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Full Length Research Paper

Heterosis for flower and fruit traits in tomato (*Lycopersicon esculentum* Mill.)

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A study was conducted in tomato using an 8 × 8 diallel set excluding reciprocals to quantify the magnitude of heterosis for yield and its five yield components: number of flowers per cluster, number of fruits set per cluster, fruit length, fruit width, fruit weight and fruit yield per plant. Seven accessions and one locally approved variety were crossed in half diallel fashion and the resulting F_1 progeny along with their parents were evaluated in a 6 × 6 Tripple Lattice Design at Agricultural Research Institute, Mingora (NWFP), Pakistan during 2007 - 2008 crop season. Highly significant differences were observed among the genotypes for all the studied traits. Highly significant heterosis of positive nature was found for flowers per cluster (53.1 and 37.2%), fruits per cluster (38.9%), fruit length (32.7 and 15.5%), fruit weight (48.7 and 45.0%) and yield per plant (34.9%) over the mid and better parents, respectively. Positive significant heterosis was observed for flowers per cluster (7.4%), fruits per cluster (10.0 and 10.0%), fruit length (8.9%), fruit width (8.7 and 7.9%), fruit weight (14.3 and 12.5%), yield per plant (24%) over the mid and better parents, respectively. Four hybrids possessed significantly useful heterobeltiosis for fruit weight. Three single cross hybrids and four of the parental genotypes were selected for use in subsequent tomato breeding programmes.

Key words: Heterosis, tripple lattice design, genotypes, traits, tomato.

INTRODUCTION

The cultivated tomato (*Lycopersicon esculentum* Mill.), belonging to family Solanaceae is the most popular garden vegetable and is the 2nd most important vegetable crop in the world in terms of consumption per capita. It contributes significantly to the dietary intake of vitamins A, C, essential mineral and nutrients as well as lycopene, a major component of red tomatoes with antioxidant properties which reduces several cancers (Rick, 1980; Giovannucci, 1999). Tomato is grown in almost every corner of the planet. On global basis, it is planted 4.6 million hectares of with a total production of 125.5 million metric tones (FAOSTAT, 2008).

In Pakistan, tomato is grown on an area of 0.0471 million hectares with an average production of 0.5023 million metric tones. The North West Frontier Province of the country shared an area of 0.0161 million hectares with 0.1608 million metric tones production (MINFAL, 2007). The average yield per hectare recorded in Pakistan and NWFP was 10.1 and 10.0 tones, respectively. During the last 17 years, substantial increase in area and production by 54 and 52% was recorded in Pakistan, respectively, while average yield remained static (MINFAL, 2007).

Plant genetic resources are the reservoir of genetic recombination of genes and their variants, resulting from the evolution of plant species over centuries. Plant populations are the result of changes accumulated over

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Abbreviations: MPH, Mid- parent heterosis; **BPH,** better parent heterosis; **LSD,** least significant difference; **CV,** co-variance.

time and concomitantly exposed the environment to the encountered. Morphological as well as biochemical parameters have been widely used in the evaluation of various crops (Rick and Holle, 1990; Weber and Wricke, 1994; Kaemmer et al., 1995). Exploitation of such traits increases our understanding of genetic variability available which could further facilitates their use in breeding for wider geographic adaptability with respect to biotic and abiotic stresses as well as short and long term breeding endeavours. The improvement programme of tomato can be enhanced to a considerable extent if some basic information relevant to the pattern and magnitude of variability is made available to tomato breeders. Heterosis in tomato was first observed by Hedrick and Booth (1968) for higher yield and more number of fruits per plant. Choudhary et al. (1965) emphasized the extensive utilization of heterosis to step up tomato production. Heterosis manifestation in tomato is in the form of the greater vigour, faster growth and development, earliness in maturity, increased productivity, higher levels of resistance to biotic and abiotic stresses (Yordanov, 1983). The present study was therefore undertaken to estimate the magnitude of genetic variability and heterosis for yield and its component traits in crosses using eight diverse-tomato genotypes in half diallel combinations.

