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HORTICULTURE

Analysis of Heterosis on Morphological and Qualitative Traits in Tomato (*Solanum Lycopersicon* Mill) for Salinity Tolerance.

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Abstract

The present study was carried out for the assessment of heterotic performance of 44 hybrids and their parents including check under saline ecosystem at Vegetable Research Form, NDUAT Kumarganj Faizabad U.P. These F1s were produced by using Line x tester mating design. The crosses, which displayed superiority over better parent and standard variety for total yield per plants, also exhibited significant heterosis for some/most of the major component traits. The most worthy common crosses selected on the basis of *per se* performance, heterobeltiosis and standard heterosis for different traits in both environments were Bilahi-2 x H-86 and Himlata x H-86 for total yield; MM x H-88 and KS-60 x H-24 for number of fruits plant^{-1} in E_2, MM x H-86 and MM x H-88 for average fruit weight in E_1 and EC 168282 x H-24 in E_2 for length of fruits; Himlata x H-88 in both experiment and NDT-2 x H-88 in E_2 for diameter of fruits and Himlata x H-86 in E_1 and NDT-2 x H-86 in E_2 for early yield plant^{-1}. However, for agronomical traits, Bilahi-2xH-86 in both environments for plant height as well as number of primary branches plant^{-1} was observed as voluble cross combination. Promising hybrid identified for the characters important to processing and quality point of view, were MM x H-88 in both environments for total soluble solids; EC 2291-2 x H-88 in both environments for Ascorbic acid content and EC 7343 x H-24 in E_1 and Bilahi-2 x H-88 in E_2 for pericarp thickness. However, none of the crosses were common for titrable acidity in both the environments in relation to above three parameters i.e. *per se* performance, standard heterosis and heterobeltiosis.

Highlights

- The G x E interactions played an important role in exhibition of heterotic response for different characters.
- None of the crosses were common for titrable acidity in relation to per *se* performance, standard heterosis and heterobeltiosis.
- Heterotic hybrids, Bilahi-2 x H-86 and Himlata x H-86 were best hybrids according to their *per se* performance, heterobeltiosis, standard heterosis and sca effects for yield and identified for developments of hybrids.

Keywords: Tomato, qualitative traits, L x T design, heterobeltiosis, standard heterosis

Tomato (*Solanum lycopersicon* Mill) as one of the most important vegetables crop for growers, consumers and industries of India, is widely grown in many parts of the world. It is very much popular among the people due to it's taste, high nutritional value, multipurpose uses and commercial importance. Being a moderate nutritional crop, tomato is considered as an important source of Vitamin A and

C and minerals which are important ingredients for table purpose, sambar preparation, chutney, pickles, ketchup, soup, juice pure etc (Sekhar *et al.* 2010).

Hybrid varieties in tomato are being most popular among the farmers as well as consumer due to its number of advantages along with higher yield potential even in stress condition. Realising the economic potential this crop, there is urgent need to identify the need base and location specific potential lines and cross combinations which have desirable horticultural traits and better quality in combination with high yield. Choudhary et al. (1965) emphasized the extensive utilization of heterosis to step up tomato production. The expression of heterosis may be due to factors such as heterozygosity, allelic interaction, non-allelic interaction or epistasis, dominance or over dominance and maternal interaction. However, in spite of intensive research a little work has been done to developed commercial cultivar suitable for saline eco system (Epstein and Rain 1987).

Today, applications and effects of heterosis in a hybrid tomato in terms of viability, better speed development of fruit, increase of yield has been identified (Hannan *et al.* 2007). Hence the present investigation was undertaken to study and generate information about hybrid vigour, combining ability which would help to assess the prepotency of parents in hybrid combinations under saline soil condition.

