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Genetic variability, heritability and genetic advance for yield and quality attributes in heat tolerant exotic lines of tomato (*Solanum lycopersicum* L.)

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Abstract
Genetic variability was investigated in twenty genotypes of tomato for yield and quality traits during *Kharif*, 2014 at Experimental Farm of Vegetable Research Station, ARI, Rajendranagar, Hyderabad. The results of the study revealed that high PCV and GCV estimates were recorded for plant height, number of primary branches, number of clusters per plant, fruit set per cent, number of fruits per plant, number of fruit per cluster, fruit length, average fruit weight, fruit yield per plant, stomatal diffusive resistance, relative water content and chlorophyll content. High heritability coupled with high genetic advance as per cent of mean indicates operation of additive gene action which was observed in characters plant height, root to shoot ratio, number of primary branches per plant, number of flowers per cluster, number of clusters per plant, fruit set (%), number of fruits per cluster, number of fruits per plant, fruit length, fruit width, average fruit weight, fruit yield per plant, number of locules per fruit, ascorbic acid, lycopene content, stomatal diffusive resistance, relative water content and chlorophyll content. Hence, directional selection for the above characters could be effective for desired genetic improvement.

Keywords: Genetic variability, heritability, genetic advance, yield and quality attributes, Heat tolerant exotic lines, tomato

Introduction

Tomato (*Solanum lycopersicum* L.) is an important vegetable crop and particularly now a commercial crop widely grown all over tropical, sub-tropical and temperate regions of the world for both fresh and processing purpose. Although tomato has a good potential to be cultivated every location in the universe but it confronts lots of abiotic stresses in which, high temperature is a crucial problem now-a-days. According to the Intergovernmental Panel on Climatic Change (IPCC), in each decade, worldwide average temperature will be enhanced by 0.3˚C (Jones *et al*., 1999) [19] and reached to around 1˚C and 3˚C higher than the current temperature by the years of 2025 and 2100, respectively and led to warming of the globe. This increased temperatures inhibit growth and development of tomato by adversely affecting plant morphological, physiological, biochemical, and molecular mechanisms (Singh *et al*., 2007) [42], eventually affecting yield (Bita and Gerats, 2013) [10].

The optimum temperature for tomato growth and development is 20–24°C. Temperatures above 34°C are considered super-optimal thermal stress. The optimum range of night temperature for fruit set is 15-20 °C (Thamburaj and Singh., 2004; Peter and Kumar., 2008) [48, 32], however above 18°C is likely to inhibit pollen production and fruit set (Peet and Bartholemew, 1996) [31]. With high day and night temperatures, the plant shows symptoms of irregular flower development, reduction in pollen production, pollen viability, fruit drop and ovule abortion, all of which ultimately lead to decreased yield (Dane *et al*., 1991; Hazara and Ansary, 2008) [13, 15]. Heat tolerance is generally defined as the ability of the plant to grow and produce economic yield under high temperatures. It is a complex trait, and understanding the genetics of heat tolerance is difficult. Villareal *et al*. (1978) [50] reported that recessive genes are responsible for heat tolerance; they are governed by multiple genes, affected by environmental conditions, and have low heritability. Additive and non-additive genes govern heat tolerance (Gabry *et al*., 2014; Solieman *et al*., 2013) [14, 45]. Heat-tolerant tomatoes are reported to have the ability to set fruit at higher temperatures than other tomatoes (AVRDC, 2001) [9]. Selection of crops for tolerance to high temperature stress is proposed as the best and easiest strategy for breeding (Warner and Erwin, 2005) [51]. Genetic variability parameters aid in selection of genotypes for inclusion in breeding. Keeping the above in view, the present investigation was taken up in exotic heat tolerant tomato lines to estimate variability parameters.

Material and methods

The experimental material comprising of a set of fifteen heat tolerant testers and five lines of tomato which were obtained from World Vegetable Centre, Taiwan (previously AVRDC) and Indian Institute of Horticultural Research, Bangalore were systematically evaluated for quantitative and quality traits. Germplasm were evaluated in a Randomized Block Design with three replications during *Kharif,* 2014 at Experimental Farm of Vegetable Research Station, ARI, Rajendranagar, Hyderabad. In each replication, each entry was grown in a single row plot of 4.5 m length. Each plot consisted of one ridge alternating with furrow accommodating only one row of germplasm line. Row-to- row spacing of 60 cm and plant-to-plant spacing of 45 cm was maintained. The recommended package of practices and necessary prophylactic plant protection measures were carried out to safeguard the entire germplasm from pests and diseases. The data on quantitative and quality characters were recorded on five competitive and randomly selected plants in each replication for all the characters under study except days to 50% flowering and fruit yield per plant which were recorded on whole plot basis. The data were analyzed by the methods of Cochran and Cox (1957) [12] using mean values of random plants in each replication from all genotypes to determine significance of genotypic effects. Genotypic and phenotypic coefficients of variation were calculated using the formulae of Burton (1952). Broad sense heritability was calculated as per Lush (1940) and genetic advance estimated by the method of Johnson *et al.* (1955) [18]. Categorization of genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) and genetic advance (GA) were done as per Sivasubramanian and Menon (1973) [44] and heritability categorized as by Johnson *et al.* (1955) [18].

