INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 12, No. 1, p. 160-167, 2018

RESEARCH PAPER OPEN ACCESS

Estimation of hybrid vigor for yield and yield related traits in tomato (*Solanum lycopersicon* MIll)

Adnan Rasheed[*1,2], Shahoor Ahmed[1], Ghulam Mustafa Wassan[3], Abdul Malik Solangi[3], Muhammad Aamer[1], Hira Khanzada[3], Ayaz Ali Keerio[3], Abdul Qadeer[2], Israr Ahmed[1]

[1]*Department of Horticultural Research and Development, National Agricultural Research Centre, Islamabad, Pakistan*

[2]*Department of Plant Breeding and Molecular Genetics, University of Poonch Rawalakot, Azad Jammu and Kashmir, Pakistan*

[3]*Wheat Research Station Tandojam, Sindh, Pakistan*

Key words: Tomato, Heterosis, Yield

http://dx.doi.org/10.12692/ijb/12.1.160-167 Article published on January 12, 2018

Abstract

Proposed research study was conducted at the experimental field of DHRD, NARC Islamabad to estimate hybrid vigor for yield related traits in tomato. Study was more important to developed indeginious hybrids to compete the exiotic hybrids to meet the demands of locan farmers because seed of exiotic hybrid is very costly. Line x Tester anakysis was used to developed hybrids. Nine parents, 15 F_1s were used in experiment. Heterotic analysis depicted that all hybrids were found superior for plant height, no. of flowers cluster^{-1}, no. of fruits cluster^{-1}, plant height, single fruit weight and fruits setting % cluster^{-1} and some hybrids showed negative heterosis and heterobeltiosis for no. of clusters plant^{-1}, no. of branches plant^{-1}, no. of locules fruit^{-1} and yield plant^{-1}. For days to 50% flowering and days to 50% fruits maturity most F_{1s} were superior. For no. of flowers cluster^{-1}Naginax 17905 and Nagina x BSX-935 for no. of fruits cluster^{-1} Naginax BSX-935 and Riogrande xBSX-935, for single fruit weight, Riogrande x Continental and Riogrande x 17905, for fruit sett % cluster^{-1} Roma x BSX-935 and Pakit x BSX-935 were superior and heterosis could be exploited in these F_{1s} for said traits. On the bais of key findings it was concluded that Nagina x 17905 (152.52*, 120.58*), Roma x 17905 (125.14**, 115.05**) and RomaxBSX-935 (123.10**, 77.21**) expressed highly significant heterosis and heterobeltiosis for yield plant^{-1} as these hybrids could be used in future breeding programme.

* **Corresponding Author:** Adnan Rasheed ✉ adnanbreeder@yahoo.com

Introduction

Tomato (*Solanum lycopersicon* MIll.) is most important vegetable crop and belongs to the family Solanaceae and it has a chromosome number of (2n=24). Its Centre of origin is country South Mexico. It is ranked on second number after potato in world. Tomato is consumed regularly and it mixed with other cooking products like potato, bringel and cabbage. This crop is grown on about fifty two thousand hectares (52.30) area with estimated annual production of about 10.10 tons/hectare (Ramzan *et al.*, 2014). In Pakistan yearly production of tomato crop reaches to 0.3 million tons (MFAL, 2015).Pakistan lack enough tomato seed for local cultivation and therefore imported 85.5 metric tons of quality seed amounting to US $ 2.45 million during the year 2013-2014 to full fill the space (MNFSR, 2015). Total production of tomato in world during 2015 was 166 million tons produced on 4.7 million hectares (FAO, 2015). Heterosis is the increase in performance of a F_1 hybrid in honor to the parent average, and can be supposed with positive or negative values (Aguiar *et al.,* 2007).

