Genetic Variation, Heritability and Interrelationships of Some Important Characteristics in Syrian Tomato Landraces (*Solanum lycopersicum* L.)

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Abstract: Fourteen tomato landraces provided by Bank of Plant Genetic Resources were evaluated under irrigated field conditions in two contrasting environments. The objectives were to estimate genotypic (GCV) and phenotypic (PCV) coefficients of variation, broad sense heritability (h^2) and genetic advance (GA) using the variance components method based on the combined analysis over locations and the variance analyses for each location for various characteristics and to determine the interrelationships among these characteristics. Because of high genotype-environment (G × E) interactions, estimates of GCV, h^2 and GA for most of the characteristics using combined analysis were generally lower than the estimates computed from the variance analyses made separately for each location. Based on the results of the individual and combined analysis of variance, high estimates of GCV, h^2 and GA (as % of the mean) were observed for number of fruits per plant, number of fruits per cluster, average fruit weight and fruit yield per plant, indicating the predominance of additive gene effects and reflecting the effectiveness of selection in the present germplasm of tomato improvement. Average fruit weight had positive and highly significant genotypic correlation with fruit yield per plant, suggesting the possibility for improvement of tomato landraces by indirect selection for this characteristic.

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1. Introduction

Landraces are often heterogeneous and composed of different genotypes which are mostly homozygous and usually exhibit considerable genetic variation for quantitative and qualitative characteristics (Frankel et al., 1995). The success of a breeding program depends upon the extent and magnitude of variability existing in the germplasm. The expression of a characteristic is the result of genetic constitution of a strain and the influence of environment on it, hence some strains can perform well under specific environmental conditions while others may not. The environmental conditions have a significant effect on the expression of yield and other quantitative characteristics. So, the evaluation of genotypes over different environments provide information regarding the relative magnitude of the genotypic and phenotypic variability and the extent of genetic advance that can be made by studying the experimental material under more than one environment and which had been earlier emphasized by Comstock and Robinson (1952); Johnson et al. (1955); Nei and Saykudd (1957); Athwal and Singh (1966).

The present study is a scientific attempt to understand the genetic behavior and relationships of different characteristics. Therefore, information gained will be useful in formulating selection criteria for tomato improvement.

2. Materials and Methods:

Fourteen tomato landraces were used for this study. These landraces selfed for several generations, were supplied by Bank of Plant Genetic Resources, General Commission of Scientific Agricultural Research ***viz.***, 20060, 20061, 20170, 20198, 20292, 20303, 20335, 20339, 20364, 20402, 20660, 20740, 20909 and 20992.

The field experiments were carried out at Jellein Agricultural Research Station (Semi-arid, 32º45' N, 35º39' E, ca 440 meters above sea level and 360 mm long-term annual average of precipitation) and Al-Somakiat Agricultural Research Station (Arid, 33º25' N, 36º25' E, ca 825 meters above sea level and 165 mm long-term annual average of precipitation) which represent two contrasting environments. The experiments were laid out in a randomized complete block design with three replications and the seeds of 14 different tomato landraces were sown in seedling trays on 1 April, 2012 and after 45 days after sowing, the transplantation of seedlings to the permanent land was done. Each genotype was accommodated in single row of 8.8 m length with distance 0.4 m between plants and 1.8 m between rows. All pre- and post-stand establishment management such as land preparation, cultivation, weeding, fertilization and drip irrigation was made as required.

Data were collected for the following nine quantitative characteristics: days to first flowering,

days to maturity, plant height (cm), number of primary branches per plant, number of leaves up to first cluster, number of fruits per plant, number of fruits per cluster, average fruit weight (g) and fruit yield per plant (kg). Data on days to first flowering and maturity were recorded on plot basis, whereas the other characteristics computed from the ten central individual plants within each plot (i.e., row). Variance components were estimated according to Nadarajan and Gunasekaran (2005). Genotypic (GCV) and phenotypic coefficients of variation (PCV), broad sense heritability (h^2), genetic advance (GA), genetic advance in percentage of mean (GA %) and genotypic correlation coefficients (r_g) were estimated as suggested by Singh and Chaudhary (1985).

3. Results:

For each of the characteristics evaluated, the descriptive statistics including the extreme genotype mean values and the means with their standard deviations obtained on the basis of averages of data at each of the two test locations have been presented in **Table 1** which shows highly significant differences among the genotypes for all the characteristics under study.