Results and discussion

Root characters

Root length exhibited medium phenotypic and genotypic variances (17.17 and 12.09 respectively) with medium PCV (11.86) and low GCV (9.96) per cent (table 1). High estimates heritability (70.43), medium genetic advance (6.01) and GA as per cent mean (17.21) recorded for this character. The results are of line with Natarajan (1992) [29], Anitha *et al.,* (2013) [2] and Shaheen *et al.,* (2016) [36]. Root to shoot ratio exhibited negligible phenotypic and genotypic variances (0.01 and 0.00 respectively) with high heritability (70.43) and low genetic advance (6.01) and moderate GA as per cent mean (17.21). High PCV (21.01 %) and moderate GCV (9.96 %) were exhibited for this character. The results are in line with Anitha *et al.,* (2013) [2] and Shaheen *et al.,* (2016) [36].

Plant growth characters

Plant height showed very high phenotypic and genotypic variances (395.68 and 316.62 respectively) coupled with high PCV (21.01 %) and moderate GCV (18.79 %). High estimates of heritability (80.02%), genetic advance (32.79) and GA as per cent of mean (34.63) were observed for this character. The results for the trait plant height are in confirmation with the findings of Samadia *et al.* (2006) [35], Arun *et al.,* (2016) and Shankar *et al.,* (2016) [38].

The character number of primary branches per plant showed with low phenotypic and genotypic variances (1.56 and 1.38 respectively) with high heritability (88.22 %) and low genetic advance (2.27) and high GA as per cent mean (37.68). High PCV (20.73 %) and moderate GCV (19.48 %) were recorded for this character. Similar results are reported by Mehta and Asati (2008) [8], Anitha *et al.,* (2013) [2], Arun *et al.,* (2016) and Shankar *et al.,* (2016) [38]. High phenotypic and genotypic variances (24.15 and 22.62 respectively) with moderate PCV and GCV (10.68 % and 10.34 % respectively) were exhibited for the character days to 50% flowering. High heritability (93.68 %) and low genetic advance (9.48) and high GA as per cent mean (20.61) as indicated the influence on non-additive gene action and considerable influence of environment on expression of this character. The results are comparable with findings of Anitha *et al.,* (2013) [2], Arun *et al.,* (2016) and Shankar *et al.,* (2016) [38]. The observed phenotypic and genotypic variances for number of flowers per cluster were low (0.50 and 0.41 respectively) with high heritability (81.99 %) and low genetic advance (1.19) and GA as per cent mean was high (23.37). The PCV and GCV (13.84 and 12.53 %, respectively) values were moderate for this trait. The results are in comparison with findings of Anjum *et al.,* (2009) [3] and Shankar *et al.,* (2016) [38]. The observed phenotypic and genotypic variances were high for number of clusters per plant (50.01 and 46.77, respectively) with high heritability (93.72 %), genetic advance (13.62) and GA as per cent mean was high (52.15). The PCV and GCV were recorded high (27.07 % and 26.18 %, respectively). The observations are in accordance with the findings of Samadia *et al*., (2006) [35], Kumari and Srivastava (2007) [23] and Asati *et al*., (2008) [8] Ansary and Hazra (2009) [6] and Marcus (2016) [25].

For stigma exertion (%), the estimates of phenotypic and genotypic variances recorded as low (14.10 and 3.53, respectively) with high PCV (22.46) and moderate GCV (11.25) coupled with high heritability (25.07 %), low genetic advance (1.62) and moderate GA as per cent mean (11.60). The results are in accordance to the findings of Kumar *et al.,* (2013) [36], Rohini Kumari (2013) [34] and Umesh *et al.,* (2015) [49]. Per cent fruit set had high phenotypic and genotypic variances (112.95 and 71.25) with high PCV and GCV (27.14 and 21.55 % respectively) along with high heritability (63.08), moderate genetic advance (13.81) and high GA as per cent of mean (35.27). The results are in line with the findings of Ahmed (1987) [1] and Singh *et al.,* (2000) [40] Anitha *et al.,* (2013) [2] Marcus (2016) [25], Shankar *et al.,* (2016) [38].

