high yield potential. Hence, it is worthwhile to have genotypes with maximum fruit weight to get higher yield. Similar results were reported by Singh *et al*. (1997) and Ghosh *et al*. (2010) who noticed positive association of average fruit weight and number of fruits per plant with fruit yield per plant.

Path analysis

Path analysis refers to direct and indirect association of component traits towards fruit yield per plant (Table 4). The characters, which produced positive and direct effect on fruit yield per plant, were no. of fruit per plant, average fruit weight, polar diameter, ascorbic acid content and protein content. These results are similar with Rai *et al*. (1998) and Joshi *et al*. (2004). The characters, which had negative direct effect on fruit yield were plant height, no. of primary branches per plant, days taken to 50% flowering, equatorial diameter, TSS and total phenol content. Dudi and Kalloo (1982), Singh *et al*. (1989), Rathod (1997), Patil (1998), Sharma and Verma (2000), Mohanty (2002), Joshi and Kohli (2003), Padda *et al*. (1971), Ghosh *et al*. (2010) and Tewari and Upadhyay (2011) suggested number of fruits per plant and average fruit weight are the major contributors of yield in tomato. Among indirect contributions of component traits through each other, it was observed that average fruit weight had maximum positive direct effect (0.837 and 0.855) via indirect effect of ascorbic acid content (0.218 and 0.071), protein content (0.043 and 0.016) and polar diameter (0.059 and 0.024) at both genotypic and phenotypic level respectively, rest of the component traits produced negative indirect effect. This was in accordance with Mahesh *et al*. (2006). The role of negative contributors via each other was important only if the variation in either of the associated contributory traits was much of positive effect than the otherwise negative one. In other words, if the characters were associated complementary, only then such combinations of characters for the improvement of yield potential of material being assessed could be exploited effectively. Islam *et al*. (2010) indicated from the path analysis that average fruit weight might be the most potential yield contributing trait for yield improvement in tomato. The residual effects appeared to be considerably low (0.04 and 0.13) both at genotypic and phenotypic level which indicated that the characters included in this study explained ample amount of variation towards yield. From the analysis and interpretation of the scientific results obtained in present investigation, it may be concluded that average fruit weight, number of fruits per plant and number of primary branches per plant were emerged as important contributing traits for tomato genetic improvement with predominant additive gene action. Genotype ST-102 responded well to organic growing conditions and will be proven as promising genotype for commercial cultivation in an organic state Sikkim. The genotype may be further utilized for future crop improvement either directly or as potent parent in hybridization program.

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