Table 1. Ranges, means, standard deviations and F values of 14 tomato genotypes for 9 characteristics at the two test locations.

Characteristic	Location	Min.	Max.	Mean	S.D. (±)	F-value for genotypes	L.D.S. $_{0.05}$
Days to first flowering	*Jellein*	50.00	61.00	57.00	3.14	3.16**	5.27
	Al-Somakiat	70.00	75.00	73.00	1.26	3.16**	2.11
Days to maturity	*Jellein*	105.00	113.00	110.00	1.66	6.16**	2.78
	Al-Somakiat	105.00	123.00	115.00	0.47	402**	0.79
Plant height (cm)	*Jellein*	78.00	113.67	92.50	4.26	24.30**	7.16
	Al-Somakiat	54.67	139.67	85.38	2.34	408**	3.93
No. of primary branches per plant	*Jellein*	3.60	7.33	5.16	0.35	41.59**	0.59
	Al-Somakiat	3.33	5.67	4.07	0.41	7.13**	0.69
No. of leaves up to first cluster	*Jellein*	5.30	11.27	8.03	0.25	140.46**	0.41
	Al-Somakiat	5.67	8.67	7.05	0.63	5.17**	1.06
No. of fruits per plant	*Jellein*	21.00	225.00	74.68	2.52	2391**	4.24
	Al-Somakiat	11.00	124.33	28.98	0.91	3326**	1.53
No. of fruits per cluster	*Jellein*	2.00	9.43	3.89	0.29	175**	0.49
	Al-Somakiat	3.00	12.33	4.91	0.55	58.75**	0.93
Average fruit weight (g)	*Jellein*	9.41	105.28	63.57	4.32	179**	7.25
	Al-Somakiat	11.00	185.33	91.86	6.38	252.97**	10.71
Fruit yield per plant (kg)	*Jellein*	1.47	4.35	2.79	0.08	350**	0.14
	Al-Somakiat	0.57	2.70	1.60	0.04	992.87**	0.07

Table 2. Estimates of mean squares, genotypic (GCV) and phenotypic coefficients of variation (PCV), broad sense heritability (h^2), genetic advance (GA) and genetic advance as a percentage of mean (GA %) for 9 characteristics of 14 genotypes of tomato, combined across two locations.

Characteristic	Mean squares of			GCV	PCV	h^2	GA	GA
	Genotypes	G x L	Error	(%)	(%)			(%)
Days to first flowering	24.95**	11.22	5.72	2.32	3.02	59.48	2.05	3.16
Days to maturity	109.58**	30.09**	6.78	3.24	3.67	78.08	5.66	5.04
Plant height	1999.45**	678.32**	11.83	16.69	19.35	74.34	22.51	25.32
No. of primary branches per plant	4.45**	1.82**	0.15	14.29	17.53	66.67	0.95	20.57
No. of leaves up to first cluster	7.81**	2.76**	0.23	12.20	14.32	72.41	1.38	18.25
No. of fruits per plant	14793.75**	3248.2**	18.15	84.64	92.24	84.17	70.83	136.65
No. of fruits per cluster	29.56**	3.44**	0.20	47.50	49.55	91.77	3.52	80.02
Average fruit weight	11559.23**	2085.9**	29.70	51.13	54.77	87.12	65.27	83.99
Fruit yield per plant	3.31**	0.73**	0.005	30.00	32.73	84.15	1.07	48.64

** Significant at the 0.01 probability level.

Estimating of GCV and PCV coefficients of variation, h^2, and GA expected from selecting the superior 10 % of genotypes for each characteristic computed using the variance components based on the combined analysis over the two test locations are shown in **Table 2**. The mean squares from the combined variance analysis over the two locations showed highly significant genetic variation for all the characteristics studied (**Table 2**). Locations and genotypes interacted significantly ($P< 0.01$) for all the characteristics except days to first flowering. GCV and PCV were high (> 20 %) just for number of fruits

per plant (84.64 % , 92.24 %), number of fruits per cluster (47.50 % , 49.55 %), average fruit weight (51.13 % , 54.77 %) and fruit yield per plant (30.00 % , 32.73 %), respectively. Heritability in broad sense was high (> 60 %) for all the characteristics studied except days to first flowering (59.48 %). Genetic advance as percentage of mean was high (> 20 %) for plant height (25.32 %), number of primary branches per plant (20.57 %), number of fruits per plant (136.65 %), number of fruits per cluster (80.02 %), average fruit weight (83.99 %) and fruit yield per plant (48.64 %).

