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GENETIC VARIABILITY, HERITABILITY, CHARACTER ASSOCIATION AND PATH ANALYSIS IN F_1 HYBRIDS OF TOMATO

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Twenty-five F_1 hybrids generated from 5×5 diallel crosses were evaluated to study the quantitative genetics of yield and some yield related traits during 2009-10. Worth of room was realized for improvement due to highly significant genetic variations among all traits studied. The highest estimates of genotypic and phenotypic coefficients of variability were recorded for number of fruits per plant while fruit width was the most heritable trait. Plant height, number of fruits per plant and fruit weight revealed significant positive genotypic and phenotypic association along with direct positive effect on fruit yield per plant. It is therefore, recommended that fruit weight, number of fruits per plant and plant height should be given due importance in selection of promising crosses to develop commercial hybrid variety in tomato.
Keywords: Tomato, genetic variability, heritability, path analysis, correlation

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is a self-pollinated diploid species with twelve pairs of chromosomes (2n = 24). It belongs to the *Solanaceae* family with other frugally important crops such as pepper, eggplant and potato. Tomato is a rich source of vitamins (A and C), minerals (Ca, P and Fe) and a strong antioxidant against cancer and heart diseases (Dhaliwal *et al.*, 2003; Anonymous, 2011b). In Pakistan, commonly grown tomato cultivars are pure lines with low yield potential. The average yield of tomato in Pakistan is 10.1 ton per hectare (Anonymous, 2011c) compared to 33.6 ton per hectare of modern agricultural systems of the world (Anonymous, 2011d). Pakistan is insufficient to produce enough tomato seed for local cultivation and imported 85.5 metric tons of quality seed amounting to US$2.45 million during 2009-10 to bridge the gap (Anonymous, 2011a).

Of 950MB of DNA of tomato, about 75% is heterochromatin mainly lacking of genes (Diez and Nues, 2008). Cultivated tomato covers less than 5% of the genetic variation of wild relatives (Ghosh *et al.*, 2010). Due to resilient genetic barriers (self-incompatibility, unilateral incompatibility, embryo rescue etc.) between cultivated and wild species of *Solanum* (Tigchelaar, 1986), the efforts to combine novel genes particularly those owing biotic and abiotic stresses and extended shelf life have met partial success. While heterosis breeding has created a large array of high yielding morphologically different hybrid varieties primarily via interaction of favorable alleles rather than introgression of alien genes from wild species into cultivated background (Acquaah, 2007).

Yield is a complex trait that shows a chain of linear and non-linear associations among yield components with varying degree of effects. Understanding of relationships among these components lead to the choice of elite genotypes, authenticates the benefits of a selection pattern and highlights real-time increase in yield through interrelated characters. Various studies on such aspect had already been conducted using genetic pool viz. cultivars, elite lines, accessions and land races of tomato. However, few studies included hybrids wherein breeders have to restrain essentially on first filial generation with precise and vigorous interactions of heterotic effects. The core objective of the present study was therefore, to estimate the extent of genetic variability, character association and direct & indirect effects between yield and yield contributing traits on F_1 crosses and to set up a selection criterion for the isolation of promising crosses to develop commercial hybrid cultivars.

MATERIALS AND METHODS

Five tomato lines namely, B23, B24, B25, B26 and B27 (salient features given in Table 1) were mated in diallel fashion following Griffing technique (1956). The subsequent 25 genotypes including direct, reciprocal and selfed were evaluated in a field following randomized complete block design with 3 replications during 2009-10 at Nuclear Institute for Agriculture and Biology, Faisalabad, Pakistan. Seedlings of four to six inches height were transplanted in the field keeping plant × plant and bed × bed distance of 50 cm and 1.5 m, respectively. Seven plants of each genotype per replication were grown by applying Nitrogen (N): Phosphorous (P): Potash (K) @ of 90:45:75 kg per acre. One third of N while full dose of P and K was applied at the time of transplanting while remaining N was applied at reproductive stages. Plants were irrigated fortnightly during

