Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 7, Issue, 12, pp.24038-24043, December, 2015

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

STUDIES ON HETEROSIS FOR VARIOUS QUALITATIVE AND QUANTITATIVE CHARACTERS IN TOMATO (*LYCOPERSICON ESCULENTUM L.*)

***Chandanshive Aniket Vilas, M. K., Rana, S. K., Dhankhar, Neha Yadav and Vikash Kumar**

Department of Vegetable Science, CCS HAU, Hisar, Haryana, India

ARTICLE INFO

Article History:
Received 07th September, 2015
Received in revised form
29th October, 2015
Accepted 05th November, 2015
Published online 30th December, 2015

Key words:
Heterosis,
Yield,
Qualitative and quantitative traits,
Tomato,
Lycopersicon esculentum L.

ABSTRACT

An experiment on heterosis for yield and other component characters of 50 F1 hybrids of tomato derived from the crosses between 10 lines and 5 testers through line x tester technique was conducted at the Research Farm of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar during 2012-13 and 2013-14. The analysis of variance indicated significantly higher amount of differences among treatments for all the characters studied, suggesting the presence of genetic variation among the studied genotypes. In this study, among crosses, the cross combinations in favourable direction was observed for EC 620380 x Punjab Chhuhara. The cross BBWR-11-1 x Palam Pink recorded significantly maximum heterosis for days to 50% flowering and number of fruits per plant and the cross Punjab Varkha Bahar-2 x Hisar Lalit (0.400), EC 620383 x Palam Pink (0.383) and BBWR-10-3-18 x Hisar Lalit (0.382) for higher early fruit yield per plant (kg) as compared to standard checks. The cross EC 620380 x Punjab Chhuhara (0.133 kg) produced the minimum early yield and the cross EC 620391 x Punjab Chhuhara (0.886 kg) the maximum total yield per plant, manifesting higher heterosis for yield per plant. Similarly, the cross Punjab Varkha Bahar-2 x Hisar Lalit (0.88%) registered acidity more than the standard check Hisar Arun.

***Citation*: Chandanshive Aniket Vilas, M. K., Rana, S. K., Dhankhar, Neha Yadav and Vikash Kumar, 2015.** "Studies on Heterosis for various qualitative and quantitative characters in Tomato (*Lycopersicon Esculentum* L.)", *International Journal of Current Research*, 7, (12), 24038-24043.

INTRODUCTION

Tomato (*Lycopersicon esculentum* L.), a member of *Solanaceae* family, is perennial in growth habit but commonly grown as an annual plant all over the world. It is gaining popularity among the consumers because of its higher content of antioxidants like vitamin C and lycopene. It has commercial value in the extraction of tomatine, a steroidal hormone, which is used as a substitute of diosgenin. Its increasing consumption makes it a high value crop for generating income to the farmers. Tomato can be exploited for hybrid seed production because of its easiness in crossing and growing under varied climatic conditions, fruit containing large number of seeds and possessing high degree of heterosis for growth and yield earliness. The choice of parents for hybridization needs to be based upon complete genetic information, the knowledge of heterosis and their combinations for the improvement of characters under consideration. Exploitation of hybrid vigour is one of important means by which the crop yield can be increased. In view of the above facts, the efforts were made to develop F_1 hybrids for high yield, qualitative and quantitative traits.

****Corresponding author: Chandanshive Aniket Vilas, M. K.,***
Department of Vegetable Science, CCS HAU, Hisar, Haryana, India

MATERIALS AND METHODS

The experimental material comprising 15 genotypes (10 lines, 5 testers and 2 checks) was sown in nursery during 2012. The crosses were made in a line x tester fashion, and the F_1 seed was extracted during 2013. Fifty F_1 crosses along with 15 parents and standard check were sown in the nursery during 2013 and 2014, and the seedlings were transplanted in Randomized Block Design with three replications accommodating 14 plants in each treatment at spacing of 75x45 cm. All the recommended cultural practices and plant protection measures were adopted to raise the crop successfully.

Crosses were made manually by using the standard procedure of hand emasculation and pollination. F_1s were evaluated along with their parents for various traits. Observations were recorded on number of flowers per cluster, number of flower clusters per plant, number of fruits per truss, total number of fruits per plant, early fruit yield per plant, total fruit yield per plant, acidity and total soluble solids. The mean values of all the above characters were subjected to statistical analysis and heterosis was determined as increase or decrease of F_1 hybrids over standard check variety Hisar Arun.

