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Short communication

Variability and association studies in tomato germplasm under high-temperature arid region

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ABSTRACT

Genetic variability and correlation studies were carried out for 12 traits in 23 genotypes of tomato grown during spring-summer of 2009 under hot, arid agro-climatic conditions. Genetic variability, heritability and expected genetic advance revealed significant differences for all the traits studied. PCV and GCV were high for fruit weight, number of fruits per plant, plant height and fruit yield per plant. High heritability with high genetic advance as percentage of mean was observed for yield per plant (93.2%) as also for average fruit weight (92.8%), number of fruits per plant (73.4%) and plant height (50.1%) indicating the role of additive gene effects and for effectiveness of selecting for these traits. Correlation studies revealed that fruit yield had significant positive correlation with fruit weight, fruit length, fruit diameter and number of fruits per plant, both at the genotypic and phenotypic levels, indicating mutual association of these traits. Negative correlation of days to flowering and days to first harvest on yield per plant suggested indirect selection for earliness for yield improvement.

Key words: Tomato, arid environment, germplasm, variability

Tomato is one of the most popular vegetables grown worldwide with production of 126.24 million tonnes. In India, it occupies an area of 0.54 million ha with production of 8.85 million tonnes and average yield of 16.39 t/ha (FAO, 2007). Plant growth characteristics range from indeterminate to highly determinate types. Branches in the indeterminate types keep growing and producing fruits until adverse temperatures kill the plant. Earlier, tomato cultivation was season-bound. Production scenario has changed in the last few years. Nowadays, tomatoes are grown round the year. However, in the North-Western parts of hot, arid regions of India, tomato production and productivity is limited by various biotic and abiotic stresses. In the recent past, despite extreme temperature regimes prevalent and environmental stresses, tomato cultivation has been gaining localized popularity. The main reasons are remunerative prices, availability of hybrid seeds from the private sector to growers, and exploitation of water sources by resourceful farmers. Yield potential is very low due to extremes of environmental in the hot, arid region of Western Rajasthan, thereby upsetting economics of the crop both ways, i.e., low market-price of the produce due to glut, and non-realization of full potential of hybrids owing to environmental susceptibility. In tomato, when the ambient temperature exceeds 35°C, seed germination, seedling and vegetative growth, flowering, fruit set and fruit ripening are adversely affected (Miller *et al*, 2001). In this part of the country, tomato does not set fruit at high temperature and ripening is greatly affected by extremes of high and low temperatures. This warrants development of genotypes for environmentally stressed arid areas, for extended crop-harvest period (Samadia, 2006). Heat tolerance is generally defined as the ability of a plant to grow and produce economic yield under high temperatures. Saeed *et al* (2007) suggested that a genotype, that produces better yields under high temperature conditions, is heat tolerant. Germplasm is considered as a reservoir of variability for various traits (Vavilov, 1951). Genetic variability is the first step in plant breeding for crop improvement readily available in the germplasm. Large diversity for various characters exists is in tomato germplasm but potential variability for marketable fruit production under hot, arid environment is very limited. Fruit set and development of colour (lycopene production) under high temperatures with maximum 48°C and minimum 30°C and mean temperature >37°C during fruit harvest period (April and May) in the summer season crop, are major breeding objectives for hot agro-climatic conditions.