Table 1. Salient features of parent genotypes of tomato

Genotype	Growth Habit	Days to maturity	Plant height (cm)	Number of fruits /plant	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Fruit yield /plant (kg)
B23	Determinate	184	76	74	37	4.75	3.81	1.93
B24	Determinate	176	107	62	41	4.98	3.62	1.98
B25	Determinate	189	89	88	41	6.75	3.54	3.09
B26	Determinate	178	121	95	57	4.04	4.97	3.72
B27	Indeterminate	181	126	48	74	4.89	6.12	3.09

winter and weekly during summer. Crop was protected from insect pest and diseases by using recommended insecticide/fungicide. Observations were recorded on five plants for days to maturity, plant height, number of fruit per plant, fruit weight, fruit length, fruit width and fruit yield per plant. Average data were subjected to analysis of variance following Steel *et al.* (1997). Broad sense heritability [$h^2_{(b.s)}$] was estimated according to Lush (1949), Johnson *et al.* (1955) and Hanson *et al.* (1956). Heritability values were categorized as low (<30%), moderate (30-60%) and high (>60%). The expected genetic advance (GA%) on 5% selection intensity was estimated and classified as low (<10%), moderate (10-20%) and high (>20%) following the method given by Lush (1949). Genotypic and phenotypic correlation coefficients were calculated by standard procedures (Johnson *et al.*, 1955; Hanson *et al.*, 1956). Correlation coefficients were further partitioned into components of direct and indirect effects by path analysis (Wright, 1921; Dewey and Lu, 1959).

RESULTS AND DISCUSSION

Analysis of variance revealed highly significant mean squares for all traits (Table 2) that show the existence of genetic variability among the genotypes as reported elsewhere (Noureen *et al*., 2010; Jilani *et al*., 2013). Coefficient of variation (C.V) was less than 20% for each trait indicating the precision in the data recorded (Table 2). A greater phenotypic coefficient of variability (PCOV) was observed than genotypic coefficient of the variation (GCOV) for all the traits (Table 2) which indicated that the apparent variation is not only due to genotypes but also due to the influence of environment. Therefore, selection for such traits sometimes might be misleading. Fruit width, fruit length, plant height, fruit weight, fruit yield per plant and number of fruits per plant had high heritability (Table 2) whereas, high genetic advance was observed for plant height, fruit weight, number of fruits per plant, fruit yield per plant, fruit width and fruit length. According to Johnson *et al.* (1955), heritability estimates along with genetic advance were normally more helpful in predicting the genetic gain under selection therefore, in present study, fruit width, fruit length, plant height, fruit weight, number of fruits per plant and fruit yield per plant were most likely to be influenced by additive gene effects and selection for the improvement of those traits would be effective in early generations (F_2-F_3) for the development of superior genotypes. Days to maturity had high heritability but low genetic advance indicating non-additive gene action (Nadarajan and Gunasekaran, 2005).Moderate heritability for days to maturity indicated favourable influence of environment rather than genotypes consequently, selection of superior genotypes to develop early maturing genotypes would not be rewarding in early generations.

Table 2. Analysis of variance and estimates of genetic parameters in tomato genotypes

Source	d.f	Days to maturity	Plant height (cm)	Number of fruits per plant	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Fruit yield per plant (kg)
Replications	2	20.13	264.74	867.65*	222.66**	0.34**	0.19	0.13
Genotypes	24	105.19**	2661.15**	1781.09**	605.37**	1.07**	1.56**	2.63**
Error	48	18.28	89.94	252.54**	34.05	0.03	0.04	0.26
Mean ± S.E		183±2.5	110±5.5	86±8.7	53±3.7	4.8±0.1	4.4±0.11	3.6±0.3
C.V (%)		2.33	8.63	17.54	11.05	3.75	4.47	14.29
σ^2g		28.97	790.49	518.51	190.44	0.35	0.50	0.79
σ^2p		47.25	880.00	744.05	224.49	0.38	0.55	1.05
GCOV		2.93	25.59	26.60	26.14	12.25	16.03	24.92
PCOV		3.74	27.00	31.85	28.38	12.81	16.64	28.73
h^2(b.s) %		61.00	89.00	70.00	85.00	91.00	93.00	75.00
G.A(% of mean)		4.7	49.2	45.52	49.25	23.94	32.13	43.76