RESULTS AND DISCUSSION

The mean performance of parents, crosses and percent of heterosis estimated over standard check variety Hisar Arun and Avinash II is presented in Table 1 to 8.

Mean performance and range

Days to 50% flowering

The genotypic difference for days to 50% flowering was found significant. The results of present study indicate that most of the hybrid combinations were found late in flowering (Table 1) but some of the lines *viz*., EC 620391, EC 620533, BBWR-11-1 and Punjab Varkha Bahar-2 showed earliness for days to 50% flowering. All the testers showed significance for days to 50% flowering except Arka Meghali. Similarly, all the lines except EC 620391, EC 620533, BBWR-10-3-17 and Punjab Varkha Bahar-2 and one tester Arka Meghali were late in flowering as compared to standard check Hisar Arun.

Similar to the present study, Brahma *et al*. (1991) and Uppal *et al*. (1997) also reported the hybrids early in flowering and maturity. On the other hand, Tayel *et al*. (1995) reported the hybrids late in flowering as compared to their parents. These findings are in close agreement with the findings of Shankar *et al*. (2013) and Chauhan *et al*. (2014).

Days to 50% fruit set

The genotypes were not significant for days to 50% fruit set, hence, the results have not been interpreted in detail. Most of the hybrid combinations were late for days to 50% fruit set (Table 2). Similarly, all the lines except EC 620391, EC 620445 and BBWR-10-3-17 and testers were also late in 50% fruit set in comparison to standard check Hisar Arun. Similar to the present study, Young *et al*. (1966), Babu *et al*. (1978), Virdewala *et al*. (1981), Khattra *et al*. (1988), Brahma *et al*. (1991) and Uppal *et al*. (1997) also observed the hybrids early in days to 50% fruit set, while Tayel *et al*. (2000) and Kumar *et al*. (2013) reported the hybrids late in 50% fruit set as compared to their parents.

Number of branches per plant

The number of branches per plant showed a range of 3.33 to 8.00 (Table 3). The line EC 620445 (7.67) and tester Arka Meghali (7.66) produced the maximum number of branches per plant. Among hybrids, the maximum number of branches per plant was observed in EC 620383 x Punjab Chhuhara (8.00) followed by EC 620533 x Arka Vikas (7.66) and BBWR-11-1 x Palam Pink (7.66). The least number of branches per plant was produced by the line EC 620534 (4.33), tester Arka Vikas (3.33) and cross combination BBWR-10-3-18 x Palam Pink (3.33).

Table 1. Mean performance of parents, crosses for Days to 50% flowering of parents and hybrids in a line x tester set of tomato

Testers	Lines	EC 620380	EC 620383	EC 620391	EC 620445	EC 620533	EC 620534	BBWR-10-3-17	BBWR-10-3-18	BBWR-11-1	Punjab Varkha Bahar-2
	Mean	32.00	34.33	29.67	30.67	28.67	33.33	32.00	30.33	28.33	26.67
Palam Pink		29.00	31.66	31.33	32.66	29.33	32.66	31.00	30.66	31.00	29.66	28.00
Punjab Chhuhara		30.66	26.33	32.00	32.33	29.66	32.66	30.33	31.66	31.66	29.66	30.66
Arka Vikas		31.33	26.66	31.66	31.66	30.33	31.66	30.66	31.66	28.33	27.00	32.66
Arka Meghali		31.66	28.66	30.66	30.33	31.66	32.33	30.33	32.00	32.00	31.33	28.66
Hisar Lalit		30.33	29.33	32.33	31.66	31.33	31.66	30.33	32.66	29.66	29.33	26.66

Mean values for standard hybrids: (i) Hisar Arun = 28.7 (ii) Avinash II = 34.66, SE(d) =1.99, C.D at 5% level of significance = 3.95, CV = 7.98

Table 2. Mean performance of parents, crosses for Days to 50% fruit set of parents and hybrids in a line x tester set of tomato