The experimental material comprised 23 genotypes of tomato including 14 germplasm lines collected from arid and semi-arid regions. Five progeny lines of selections too were included. The experimental material was grown in randomized block design with three replications, under field conditions in the summer of 2009 at Central Institute for Arid Horticulture, Bikaner. The climate of this eco sub-region is very hot, with dry summers and chilling winters. The material was sown in January in a nursery, and transplanted after 35 days in furrows 20-25cm deep and 10m long, in rows at 60 x 45cm plant spacing and accommodating 22 plants of each genotype in every replication. The crop stood in the field for four months (February 22 to June 20) as a spring-summer crop for evaluation and tomato lines were characterized under hot arid conditions. Observations were recorded on five competitive plants in respect of twelve horticultural traits, namely, plant height, number of branches, days to flowering, days to first harvest, number of fruits per plant, fruit weight, fruit length, fruit diameter, number of locules per fruit, pericarp thickness, Total Soluble Solids (TSS) and fruit yield per plant. Observations were also recorded on growth habit (determinate/indeterminate), number of flowers per cluster, per cent fruit-set under varying temperature conditions, and fruit colour development (lycopene). During April – June, maximum day temperature was > 40^{o}C, except for six days. To assess yield potential of the genotypes, fruits harvested per plant during the 60 days of harvest period (15th April-15th June) were accounted for. Data were analyzed using standard procedures of Gomez and Gomez (1984) and statistical package INDOSTAT Version 8.5. Genotypic and phenotypic co-efficient of variation, heritability (in a broad sense) and genetic advance were calculated following Burton and de Vane (1953).

Data pertaining to growth and yield attributes of 23 tomato genotypes are presented in Table 1. Mean, range and coefficient of variation of 12 characters of the 23 genotypes is presented in Table 2. Analysis of Variance revealed a wide range of variability and highly significant differences among the tomato lines for all the characters studied (Tables 1 and 2). However, absolute variability among various characters cannot form the criteria for assigning a specific character as showing the highest degree of variability. Genotypic and phenotypic coefficients of variation (GCV and PCV), expressed as percentage, were high for fruit weight, plant height, number of fruits per plant, and fruit yield per plant; these were moderate for days to flowering, fruit length, fruit diameter, number of branches per plant, number of locules per fruit, pericarp thickness and TSS. GCV which indicates the extent of genetic variability in a population, ranged from 3.81% in days to first harvest, to 45.61% in fruit weight results on yield and component characters are in accordance with Sharma *et al* (2009) and Satesh *et al* (2007). GCV estimates were considerably high for yield-component characters such as fruit weight, number of fruits per plant and yield per plant. These, thus, offer a better scope for improvement through selection. Differences in magnitude of GCV and PCV were found to be very low (Table 2) indicating little influence of environmental factors on expression of the traits observed. In such a situation, selection can be effective on the basis of phenotype alone. Similar projections have been made by Samadia *et al* (2006) in tomato. Two lines, namely, SM2 L1 P9 and SM2 L2 P3, were found to have the best potential for yield per plant (5.15 kg and 4.46 kg, respectively). These lines were also superior in terms of red ripened quality fruits. Of the 23 lines evaluated, 12 were indeterminate in growth habit, four lines semi-determinate and seven determinate. Only five lines, viz., KSB-54, KSB-76, SM2 L1 P9, SM2 L2 P3 and SM2 L8 P5, developed fully-red fruit under high temperature (maximum day temperature > 42^{o}C). Highest fruit weight was observed in SM2 L1 P9 (95.83g), followed by SM2 L8 P5 (80.40g). Maximum pericarp thickness was observed in SM2 L1 P9. Pooled data on average number of fruit/plant showed maximum number fruits per plant in KSB-54 (102.9), followed by KSB-57 (93.8); however both these lines were indeterminate type, bearing small-sized fruits and failed to develop red fruits in of May and June. All determinate type genotypes, except SM2 L1 P9, stopped fruit-set by 10th May (when maximum day temperature exceeded 45^{o}C). Three lines, KSB-54, KSB-57 and SM2 L1 P9, set fruit at high temperatures in the month of May. In the second fortnight of June, indeterminate lines too stopped growing; fruit development was inhibited, followed by their entry into the senescence phase.