*, ** = Significant at 0.05 and highly significant 0.01 level of probability

Genotypic and phenotypic coefficients of correlation (rp and rg) are presented in Table 3. Days to maturity possessed negative and non-significant correlations (rg =-0.2978, rp = -0.2609) with fruit yield per plant. Plant height had highly significant positive genotypic and phenotypic association (rg = 0.7485, rp = 0.6382) with fruit yield per plant as reported earlier in some research articles (Singh *et al.,* 2006; Sivaprasad, 2008; Gosh *et al.,* 2010). This trait also shared similar association with fruit width and fruit weight. However, it possessed significantly negative correlation with fruit length but non-significant positive association with number of fruits per plant. Number of fruits per plant disclosed significant positive association at genotypic and phenotypic levels (rg = 0.4873, rp = 0.5306) with fruit yield per plant, which is in accordance with Haydar *et al.* (2007), Sivaprasad (2008) and Islam *et al.* (2010) but in contrast to Rani *et al.* (2010). Nevertheless, it had significantly negative correlations with fruit length and fruit width. Moreover, number of fruits per plant had significant negative phenotypic and non-significant genotypic association with fruit weight. Genotypic and phenotypic correlation coefficients (rg = 0.5378, rp = 0.4430) between fruit weight and fruit yield per plant were positive and significant. The result was in full agreement with some earlier studies (Hidayatullah *et al.,* 2008; Rani *et al.,* 2010). Besides fruit yield per plant, fruit weight had significant positive correlation with fruit width but significant negative correlation with fruit length. Fruit length had significant negative associations (rg = -0.3507, rp = -0.2674) with fruit yield per plant since all the test entries had increased width *visa vie* length. However, Singh *et al.* (2006) and Islam *et al.* (2010) reported significant positive correlations between fruit length and fruit yield per plant in tomato. Fruit length was significantly negative correlated with fruit width. Fruit width had significant positive relationship (rg = 0.5420, rp = 0.4707) with fruit yield per plant. Formerly, Susic *et al.* (2012) reported similar positive correlation between fruit yield per plant and fruit length from a study involving 21 F_1 hybrids and seven parent lines. On overall basis, fruit yield per plant had significant positive association with plant height, number of fruits per plant, fruit weight and fruit width in the current study. This phenomenon can be explained in a way that total fluctuations in yield are governed principally by changes in one or more component; though all fluctuations in components as in our case were not expressed in yield due to indecisive ratings of desirable and undesirable associations among yield and yield related traits as reported earlier (Graffius, 1964).

Correlations between yield and yield components were partitioned into direct and indirect effects to know the particular factor responsible for that correlation (Table 4 and Fig. 1). Plant height employed direct positive effect (0.0060) on fruit yield per plant as well as indirect positive effects via days to maturity, number of fruits per plant, fruit weight and fruit length . The result was in line with findings of various investigators (Singh *et al.,* 2006; Hayadar *et al.,* 2007) but contrast to Gosh *et al.* (2010) who reported negative direct effect of plant height on yield per plant in tomato. Number of fruits per plant applied positive direct effect (0.8929) and positive indirect effects by means of plant height, fruit length and fruit width on fruit yield per plant however, negative indirect effect of days to maturity and fruit weight curtailed it. Supporting evidence of direct positive influence of number of fruit per plant on yield per plant had been reported earlier (Rani *et al.,* 2008; Islam *et al.,* 2010). Fruit weight revealed positive direct effect (1.3447) and positive

Table 3. Genotypic and phenotypic correlation coefficients in tomato genotypes

Trait	Correlation	Days to maturity	Plant height (cm)	Number of fruits per plant	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)
Days to maturity	rg	-	-	-	-	-	-
	rp	-	-	-	-	-	-
Plant height	rg	-0.5453**	-	-	-	-	-
	rp	-0.4136*	-	-	-	-	-
No. of fruits /plant	rg	0.2834	0.1318	-	-	-	-
	rp	0.0744	0.1227	-	-	-	-
Fruit weight	rg	-0.5651**	0.6324**	-0.4451	-	-	-
	rp	-0.3870	0.5536**	-0.4368*	-	-	-
Fruit length	rg	0.4226*	-0.4488*	-0.1914*	-0.1900*	-	-
	rp	0.3482	-0.4061*	-0.2120*	-0.0086*	-	-
Fruit width (cm)	rg	-0.5697**	0.6459**	-0.3533**	0.9502**	-0.3640**	-
	rp	-0.4072*	0.5825**	-0.3512**	0.9172**	-0.2685**	-
Fruit yield /plant	rg	-0.2978	0.7485**	0.4873*	0.5378**	-0.3507**	0.5420*
	rp	-0.2609	0.6382**	0.5306**	0.4430*	-0.2674*	0.4707*

*, ** = Significant at 0.05 and highly significant 0.01 level of probability

Table 4. Direct (in parenthesis) and indirect effect matrix in tomato genotypes

Traits	Days to maturity	Plant height (cm)	Number of fruits per plant	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Correlation with fruit yield per plant
Days to maturity	**(-0.0060)**	-0.0330	0.2531	-0.7599	-0.0307	0.2786	-0.2978
Plant height	0.0033	**(0.0060)**	0.1176	0.8504	0.0326	-0.3160	0.7485**
No. of fruits	-0.0017	0.0080	**(0.8929)**	-0.5986	0.0139	0.1728	0.4873*
Fruit weight	0.0034	0.0383	-0.3975	**(1.3447)**	0.0138	-0.4649	0.5378**
Fruit length	-0.0025	-0.0272	-0.1709	-0.2555	**(-0.0726)**	0.1781	-0.3507**
Fruit width	0.0034	0.0391	-0.3155	1.2777	0.0264	**(-0.4892)**	0.5420**