Testers	Lines	EC 620380	EC 620383	EC 620391	EC 620445	EC 620533	EC 620534	BBWR-10-3-17	BBWR-10-3-18	BBWR-11-1	Punjab Varkha Bahar-2
	Mean	66.67	65.00	64.33	64.33	65.67	66.33	66.33	64.33	66.33	65.67
Palam Pink		29.00	66.33	66.00	65.66	63.66	65.66	60.66	64.66	65.33	63.00	58.00
Punjab Chhuhara		63.66	63.00	62.66	65.00	65.33	64.00	63.33	62.66	63.33	61.66	64.66
Arka Vikas		63.00	63.33	63.00	63.33	66.66	61.66	64.33	60.33	65.00	62.33	63.00
Arka Meghali		65.33	58.66	62.00	65.00	62.66	61.66	58.66	62.66	58.33	65.33	63.00
Hisar Lalit		66.33	62.66	61.33	65.33	62.66	65.66	56.66	65.00	65.66	64.00	62.33

Mean values for standard hybrids: (i) Hisar Arun = 61 (ii) Avinash II = 68.11, SE(d) = 4.55,
C.D at 5% level of significance = 9.02, CV = 8.85

Table 3. Mean performance of parents, crosses for Number of branches per plant of parents and hybrids in a line x tester set of tomato

Testers	Lines	EC 620380	EC 620383	EC 620391	EC 620445	EC 620533	EC 620534	BBWR-10-3-17	BBWR-10-3-18	BBWR-11-1	Punjab Varkha Bahar-2
	Mean	4.67	5.00	6.33	7.67	6.67	4.33	5.00	5.33	7.67	6.67
Palam Pink		5.66	7.66	5.33	6.66	4.00	4.66	4.66	7.00	3.33	7.66	4.33
Punjab Chhuhara		5.66	5.33	8.00	6.00	4.33	7.00	5.66	4.33	7.33	7.66	7.00
Arka Vikas		3.33	5.66	5.33	6.33	6.66	7.66	5.66	5.66	4.33	5.66	6.33
Arka Meghali		7.66	4.33	4.00	4.66	7.00	5.66	4.66	5.00	7.66	6.33	5.66
Hisar Lalit		6.66	4.66	5.66	5.00	6.00	6.66	5.00	5.66	5.33	5.66	4.66

Mean values for standard hybrids: (i) Hisar Arun = 6.33 (ii) Avinash II = 8.66, SE(d) = 0.42 , C.D at 5% level of significance = 0.85, CV = 9.11

The increased branching in hybrids was in accordance with the findings of Singh *et al*. (1993) and Kumar *et al*. (1995) but less number of branches per plant in hybrids was observed by Dokic *et al*. (1954), Tayel *et al*. (1959), Khanna and Chaudhary (1984), Kumar *et al*. (2006), Singh *et al*. (2008), Mohamed *et al*. (2012) and Yadav *et al*. (2013).

Reduction in fruit weight was also prevalent in hybrids as reported by Babu *et al*. (1978) and Kanthaswamy *et al*. (1989). Similar results were also observed by Rao *et al*. (2007), Gul *et al*. (2010), Singh *et al*. (2011), Kumari *et al*. (2011) and Chauhan *et al*. (2014) for average fruit weight (g).

Table 4. Mean performance of parents, crosses for Average fruit weight (g) of parents and hybrids in a line x tester set of tomato

Testers	Lines	EC 620380	EC 620383	EC 620391	EC 620445	EC 620533	EC 620534	BBWR-10-3-17	BBWR-10-3-18	BBWR-11-1	Punjab Varkha Bahar-2
	Mean	31.47	32.21	27.57	29.28	40.26	22.07	32.30	30.15	28.70	27.92
Palam Pink	37.02	27.63	26.43	25.63	27.32	34.48	31.69	26.38	30.76	39.21	26.88
Punjab Chhuhara	30.94	26.88	23.52	26.06	37.76	24.83	27.95	22.84	28.31	35.19	27.26
Arka Vikas	27.05	33.22	24.50	24.54	20.09	30.07	25.63	33.46	25.64	18.38	34.57
Arka Meghali	24.90	30.43	25.53	28.24	32.16	28.27	36.64	26.24	27.12	33.32	36.30
Hisar Lalit	30.22	26.27	24.95	28.14	23.85	29.57	34.15	27.41	31.32	25.01	38.05

Mean values for standard hybrids: (i) Hisar Arun = 28 (ii) Avinash II = 19.33, SE(d) = 2.24,
C.D at 5% level of significance = 4.45, CV = 9.45

Table 5. Mean performance of parents, crosses for Number of locules per fruit of parents and hybrids in a line x tester set of tomato