The character days to first fruit harvest high phenotypic and genotypic variances (47.02 and 42.75) with high heritability (90.98 %), genetic advance was moderate (12.84) and moderate GA as per cent of mean (16.17). The PCV and GCV were low (8.64 and 8.23 % respectively) for this trait. Similar kind of results is reported by Hidayatullah *et al.,* (2008) [16] Anoop *et al.,* (2013) [5], Arun *et al.,* (2016) and Shankar *et al* (2016) [38]. The character days to last fruit harvest are recorded low PCV and GCV (7.25 and 5.88) coupled with high heritability (65.87 %), moderate genetic advance (12.70) and low GA as per cent of mean (9.83). Phenotypic and genotypic variances (87.54 and 57.66, respectively) were recorded high for this trait. These results are in line with the findings of Anoop *et al.,* (2013) [5], Meitei *at al.,* (2014) [28], Arun *et al.,* (2016) and Shankar *et al* (2016) [38].

For number of fruits per cluster, the genotypic and phenotypic coefficient of variation were higher (26.80 and 24.40, respectively) with high heritability (82.86 %), high genetic advance (0.91) and high GA as per cent of mean (45.75). The phenotypic and genotypic variances were recorded low (0.28 and 0.23, respectively) for this trait. Similar results are reported by Joshi *et al.,* (2004) [20], Anjum *et al.,* (2009) [3] and Shankar *et al.,* (2013 and 2016) [37, 38]. The trait number of fruits per plant recorded high phenotypic and genotypic variances (70.53 and 59.07, respectively) with high

heritability (83.76 %), moderate genetic advance (14.49) and high GA as per cent of mean (43.62). The PCV and GCV (25.28 and 23.14 %, respectively) were recorded higher for this trait. These results are in agreement in the findings of Singh (2005) [41], Ranjodh *et al.,* (2005) [33] and Shankar *et al.,* (2013) [37].

With respect to the trait fruit length low phenotypic and genotypic variances (1.49 and 1.43, respectively) with high heritability (0.96 %), low genetic advance (2.42) and high GA as per cent of mean (52.01). High PCV and GCV (26.20 and 21.72 %, respectively) with high heritability and low genetic advance indicating the influence of non additive gene action. The results are in accordance with the findings of Kumar and Thakur (2007) [21], Hidayatullah *et al*., (2008) [16], Singh (2009) [43] Anoop *et al.,* (2013) [5], Umesh *et al.,* (2015) [49], Arun *et al.,* (2016) and Shankar *et al* (2016) [38]. With regard to the trait fruit width moderate PCV and GCV (15.83 and 14.86 %, respectively) were recorded along with high heritability (88.16), low genetic advance (1.36) and high GA as per cent of mean (28.75). The results are in the agreement in the findings of Singh (2009) [43], Anoop *et al.,* (2013) [5], Shokat *et al*., (2013) [39], Umesh *et al.,*(2015) [49], Arun *et al.,* (2016) and Shankar *et al* (2016) [38].

The character average fruit weight recorded very high phenotypic and genotypic variances (255.43 and 233.93 %, respectively) coupled with high heritability (91.58 %), high genetic advance (30.15) and high GA as per cent of mean (54.92). for this character PCV and GCV (29.11 and 27.86 % respectively) were recorded higher indicating the existence of wider genetic variability. High heritability coupled with high genetic advance as per cent of mean indicated the importance of additive gene action. The results are in line with the findings of Anoop *et al.,* (2013) [5], Sunil *et al.,* (2013) [46], Osekita and Ademiluyi (2014) [30], Umesh *et al.,* (2015) [49], Arun *et al.,* (2016) and Shankar *et al* (2016) [38].

Average fruit yield per plant recorded very low phenotypic and genotypic variances (0.28 and 0.24 %, respectively) but high PCV and GCV (30.02 and 27.85 % respectively) along with high heritability (86.06 %), low genetic advance (0.94) and high GA as per cent of mean (53.23). The results are in accordance with the findings of Ranjodh *et al*., (2005) [33], Anoop *et al.,* (2013) [5], Meena and Bahadur (2014), Umesh *et al.,* (2015) [49], Arun *et al.,* (2016) and Shankar *et al* (2016) [38].