Estimates for heritability are a predictive instrument in expressing reliability of the phenotypic value. It, therefore, helps the breeder select for a particular trait when its heritability is high. In the present study, all the traits exhibited high heritability. Highest broad-sense heritability (e” 98%) was recorded for fruit weight, fruit length, fruit diameter, number of fruits/plant, plant height, number of locules in the trait and TSS (^{o}Brix). In the present study, fruit weight and yield per plant were seen to be highly variable. Based on variability and heritability estimates, it is concluded that improvement by direct or indirect selection in tomato is possible for traits like fruit weight, number of fruits per plant/ per cluster, and yield per plant. Genetic advance also showed a pattern similar to that of heritability in broad-sense. Genetic advance, as per cent mean, was higher for a trait of much interest to the breeder, that is, yield per plant (93.2%) as also for average fruit weight (92.8%), number of fruits per plant (73.4%) and plant height (50.1%). Genetic advance (as per cent of mean) was the least for days to first harvest (7.5%), followed by days to flowering (17.6). In general, traits that show high heritability, with high genetic advance as per cent of mean, are genetically controlled by additive gene action, indicating easy selection and improvement in the breeding lines; Whereas, traits showing high heritability, with moderate or low genetic advance as per cent of mean, can be improved by inter-mating superior genotypes, and subsequent selection in the segregating population. These results corroborate the view of Ara *et al* (2009). High genotypic and phenotypic coefficients of variation, heritability and genetic advance as percentage of mean for number of fruits/plant, yield per plant and average fruit weight suggests their importance in selection for tomato improvement. Phookan *et al* (1998) and Mariame *et al* (2003) also observed similar trends in their study on 29 genotypes of tomato under summer conditions. Figure 1 shows average linkage dendrogram of standardized Euclidean distance. The more distant genotypes, falling in different clusters are expected to be better parents in a hybridization programme.

Data on genotypic and phenotypic co-efficient of variation in traits is presented in Table 2. Phenotypic co-efficients of correlation, in general, were higher in magnitude than corresponding genotypic ones thereby, suggesting, an inherent association among the various characters studied. Similar observations were made by Singh (2005) and Samadia *et al* (2006). Days to flowering showed significant negative-correlation with fruit weight, fruit length, fruit

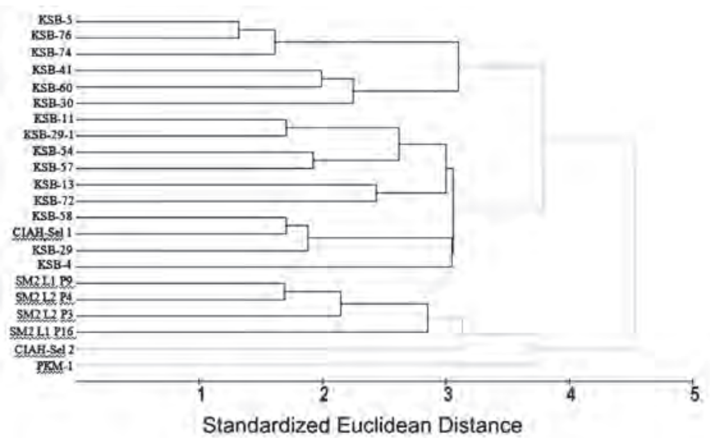

Fig 1. Average linkage dendrogram of 23 tomato genotypes. Vertical distances are arbitrary, while, horizontal distances indicate linkage between genotypes