Heterosis in tomato was first worked out by two known scientists named (Hedrick and Booth, 1968). Better parent heterosis was first reported for plant height and number of primary branches plant^{-1} by (Amin et al., 2001) and for early and total yield by Khalil (2004). Meanwhile, such a type of heterosis was found absent for average fruit weight in study conducted by (El-Gazar *et al.,* 2002) who demonstrated that all hybrids yielded fruits of smaller size than their best parent. The importance of hybrid vigor is that through the exploitation of heterosis we can increase the yield of crops. Heterosis in tomato is in form of earliness in maturity, increased productivity, faster growth and development and greater vigor (Yordanov, 1983). So a speedy improvement can be carried about by exploiting heterosis for several yield related features. When hybrid performs best from its superior parent in one or more traits is called heterobeltiosis. Tomato breeders are working on tomato hybridization by crossing genotypes of different characters.

During the last century breeders used improved breeding techniques in tomato which directed to the development of tomato cultivars which have high genetic potential as well as their F_1s having desireable yield along quality features also as described by (Chattopadhyay and Paul, 2012). Vigorous hybrids provide several benefits to farmers and consumers, including increased yield, early maturity of crop, early fruits uniformity, quality of fruit, increasing diseases resistance and insect attack and reducing seed charge per unit area as described by (Souza *et al.*, 2012).

A main cause of concern is the hindrance to choose hybrid vigor with satisfactory fruit production. Therefore, trustworthy and practical tools to find tomato genotypes of potential interest to be used in breeding schemes as parents (Male and Female). Many breeders have completed their study on hybrid vigor in tomato (Bhatt *et al.*, 2001). Lot of studies have been completed on gene action, combining ability and hybrid vigor but work on tomato hybrid seed production on commercial levels has been restricted due to non-availability of best combiners parents of tomato in Pakistan. Most commonly grown tomato varieties in the country are pure lines (with low yield potential). The aims of the study were estimation of hybrid vigor for yield and yield related traits of tomato and to reduce the price of hybrid seed up to 3 rupee/seed as compared to 5 rupee/seed of exotic seed through development of indigenous hybrids.

Materials and methods

The proposed research study was conducted at the experimental field of Department of Horticultural Research and Development, National Agricultural Research Center, Islamabad during 2016. The aim of study was ˝ Estimation of hybrid vigor for yield and yield related traits in tomato˝. The experimental design used was Randomized Complete Block Design with three replications. Size of plot was 1.25cm x 4cm (L x W). For Experimental material the seed of parents and F_1s was placed in incubator for one week at 30˚C. After one week the germinated seed was sown in trays.

These trays were placed in tunnels so that required temperature can be provided. Plant to and row to row distance was (50 cm, 75cm). Five plants sample was used to collect data. Eight parents included e testers and five lines and their 15 F_1s crosses were used in experiment. This project was done with zero fertilizer input to know the actual yield potential of genotypes. The main reason of using these parents in study was that these parents have been tested with specific objective of their combining ability at Directorate of Vegetables, Department of Horticultural Research and Development (DHRD), National Agricultural Research Center, Islamabad. The main reason of using these parents and hybrids again was that for approval of hybrid we need two year on station data and two year data of multi-locational trail. These parents and hybrids would be further evaluated for two years more. Specific combining ability was tested by using Line x Tester model included five lines and three testers. The parents showed good specific combining ability that's why these parents were used in this study. Combinations incorporated in study have good combining ability. Data was recorded on following plant parameters viz. Plant height, days to 50% flowering, number of branches plant^{-1}, number of clusters plant^{-1}, number of flowers cluster^{-1}, number of fruits cluster^{-1}, days to 50% fruits maturity, single fruit weight, number of locules fruit^{-1}, fruits setting percentage cluster^{-1} and yield plant^{-1}

Statistical analysis

Here is the method and formula for heterosis given below. Values of heterosis and heterobeltiosis for yield and yield associated characters were calculated as followed by method of (Turner, 1953) and (Hayes *et al*., 1956). Heterosis = (F1 - MP)/MP) x 100 Where, F1 = mean performance of hybrid, MP = average performance of both parents. Heterobeltiosis = (F1 - BP)/BP) x 100 Where, F1 = mean performance of hybrid, BP = mean performance of better parents.