Materials and Methods

The present study was carried out at "Main Experiment Station" Department of Vegetable Science, Narendra Deva University of Agriculture and Technology, Narendra Nagar (Kumarganj) Faizabad. The experimental materials for the present study were generated by involving thirteen diverse tomato varieties/genotypes differing in growth habits (determinate and indeterminate) and fruit characters. These genotypes were selected as parents from the genetic stocks maintained in the department of vegetable science of the university. These strains were crossed in line x tester mating fashion. The experimental material is comprised of 30 F_1's with their parents, ten lines and three testers along with a check NDTH-7. All the 44 genotypes including F_1 progenies were grown in two separate salt affected plots as well as Pot cultured at one-month interval during October (E_1) and November (E_2) in Randomized Block Design with 3 replications. Observations were taken on the twelve morphological as well as qualitative characters by selecting five competitive plants randomly from each genotype in each replication. The mean values of observations recorded on the five plants of each genotype in each replication were taken for the analysis. The data were analyzed by appropriate statistical analysis (Gomez and Gomez 1984) using CropStat 7.2 (IRRI, 2009) programme. Heterosis expressed as per cent increase or decreases of hybrids (F_1) over better-parent (heterobeltiosis) and standard variety (standard heterosis) were calculated according to the method suggested by Hayes *et al.* (1955).

Results and Discussion

In the present investigation the relative magnitude of heterosis over better parent and standard variety were studied for 12 characters in 30 hybrids. Nature and magnitude of hybrid vigour differed for different trait in various hybrid combinations. The presence of high degree of heterobeltiosis and standard heterosis in either direction were observed for all twelve characters in both the environments and provided good possibility of isolating high heterotic combinations in desirable direction for these characters.

In case of total yield plant^{-1} a wide range of variation were recorded for heterobeltiosis from -7.69 (KS-60 x H-88) to 58.56 per cent (Bilahi-2 x H-86) in E_1 and from -10.86 for (MM x H-86) to 57.98 for EC 168282 x H-24. The remaining 11 characters also exhibited a wide magnitude of variation in both the directions under, E_1 and E_2. Earlier workers have also reported a wide range of heterosis from 1.46 to 185.71 per cent for total yield in tomato (Pandey 1998 and Bhatt et al. 2001).

Nine hybrids each in, E_1 and E_2, environments exhibited higher magnitude of standard heterosis for total yield plant^{-1} in desirable direction. Among these Bilahi-2 x H-86 and Himlata x H-86 were found as two best heterotic combination for total yield in both the environments when compared on the basis of *per se* performance, standard heterosis and heterobeltiosis together. These crosses may be treated as valuable breeding materials or hybrid varieties after confirmation of results with further testing.

Total yield plant^{-1} being a complex trait, is a multiplicative product of several basic component traits of yield. The improvement in heterosis for yield component may not necessarily be reflected in increased yield. In other hand, the increased fruit yield will definitely because of increase in one or more component traits. The major components of yield in tomato are average fruit weight, length of fruit, diameter of fruit and number of fruits plant^{-1}. In the present study, heterosis over standard variety was to the extent of 126.87 per cent (EC 2291-2 x H-24) and 85.11 per cent (MM x H-88) for number of fruits plant^{-1} in E_1 and E_2; 58.11 per cent (MM x H-86) and 119.17 per cent (KS-60 x H-88) for average fruit weight in E_1 and E_2; 23.48 per cent (MM x H-86) and 24.45 per cent (Bilahi 2 x H-24) for length of fruits in E_1 and E_2 and 38.27 per cent (Himlata x H-88) and 57.71 per cent (Himlata x H-88) for diameter of fruit in E_1 and E_2, respectively. While highest magnitude of heterobeltiosis was recorded as 23.85 per cent (EC 2291-2 x H-24) and 14.74 per cent (MM x H-86) for number of fruits plant^{-1}; 43.12 per cent (EC 168282 x H-24) and 79.47 per cent (EC 6148 x H-24) for average fruit weight; 17.50 per cent (EC 168282 x H-24) and 19.05 per cent (EC 168282 x H-24) for length of fruit; 36.59 and 49.86 per cent (Himlata x H-88) for diameter of fruits under E_1 and E_2, environments respectively. The extent of heterosis, number and identity of crosses exhibiting desirable standard and better parent heterosis for different component traits expressed considerable differences under different environment. The ranking of crosses in the two environments were also found drastically different for several characters. This indicated that the genotype x environmental interactions played an important role in exhibition of heterotic response in F_1's for different characters under study. It is, therefore, suggested that different set of elite hybrids for different environment conditions should be evaluated further for the proper identification of environmental specific hybrids. The best five crosses selected on the basis of *per se* performance, standard heterosis heterobeltiosis and sca effects for different characters in two environments are presented in Table 1. The cross combinations selected on the basis of mean performance and standard heterosis were usually common for most of the characters in each environment. However, the hybrids selected on the basis of heterobeltiosis and standard heterosis were not always common. The above observations are logical, as crosses with higher mean performance would obviously exceed the standard parent by greater margin than those with low mean performance. In case of heterobeltiosis the estimates resulted from F_1–BP and depend more or less on the mean of better parent in question.