MATERIALS AND METHODS

Sixty tomato accessions available in the Plant Genetic Resources Institute at National Agricultural Research Centre (NARC), Islamabad, Pakistan were evaluated to study genetic diversity for important morphological and yield parameters during 2006. Based on the results of preliminary study, seven accessions viz P28, P30, P38, P45, P51, P54, P59 and a local approved variety Elum-02 were crossed in a diallel fashion (excluding reciprocals) during 2007. The parents and resultant 28 F_1 hybrids were evaluated in a 6 × 6 Triple Lattice Design during 2008 at Agricultural Research Institute, Mingora, Swat. Thirty five days old seedlings were transplanted in plots of 15.6 m^2 size having four rows, each of three meter length. Row to row and plant to plant spacing was kept 1.30 and 0.30 m, respectively, so as to accommodate 40 plants in each plot per replication. Standard crop production technology as needed for tomato crop was used in the experiment.

Data were collected from two central rows on individual plant basis as mean values of five plants of each genotype selected at random for the following characters: yield plant^{-1} at fresh marketable stage, flowers per cluster on clusters 2 - 6 on the main stem, fruits per cluster on clusters 2 - 6 on the main stem, fruit length, fruit width and fruit weight.

The data were subjected to statistical analysis according to Steel and Torrie, (1980) using MSTATC package version 1.2 (Freed, 1990) and least significant difference (LSD) test was used for mean separation. Mid- parent heterosis (MPH) was calculated in terms of percent increase (+) or decrease (-) of the F_1 hybrids against its mid parent value as suggested by Fehr (1987).

$$MPH (\%) = [F_1\text{-}MP /MP]*100$$

Similarly, heterobeltiosis or better parent heterosis (BPH) was also estimated in terms of percent increase or decrease of the F_1 hybrid over its better parent.

$$BPH (\%) = [F_1\text{-}BP/BP]*100$$

Significance of mid and better parent heterosis was determined following the "t" test suggested by Wynne et al. (1970).

$$MP (t) = F_1\text{-}MP/ \sqrt{(3/2r)EMS}$$

$$BP (t) = F_1\text{-}BP/ \sqrt{(2/r)EMS}$$

Where F_1 = Mean of the F_1 hybrid for a specific trait, MP = mid parent value for the cross, BP = Mean of better parent in the cross, and EMS = Error mean square.

RESULTS AND DISCUSSION

Number of flowers per cluster

Highly significant differences (p < 0.01) were observed among the genotypes (parents and crosses) for flowers cluster^{-1} (Table 1). Among the parents, flowers per cluster ranged from 4.9 for P38 to 9.7 for P30. The maximum mean value (9.7) was statistically at par with mean value for P38 (9.3), immediately followed by P45 and P51 with mean values of 8.3 and 8.2, respectively. Hybrids showed maximum mean value of 9.8 for the cross P45 × P51 followed by P51 × P59 and P38 × P54 with the same mean value of 8.6. Minimum number of flowers cluster $^{-1}$ (3.8) was recorded for hybrid E-02 × P59 preceded by E-02 × P38 with mean value of 4.9 (Table 2). Hybrids exhibited greater variation as compared to parental genotypes.

Mid-parent heterosis ranged from 7.3 to 53.1% and better parent heterosis from 18.5 to 37.2% (Table 2). Highly significant positive heterosis was observed for four hybrids P38 × P54 (53.1%), P38 × P59 (29.2%), P45 × P51 (19.2%) and P30 × P38 (15.7%) over mid parent in comparison to two hybrids (P38 × P54, P45 × P51) with heterotic effects of 37.2 and 18.5%, respectively, over better parent. Two hybrids (P51 × P54 and P51 × P59) were found with significant useful heterosis (7.4 and 7.3%), respectively, over mid parent but no hybrid displayed significant positive heterosis over high parent.