Rseults and discussion

Hybrid vigor was estimated for yield and yield related traits presented below. Numbers of crosses used for estimation of heterosis were presented below along with mean values of their paresnts (Table 02 and 02). Hybrid showed highly significant heterosis for most of the character. According to (Ahmed and Mustafa, 2000) heterosis observed for most of the characters, plant height, number of branches plant^{-1}, single fruit weight, number of fruit cluster^{-1} and yield plant^{-1} was high and in varying proportion.

Table 1. List of parents and hybrids used in the experiment.

Parents	Hybrids	Hybrids
17905 (tester)	Nagina × 17905	Riogrande × Continental
Riogrande (line)	Nagina × BS-X935	Pakit × 17905
Pakit (line)	Nagina × Continental	Pakit × BSX-935
BSX-935 (tester)	Roma × 17905	Pakit × Continental
Roma (line)	Roma × BSX-935	VCT-01 × 17905
VCT-01 (line)	Roma × Continental	VCT-01 × BSX-935
Pakit (Line)	Riogrande × 17905	VCT-01 × Continental

With respect to plant height all crosses revealed highly significant heterosis except one (Table 2). T-test for all hybrids demonstrated positive values which depicted that plant height got increased in all hybrid combinations as compared to their parents. Maximum and highly significant heterosis regarding plant height was reported for hybrid Nagina x Continental (52.50%) followed by Nagina x 17905 (50.90%), Nagina x BSX-935 (50.85%). These heterotic combinations also exhibited positive and highly significant heterobeltiosis viz, Nagina x Continental (46.90%), Nagina x 17905 (49.76%) and Nagina x BSX-935 (47.31%). Hybrid Naginax Continental revealed highest significant positive heterosis (52.50%) along with highly significant positive heterobeltiosis (46.90%) which showed that for increasing plant height heterosis could be exploited in this cross. With respect to plant height minimum positive and highly significant heterosis was shown by cross, Pakit x BSX-935 (8.09%), Pakitx Continental (10.98%) while among these hybrids heterobeltiosis was found negative and non-significant for Pakitx BSX-935 (-3.19%), positive and significant for Pakit x Continental (5.21%) respectively. Some researchers reported significant positive hybrid vigor for plant height in tomato crosses in their studies (Ahmed *et al.*, 1988).

Table 2. Hybrid vigor for 11 yield and yield related traits in tomato (*Solanum lycoersicon* Mill).

Traits	Plant height (cm)		Days to 50% flowering		Number of branches plant^{-1}		Number of clusters plant^{-1}		Number of flowers cluster^{-1}	
Hybrids	MPH (%)	BPH (%)	MPH (%)	BHP (%)	MPH (%)	BPH (%)	MPH (%)	BPH (%)	MPH (%)	BPH (%)
Nagina × 17905	50.90**	49.76**	-34.09**	-34.09**	17.96**	13.72**	11.42**	3.34	99.10**	81.96**
Nagina × BSX-935	50.85**	47.31**	-5.66**	-14.77**	-5.76**	-7.54**	7.72**	3.04	92.95**	73.80**
Nagina × Continental	52.50**	46.90**	-31.42**	-31.81**	12.92**	8.49**	3.40	1.25	78.48**	49.33**
Roma × 17905	43.47**	41.30**	-17.44**	-19.31**	22.10**	21.67**	0.54	-1.77	21.25**	5.45**
Roma × BSX-935	45.83**	39.29**	-7.09**	-14.28**	4.63**	-0.62	14.22**	-0.35	68.38**	48.48**
Roma × Continental	46.50**	44.31**	-16.95**	-18.39**	9.15**	8.39**	-0.38	-7.80**	54.28**	47.27**
Riogrande × 17905	40.60**	33.66**	-17.97**	-18.88**	2.72	-7.04**	-10.18**	-11.52**	52.89**	51.63**
Riogrande × BSX-935	23.51**	13.99**	-1.86	-12.22**	-5.83**	-18.86**	15.49**	4.21*	73.17**	69.04**
Riogrande × Continental	27.39**	24.71**	2.82	1.11	39.06**	26.24**	10.97**	6.51**	77.77**	60.00**
Pakit × 17905	20.17**	10.72**	-9.30**	-11.36**	18.54**	14.77**	7.04**	-1.11	69.64**	61.48**
Pakit × BSX-935	8.09**	-3.19**	-4.51*	-11.90**	6.84**	-1.88	3.88	-0.21	60.91**	55.55**
Pakit × Continnetal	10.98**	5.21**	-9.94**	-11.49**	1.45	-1.41	24.35**	21.25**	36.84**	30.00**
VCT-01 × 17905	21.32**	10.44**	-21.25**	-28.40**	-10.20**	-13.15**	-10.30**	-12.63**	18.63**	10.63**
VCT-01 × BSX-935	30.45**	15.47**	-14.68**	-15.27*8	-3.53*	-5.66**	38.49**	26.27**	48.31**	40.42**
VCT-01 × Continental	39.70**	30.77**	-8.17**	-16.09**	4.43**	0.65	13.93**	10.58**	64.94**	60.00**