Number of seeds per fruit exhibited low phenotypic and genotypic variances (9.83 and 4.07 %, respectively) and also low PCV and GCV (8.89 and 5.72 % respectively) coupled with high heritability (41.36 %), low genetic advance (2.67) and low GA as per cent of mean (7.58). The results are closely supported by Ranjodh *et al.,* (2005) [33] and Surender Kumar *et al.,* (2013) [47].

Quality characters

Number of locules per fruit was recorded low phenotypic and genotypic variances (0.41 and 0.35 %, respectively) but moderate PCV and GCV (19.08 and 17.74 % respectively), high heritability (86.42 %), low genetic advance (1.13) and high GA as per cent of mean (33.98). The results are similar to the findings of Anoop *et al.,* (2013) [5], Surender Kumar *et al.,* (2013) [47] and Shankar *et al.,* (2013) [37].

The trait Ascorbic acid exhibited low phenotypic and genotypic variances (7.43 and 5.81 %, respectively) with moderate PCV and GCV (13.32 and 11.78 % respectively), high heritability (78.22 %), low genetic advance (4.39) and high GA as per cent of mean (21.47) which are under the influence of additive genes. The results are in line with Kumar *et al.,* (2006), Anitha *et al.,* (2013) [2], Shankar *et al.,* (2013) [37], Arun *et al.,* (2016) and Shankar *et al.,* (2016) [38]. Total soluble solids showed low phenotypic and genotypic variances (0.34 and 0.25 %, respectively) with moderate PCV (11.65 %) and low GCV (9.95 %), high heritability (72.91 %), low genetic advance (0.88) and moderate GA as per cent of mean (17.50) which are influenced of additive genes. The results are in consonance with the findings of Arun and Veeraraghavatham *et al.,* (2005), Kumar and Thakur (2007) [21] Anitha *et al.,* (2013) [2], Shankar *et al.,* (2013) [37], Arun *et al.,* (2016) and Shankar *et al.,* (2016) [38].

Lycopene content exhibited low phenotypic and genotypic variances (0.88 and 0.69 %, respectively) with moderate PCV and GCV (16.02 % and 14.15 %, respectively), high heritability (77.97 %), low genetic advance (1.51) and high GA as per cent of mean (25.73) which are in agreement with the findings of Kumar *et al.* (2006), Anitha *et al.,* (2013) [2], Shankar *et al.,*(2013) [37], Arun *et al*.,(2016) and Shankar *et al.,* (2016) [38]. Stomatal diffusive resistance showed low phenotypic and genotypic variances (4.56 and 4.03 %, respectively) with high PCV and GCV (32.57 % and 30.60 %, respectively) with high heritability (88.27 %), low genetic advance (3.88) and high GA as per cent of mean (59.21). The results are in close conformity to the findings Anitha *et al.,* (2013) [2], Surender Kumar *et al.,* (2013) [47] and Ankitha Chandola *et al.,* (2015).

Relative water content exhibited high phenotypic and genotypic variances (89.46 and 86.63 %, respectively) with high PCV and GCV (21.39 % and 21.05 %, respectively) with high heritability (96.84 %), moderate genetic advance (18.87) and high GA as per cent of mean (42.68). The results are in line with findings of Anitha *et al.,* (2013) [2] and Ankitha Chandola *et al.,* (2015). Chlorophyll content recorded low phenotypic and genotypic variances (0.13 and 0.12 %, respectively) with high PCV and GCV (35.89 % and 34.93 %, respectively) with high heritability (94.74 %), and low genetic advance (0.70) and high GA as per cent of mean (70.05). The findings are in accordance Anitha *et al.,* (2013) [2], Surender Kumar *et al.,* (2013) [47] and Ankitha Chandola *et al.,* (2015) [4].

High PCV and GCV estimates were recorded for plant height, number of primary branches, number of clusters per plant, fruit set per cent, number of fruits per plant, number of fruit per cluster, fruit length, average fruit weight, fruit yield per plant, Stomatal diffusive resistance, Relative water content and chlorophyll content indicating the existence of wider genetic variability for these genotypes under study. On the other side, PCV and GCV estimates were moderate to low for traits *viz.,* root length, days to fifty per cent flowering, days to first fruit harvest, days to last fruit harvest, fruit width Number of seeds per fruit, number of locules per fruit, ascorbic acid, total soluble solids and lycopene content suggesting moderate to narrow range of genetic variability.