Testers	Lines	EC 620380	EC 620383	EC 620391	EC 620445	EC 620533	EC 620534	BBWR-10-3-17	BBWR-10-3-18	BBWR-11-1	Punjab Varkha Bahar-2
	Mean	4.13	4.30	4.20	5.03	4.00	2.62	3.13	2.70	4.60	5.20
Palam Pink	3.56	4.63	3.54	4.66	3.33	6.18	5.69	5.94	3.64	5.68	3.40
Punjab Chhuhara	3.60	4.53	5.17	4.22	4.26	5.81	4.79	4.53	4.60	6.27	4.80
Arka Vikas	4.79	2.86	5.54	4.43	3.40	6.41	4.72	3.63	3.26	4.96	6.53
Arka Meghali	6.38	3.60	4.64	3.53	5.63	6.02	5.86	3.92	3.43	4.46	2.46
Hisar Lalit	3.60	3.63	4.77	3.73	6.46	4.55	4.56	6.63	4.86	5.86	3.40

Mean values for standard hybrids: (i) Hisar Arun = 5.33 (ii) Avinash II = 3.33, SE(d) = 0.38, C.D at 5% level of significance = 0.75, CV= 10.25

Table 6. Mean performance of parents, crosses for Total soluble solids content (%) of fruits of parents and hybrids in a line x tester of tomato

Testers	Lines	EC 620380	EC 620383	EC 620391	EC 620445	EC 620533	EC 620534	BBWR-10-3-17	BBWR-10-3-18	BBWR-11-1	Punjab Varkha Bahar-2
	Mean	4.05	7.25	5.16	7.88	6.24	5.44	4.29	5.33	5.57	4.91
Palam Pink	3.21	3.66	4.20	6.60	6.40	5.10	4.60	3.73	6.57	4.43	6.23
Punjab Chhuhara	4.06	5.66	6.53	7.76	5.83	6.43	7.18	6.53	7.10	7.53	4.26
Arka Vikas	5.02	6.53	4.56	7.86	6.53	4.50	7.41	7.36	6.26	4.16	5.86
Arka Meghali	6.32	6.10	5.26	5.43	6.44	5.53	6.46	7.43	7.13	5.46	4.83
Hisar Lalit	5.14	7.26	7.16	4.70	6.15	5.76	5.63	3.83	7.13	4.43	5.53

Mean values for standard hybrids: (i) Hisar Arun = 5.1 (ii) Avinash II = 3.63, SE(d) = 0.10,
C.D at 5% level of significance = 0.21, CV = 2.29

Table 7. Mean performance of parents, crosses for Acidity (%) of fruits of parents and hybrids in a line x tester set of tomato

Testers	Lines	EC 620380	EC 620383	EC 620391	EC 620445	EC 620533	EC 620534	BBWR-10-3-17	BBWR-10-3-18	BBWR-11-1	Punjab Varkha Bahar-2
	Mean	0.58	0.67	0.67	0.73	0.76	0.71	0.78	0.56	0.76	0.74
Palam Pink	0.67	0.65	0.81	0.62	0.66	0.56	0.67	0.81	0.74	0.71	0.71
Punjab Chhuhara	0.62	0.74	0.62	0.66	0.61	0.65	0.71	0.76	0.67	0.78	0.61
Arka Vikas	0.56	0.54	0.81	0.76	0.77	0.78	0.74	0.73	0.71	0.71	0.68
Arka Meghali	0.65	0.75	0.61	0.67	0.71	0.55	0.78	0.66	0.76	0.65	0.77
Hisar Lalit	0.76	0.65	0.71	0.72	0.71	0.78	0.80	0.77	0.66	0.58	0.88

Mean values for standard hybrids: (i) Hisar Arun = 0.66 (ii) Avinash II = 0.54, SE(d) = 0.01, C.D at 5% level of significance = 0.02, CV = 2.46

Average fruit weight (g)

The average fruit weight ranged from 18.38 to 39.21. The cross BBWR-11-1 x Palam Pink (39.21 g) and Punjab Varkha Bahar-2 x Hisar Lalit (38.05g) produced fruits with maximum average fruit weight and surpassed the standard check Hisar Arun as well (Table 4). The fruits having least average weight were born by the cross BBWR-11-1 x Arka Vikas (18.38). The earlier reports also suggested an increase in average fruit weight of tomato hybrids (Jasmine *et al*., 1993; Padmini *et al*., 1997).