Con. **Table 2** Hybrid vigor for 11 yield and yield related traits in tomato (*Solanum lycoersicon* Mill).

Traits	Number of fruits cluster^{-1}		Days to 50% fruits maturity		Single fruit weight (g)		Number of locules fruit^{-1}		Fruits setting % cluster^{-1}		Yield plant^{-1} (kg)	
Hybrids	MPH (%)	BPH (%)	MPH (%)	BHP (%)	MPH (%)	BPH (%)	MPH (%)	BPH (%)	MPH (%)	BPH (%)	MPH	BPH
Nagina × 17905	133.33**	101.06**	-6.96**	-17.60**	51.57**	18.06**	28.04**	8.24*	16.08**	8.80*	152.52**	120.58**
Nagina × BSX-935	171.62**	167.64**	-9.64**	-12.28**	28.61**	24.39**	26.76*8	20.00**	36.32**	21.44**	54.79**	32.91**
Nagina × Continental	107.56**	64.10**	-5.20**	-8.05**	23.20**	12.37**	-32.96**	-46.42**	18.25**	10.41*	120.85**	89.47**
Roma × 17905	51.57**	50.00**	2.04	-11.61**	47.81**	22.89**	15.84**	9.27*	20.59**	5.62	125.14**	115.05**
Roma × BSX-935	135.80**	98.95**	4.16**	-1.36	29.56**	23.13**	9.31*	2.32	40.22**	33.87**	123.10**	77.21**
Roma × Continental	89.67**	72.65**	-3.51*	-4.00*	28.18**	8.54**	-39.39**	-46.42**	21.77**	6.29	98.93**	57.89**
Riogrande × 17905	63.93**	59.57**	8.62**	-4.26*	63.90**	41.10**	1.53	1.02	6.98	4.84	99.31**	76.82**
Riogrande ×BSX-935	136.12**	105.61**	-7.92**	-11.09**	42.90**	30.54**	-9.82**	-20.40**	34.82**	15.41**	-10.22*	-24.05*8
Riogrande x Continental	103.88**	79.48**	-6.07**	-8.40**	88.45**	54.25**	-27.61**	-32.14**	14.16**	11.44*	104.23**	72.63*8
Pakit × 17905	80.61**	73.52**	32.68**	22.26**	35.69**	8.87**	8.07*	-10.30**	4.62	3.43	48.78**	16.85**
Pakit × BSX-935	113.09**	75.49**	12.32**	10.73**	48.38**	47.42**	32.37**	22.66**	37.22**	16.61**	-28.18**	-30.38**
Pakit × Continnetal	47.03**	37.60**	6.45**	-1.00	27.42**	12.14**	18.18**	-7.14*	6.37	4.74	84.78**	78.94**
VCT-01 × 17905	32.62**	31.91**	21.58*8	8.69**	29.85**	2.73	-10.85**	-19.58**	10.82*	2.01	-1.43	-17.15**
VCT-01 × BSX-935	81.13**	54.83**	-5.26**	-7.06**	10.93**	9.57**	-0.65	-2.56	22.45**	10.99*	41.67**	26.58*8
VCT-01 × Continental	74.28**	56.41**	-15.46**	-11.14**	18.14**	5.71**	1.05	-14.28**	6.32	-2.48	53.30**	36.84**

MPH = mid parent heterosis, BPH = better parent heterosis, Significant at 5% and 1% levels of probability.