High heritability coupled with high genetic advance as per cent of mean indicates operation of additive gene action which was observed in characters plant height, root to shoot ratio, number of primary branches per plant, number of flowers per cluster, number of clusters per plant, fruit set (%), number of fruits per cluster, number of fruits per plant, fruit length, fruit width, average fruit weight, fruit yield per plant, number of locules per fruit, ascorbic acid, lycopene content, stomatal diffusive resistance, relative water content and chlorophyll content. Hence, directional selection could be effective for desired genetic improvement. Moderate to low genetic advance root length, stigma exertion (%), days to first fruit harvest, days to last fruit harvest, number of seeds per

fruit and total soluble solids suggests the action of both additive and non-additive genes and favorable influence of environment in the expression.

Therefore, the breeder should adopt suitable breeding methodology to utilize both additive and non-additive gene effects simultaneously, since varietal and hybrid development will go a long way in the breeding programmes.

Table 1: Estimates of variability, heritability and genetic advance as per cent of mean for twenty five characters in tomato.

S. No.	Character	Range		Mean	Variance		PCV (%)	GCV (%)	h^2 (%)	Genetic Advance	GA % of mean
		Min.	Max.		Phenotypic	Genotypic					
1	Plant height (cm)	64.42	129.73	94.69	395.68	316.62	21.01	18.79	80.02	32.79	34.63
2	Root length (cm)	25.62	39.72	34.93	17.17	12.09	11.86	9.96	70.43	6.01	17.21
3	Root to shoot ratio	0.29	0.54	0.38	0.01	0.00	20.30	16.96	69.87	0.11	29.21
4	No. of primary branches	3.47	8.00	6.03	1.56	1.38	20.73	19.48	88.22	2.27	37.68
5	Days to 50% flowering	37.00	52.33	46.02	24.15	22.62	10.68	10.34	93.68	9.48	20.61
6	No. of flowers per cluster	4.00	6.80	5.11	0.50	0.41	13.84	12.53	81.98	1.19	23.37
7	No. of clusters per plant	18.27	40.00	26.13	50.01	46.77	27.07	26.18	93.52	13.62	52.15
8	Stigma exertion (%)	10.87	21.22	16.71	14.10	3.53	22.46	11.25	25.07	1.94	11.60
9	Fruit set (%)	22.35	60.33	39.16	112.95	71.25	27.14	21.55	63.08	13.81	35.27
10	Days to first fruit harvest	65.00	92.67	79.40	47.02	42.75	8.64	8.23	90.91	12.84	16.17
11	Days to last fruit harvest	114.67	141.33	129.13	87.54	57.66	7.25	5.88	65.87	12.70	9.83
12	No. of fruits per cluster	1.20	3.40	1.98	0.28	0.23	26.80	24.40	82.86	0.91	45.75
13	No. of fruits per plant	21.10	54.40	33.22	70.53	59.07	25.28	23.14	83.76	14.49	43.62
14	Fruit length (cm)	2.82	7.09	4.65	1.49	1.43	26.20	25.72	96.36	2.42	52.01
15	Fruit width (cm)	3.06	5.73	4.75	0.56	0.50	15.83	14.86	88.16	1.36	28.75
16	Average fruit weight (g)	25.57	84.41	54.90	255.43	233.93	29.11	27.86	91.58	30.15	54.92
17	Fruit yield per plant (kg)	1.06	2.72	1.77	0.28	0.24	30.02	27.85	86.06	0.94	53.23
18	No. of seeds per fruit	32.33	41.47	35.26	9.83	4.07	8.89	5.72	41.36	2.67	7.58
19	No. of locules per fruit	2.47	4.33	3.34	0.41	0.35	19.08	17.74	86.42	1.13	33.98
20	Ascorbic acid (mg/100 g)	16.75	25.88	20.46	7.43	5.81	13.32	11.78	78.22	4.39	21.47
21	Total soluble solids (°Brix)	4.10	6.57	5.04	0.34	0.25	11.65	9.95	72.91	0.88	17.50
22	Lycopene content (mg/100 g)	4.53	8.10	5.85	0.88	0.69	16.02	14.15	77.97	1.51	25.73
23	Stomatal diffusive resistance (sec/cm)	3.73	9.34	6.56	4.56	4.03	32.57	30.60	88.27	3.88	59.21
24	Relative water content (%)	31.10	62.79	44.21	89.46	86.63	21.39	21.05	96.84	18.87	42.68
25	Chlorophyll content (%)	0.55	1.64	1.00	0.13	0.12	35.89	34.93	94.74	0.70	70.05

PCV and GCV: Phenotypic and genotypic coefficient of variation, h2: Heritability in broad sense, GA: Genetic Advance

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