Number of fruits per cluster

Analysis of variance revealed highly significant (P < 0.01) difference for number of fruits per cluster among the parents and their 28 F_1 cross combinations (Table 1). Mean data showed that number of fruit per cluster ranged from 3.0 (P54 and P59) to 5.1 (P45) among the parents and from 2.5 for cross P38 × P54, P38 × P59 to 6.6 for cross P28 × P30 among the hybrids. Three of the parents (P28, P51 and P45) were among the better range of 5.0 to 5.1 while six hybrids (P30 × P51, P30 × P54, P45 ×

Table 1. Mean squares for flowers per cluster, fruits per cluster, fruit length, fruit width, fruit weight and yield per plant of tomato during 2008.

Source of variation	Df	Flowers cluster^{-1}	Fruits cluster^{-1}	Fruit length	Fruit width	Fruit weight	Yield per plant^{-1}
Replications	2	0.05	0.14	0.03	0.05	7.0	445
Genotypes	35	6.7**	2.8**	1.1**	1.3**	208.3**	93381**
Error	55	0.12	0.06	0.04	0.02	3.6	4356

** Significant at 1% probability level.

P51, P28 × P51, E-02 × P28 and P28 × P30) out of 28 were found in the range of 5 .0 - 6.6 (Table 2). A total of 21 hybrid combinations occupied position in the range of 4.0 to the maximum mean value of 6.6, indicating positive role in enhancing total yield as suggested by Williams and Gilbert (1960).

Heterosis was found in a range of 10.0 to 38.9% for mid parent and 10.0 to 32.0% over better parent (Table 2). The magnitude of useful heterosis was found for seven hybrids over mid parent and for three hybrids over better parent. Maximum highly significant positive heterosis was observed for cross P28 × P30 (38.9%) followed by P28 × P54 (20.0%) over mid parent and for hybrid P28 × P30 (32.0%) over better parent. Significant positive heterosis was observed for hybrids P28 × P51 (10%), P45 × P59 (11.1%) and P51 × P59 (12.5%). The hybrid combination of parents P28 and P30 showed highly significant heterosis both over mid and better parent for number of fruits per cluster.

Fruit length (cm)

The statistical analysis displayed highly significant differences (P < 0.01) among the accessions and their F_1s for fruit length (Table 1). Mean fruit length varied from 2.4 to 4.6 cm among the parents. Maximum fruit length of 4.6 cm was recorded for parent P51, followed by P28 and E-02 each with mean fruit length of 4.5 cm. Similarly, parent P51, P54 and P59 were found to have fruit length of 4.6, 4.2 and 4.4 cm, respectively. Minimum fruit length was observed for the parent P38 (2.4 cm). Hybrids revealed a range of 3.0 to 5.2 cm for the character studied. Hybrid E-02 × P30 displayed maximum fruit length of 5.2 cm followed by E-02 × P51 with mean value of 4.7 cm, an indication for oval shape fruit. Minimum fruit length was recorded in crosses P28 × P38, P30 × P51 and P30 × P54 measuring 3.0 cm, which represents the tendency towards round shape of the fruit. The remaining 23 hybrids ranked intermediate between the two extremes.

Heterosis varied from 14.8 to 32.7% over mid parent. Maximum value for highly significant positive heterosis was observed in hybrid E-02 × P38 (32.7%) over mid parent followed by E-02 × P30 (28.9%), P38 × P45 (26%), P38 × P54 (20.6%) and P28 × P45 (14.8%) whereas, E-02 × P30 exhibited highly useful heterosis of 15.5% over better parent. One cross P45 × P51 revealed significant positive heterosis of 8.9% over mid parent. However, no significant useful heterosis was found over high parent for fruit length (Table 3).

Fruit width (cm)

The analysis of variance showed the existence of highly significant variation (P < 0.01) for fruit width, indicating a wide range of variability among the genotypes (Table 1). Mean values for fruit width ranged from 3.7 (P45) to 4.8 cm (P54) among the parents (Table 2.2). The maximum mean value was followed by P30 and P51 with the same mean fruit width of 4.3 cm. Among the hybrids, maximum fruit width was recorded for crosses P51 × P54 and E-02 × P54 with the same mean fruit width of 4.6 cm, closely followed by hybrids P45 × P51 (4.5 cm) and E-02 × P28 (4.5 cm). Minimum same mean value of 2.3 cm was observed for cross P28 × P38 and cross P28 × P54. A wide range of variation was observed among the hybrids as compared to their parents

Regarding heterosis, maximum value of 10.6% was recorded for hybrid E-02 × P45 followed by E-02 × P28 with heterotic value 8.7% of significant useful effects over mid parent (Table 2.2). None of the hybrids was found with highly significant useful effects, both over mid and high parents, respectively. Over all, positive significant heterosis was displayed by five crosses over mid parent, while only a single cross hybrid E-02 × P28 with value of 7.9% exhibited significant effect over better parent.