Days to 50% flowering indicated earliness or late maturity behavior of genotypes. T-test for most of the hybrids showed negative values which confirmed superiority of hybrids over parents for earliness. Highly significant negative heterosis for days to 50% flowering was recorded for hybrid *viz*. Nagina x 17905 (-34.09%) and Nagina x Continental (-31.42%). Negative and highly significant heterobeltiosis was also observed for these hybrids viz, Nagina x 17905 (-34.09%) and Nagina x Continental (-31.81%) indicated superiority of these hybrids over their better parent. Minimum value of negative heterosis with respect to days to 50% flowering was estimated for heterotic combination Riogrande x BSX-935 (-1.86%) along with negative and negative and highly significant better parent heterobeltiosis (-12.22%).

Riogrande x Continental exhibited positive and non-significant heterosis (2.82%) and heterobeltiosis (1.11%) for days to flowering (50%) which showed its late maturing behavior as compared to its parents. Present research work was in accordance with (Singh and Singh, 1993; Joshi and Thakur, 2003) who also observed earliness in heterotic combinations of tomato.

Heterotic analysis regarding number of branches plant^{-1} revealed that most of cross combinations except 4 responded positively towards this character. Highly significant and positive heterosis was reported for Riogrande x Continental (39.06%) and by Roma x 17905 (22.10%) along with same pattern of heterobeltiosis (26.24%), (21.67%). There found an increase in number of branches plant^{-1} in most of heterotic combinations over their parents. Lowest degree of hybrid vigor was estimated for, Pakit x Continental (1.45%) along with negative and non-significant heterobeltiosis (-1.41%). VCT-01 x 17905 showed negative and highly significant heterosis (-10.20%) and heterobeltiosis (-13.15%) showed inferior response to both parents. Singh and Singh (1993%) reported positive significant hybrid vigor regarding number of branches plant^{-1} in tomato hybrids.

Most of crosses showed significant positive heterosis regarding number of clusters plant^{-1} while three hybrids demonstrated negative heterosis and heterobeltiosis for this character. Maximum hybrid vigor was shown by heterotic combinations, VCT-01 x BSX-935 (38.49%) and Pakit x Continental (24.35%) along with same behavior of heterobeltiosis (26.27%) and (21.25%) respectively. Minimum value of heterosis was reported for hybrids Roma x 17905 (0.54%) and Nagina x Continental (3.40%) showed positive and non-significant heterosis. Regarding heterobeltiosis Roma x 17905 showed negative and non-significant heterobeltiosis (-1.77%) and Nagina x Continental with positive and non-significant heterobeltiosis (1.25%). VCT-01× 17905 and Riogrande x 17905 expressed highly significant negative heterosis (-10.30%), (-10.18%) along with considerable range of better parent heterobeltiosis (-12.63%) and (-11.52%). (Sekhar *et al.*, 2010) observed positive and highly significant e hybrid vigor for number of clusters plant^{-1}. Some crosses had non-significant heterosis for this trait.

Heterotic analysis showed that all cross combinations exhibited considerable amount of heterosis and heterobeltiosis for number of flowers cluster^{-1}. Highest value of heterosis or hybrid vigor was observed for hybrids viz, Nagina x 17905 (99.90%) along with Nagina xBSX-935 (92.95%) with same behavior of better parent heterosis (81.96%), (73.80%) respectively. Lowest value of highly significant heterosis for number of flowers cluster^{-1} was scored by crosses viz, VCT-01 x 17905 (18.63%) and Roma x 17905 (21.25%) along with highly significant better parent heterosis (10.63% and (5.45%). These crosses showed lowest degree of superiority over their parents in terms of both heterosis and heterobeltiosis. Results are in accordance with (Rahmani *et al.*, 2010).