The most worthy common crosses selected on the basis of *per se* performance, heterobeltiosis and standard heterosis for different traits in E_1 and E_2, environments were Bilahi-2 x H-86 and Himlata x H-86 for total yield in both environments; MM x H-88 and KS-60 x H-24 for number of fruits plant^{-1} in E_2; MM x H-86 and MM x H-88 in E_1 and EC168282 x H-24 in E_2 for length of fruits; Himlata x H-88 in both experiments and NDT-2 x H-88 in E_2 for diameter of fruits and Himlata x H-86 in E_1 and NDT-2 x H-86 in E_2 for early yield per plant. However, for agronomical traits, Bilahi-2 x H-86 in both environments for plant height and number of primary branches plant^{-1} were found to be most promising hybrids.

The cross combinations identified as most promising for the characters important to processing and quality point of view, were MM x H-88 in both environments for total soluble solids; EC 2291-2 x H-88 in both environments for Ascorbic acid content and EC 7343 x H-24 in E_1 and Bilahi-2 x H-88 in E_2 for pericarp thickness. However, none of the crosses were common for titrable acidity in both the environments in relation to above three parameters i.e. *per se* performance, standard heterosis and heterobeltiosis.

Table 1: Top ranking five cross combinations for twelve characters based on *per se* performance, standard heterosis, heterobeltiosis and sca effects in tomato under E_1 and E_2 environments

Best five hybrids based on	Plant Height (cm)		Number of primary branches plant^{-1}	
	E_1	E_2	E_1	E_2
***per se* performance**	EC 168282 x H 24 (141.00)	MM x H 88 (70.60)	MM x H 86 (93.07)	KS 60 x H 86 (53.89)
	NDT 3 x H 88 (79.50)	EC 148 x H 88 (61.89)	MM x H 88 (84.20)	EC 168282 x H 86 (49.70)
	NDT 3 x H 86 (71.99)	EC 7343 x H 88 (54.34)	NDT 2 x H 88 (79.06)	Himlata x H 88 (49.24)
	EC 7343 x H 24 (69.49)	KS 60 x H 24 (49.34)	NDT 2 x H 86 (73.39)	EC 168282 x H 24 (48.60)
	EC 7343 x H 88 (68.36)	MM x H 86 (48.26)	Bilahi 2 x H 86 (70.69)	NDT 2 x H 86 (45.92)
Heterosis over standard parent	EC 168282 x H 24 (44.83)	EC 168282 x H 24 (38.01)	Bilahi 2 x H 86 (36.33)	Bilahi 2 x H 86 (49.00)
		MM x H 24 (36.28)	EC 168282 x H 24 (21.36)	EC 6148 x H 86 (39.41)
			EC 6148 x H 86 (19.54)	MM x H 86 (29.03)
			MM x H 24 (19.27)	KS 60 x H 88 (28.53)
			EC 2291-2 x H 86 (14.40)	MM x H 24 (24.57)
Heterosis over better parent	Bilahi 2 x H 86 (53.94)	Bilahi 2 x H 86 (68.96)	Bilahi 2 x H 86 (34.22)	Bilahi 2 x H 86 (48.20)
		MM x H 24 (63.60)	KS 60 x H 88 (17.90)	EC 6148 x H 86 (38.66)
		Bilahi 2 x H 24 (54.73)	Himlata x H 86 (17.70)	KS 60 x H 88 (27.84)
		MM x H 86 (41.75)	EC 6148 x H 86 (15.28)	MM x H 86 (17.36)
		EC 2291 x H 88 (9.44)		
Desirable sca effects	EC 168282 x H 24 (30.44)	EC 168282 x H 24 (30.98)	Bilahi 2 x H 86 (0.75)	Bilahi 2 x H 86 (1.05)
	KS 60 x H 86 (20.91)	KS 60 x H 86 (20.27)	EC 168282 x H 24 (0.59)	EC 2291-2 x H 88 (0.80)
	Bilahi 2 x H 86 (16.53)	NDT 2 x H 88 (16.23)	MM x H 24 (0.45)	NDT 3 x H 24 (0.62)
	NDT 3 x H 88 (16.12)	EC 6148 x H 88 (15.45)	NDT 2 x H 88 (0.41)	EC 168282 x H 24 (0.57)
		EC 2291-2 x H 86 (15.31)	KS 60 x H 24 (0.39)	EC 6148 x H 88 (0.54)