The results of **Table 3** showed, in general, that the magnitudes of GCV, PCV, h^2 and GA % were higher when they were computed based on the results of the variance analyses made separately for each of the two test locations. Moreover, estimates of these genetic parameters were affected by the yield level of the environment. Out of the nine characteristics studied, days to first flowering, number of primary branches per plant, number of leaves up to first cluster and number of fruits per cluster showed relatively higher estimates of GCV, PCV, h^2 and GA (%) at Jellein than at Al-Somakiat location, while the other characteristics showed higher GCV, PCV, h^2 and GA (%) at Al-Somakiat than at Jellein location. Considering the values of GCV, PCV, h^2 and GA (%) simultaneously as the best estimators of the amount of advance expected, number of fruits per plant, number of fruits per cluster, average fruit weight and fruit yield per plant gave the highest values at both locations.

Table 3. Estimates of variance components, genotypic (GCV) and phenotypic coefficients of variation (PCV), broad sense heritability (h^2), genetic advance (GA) and genetic advance as a percentage of mean (GA %) for 9 characteristics of 14 genotypes of tomato at the two test locations.

Characteristic	Location	Source of variance			GCV (%)	PCV (%)	h^2	GA	GA (%)
		V_g	V_e	V_{ph}					
Days to first flowering	*Jellein*	7.11	9.85	16.96	4.71	7.26	41.92	3.04	5.36
	Al-Somakiat	1.14	1.58	2.72	1.46	2.25	41.91	1.22	1.67
Days to maturity	*Jellein*	4.70	2.74	7.44	1.98	2.49	63.17	3.04	2.77
	Al-Somakiat	29.85	0.22	30.07	4.76	4.78	99.27	9.58	8.35
Plant height	*Jellein*	141.25	18.18	159.43	12.85	13.65	88.60	19.70	21.30
	Al-Somakiat	743.45	5.48	748.93	31.94	32.06	99.27	47.82	56.01
No. of primary branches per plant	*Jellein*	1.65	0.12	1.77	25.00	25.78	93.22	2.18	42.29
	Al-Somakiat	0.34	0.17	0.51	14.25	17.69	66.67	0.85	20.89
No. of leaves up to first cluster	*Jellein*	2.82	0.06	2.88	20.92	21.17	97.92	2.93	36.49
	Al-Somakiat	0.55	0.40	0.95	10.50	13.90	57.90	1.00	14.18
No. of fruits per plant	*Jellein*	5086.4	6.39	5092.8	95.50	95.56	99.88	125.4	167.97
	Al-Somakiat	923.6	0.83	924.4	104.9	104.9	99.91	53.46	184.46
No. of fruits per cluster	*Jellein*	4.98	0.09	5.07	57.33	57.84	98.23	3.89	100.00
	Al-Somakiat	5.89	0.31	6.20	49.49	50.71	95.00	4.16	84.73
Average fruit weight	*Jellein*	1106. 7	18.66	1125.3	52.34	52.78	98.34	58.07	91.35
	Al-Somakiat	3421. 9	40.74	3462.6	63.68	64.05	98.82	102.3	111.41
Fruit yield per plant	*Jellein*	0.77	0.01	0.78	31.54	31.54	98.72	1.53	54.80
	Al-Somakiat	0.58	0.002	0.582	47.50	47.50	99.66	1.33	83.32

Genotypic correlation coefficients among the pairs of characteristics studied at Jellein and Al-Somakiat locations are presented in **Table 4**. Days to first flowering at both locations had a negative and highly significant correlation with plant height, number of fruits per plant and number of fruits per cluster, but showed a positive and highly significant correlation with average fruit weight. Days to maturity at both locations was negatively and high significantly associated with plant height, number of primary branches per plant, number of leaves up to first cluster, number of fruits per plant and number of fruits per cluster, but positively with average fruit weight and fruit yield per plant. Plant height exhibited a positive highly significant correlation with number of primary branches per plant, number of fruits per plant and number of fruits per cluster at both locations. Average fruit weight had a negative and highly significant correlation with number of leaves up to first cluster, number of fruits per plant and number of fruits per cluster at the two experimental sites. The correlation of fruit yield per plant with days to maturity and average fruit weight was always positive and significant regardless of the location.