All of crosses exhibited highly significant positive heterosis regarding number of fruits cluster^{-1} which showed an increased number of fruits cluster^{-1} as compared to their parents. Maximum heterosis was reported for heterotic combinations *viz.*, Nagina x BSX-935 (171.62%) followed by Riogrande x BSX-935 (136.12%) along with same behavior towards better parent (167.64%) and (105.61%). Minimum hybrid vigor was reported for VCT-01 x 17905 (32.62%) and Pakit x Continental (47.03%) along with considerable range of heterobeltiosis (31.91%), (37.60%). (Williams and Gilbert, 1960, Mirshamssi *et al.*, 2006; Rani and Veeraragavathatham, 2008; suggested that number of fruits cluster^{-1} significantly increased in most of the hybrids as compared to their parents.

Heterotic analysis for days to 50% fruits maturity depicted that out of 15 hybrids 8 hybrids showed significant negative heterosis while rest of 7 hybrid combinations revealed positive heterosis regarding this character. Negative heterosis with respect to days to 50% fruits maturity was desirable because less the number of days to 50% fruits maturity more early the produce will be supplied in market.

Maximum and highly significant negative heterosis was observed for hybrid *viz*., VCT-01 x Continental (-15.46%) and Nagina x BSX-935 (-9.64%) along with negative and highly significant heterobeltiosis (-11.14%), (-12.28%) respectively. Pakit x 17905 (32.68%) and VCT-01 x 17905 (21.58%) showed significant heterosis and same pattern of heterobeltiosis (22.26%) and (8.69%) indicating late maturity than their parents. Delayed maturity in tomato crosses or hybrids was also observed by (Hewitt and Stevens, 1979).

Heterotic analysis depicted positive and significant heterosis as well as heterobeltiosis for individual fruit weight in cross combinations. Highly significant and positive heterosis and heterobeltiosis demonstrated that fruit weight got increased in all crosses as compared to their parents. Maximum and highly significant heterosis was reported for Riogrande x Continental (88.45%) and Riogrande x 17905 (63.90%) while heterobeltiosis was also in highly significant for these crosses (54.25%) and (41.10%). VCT-01x BSX-935 (10.93%) along with VCT-01 x Continental (18.14%) showed lowest value of heterosis and heterobeltiosis was also on same pattern (9.57%) and (5.71%). (Larson and Currence, 1944 and Sundaram *et al*., 1994) who also stated highly significant and positive hybrid vigor for single fruit weight in tomato hybrids.

Nine hybrids exhibited positive heterosis while 6 hybrids revealed negative heterosis regarding number of locules fruit^{-1}. Pakit x BSX-935 (32.37%) along with Nagina x 17905 (28.04%) showed maximum heterosis and heterobeltiosis was highly significant for Pakit x BSX-935 (22.66%) and Nagina x 17905 with significant heterosis (8.24%). Roma x Continental (-39.39%) and Nagina x Continental (-32.96%) expressed negative heterosis and heterobeltiosis (-46.42%) and (-46.42%) respectively. Locules number is not an important yield component but it is focused for hybrid processing. In beef tomato more number of locules is desireable to increase single fruit weight which is correlated with yield. Heterobeltiosis and relative heterosis for locules fruit^{-1} were reported earlier by (Anbu *et al*., 1976).

Heterotic analysis regarding fruits setting percentage cluster^{-1} revealed significant positive heterosis for all cross combinations. Roma x BSX-935 (40.22%) strongly followed by Pakit x BSX-935 (37.22%) expressed maximum heterosis and indicating that % fruit sett got increased in all hybrids than their parents. Better parent heterosis was also highly significant for these two crosses (33.87%) and (16.61%).

Hybrids *viz*. Pakit x 17905 (4.62%) and VCT-01 x Continental (6.32%) showed minimum heterosis and heterobeltiosis was positive for Pakit x17905 (3.43%) and negative for VCT-01 x Continental (-2.48%). Romax BSX-935 expressed maximum heterosis (40.22%) and heterobelti6osis (33.87%) for setting percentage cluster^{-1}. It demonstrated (40.22%) more fruits set than its mid parent and (33.87%) than its better parent. Our results were strongly supported by findings of some earlier researchers (Popova and Petrova, 1979).