Table 1. Performance of tomato lines *per-se* under hot, arid agro-climate

Line	DF	DH	FW	FL	FD	F/P	PH	BR/P	NL/F	PCTH	TSS	Y/P
KSB-4	26.3	59.7	45.10	2.91	3.60	31.7	78.1	6.74	3.8	3.8	5.87	1.428
KSB-5	21.0	58.3	25.05	3.21	4.23	44.1	107.7	8.31	3.1	3.0	7.83	1.099
KSB-11	21.7	57.0	23.53	2.84	3.79	79.8	149.8	10.89	3.6	2.8	6.17	1.879
KSB-13	21.3	54.7	35.20	3.21	3.92	74.3	147.9	9.62	3.2	3.2	8.00	2.616
KSB-29	22.0	59.0	32.83	3.09	4.31	55.0	132.5	8.59	3.4	3.0	6.73	1.805
KSB-30	22.7	57.7	35.63	3.20	4.25	86.7	110.2	9.67	3.0	3.1	7.36	3.093
KSB-41	20.3	60.6	41.57	3.13	4.21	76.6	123.1	8.26	3.2	3.7	6.83	3.186
KSB-54	20.0	55.3	31.30	3.14	3.93	102.9	132.7	8.62	4.0	3.4	6.47	3.220
KSB-57	20.3	53.3	32.13	2.54	3.19	93.8	123.9	7.40	4.1	3.0	6.17	3.015
KSB-58	22.7	57.7	36.04	3.22	3.58	40.4	132.8	7.65	3.5	3.1	5.90	1.453
KSB-60	20.3	57.3	47.67	3.07	3.97	70.9	89.3	8.00	3.9	3.8	7.00	3.358
KSB-72	21.0	55.3	38.57	3.34	4.22	55.6	144.8	6.56	3.3	3.3	7.33	2.140
KSB-74	21.7	58.3	20.44	2.98	3.67	41.8	122.3	7.28	3.0	2.9	7.10	0.854
KSB-76	21.7	60.0	26.97	3.26	3.80	40.8	121.5	9.31	3.2	3.4	7.53	1.100
PKM-1	20.3	53.3	67.60	3.71	4.82	38.6	89.8	6.14	4.2	3.8	6.20	2.610
KSB-29-1	21.7	57.7	34.50	3.14	4.29	66.7	117.0	8.17	3.4	3.5	7.27	2.303
CIAH-SEL 1	21.3	58.0	32.17	3.20	4.13	82.8	139.7	9.17	3.6	3.6	5.87	2.662
CIAH-SEL 2	22.3	58.7	21.10	2.89	3.42	69.4	107.1	6.44	3.7	3.0	6.03	1.464
SM2 L1 P9	19.0	59.0	95.83	4.94	6.08	53.7	80.8	5.61	5.2	5.3	7.50	5.152
SM2 L1 P16	18.3	59.6	66.93	4.32	5.45	39.6	61.2	5.56	4.4	5.0	7.37	2.649
SM2 L2 P3	18.3	59.3	53.37	4.38	5.38	83.7	71.2	5.60	4.5	4.9	8.07	4.462
SM2 L2 P4	18.6	60.3	45.64	3.65	4.81	38.5	81.3	5.61	4.3	4.8	7.83	3.363
SM2 L8 P5	17.3	61.7	80.40	4.74	5.79	40.7	73.7	6.31	4.3	5.1	7.37	3.269
CD at (*P=0.05*)	0.89	1.15	2.51	0.14	0.18	3.56	5.03	0.51	0.15	0.19	0.16	0.195

DF= days to flowering, DHR= days to harvest, FW= fruit weight (g), FL= fruit length (cm), FD= fruit diameter (cm), F/P= number of fruits per plant, PH= plant height (cm), BR/P= number of branches per plant, NL/F= number of locules per fruit, PCTH= pericarp thickness (mm), TSS= Total Soluble Solids (°Brix), Y/P= yield per plant (kg)

Table 2. Analysis of Variance (ANOVA) for yield and yield-contributing traits in tomato

Trait	Grand mean	Range	SE	Co-efficient of variation		Heritability % (H)	Genetic advance	
				GCV	PCV		GA	GA % of mean
DF	20.84	17-27	0.689	8.89	9.27	92	3.66	17.6
DH	57.93	53-62	0.681	3.81	3.99	91	4.34	7.5
FW	42.14	19.2 - 97.6	4.964	45.61	45.93	99	39.53	92.8
FL	3.40	2.45 - 5.02	0.165	18.25	18.42	98	1.26	37.2
FD	4.30	3.12 - 6.2	0.198	17.65	17.82	99	1.55	36.1
F/ P	59.61	30.5 -107.3	4.827	35.83	36.05	98	44.00	73.4
PH	110.3	59.8 -154.3	5.929	24.47	24.63	98	55.60	50.1
BR/P	7.63	5.2 - 11.3	0.518	18.86	20.26	86	3.05	40.1
NL/F	3.72	3.40 - 5.20	0.432	15.82	17.50	98	0.55	9.2
PCTH	3.63	2.8	5.3	15.64	16.84	93	1.2	28.3
TSS	6.93	5.8 - 8.2	0.154	10.47	10.56	98	1.48	21.4
Y/P	2.438	0.790 - 5.17	0.276	45.48	47.74	91	2.26	93.2