Number of locules per fruit

The number of locules per fruit was recorded in a narrow range of 2.46 to 6.63 (Table 5). The maximum number of locules per fruit was found in line Punjab Varkha Bahar-2 (5.20) followed by EC 620445 (5.03), BBWR-11-1 (4.60) and EC 620383(4.30) and in cross combination BBWR-10-3-17 x Hisar Lalit (6.63). Among testers, the number of locules per fruit was found high in Arka Meghali (6.38). The highest number of locules per fruit was observed in cross BBWR-10-

3-17 x Hisar Lalit (6.63). For number of locules per fruit, these crosses surpassed the standard check. Among the lines, none of the lines recorded more number of locules per fruit than the standard check Hisar Arun, but in case of another check Avinash II, six lines, *i.e*., EC 620380, EC 620383, EC 620391, EC 620445, BBWR-11-1 and Punjab Varkha Bahar-2, had more locules per fruit than the standard check Avinash II. The tester Palam Pink (3.56) possessed the least number of locules per fruit. Close results have also been reported by various workers (Kurian *et al*., 1997; Singh *et al*., 1998) who found that the hybrids with high shape index possessed fewer number of locules per fruit, whereas, the increase in number of locules per fruit was reported by Singh *et al*. (2008), Ahmad *et al*. (2011) and Farzane *et al*. (2012).

Total soluble solids (%)

The total soluble solids of fruits ranged from 3.66 to 7.41% (Table 6). The highest TSS was noted in line EC 620445 (7.88%). The tester Hisar Meghali (6.32%) and Hisar Lalit (5.14%) had more TSS than the check variety Hisar Arun. The least amount of total soluble solids was present in Palam Pink (3.21%). Among crosses, the cross EC 620534 x Arka Vikas (7.41%) recorded the highest TSS. The lowest TSS in case of hybrids was noted in cross EC 620380 x Palam Pink (3.66%). The TSS to acidity ratio of fruits is important in maintaining balanced taste for fresh table use as well as for processing. In present study, higher TSS content was in conformity with the earlier results of Das *et al*. (1984), Patil *et al*. (1985), Bhardwaj *et al*. (1995), Padmini *et al*. (1997), Chaudhary *et al*. (2001), Singh *et al*. (2008), Kumari *et al*. (2011), Droka *et al*. (2012) and Agarwal *et al*. (2014) but contrary to the report of Kanthaswamy and Balkrishnan (1989).

Acidity (%)

The titrable acidity percentage of fruits ranged from 0.54 to 0.88 (Table 7). Six out of ten lines *viz*., EC 620445, EC 620533, EC 620534, BBWR-10-3-17, BBWR-11-1 and Punjab Varkha Bahar-2, and one tester Hisar Lalit had more acidic fruits than standard check Hisar Arun. Similarly, the cross Punjab Varkha Bahar-2 x Hisar Lalit (0.88) registered acidity more than the standard check Hisar Arun. Among lines, the line BBWR-10-3-17 (0.78) showed the highest acidity. The tester Hisar Lalit also exhibited the highest acidity of fruits (0.76), and Palam Pink (0.67) was next in the order. High acidity of fruits is important for processing purposes, while the fruits with low acidity are preferred for fresh table use. Hence, fruits of both kinds fetch higher price in the market. High acidity of fruits was also revealed by some workers (Bhardwaj *et al*., 1995; Shrivastava *et al*., 1998), while low acidity of tomato fruits was recorded by Mochizuki *et al*. (1986), Kanthaswamy and Balkrishnan (1989), Kurian and Peter (1997) and Droka *et al*. (2012).

Ascorbic acid content (mg/100 g of fruit)

The ascorbic acid content of tomato fruits varied from 16.94 to 28.63 (Table 8). In lines, the highest value for ascorbic acid content was observed for EC 620380 (28.62). Among the crosses, the cross EC 620533 x Arka Meghali (28.63) exhibited the highest amount of ascorbic acid. Among the crosses, most of the cross combinations were found over the best standard check Hisar Arun for ascorbic acid and exhibited superiority for ascorbic acid content of fruits. In crosses, the lowest ascorbic acid content was recorded in cross EC 620391 x Hisar Lalit (16.94). The character ascorbic acid is much important from nutrition point of view. The high ascorbic acid content in tomato fruits was earlier reported by Singh *et al*. (1979), Jamwal *et al*. (1984), Kumar *et al*. (1997) and Bhatt *et al*. (1998), while Kanthaswamy and Balkrishnan (1989); Kumari *et al*. (2011) and Droka *et al*. (2012) noticed low ascorbic content in all the inter-varietal crosses.