Fruit weight (g)

Mean square value for average fruit weight revealed highly significant (P < 0.01) differences among the parents and the resultant hybrids (Table 1). Among the parents, the highest fruit weight was recorded for P54 followed by P28 with mean fruit weight of 55 and 45 g, respectively. Three parents (P30, P45 and P51) showed identical mean fruit weight with mean weight of 40 g. Minimum fruit weight

Table 2. Mean performance of genotypes and extent of heterosis (%) for flowers and fruits per cluster of 28 hybrids from an 8 x 8 half diallel.

Genotypes	Flowers cluster^{-1}			Fruits cluster $^{-1}$		
	Mean	MPH	BPH	Mean	MPH	BPH
Parents						
E-02	7.0	-	-	4.2	-	-
P28	9.3	-	-	6.3	-	-
P30	9.7	-	-	4.5	-	-
P38	4.9	-	-	3.3	-	-
P45	8.3	-	-	5.2	-	-
P51	8.2	-	-	5.5	-	-
P54	6.2	-	-	5.2	-	-
P59	7.8	-	-	5.6	-	-
Parents mean	7.7	-	-	5.0	-	-
Hybrids						
E-02 × P28	5.7	-29.1	-37.8	3.7	15.2**	6.0
E-02 × P30	3	-35.5	-44.5	4.1	-19.5	-22.2
E-02 × P38	4.9	-16.4	-28.65	3.4	-9.3	-19.0
E-02 × P45	6.3	-17.7	-24.1	4.6	-3.2	-11.8
E-02 × P51	6.1	-17.1	-23.2	4.3	-8.7	-16.0
E-02 × P54	5.1	-23.1	-27.1	4.6	-19.4	-3.3
E-02 × P59	3.8	-49.7	-52.3	2.9	5.6	-9.5
P28 × P30	7.9	-17.2	-19.2	2.8	38.9**	32.0**
P28 × P38	7.1	0.7	-22.7	5.2	8.4	-10.0
P28 × P45	6.3	-28.3	-32.0	4.4	-20.8	-20.0
P28 × P51	7.5	-13.7	-18.7	5.0	10.0*	10.0*
P28 × P54	6.2	-20.2	-33.1	5.6	20.0**	-4.0
P28 × p59	5.2	-39.6	-44.2	4.2	2.5	-18.0
P30 × P38	8.5	15.7**	-12.7	3.8	2.6	-11.1
P30 × P45	7.8	-12.8	-19.2	4.5	-8.3	-13.7
P30 × P51	5.1	-43.9	-48.3	4.0	5.3	0.0
P30 × P54	6.9	-12.5	-28.1	4.0	14.9**	11.1
P30 × P59	6.2	-29.4	-36.3	3.9	6.7	-11.1
P38 × P45	5.5	-17.6	-34.1	2.9	7.1	-11.8
P38 × P51	5.7	-13.4	-30.5	3.1	8.4	-10.0
P38 × P54	8.6	53.1**	37.2**	5.0	-33.3	-40.5
P38 × P59	8.3	29.2**	5.5	4.2	-20.6	-16.7
P45 × P51	9.8	19.2**	18.5**	5.5	5.0	6.0
P45 × P54	6.5	-10.8	-21.7	4.9	-3.2	-11.7
P45 × P59	5.8	-28.1	-30.1	2.5	11.1*	-11.8
P51 × P54	7.8	7.4*	-5.3	5.0	-2.2	-10.0
P51 × P59	8.6	7.3*	4.9	4.8	12.5*	-10.0
P54 × P59	7.8	-9.7	-1.3	4.3	-25.0	-35.7
Hybrids mean	6.8	-	-	4.2	-	-
LSD (0.05)	0.5	-	-	0.4	-	-
CV (%)	5.2	-	-	5.8	-	-