DF= days to flowering, FW= fruit weight (g), FL= fruit length (cm), FD= fruit diameter (cm), F/P= number of fruits per plant, PH= plant height (cm), BR/P= number of branches per plant, NL/F= number of locules per fruit, PCTH= pericarp thickness (mm), TSS= Total Soluble Solids (°Brix), Y/P= yield per plant (kg)

Table 3. Correlation coefficient for 12 traits in tomato lines

	DF	DH	FW	FL	FD	F/P	PH	BR/P	NL/F	PCTH	TSS	Y/P
DF		-0.115	-0.523**	-0.267*	-0.277*	-0.095	0.366**	0.374**	0.152	0.121	-0.502**	-0.522**
DH			0.202	-0.280*	-0.372**	-0.402**	-0.146	-0.211	0.128	0.282*	0.163	-0.263*
FW				0.878**	0.863**	0.201	-0.187	-0.615**	0.223*	0.624**	0.237*	0.686**
FL					0.958**	-0.250*	-0.149	-.0291*	0.168	0.524**	0.214	0.627**
FD						-0.178	-0.206	-0.332**	0.147	0.554**	0.234*	0.628**
F/P							0.307*	0.285*	0.115	-0.283*	-0.424**	0.519
PH								0.738**	-0.173	-0.153	-0.181	-0.123
BR/P									-0.182	-0.193	-0.166	-0.203
NL/F										-.0201	-0.208	0.154
PCTH											0.283*	0.546**
TSS												0.156
Y/P												

*, ** significant correlation at 5% and 1%, respectively
DF= days to flowering, DHR= days to harvest, FW= fruit weight (g), FL= fruit length (cm), FD= fruit diameter (cm), F/P= number of fruits per plant, PH= plant height (cm), BR/P= number of branches per plant, NL/F= number of locules per fruit, PCTH= pericarp thickness (mm), TSS= Total Soluble Solids (°Brix), Y/P= yield per plant (kg)

diameter, TSS, and fruit yield per plant. This indicates that under high temperature conditions, early-flowering lines gave superior performance with respect to fruit yield and quality. Similarly, days-to-first-harvest was also negatively associated with fruit length, fruit diameter and yield per plant suggesting, that, early harvest is preferred for indirect selection for higher yield and larger fruit size under high temperature conditions. Fruit weight showed significant positive-correlation with fruit length, fruit diameter, TSS and yield per plant, whereas it showed negative correlation with number of primary branches. In this study, indeterminate-type lines having higher number of branches had smaller fruits. Fruit length showed significant positive-correlation with fruit diameter and yield per plant, whereas, it showed significant negative-correlation with number of fruits and branches per plant. Fruit diameter also showed positive correlation with TSS and yield per plant while showing negative correlation with number of branches/plant. Number of fruits/plant showed positive correlation with plant height, number of branches per plant and yield, whereas it showed negative correlation TSS and pericarp thickness. Pericarp thickness showed significant positive-correlation with fruit weight, fruit length, fruit width and yield per plant. A strong association of number of branches with days to flowering and plant height was noticed; however, it had significant negative-association with fruit weight. Hence, selection for early flowering and higher fruit weight and number of fruits per plant can indirectly help improve fruit yield per plant. Similar results were noticed by Mohanty (2002) and Singh *et al* (2002).

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