Best five hybrids based on	Number of fruits plant^{-1}		Average fruit weight (gm)	
	E_1	E_2	E_1	E_2

***per se* performance**	EC 2291 x H 24 (85.98)	MM x H 88 (70.60)	MM x H 86 (93.07)	KS 60 x H 86 (53.89)
	NDT 3 x H 88 (79.50)	EC 6148 x H 88 (61.89)	MM x H 88 (84.20)	EC 168282 x H 86 (49.70)
	NDT 3 x H 86 (71.99)	EC 7343 x H 88 (54.34)	NDT 2 x H 88 (79.06)	Himlata x H 88 (49.24)
	EC 7343 x H 24 (69.49)	KS 60 x H 24 (49.34)	NDT 2 x H 86 (73.39)	EC 168282 x H 24 (48.60)
	EC 7343 x H 24 (68.36)	MM x H 86 (48.26)	Bilahi x H 88 (70.69)	NDT 2 x H 86 (45.92)
Heterosis over standard parent	EC 2291 x H 24 (126.80)	MM x H 88 (85.11)	MM x H 86 (58.11)	KS 60 x H 88 (119.17)
	NDT 3 x H 88 (109.75)	EC 6148 x H 88 (62.68)	MM x H 88 (43.03)	EC 168282 x H 86 (102.12)
	NDT x H 86 (89.95)	EC 7343 x H 88 (42.36)	NDT 2 x H 88 (34.31)	Himlata x H 88 (100.28)
	EC 7343 x H 24 (83.36)	KS 60 x H 24 (29.26)		EC 168282 x H 24 (97.67)
	EC 7343 x H 88 (80.38)	MM x 86 (26.44)		NDT 2 x H 86 (86.75)
Heterosis over better parent	EC 2291-2 x H 24 (71.10)	MM x H 88 (124.40)	EC 168282 x H 24 (43.12)	EC 6148 x H 24 (79.47)
	EC 168282 x H 88 (51.89)	EC 6148 x H 88 (58.47)	Bilahi 2 x H 86 (41.03)	Bilahi 2 x H 24 (77.03)
	Himlata x H 86 (49.09)	KS 60 x H 24 (44.10)	MM x H 86 (39.97)	EC 6148 x H 86 (59.54)
	NDT 2 x H 24 (39.77)	EC 2291-2 x H 24 (26.68)	NDT 2 x H 88 (28.17)	Himlata x H 24 (59.41)
	Bilahi 2 x H 24 (34.76)		MM x H 88 (26.64)	EC 7343 x H 24 (58.58)
Desirable sca effects	EC 2291-2 x H 24 (23.85)	MM x H 86 (14.74)	EC 168282 x H 24 (21.07)	KS 60 x H 86 (14.12)
	Himlata x H 86 (14.27)	KS 60 x H 24 (14.31)	Himlata x H 88 (13.54)	Himlata x H 88 (10.79)
	KS 60 x H 86 (10.26)	EC 2291-2 x H 24 (12.27)	NDT 3 x H 24 (12.99)	EC 6148 x H 24 (8.41)
	NDT 3 x H 88 (8.39)	Bilahi 2 x H 86 (10.97)	Bilahi x H 86 (12.32)	Bilahi 2 x H 24 (8.41)
	NDT 2 x H 24 (7.72)	NDT 3 x H 86 (7.07)	NDT 2 x H 88 (12.05)	EC 168282 x H 24 (7.48)
Best five hybrids based on	Length of fruits (cm)		Diameter of fruits (cm)	
	E_1	E_2	E_1	E_2
***per se* performance**	MM x H 86 (4.41)	MM x H 86 (4.41)	Himlata x H 88 (7.47)	Himlata x H 88 (5.32)
	MM x H 88 (5.13)	Bilahi 2 x H 86 (3.77)	NDT 2 x H 88 (6.27)	NDT 2 x H 88 (4.55)
	Bilahi 2 x H 86 (5.10)	MM x H 88 (3.71)	KS 60 x H 86 (6.10)	KS 60 x H 86 (4.39)
	KS 60 x H 86 (5.03)	EC 168282 x H 24 (3.60)	MM x H 86 (5.77)	NDT 2 x H 86 (6.27)
	MM x H 24 (4.90)	KS 60 x H 86 (3.50)	Bilahi 2 x H 86 (5.73)	Bilahi 2 x H 86 (4.25)
Heterosis over standard parent	Length of fruits (cm)		Diameter of fruits (cm)	
	MM x H 86 (23.48)	Bilahi x H 86 (24.45)	Himlata x H 88 (38.27)	Himlata x H 88 (51.71)
	MM x H 88 (16.17)	MM x H 88 (22.69)	NDT 2 x H 88 (16.05)	NDT 2 x H 88 (29.66)
	Bilahi 2 x H 86 (15.91)	EC 168282 x H 24 (18.94)		Bilahi 2 x H 86 (21.29)
	KS 60 x H 86 (14.39)	KS 60 x H 86 (15.86)		NDT 2 x H 86 (21.66)
	MM x H 24 (9.85)			KS 60 x H 86 (25.29)