was recorded for P38 with mean value of 24.0 g. The hybrid E-02 × P30 had the highest fruit weight (59.0 g) immediately followed by E-02 × P51 and E-02 × P28 with mean value of 56.0 g each. Minimum fruit weight of 30.0 g was recorded for hybrids P28 × P38, P30 × P38, P30 × P59 and P54 × P59 (Table 4).

The estimates of useful heterosis varied from 9.6 to 48.7% over mid parents. Among the 28 single cross

Table 3. Mean performance of genotypes and extent of heterosis (%) for fruit length and fruit width of 28 hybrids from an 8 x 8 half diallel.

Genotypes	Fruit length (cm)			Fruit width (cm)		
	Mean	MPH	BPH	Mean	MPH	BPH
Parents						
E-02	4.5	-	-	4.2	-	-
P28	4.5	-	-	4.2	-	-
P30	3.5	-	-	4.3	-	-
P38	2.4	-	-	3.9	-	-
P45	3.6	-	-	3.7	-	-
P51	4.6	-	-	4.3	-	-
P54	4.2	-	-	4.8	-	-
P59	4.4	-	-	3.8	-	-
Parents mean	4.0	-	-	4.2	-	-
Hybrids						
E-02 × P28	4.3	-0.4	-0.7	4.5	8.7*	7.9*
E-02 × P30	5.2	28.9**	15.5**	4.3	0.8	-0.8
E-02 × P38	4.6	32.7**	2.2	4.1	5.5	-0.8
E-02 × P45	4.3	6.2	-4.4	4.3	10.6*	4.0
E-02 × P51	4.7	4.0	2.1	4.2	-0.4	-2.3
E-02 × P54	4.5	3.5	0.0	4.6	4.1	-2.8
E-02 × P59	4.3	-3.7	-4.4	4.1	2.1	-2.8
P28 × P30	3.6	-11.1	0.9	3.2	-23.4	-24.0
P28 × P38	3.0	-12.9	-33.1	2.3	-42.6	-46.5
P28 × P45	4.6	14.8**	2.9	4.1	4.6	-2.4
P28 × P51	3.2	-30.4	-31.4	2.6	-37.7	-38.5
P28 × P54	3.4	-19.8	-22.8	2.3	-49.1	-52.1
P28 × p59	4.1	-7.1	-8.1	3.8	-2.9	-8.7
P30 × P38	4.1	-3.3	-18.7	4.1	-4.5	-9.3
P30 × P45	3.8	6.0	5.6	4.2	6.3*	-1.6
P30 × P51	3.0	-27.1	-35.7	2.9	-32.0	-32.3
P30 × P54	3.0	-22.7	-28.6	2.3	-48.0	-50.7
P30 × P59	3.6	-8.3	-17.3	3.6	-10.4	-16.3
P38 × P45	3.8	26.0**	5.6	3.8	-1.8	-4.3
P38 × P51	3.4	-2.4	-25.7	4.2	4.1	-1.5
P38 × P54	4.0	20.6**	-4.8	3.5	-19.2	-27.1
P38 × P59	3.6	6.8	-17.3	3.8	1.8	0.0
P45 × P51	4.5	8.9*	-3.6	4.2	6.7*	-1.5
P45 × P54	4.0	3.4	-4.0	4.5	5.5	-6.9
P45 × P59	3.5	-11.2	-19.6	3.6	-2.7	-3.6
P51 × P54	4.6	4.5	-0.7	4.9	6.6*	1.4
P51 × P59	3.7	-18.0	-20.0	3.7	-12.4	-18.5
P54 × P59	4.0	-5.8	-8.3	4.3	0.0	-11.1
Hybrids mean	3.9	-	-	3.8	-	-
LSD (0.05)	0.4	-	-	0.3	-	-
CV (%)	5.3	-	-	4.5	-	-

hybrids, five crosses showed highly significant positive heterosis along with two hybrids having significant positive heterotic effects over mid parents (Table 4). Maximum highly significant positive relative heterosis for average fruit weight was observed for hybrid E-02 × P30 (48.7%) followed by E-02 × P28 (34.9%). Hybrids E-02 × P45 and

Table 4. Mean performance of genotypes and extent of heterosis (%) for fruit weight and yield per plant of 28 hybrids from an 8 x 8 half diallel.