Yield plant^{-1} got increases in most of the locally developed hybrids. Heterotic analysis exhibited positive heterosis for yield plant^{-1} for all hybrids except 3. Maximum hybrid vigor was found for Nagina x 17905 (152.52), Romax 17905 (125.14%) and Roma x BSX-935 (123.10%) while better parent heterosis was also highly significant (120.58%), (115.05%) and (77.21%).

Minimum positive and highly significant mid parent heterosis was observed for VCT-01xBSX-935 (41.67%) and Pakit x 17905 (48.78%) while better parent heterosis was significant heterobeltiosis. Range of heterobeltiosis for these crosses was on same pattern (26.58%), (16.8%5). Pakit x BSX-935 showed negative and highly significant heterosis (-28.13%) and heterobeltiosis (-30.38%) indicating inferior response to its mid parent and better parent. Highly significant heterosis for yield plant^{-1} was also reported by (Wang *et al*., 2011; Ahmad *et al*., 2011) while (Courtney and Peirce, 1979) reported negative response of heterotic combinations for yield plant^{-1}.

Conclusion

From current study it was concluded that all the hybrids were found superior for traits *viz.* plant height, number of flowers cluster^{-1}, number of fruits cluster^{-1}, plant height, single fruit weight and fruits setting percentage cluster^{-1} and some hybrids showed negative heterosis and heterobeltiosis for number of clusters plant^{-1}, number of branches plant^{-1}, number of locules fruit^{-1} and yield plant^{-1}. For days to 50% flowering and days to 50% fruits maturity most of the crosses were found superior. Keeping in mind the main focus on yield which is the primary target of plant breeder the hybrids *viz.* Nagina x17905, Roma x 17905 and Roma x BSX-935 were found superior as they expressed highly significant heterosis and heterobeltiosis for yield plant^{-1} and days to 50% fruits maturity indicating early maturing behaviour and these hybrids could be used in future breeding programme.

Acknowledgements

Authors expressed their feelings to field staff of Department of Horticultural Research and Development, National Agricultural Research Centre, Islamabad, Research fellows and Research Internees for their kind cooperation during whole research period.

References

Aguiar PA, Penna JCB, Freire EC, Melo LC. 2007. Diallel analysis of upland cotton cultivars. Journal of Crop Breeding and Biotechnology **7,** 353-359.

Ahmad SU, Shaha HK, Sharfuddin AFM. 1988. Study of heterosis and correlation in tomato (*Solanum lycopersicon* Mill.).Thailand Journal of Agriculture Sciences **21**, 117-123.

Ahmad SA, Quamruzzaman KM, Islam MR. 2011. Estimation of heterosis in tomato (*Solanum lycopersicon* Mill.). Bangladesh Journal of Agricultural Research **36,** 521-527.

Amin ES, Abid MM, Maksoud E, Rahim AM. 2001. Genetic studies on F_1 generation and genetic parameters associated with it in tomato (*Lycopersicon esculentum* Mill.). Journal of Agricultural Sciences Man University **26**, 3667-3675.

Anbu SC, Muthukrishna R, Irulappan I. 1976. Line x tester analysis in tomato *(Lycopersicon esculentum* Mill.). South Indian Horticulture**2**, 49-53.

Bhatt RP, Biswas VR, Kumar N. 2001. Heterosis, combining ability, genetics for vitamin C, total soluble solids and yield in tomato (*Lycopersicon esculentum* Mill.) at 1700 m altitude. Journal of Agricultural Sciences **7**, 71-75.

Chattopadhyay A, Paul A. 2012. Studies on heterosis for different fruit quality parameters in tomato. International Journal of Agricultural Environment and Biotechnology**4**, 405-409.

Chaudhary DR, Malhotra SK. 2001. Studies on hybrid vigor in tomato (*Solanum lycopersicon* Mill.). Indial Journal of Agricultural Research **35**, 176-180.

Courtney WH, Peirce LC. 1979. Parent selection in tomato based on morpho-physiological traits. Horticultural Sciences **14,** 458-461.