Heterosis over better parent	EC 168282 x H 24 (17.50)	EC 168282 x H 24 (19.05)	Himlata x H 88 (36.59)	Himlata x H 88 (49.86)
	MM x H 86 (7.95)		KS 60 x H 86 (24.44)	NDT 2 x H 88 (29.66)
	KS 60 x H 24 (7.86)			KS 60 x H 86 (21.81)
Desirable sca effects	EC 168282 x H 24 (0.70)	EC 168282 x H 24 (0.69)	Himlata x H 88 (1.60)	Himlata x H 88 (1.04)
	NDT 2 x H 88 (0.34)	EC 6148 x H 88 (0.50)	EC 168282 x H 24 (0.91)	Bilahi 2 x H 86 (0.53)
	Himlata x H 88 (0.32)	MM x H 86 (0.37)	NDT 2 x H 88 (0.67)	EC 2291-2 x H 86 (0.50)
	Bilahi 2 x H 86 (0.21)	Bilahi 2 x H 86 (0.30)	KS 60 x H 86 (0.48)	KS 60 x H 86 (0.46)
	EC 6148 x H 88 (0.21)	Himlata x H 88 (0.28)	Bilahi 2 x H 86 (0.41)	KS 60 x H 24 (0.28)
Best five hybrids based on	Pericarp thickness (cm)		Total soluble solid (per cent)	
	E_1	E_2	E_1	E_2
***per se* performance**	Bilahi 2 x H 88 (0.70)	Bilahi 2 x H 86 (0.68)	MM x H 88 (6.13)	MM x H 88 (7.00)
	EC 168282 x H 86 (0.70)	NDT 2 x H 88 (0.62)	NDT 2 x H 86 (6.0)	EC 168282 x H 86 (6.73)
	EC 7243 x H 24 (0.67)	MM x H 88 (0.57)	NDT 2 x H 88 (5.93)	NDT 2 x H 88 (6.60)
	EC 6148 x H 24 (0.66)	Bilahi 2 x H 24 (0.57)	EC 168282 x H 86 (5.92)	NDT 2 x H 86 (6.13)
	NDT 2 x H 88 (0.63)	EC 168282 x H 86 (0.57)	Bilahi 2 x H 86 (5.47)	Bilahi 2 X H 86 (5.98)
Heterosis over standard parent	Bilahi 2 x H 88 (25.0)	Bilahi 2 x H 88 (43.05)	MM x H 88 (41.54)	MM x H 88 (37.23)
	EC 168282 x H 86 (25.0)	NDT 2 x H 88 (30.43)	NDT 2 x H 86 (38.46)	EC 168282 x H 86 (32.03)
	EC 7343 x H 24 (19.05)	EC 168282 x H 86 (21.13)	EC 168282 x H 86 (36.92)	NDT 2 x H 88 (29.41)
	EC 6148 x H 24 (17.86)	MM x H 88 (21.09)	NDT 3 x H 88 (36.92)	NDT 2 x H 86 (20.26)
	NDT 2 x H 88 (13.10)	Bilahi 2 x H 24 (19.44)	Bilahi 2 x H 86 (26.15)	Bilahi x H 86 (17.16)
Heterosis over better parent	EC 7343 x H 24 (66.67)	NDT 3 x H 88 (22.66)	MM x H 88 (16.95)	NDT 2 x H 88 (36.92)
	EC 6148 x H 24 (65.0)	Bilahi 2 x H 88 (12.54)	EC 168282 x H 86 (14.59)	MM x H 88 (29.60)
	EC 6148 x H 88 (45.0)			NDT 2 x H 86 (26.03)
	EC 7343 x H 88 (41.67)			Bilahi x H 86 (19.50)
	EC 2291-2 x H 88 (33.33)			Bilahi x H 88 (18.67)
Desirable sca effects	Pericarp thickness (cm)		Total soluble solid (per cent)	
	E_1	E_2	E_1	E_2
	EC 168282 x H 86 (0.16)	NDT 2 x H 88 (0.16)	MM x H 88 (0.93)	MM x H 88 (1.21)
	NDT 2 x H 88 (0.15)	EC 168282 x H 86 (0.12)	EC 168282 x H 86 (0.69)	EC 168282 x H 86 (0.75)
	Bilahi 2 x H 88 (0.10)	Bilahi 2 x H 88 (0.09)	Himlata x H 24 (0.66)	EC 2291-2 x H 24 (0.61)
	NDT 3 x H 86 (0.09)	NDT 3 x H 86 (0.07)	EC 2291-2 x H 24 (0.54)	Himlata x H 24 (0.58)
	EC 2291-2 x H 88 (0.05)	KS 60 x H 24 (0.06)	KS 60 x H 24 (0.27)	NDT 2 x H 88 (0.56)
Best five hybrids based on	Ascorbic acid content (mg per 100 gm)		Titrable acidity (%)	
	E_1	E_2	E_1	E_2