Genotypes	Fruit weight (g)			Yield plant $^{-1}$(g)[1]		
	Mean	MPH	BPH	Mean	MPH	BPH
Parents						
E-02	38.0	-	-	567.3	-	-
P28	45.0	-	-	830.3	-	-
P30	40.0	-	-	861.7	-	-
P38	24.0	-	-	391.3	-	-
P45	40.0	-	-	924.0	-	-
P51	40.0	-	-	894.0	-	-
P54	55.0	-	-	561.0	-	-
P59	35.0	-	-	467.3	-	-
Parents mean	39.6	-	-	687.1	-	-
Hybrids						
E-02×P28	56.0	34.9**	24.4**	953.0	34.9**	14.7*
E-02×P30	59.0	48.7**	45.0**	651.7	-8.8	-24.4
E-02×P38	36.0	14.3*	-5.3	594.3	24.0*	4.8
E-02×P45	45.0	15.4**	12.5*	894.0	19.9**	-3.3
E-02×P51	45.0	15.4**	12.5*	872.0	19.3**	-2.5
E-02×P54	56.0	20.4**	1.8	493.3	1.0	0.5
E-02×P59	41.0	9.6*	5.3	488.3	2.4	-6.6
P28×P30	35.0	-17.6	-22.2	931.3	10.1	8.1
P28×P38	30.0	-14.3	-33.3	661.0	8.2	-20.4
P28×P45	45.0	5.9	0.0	947.0	8.0	2.5
P28×P51	35.0	-17.6	-22.2	873.3	1.3	-2.3
P28×P54	35.0	-30.0	--36.4	582.3	-16.3	-29.9
P28×p59	45.0	-12.5	-22.2	563.3	-13.2	-32.2
P30×P38	30.0	-7.7	-25.0	568.3	-9.3	-34.0
P30×P45	35.0	5.0	5.0	880.0	3.0	-0.4
P30×P51	45.0	-12.5	-12.5	852.7	1.4	-0.4
P30×P54	38.0	-20.0	-30.9	706.0	-0.8	-18.4
P30×P59	30.0	-20.0	-25.0	541.0	-18.6	-37.5
P38×P45	35.0	7.7	-12.5	709.3	7.9	-23.2
P38×P51	34.0	4.6	-15	675.3	5.1	-24.5
P38×P54	40.0	0.0	-27.3	440.0	-7.6	-21.6
P38×P59	30.0	0.0	-14.3	394.3	-1.0	-9.1
P45×P51	40.0	0.0	0.0	756.7	1.6	-0.1
P45×P54	50.0	5.3	-9.1	732.0	1.0	-18.8
P45×P59	35.0	-6.7	-12.5	577.0	-17.1	-37.6
P51×P54	40.0	-15.8	-27.3	709.3	-2.5	-20.7
P51×P59	30.0	-20.0	-25.0	582.3	-14.4	-34.9
P54×P59	30.0	-33.3	-45.5	417.3	-18.8	-25.6
Hybrids mean	39.5	-	-	680.2	-	-
LSD (0.05)	3.1	-	-	108.0	-	-
CV (%)	4.8	-	-	9.6	-	-

E-02 × P51 were found with 15.4% relative positive heterosis. Only two hybrids (E-02 × P28 and E-02 × P30) exhibited highly significant useful heterotic effects of 45.0 and 24.4%, respectively.The increased fruit weight observed in the hybrids was in agreement with Larson and Currence (1994) and Hannan et al. (2007) who reported larger fruit size from those inbred lines having larger fruits.The results of the hybrids with the intermediate fruit size between parents were also reported by Tesi et al. (1970) and Conti (1974). E-02 × P30, E-02 × P28, E-02 × P45 and E-02 × P51 were the best among hybrids which showed the highest per se performance.