FAOSTAT. 2015. Food and Agriculture Organization of the United Nations, FAOSTAT Database (Last accessed on 10 October 2016).

Gazar T, Sayed HE, Zanata O. 2002. Inheritance of vegetative and fruit quality of some tomato crosses in late summer season. Journal of Agricultural Science Mansoura University **27,** 5473-5484.

Gul RH, Rahman U, Khalil IH, Shah SM, Ghafoor A. 2011. Estimate of heterosis in tomato (*Solanum lycopersicon* Mill.). Bangladesh Journal of Agriccultural Research **36,** 521-527.

Ahmad H, Mustafa K. 2002. Study of heterosis for yield and quality traits in tomato (*Solanum lycopersicon* Mill.). International Journal of Science and Nature **23**, 421-4428.

Hayes HK, Immer IR, Smith DC. 1956. Methods of plant breeding. New York, McGraw Hill Company Inc, 535-442 P.

Hedrick UP, Booth NO. 1968. Mendelian characters in tomato. American Society of Horticulture Science **5**, 19-24.

Josh A, Thakur MC. 2003. Exploitation of heterosis for yield and yield contributing traits in tomato (*Solanum lycopersicon* Mill.). Progressive Horticulture **35,** 64-68.

Kurian A, Peter KV, Rajan S. 2001. Heterosis for yield components and fruit characters in tomato. Journal of Tropical Agriculture **39,** 5-8.

Larson RE, Currence TM. 1944. The extent of hybrid vigor in FI and F2 generation of tomato crosses with particular reference to early yield, total yield and fruit size. Journal of Tropical Agriculture **164,** 11-32.

MFAL. 2015. Ministry of Food, Agriculture and Livestock, Islamabad, Html. (Last accessed on 20 September 2016).
www.paktive.com/mfal.265EB23.

Mirshamssi A, Farsi M, Shahriari F, Nemati H. 2006. Estimation of heterosis and combining ability for yield components and crossing method. Agricultural Science and Technology **20**, 3-12.

Popova KM, Petrova N. 1979. Some manifestation of heterosis in the F1 of tomato (*Solanum lycopersicon* Mill.) Journal of Srilankan Agriculture**12**, 307-314.

Rahmani GL, Rahman H, Khalil IH, Shah SMS, Ghafoor A. 2010. Heterosis for flower and fruit traits in tomato (*Solanum lycopersicon* Mill.). African Journal of Biotechnology **9**, 4144-4151.

Ramzan A, Khan TN, Nawab N, Hina A, Noor T, Jillani G. 2014. Estimation of genetic components in f1 hybrids and their parents in determinate tomato (*Solanum lycopersicon* Mill.). Pakistan Journal of Agricultural Research **521**, 65-75.

Rani I, Veeraragavathatham D, Sanjutha D. 2008. Studies on correlation and path coefficient analysis on yield attributes in root knot nematodes resistant F1 hybrids of tomato. Journal of Applied Sciences Research **4,** 287-295.

Sekhar L, Prakash BG, Salimath PM, Patil AA. 2010. Implications of heterosis and combining ability among productive Single cross hybrids in tomato (*Solanum lycopersicon* Mill). Electronic Journal of Plant Breeding **1,** 706-711.

Singh RK, Singh VK. 1993. Heterosis breeding in tomato (*Solanum lycopersicon* Mill.). Annals of Agricultural Research **14,** 416-420.

Souza LMD, Melo PCT, Luders RR, Melo AM. 2012. Correlations between yield and fruit quality characteristics of fresh market tomatoes. Horticulture Brasileira **30**, 627-631.

Turner JHJ. 1953. Agronomy Journal **43,** 92-97.

Wang L, Wang M, Ying S, Shopingand T. 1998. Genetic and correlation studies on quantitative characters in processing tomato. Advances in Horticulture **2**, 378-383.

Williams W, Gilbert M. 1960. Heterosis and inheritance of yield in tomato. International Journal of Heredity and Nature**14**, 113-149.

Yordanov M. 1983. Heterosis in tomato. Journal of Theoretical and Applied Genetics **6,** 189- 219.