***per se* performance**	EC 2291-2 x H 88 (47.08)	EC 2291-2 x H 86 (40.41)	KS 60 x H 24 (0.50)	KS 60 x H 24 (0.48)
	NDT 3 x H 88 (44.91)	NDT 3 x H 88 (40.39)	EC 7343 x H 86 (0.55)	EC 7343 x H 86 (0.53)
	EC 7343 x H 86 (43.11)	EC 2291-2 x H 88 (40.15)	NDT 2 x H 86 (0.55)	NDT 2 x H 86 (0.53)
	EC 2291-2 x H 24 (43.02)	EC 2291-2 x H 24 (39.08)	NDT 3 x H 86 (0.64)	NDT 3 x H 86 (0.61)
	KS 60 x H 88 (44.91)	KS 60 x H 88 (39.07)	Himlata x H 24 (0.67)	Himlata x H 24 (0.64)
Heterosis over standard parent	EC 2291-2 x H 88 (46.15)	EC 2291-2 x H 86 (37.40)	KS 60 x H 24 (-43.96)	KS 60 x H 24 (-43.96)
	NDT 3 x H 88 (39.42)	NDT 3 x H 88 (36.52)	EC 7343 x H 86 (-39.17)	NDT 2 x H 86 (-39.17)
	EC 7343 x H 24 (35.07)	EC 2291-2 x H 88 (36.52)	NDT 2 x H 86 (-39.17)	EC 7343 x H 86 (-39.17)
	EC 2291-2 x H 24 (33.56)	EC 2291-2 x H 24 (32.87)	NDT 3 x H 86 (-28.89)	NDT 3 x H 86 (-28.89)
	KS 60 x H 24 (30.91)	KS 60 x H 88 (32.83)	Himlata x H 24 (-25.63)	Himlata x H 24 (-25.63)
Heterosis over better parent	EC 168282 x H 86 (86.20)	EC 168282 x H 24 (66.26)	MM x H 88 (-14.89)	EC 168282 x H 88 (-13.04)
	EC 2291-2 x H 88 (39.34)	MM x H 24 (31.86)		NDT 3 x H 88 (-12.55)
	NDT 3 x H 88 (38.24)	EC 2291-2 x H 86 (31.63)		
	NDT 2 x H 86 (36.05)	NDT 3 x H 88 (31.06)		
	EC 2291-2 X H 24 (27.34)	EC 2291-2 x H 88 (30.27)		
Desirable sca effects	EC 168282 x H 86 (7.94)	EC 168282 x H 86 (6.31)	KS 60 x H 24 (-0.17)	KS 60 x H 24 (-0.18)
	EC 7343 x H 86 (7.31)	MM x H 24 (6.01)	NDT 2 x H 86 (-0.16)	NDT 3 x H 88 (-0.16)
	NDT 3 x H 88 (6.59)	EC 6148 x H 24 (5.50)	Bilahi 2 x H 86 (-0.14)	NDT 2 x H 86 (-0.15)
	EC 6148 x H 24 (6.15)	NDT 3 x H 88 (5.46)	MM x H 88 (-0.13)	MM x H 88 (-0.14)
	KS 60 x H 24 (5.85)	EC 7343 x H 86 (4.83)	NDT 3 x H 88 (-0.13)	Bilahi 2 x H 24 (-0.14)