Yield per plant (g)

Statistical analysis manifested highly significant differences (P < 0.01) among the genotypes for tomato yield plant^{-1} (Table 1). Among the parents, mean values for yield plant $^{-1}$ ranged from 391.3 to 924.0 g for parents P38 and P45, respectively. Parents P51, P30 and P28 showed relatively better performance with mean values of 894.0, 861.7 and 830.3 g, respectively for yield plant^{-1}.

Hybrids displayed a range of 394.3 and 953.0 g for hybrid P38 × P59 and E-02 × P28, respectively. Maximum mean value was immediately followed by cross P28 × P45 (947.0 g). Mean value for hybrid P28 × P30 (931.0 g) remained at par with cross E-02 × P45 (894.0), P30 × P45 (880.0), P28 × P51 (873.0) and E-02 × P51 (872.0 g), respectively (Table 4). Most of the parents contributed positively for enhancing yield plant $^{-1}$ in 16 hybrids. Seven hybrids exhibited better yield plant $^{-1}$ (> 830.3 g) whereas five parents performed better in the same range.

The estimates of heterosis ranged from 19.3 (E-02 × P51) to 34.9% (E-02 × P28) over mid parent (Table 4). Three crosses showed highly significant positive heterosis that is, E-02 × P28 (34.9%), E-02 × P45 (19.9%), E-02 × P51 (19.3%) in addition to one cross E-02 × P38 (24.0%) with significant positive heterotic effects over mid parent while, only a single cross (E-02 × P28) exhibited significant positive heterobeltiosis of 14.7%. Positive heterobeltiosis was found in three of the remaining hybrids but were non significant for yield plant^{-1}. Nine hybrids displayed non significant positive relative heterosis for the trait. The increased yield in these hybrids may be due to the high yielding parents selected for hybridization as suggested by Courtney and Peirce (1979).

Conclusion

Heterosis in hybrid plants has often been exploited as an efficient tool for increasing yields. Among other vegetables, heterotic hybrids have been commercially used in tomatoes. In spite of the several possible genetic explanations for the phenomenon of heterosis, it is clear that its manifestation depends on genetic divergence of the two parental varieties. Genetic divergence among varieties usually is unknown and the only recourse is to determine the level of genetic divergence empirically by means of variety crosses. Genetic divergence of the parental varieties is inferred from the heterotic patterns manifested in the series of variety crosses. If heterosis manifested from the two parental varieties is relatively large, it is concluded that these varieties are genetically more diverse than two other varieties that manifested little or no heterosis in their crosses. Therefore, the present study was carried out, to find out genetic variability and the extent of heterosis for yield and yield related attributes in tomato: number of flowers per cluster, number of fruits per cluster, fruit length, fruit width, fruit weight and fruit yield per plant. Maximum positive high significant heterosis was observed for flowers per cluster (53.1, 37.2%), fruits per cluster (38.9, 32.0%), fruit length (32.7, 15.5%), fruit weight (48.7, 45.0%) and yield per plant, (34.9, 0%) over the mid (MPH) and better parent (BPH), respectively. Maximum positive significant heterosis was observed for flowers per cluster (7.4, 0%), fruits per cluster (10.0, 10.0%), fruit length (8.9, 0%), fruit width (8.7, 7.9%), fruit weight (14.3, 12.5%) and yield per plant (24, 0%) over mid and better parent, respectively. Four hybrids possessed significant positive heterobeltiosis for fruit weight. Based on their per se performance, three single cross hybrids (E-02 × P28, E-02 × P45 and E-02 × P51) were selected for exploitation in subsequent tomato breeding programmes. Four of the parents, that is, P28, P30, P45 and P51 were also considered for re-evaluation of their higher yield potential. In conclusion, the present study suggests that hybrid breeding can be used efficiently to improve yield together with its yield components in tomato.

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