Table 8. Mean performance of parents, crosses for Ascorbic acid content (mg/ 100g of fruit) of fruits and hybrids in a line x tester set of tomato

Testers	Lines	EC 620380	EC 620383	EC 620391	EC 620445	EC 620533	EC 620534	BBWR-10-3-17	BBWR-10-3-18	BBWR-11-1	Punjab Varkha Bahar-2
	Mean	28.62	26.97	20.83	21.35	22.44	19.03	19.92	23.06	25.36	22.47
Palam Pink		25.99	20.92	26.91	18.76	26.81	25.45	27.36	24.96	28.13	22.79	18.96
Punjab Chhuhara		25.87	21.27	25.93	21.84	23.52	26.57	24.73	19.88	22.59	25.17	19.54
Arka Vikas		17.20	28.40	26.75	27.32	23.15	22.90	26.97	20.22	25.56	24.75	23.99
Arka Meghali		14.71	21.94	23.63	21.70	17.05	28.63	23.50	23.62	22.82	23.87	23.64
Hisar Lalit		19.00	26.48	23.30	16.94	28.11	17.92	25.91	24.95	22.59	18.99	25.85

Mean values for standard hybrids: (i) Hisar Arun = 21.93 (ii) Avinash II = 17.1, SE(d) = 0.43,
C.D at 5% level of significance = 0.85, C V = 2.25

DISCUSSION

The results discussed in detail reveal that there was considerable heterosis for almost all the 8 characters studied. It also indicated the possibility of increasing yield by exploiting heterosis. The presence of high heterosis indicated genetic diversity between parents. Therefore, with increased diversity among genotypes, higher level of heterosis is expected in F_1 hybrid. Jamwal *et al*. (1984) observed that the increase in yield of hybrids was mainly due to the increase in the number of flowers per cluster, early fruit yield per plant and total fruit yield per plant, while Farzane *et al*. (2012) reported that heterosis in yield was attributed to the increase in number of flower clusters per plant and number of fruits per truss. In this study, the maximum heterosis in number of flowers per cluster was recorded in cross EC 620380 x Arka Meghali (9.66) and EC 620383 x Palam Pink. The cross EC 620391 x Hisar Lalit (10.66) produced the more number of flower clusters per plant, the cross EC 620533 x Arka Vikas (6.33) the highest number of fruits per truss and the cross BBWR-11-1 x Palam Pink (30.66) the highest number of fruits per plant, while the cross Punjab Varkha Bahar-2 x Hisar Lalit (0.400) showed the maximum early fruit yield per plant and the cross EC 620391 x

Punjab Chhuhara the maximum total yield per plant (0.886). So, it could be concluded that higher percent of heterosis is responsible for the characters studied and subsequently, the cross combinations manifested the higher heterosis over better parent for various qualitative and quantitative characters in tomato.

Acknowledgment

The authors would like to express their sincere gratitude to the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar, Haryana for providing necessary facilities to carried out the experiment.

REFERENCES

Agarwal, A. Arya, D. N. Ranjan, R. and Ahmed, Z. 2014. Heterosis, combining ability and gene action for yield and quality traits in tomato (*Solanum lycopersicum* L.). *Helix*. 2: 511-515.

Ahmad, S.K. Quamruzzaman, M. and Islam, M.R. 2011. Estimate of heterosis in tomato *(Solanum lycopersicum* L.). *Bangladesh Journal of Agriculture Research*, 36(3): 521-527.

Babu, R.Y. 1978. Studies on heterosis in tomato (*Lycopersicon esculentum* Mill.). *Mysore Journal Agricultural Sciences*, 19: 676-677.

Bhardwaj, M.L. Kumari, A. Pathania, N.K. and Raj, H. 1995. Studies on quality attributes in different genotypes of tomato. *Advances in Horticulture and Forestry*, 4: 61-65.

Brahma, R.C. Bhowmik, A. and Ali, M.S. 1991. Inheritance of four quantitative traits in tomato (*Lycopersicon esculentum* Mill.). *Annals of Bangladesh Agriculture*, 1(1): 41-43.