Table 4. Genotypic correlation coefficients (r_g) among the various pairs of 9 tested characteristics in 14 tomato genotypes at the two test locations.

No.	Characteristic	Location	2	3	4	5	6	7	8	9
1	Days to first flowering	*Jellein*	0.301	-0.704**	-0.738**	-0.297	-0.852**	-0.800**	0.530**	0.027
		Al-Somakiat	0.684**	-0.394*	-0.226	-0.772**	-0.760**	-0.811**	0.689**	0.580**
2	Days to maturity	*Jellein*		-0.793**	-0.785**	-0.852**	-0.880**	-0.814**	0.927**	0.505**
		Al-Somakiat		-0.696**	-0.495**	-0.282	-0.514**	-0.415*	0.657**	0.389*
3	Plant height	*Jellein*			0.845**	0.673**	0.847**	0.894**	-0.960**	-0.640**
		Al-Somakiat			0.832**	0.293	0.726**	0.620**	-0.608**	-0.203
4	No. of primary branches per plant	*Jellein*				0.625**	0.821**	0.923**	-0.896**	-0.460**
		Al-Somakiat				0.000	0.755**	0.592**	-0.293	0.182
5	No. of leaves up to first cluster	*Jellein*					0.754**	0.587**	-0.714**	-0.243
		Al-Somakiat					0.586**	0.556**	-0.831**	-0.712**
6	No. of fruits per plant	*Jellein*						0.909**	-0.885**	-0.423*
		Al-Somakiat						0.964**	-0.623**	-0.171
7	No. of fruits per cluster	*Jellein*							-0.915**	-0.556**
		Al-Somakiat							-0.566**	-0.162
8	Average fruit weight	*Jellein*								0.686**
		Al-Somakiat								0.796**
9	Fruit yield per plant	*Jellein*								1.000
		Al-Somakiat								1.000

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

4. Discussion:

The highly significant differences observed among the genotypes evaluated indicates existence of good deal of variability with respect of the nine characteristics assessed and offers ample chances for the genetic improvement of the tomato germplasm. Similar diversity among tomato genotypes was reported by Dar and Sharma (2011), Saeed et al. (2007).

Because of high genotype-environment interactions, estimates of genetic parameters i.e., GCV, PCV, h^2 and GA (%) using combined analysis of variance for most of the characteristics were generally lower than the values computed based on the results of the variance analyses made separately for each of the two test locations. Significant genotype-environment interaction was observed by Mulge and Aravindakumar (2003) for plant height and number of primary branches per plant and by Kalloo et al. (1998) for average fruit weight and fruit yield per plant.

Although, range can provide a preliminary idea about the variability, coefficient of variation is more reliable as it the independent unit of measurement. Also, absolute variation values of different characteristics do not reveal, which of them showing the high variability which could be assessed through standardizing the genotypic and phenotypic variance estimates by obtaining the coefficients of variation. A comparison of GCV and PCV in the present germplasm computed using individual and combined analysis of variance for nine characteristics indicated that the estimates of PCV were generally higher than the corresponding estimates of GCV for all the characteristics. This may be due to involvement of environmental effects and genotype-environment interaction in the expression of characteristic. The high estimates of GCV and PCV for number of fruits per plant, number of fruits per cluster, average fruit weight and fruit yield per plant can be attributed to the predominance of repulsion phase of linkage for these characteristics. Our results confirmed earlier findings of Prema et al. (2011), Ghosh et al. (2010), Pradeepkumar et al., (2001).

The high estimates of GCV, h^2 and GA(%) were observed for number of fruits per plant, number of fruits per cluster, average fruit weight and fruit yield per plant regardless of the location which suggests the predominance of additive gene effects and selection would be useful for the improvement of these characteristics. Similar results have also been reported by Dar and Sharma (2011), Saeed et al. (2007), Mohanty (2003).

Significant and positive association observed between average fruit weight and fruit yield per plant indicated a strong genotypic relationship between them and fruit yield can be increased by simple selection for this characteristic. In addition to, negative and significant correlation was observed between number of fruits per plant and average fruit weight at both locations indicates apparently impossibility to improve number of fruits per plant and average fruit weight simultaneously to ameliorate the fruit yield of tomato and suggests that selection should be practiced for plants owning more number of fruits with optimal weight. These findings were in conformity with the results of Singh et al. (2004), Mohanty (2002).

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