Best five hybrids based on	Early yield plant^{-1} (Kg)		Total yield plant^{-1} (Kg)	
	E_1	E_2	E_1	E_2
***per se* performance**	KS 60 x H 86 (1.64)	NDT 3 x H 88 (1.68)	MM x H 86 (2.89)	Bilahi 2 x H 88 (1.93)
	Himlata x H 86 (1.21)	NDT 3 x H 24 (1.30)	Bilahi 2 x H 86 (2.87)	MM x H 88 (1.84)
	KS 60 x H 88 (1.18)	NDT 2 x H 86 (1.11)	MM x H 88 (2.86)	MM x H 86 (1.64)
	EC 7343 x H 86 (1.13)	NDT 3 x H 86 (1.08)	Himlata x H 86 (2.79)	Himlata x H 86 (1.59)
	NDT 2 x H 88 (0.99)	KS 60 x H 24 (1.04)	NDT 3 x H 86 (2.75)	NDT 3 x H 86 (1.57)
Heterosis over standard parent	KS 60 x H 86 (113.70)	NDT 3 x H 88 (110.42)	MM x H 86 (73.25)	MM x H 88 (96.38)
	Himlata x H 86 (56.49)	NDT 3 x H 24 (62.71)	Bilahi 2 x H 86 (72.20)	MM x H 86 (75.78)
	KS 60 x H 88 (52.60)	NDT 2 x H 86 (38.17)	MM x H 88 (71.43)	Bilahi 2 x H 86 (74.72)
	EC 7343 x H 86 (47.19)	NDT 3 x H 86 (35.42)	Himlata x H 86 (67.16)	Himlata x H 86 (69.60)
		KS 60 x H 24 (30.12)	NDT 3 x H 86 (64.82)	NDT 3 x H 86 (67.22)
Heterosis over better parent	NDT 2 x H 88 (120.37)	NDT 2 x H 88 (113.19)	Bilahi 2 x H 86 (58.56)	EC 168282 x H 24 (57.98)
	Bilahi 2 x H 88 (102.27)	Himlata x H 88 (109.77)	EC 168282 x H 24 (57.90)	Bilahi 2 x H 86 (57.69)
	Himlata x H 86 (88.28)	NDT 2 x H 86 (105.20)	Himlata x H 86 (53.92)	MM x H 88 (55.64)
	EC 7343 x H 86 (77.08)	NDT 2 x H 24 (101.11)	NDT 2 x H 88 (53.77)	Himlata x H 86 (53.08)
	NDT 2 x H 24 (75.53)	KS 60 x H 24 (100.42)	EC 6148 x H 88 (46.33)	EC 7343 x H 88 (46.95)
Desirable sca effects	Himlata x H 86 (0.39)	KS 60 x H 24 (0.42)	EC 168282 x H 24 (0.36)	EC 168282 x H 24 (0.58)
	NDT 3 x H 88 (0.38)	NDT 3 x H 88 (0.26)	Bilahi 2 x H 86 (0.24)	Bilahi 2 x H 86 (0.45)
	EC 2291-2 x H 88 (0.38)	Bilahi 2 x H 24 (0.17)	Himlata x H 86 (0.24)	KS 60 x H 86 (0.40)
	MM x H 86 (0.27)	EC 6148 x H 88 (0.15)	EC 6148 x H 88 (0.23)	EC 6148 x H 88 (0.40)
	KS 60 x H 86 (0.25)	MM x H 24 (0.14)	NDT 3 x H 24 (0.18)	Himlata x H 86 (0.36)