*, ** = Significant at 0.05 and highly significant at 0.01 level of probability

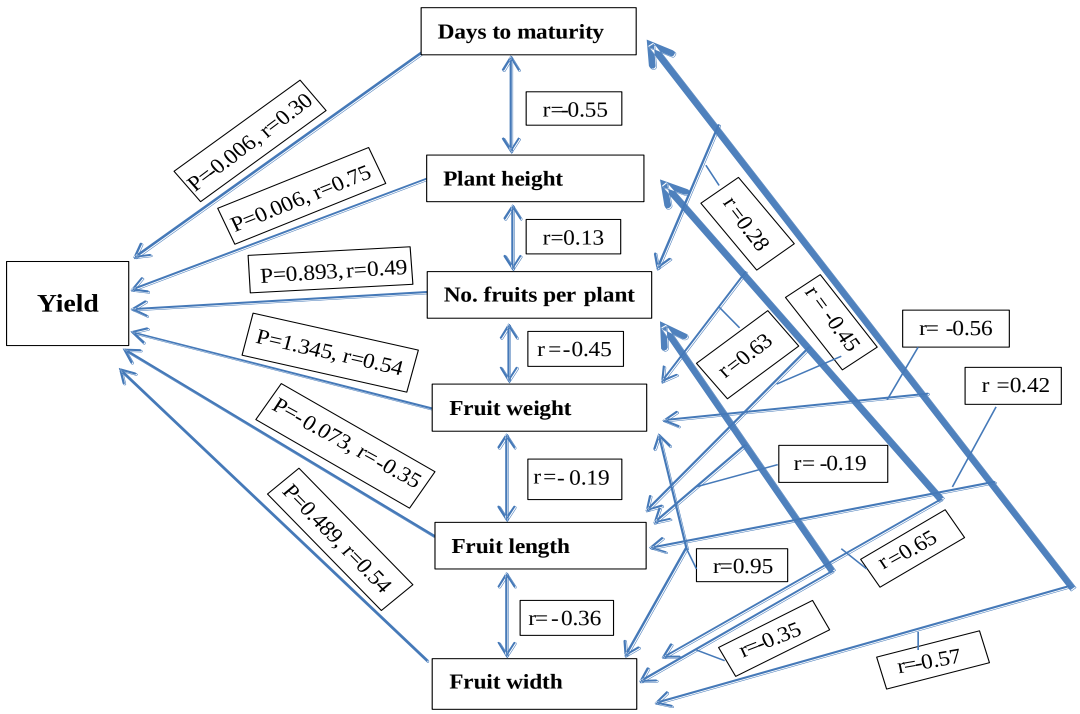

Figure 1. Path diagram showing genotypic relationship (r) and direct effects (P) among and between yield and yield components in tomato

indirect effect through days to maturity, plant height and fruit length on fruit yield per plant however, it was lessened via number of fruits per plant and fruit width. Because of significant genotypic associations and direct positive effects of fruit weight, number of fruits per plant and plant height on fruit yield per plant, direct selection of these traits would be effective to enhance yield. Tomato growth is affected by foliar feeding of N and Zn (Ejaz *et al*., 2012).

There were certain other traits like days to maturity, fruit length and width which could not be regarded ideal for devising selection criteria in current study. Days to maturity had negative direct effect (-0.0060) on yield per plant. This trait also exhibited negative indirect effects on plant height, fruit weight and fruit length. Fruit length had negative direct (-0.0726) and indirect effects on fruit yield per plant through all the characters except fruit width. Similarly fruit width had also negative direct (-0.4892) and indirect effects through number of fruits per plant on fruit yield per plant. These results confirmed the finding of Islam *et al.* (2010) where in fruit length exerted negative direct effect on yield per plant while in contradiction to Singh *et al.* (2006) who reported direct positive effect of fruit width on yield per plant. There were similarities and dissimilarities in findings of earlier workers and ours which could be attributed to different breeding material and environmental conditions.

In perusal to coefficient of variation, heritability with high genetic advance, significant positive genotypic correlation and desirable direct effect of fruit weight, number of fruits per plant and plant height on yield per plant, it could be concluded that these parameters could be used as selection parameters for the development of elite hybrids via heterosis breeding or for the development of inbred lines following pure line selection scheme in succeeding generations in tomato.

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