Chaudhary, D.R. and Malhotra, S.K. 2001. Studies on hybrid vigour in tomato (*Lycopersicon esculentum* Mill.). *Indian Journal Agricultural Research,* 35(3): 176-180.

Chauhan, V.B.S. Kumar, R. Behera, T.K. and Yadav, R.K. 2014. Studies on heterosis for yield and its attributing traits in tomato (*Solanum lycopersicum* L.). *International Journal of Agriculture Environment and Biotechnology,* 7(1): 95-100.

Das, B. Hazarika, M.H. and Das, P.K. 1998. Genetic variability and correlation in fruit characters of tomato (*Lycopersicon esculentum* Mill.). *Annals of Agricultural Research*, 19(1): 77-80.

Dockic, A. 1954. Studying dominant character in inter-varietal tomato hybrids. *Plant Breeding Abstract*, 25: 253.

Droka, D. Kumar, R. Joshi, S. and Yadav, R.K. 2012. Genetic studies of quality traits in tomato (*Solanum lycopersicum* L.) under low temperature *Vegetable Science,* 39(2): 189-191.

Farzane, A. Nemati, H. Arouiee, H. Kakhki, A. M. and Vahdati, N. 2012. The estimate of combining ability and heterosis for yield and yield components in tomato (*Lycopersicon esculentum* M.). *J. Biol. Environ. Sci.* 6(17): 129-134.

Gill, H. S. Arora, R. S. Tiwari, R.N. and Sharma, R. K. 1976. Exploitation of heterosis in tomato (*Lycopersicon esculentum* Mill.). *Indian J. Hort.* 33(2): 176-181.

Gul, R., Rahman, H.U. Khalil, I.H. Shah, S.M.A. and Ghafoor, A. 2010. Heterosis for flower and fruit traits in tomato (*Lycopersicon esculentum* M.). *African Journal of Biotechnology,* 9(27): 4144-4151.

Jamwal, R. S. Rattan, R. S. and Saini, S.S. 1984. Hybrid vigour and combining ability in tomato. *South Indian Hort.* 32(2): 69-74.

Jasmine, A.P.J. and Ramadas, S. (1993). Evaluation of certain F_1 hybrids and cultivars of tomato for yield and yield components. *South Indian Horticulture*, 41(5): 248-250.

Kanthaswamy, V. and Balakrishnan, R. 1989. Studies on hybrid vigour in F_1 and its retention in F_2 generation of tomato (*Lycopersicon esculentum* Mill.). *South Indian Horticulture*, 37(2): 77-83.

Khanna, K.R. and Chaudhary, R.C. 1984. The nature of gene action and combining ability for some vegetative characters in tomato. *Euphytica*, 23: 159-165.

Khattra, A.S. Nandpuri, K.S. and Thakur, J.C. 1988. Heterosis and heritability studies in tomato. *Punjab Vegetable Grower*, 23: 6-10.

Kumar, R. Mishra, N.K. Singh, J. Rai, G.K. Verma, A. and Rai, M. 2006. Studies on yield and quality traits in tomato [*Solanum lycopersicon* (Mill). Wettsd.]. *Vegetable Science*, 33(2): 126-132.

Kumar, R. Srivastava, K. Singh, N.P. Vasistha, N.K. Singh, R.K. and Singh, M.K. 2013. Combining ability analysis for yield and quality traits in tomato (*Solanum lycopersicum* L.). *Journal of Agricultural Science*, 5(2): 213-218.

Kumar, T.P. Tewari, R.N. and Pachauri, D.C. 1997. Line x tester analysis for processing characters in tomato. *Vegetable Science*, 24(1): 34-38.

Kumari, S. and Sharma, M.K. 2011. Exploitation of heterosis for yield and its contributing traits in tomato, (*Solanum lycopersicum* L.). *International Journal of Farm Science*, 1(2): 45-55.

Kurian, A. and Peter, K.V. 1997. Association of fruit shape index and quality characters in tomato. *Indian Journal of Genetics and Plant Breeding*, 57(1): 82-86.

Mohammad, Y.S. Muhammad. Q. Iqbal, A.R. and Muhammad, A. 2013. Diallel analysis of yield and some yield components in tomato (*Solanum lycopersicum* L.). *Pakistan Journal of Botany*, 45(4): 1247-1250.