The most valuable heterotic cross combinations identified for total yield also exhibited significant and desirable heterosis for other characters when compared with above three parameters. Among these, Bilahi-2 x H-86 showed high magnitude of heterosis for number of primary branches plant^{-1} and plant height in both the environments and for average fruit weight in E_1 besides total yield plant^{-1}. Himlata x H-86 was exhibited high degree of heterosis for early yield in E_1 along with total yield plant^{-1}. MM x H-88 recognized as high heterotic combination for total yield also showed higher magnitude of heterosis for number of fruits per plant in E_2 and for total soluble solid in both the season. While, MM x H-86 exhibited considerable amount of heterobeltiosis i.e. 42.07 and 39.32 per cent for total yield plant^{-1} in E_1 and E_2, respectively and was also found to be promising hybrid for length of fruits, average fruit weight in E_1 and number of primary branches plant^{-1} under E_2 conditions. Considering the above facts it may be said that high yield of heterotic combinations were obtained due to higher magnitude of heterosis for number of primary branches, plant height and length of fruits besides significant and high degree of heterosis for number of fruits plant^{-1} and average fruit weight. Kumar et al. (1995) and Singh *et al.* (1995) have also reported heterosis for total yield due to increase in fruit number and fruit size.

Heterosis observed in present study for the above mentioned characters in tomato are in conformity with those of Singh *et al.* (1988) for plant height and number of primary branches plant^{-1}; Kumar *et al.* (1995) for number of fruits; Singh *et al.* (1995) for fruit weight and early yield plant^{-1} and Dod and Kale (1992) for pericarp thickness. Therefore, those crosses, which showed high *per se* performance and sca effects, should be selected.

Conclusion

On the basis of results obtained in the present investigation, it may be concluded that heterotic hybrids, Bilahi-2 x H-86 and Himlata x H-86 were found to be common among best five hybrids selected according to their *per se* performance, heterobeltiosis, standard heterosis and sca effects for total yield in both the environment and identified as most valuable breeding material for developments of hybrids. Other cross combinations identified as promising hybrids for yield and its component traits according to their standard heterosis and *per se* performance were MM x H-86, MM x H-88 and NDT-3 x H-86, KS-60 x H-24, EC 168282 x H-86, KS-60 x H-86 and NDT-2 x H-86 were also found to be valuable breeding material for major component characters other than yield in E_1 and/or E_2 environments.

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