Mohammad, Y.S. Muhammad. Q. Iqbal, A.R. and Muhammad, A. 2013. Diallel analysis of yield and some yield components in tomato (*Solanum lycopersicum* L.). *Pakistan Journal of Botany*, 45(4): 1247-1250.

Padmini, K. and Vadivel, E. 1997. Studies on genetic variability and heritability in F_2 generation of tomato (*Lycopersicon esculentum* Mill.). *South Indian Horticulture*, 45(1- 2): 1-4.

Padmini, K. and Vadivel, E. 1997. Studies on genetic variability and heritability in F_2 generation of tomato (*Lycopersicon esculentum* Mill.). *South Indian Horticulture*, 45(1- 2): 1-4.

Pandey, S. K. Dixit, J. Pathak, V. N. and Singh, P. K. 2006. Line x tester analysis for yield and quality characters in tomato (*Solanum lycopersicon* M.). *Veg. Sci.* 33: 13-17.

Patil, A.A. 1985. Studies on correlation, path analysis, genetic divergence, heterosis and combining ability in ten parent diallel cross of tomato (*Lycopersicon esculentum* Mill.). *Mysore Journal of Agricultural Sciences*, 19(1): 48-49.

Rao, E.S. Munshi, A.D. Singh, B. and Kumar, R. 2007. Studies on heterosis and combining ability for yield and resistance

to early blight in tomato. *Indian Journal of Horticulture,* 64(3): 331-334.

Shankar, A. Reddy, R.K. Sujatha, M. and Pratap, M. 2013. Combining ability and gene action studies for yield and yield contributing traits in tomato (*Solanum lycopersicum* L.). *Helix,* 6: 431-435.

Shrivastava, A.K. 1998. Heterosis and inbreeding depression for acidity, total soluble solids, reducing sugar and dry matter content in tomato (*Lycopersicon esculentum* Mill.). *Advances in Plant Science*, 11(2): 105-110.

Singh, B. Rawat, P.S. and Pant, P.C. 1979. Heterosis for ascorbic acid in tomato. *Indian Journal of Agricultural Sciences*, 49(3): 177-178.

Singh, C.B. Rai, N. Singh, R.K. Singh, M.C. Singh, A.K. and Chaturvedi, A.K. (2008). Heterosis, combining ability and gene action studies in tomato (*Solanum lycopersicum* L.). *Vegetable Science*, 35(2): 132-135.

Singh, N. B. Shabir, H. Wani, A. and Haribhushan, Rita. 2012. Heterosis studies for yield and its components in tomato (*Solanum lycopersicum* L.) under Valley conditions of Manipur. *Vegetos*. 25(2): 257-265.

Singh, N.B. Wani, S.H. Haribhushan, A. and Nongthombam, R. 2012. Heterosis Studies For Yield and Its Components in Tomato (*Solanum lycopersicum* Mill.) under valley conditions of Manipur. *Vegetos*, 25(2): 257-265.

Singh, R.K. and Singh, V.K. 1993. Heterosis breeding in tomato. (*Lycopersicon esculentum* Mill.). *Annals of Agricultural Research*, 14(4): 416-420.

Singh, S. 1972. Hybrid vigour studies in tomato (*Lycopersicon esculentum* Mill.). *PAU Journal of Research*, 9(1): 19-26.

Singh, S. Dhaliwal, M.S. Cheema, D.S. and Brar, G.S. 1998. Diallel analysis of some processing attributes in tomato. *Journal of Genetics and Plant Breeding,* 52(3): 265-269.

Tayel, M.A. Kamel, S.A. and Gafar, M.E. 1959. Analysis of yield in an inter-varietal cross of tomato. *Annals of Agricultural Sciences*, Cairo, 5: 1-15.

Uppal, G.S. Lal, T. and Cheema, D.S. 1997. Performance of tomato hybrids with regard to yield and quality characters. *PAU Journal of Research,* 34(1): 45-56.

Yadav, S.K., Singh, B.K., Baranwal, D.K. and Solankey, S.S. 2013. Genetic study of heterosis for yield and quality components in tomato (*Solanum lycopersicum* Mill.). *African Journal of Agricultural Research,* 8(44): 123-128.

Young, W.A. 1966. A study of factor affecting earliness and mode of inheritance of this character in tomato (*Lycopersicon esculentum* Mill.). *Dissertation Abstract*, 26: 4159-4160.

****