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## Studies on heterosis for yield and yield contributing traits in tomato (*Solanum lycopersicum* L.)

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### Abstract

Seven superior lines of tomato viz., Pusa Ruby, EC 620441, EC 914100, EC 914093, EC 914090, EC 620481 and EC 620452 were crossed with three testers (AVTO 1219, AVTO 1314 obtained from World Vegetable Center, Taiwan and one high yielding genotype Money Maker from Yates, New Zealand) in line x tester mating design to study the estimates of average heterosis, heterobeltiosis and standard heterosis for seven yield and yield contributing traits in tomato. The parent material was sown to generate F<sub>1</sub> s during *Rabi* season 2018-19 and the parents along with F<sub>1</sub>s were raised in early *Summer* 2019 in Randomized Block Design with three replications at college of horticulture, SKLTSU, Telangana. The results revealed that analysis of variance indicated highly significant differences for all the characters, indicating that there is a variation between the characters studied. Top five cross combinations EC 620452 x Money Maker, Pusa Ruby x Money Maker, EC 620441 x AVTO 1314, Pusa Ruby x AVTO 1219 and EC 914100 x AVTO 1314 were found to be promising for fruit yield per plant. These heterotic hybrids found superior over better parent and three standard checks (Arka Rakshak, Arka Vikas and PKM-1) have the potential to be exploited commercially.

**Keywords:** Tomato, heterosis, hybrids, yield

### Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crops belongs to the family solanaceae and chromosome number  $2n=2x=24$ . Tomato is a perennial plant but commonly cultivated as an annual (Rick, 1978), and ranks second to potato in many countries. On the basis of availability of numerous wild and cultivated relatives of tomato in Peru, Equador and Bolivia, these areas are considered as centres of origin. In India, it is introduced by Portuguese merchants and English traders of East-India Company. Tomato is considered as protective food crop because of having rich source of minerals, vitamins and organic acids. On an average it contains 900 IU of vitamin A and 23 mg of vitamin C per 100g of fruit pulp. Tomato is one of the rich source of lycopene i.e., 20-50mg per 100g of fruit pulp, which imparts red colour to ripe tomatoes. Lycopene reported to possess anticancerous properties (Srinivasan *et al.*, 2010) [18] and it is powerful natural antioxidant (most efficient quencher of singlet oxygen) used in pharmaceuticals (Mascio *et al.*, 1989).

It is typical day neutral plant and self pollinated crop, but certain percentage of cross pollination may also occur. Although tomato is a selfpollinated crop, heterosis is being commercially exploited on large scale. Tomato can be well exploited for hybrid seed production because of its easiness in crossing among varieties and new genotypes, fruits containing large number of seeds and easiness in growing under varied agro climatic conditions, above all possessing high degree of heterosis for growth, yield and earliness. New cultivars have been developed to meet the diverse needs and their suitability to different agro climatic conditions. But there is huge gap between national average yield of India, when compared with average yield of Telangana. The low yield is due to non availability of high yielding varieties and lack of quality seed. To increase productivity of this crop, there is a need for development of hybrids and varieties with improvement in yield and quality. Heterotic crosses usually show increase in size, vigour, seed producing ability, increased metabolic activity and usually better resistance to insect pests, diseases or extreme temperatures and thus ultimately result in better performance of hybrids than parents. Usually, these hybrids show better fitness and breeding value as compared to parents from which they are made. Higher yield and better fruit quality are universally desired.

## Materials and Methods

### Experimental material

The experimental material consists of seven diverse genotypes of tomato *viz.*, Pusa Ruby, EC 620441, EC 914100, EC 914093, EC 914090, EC 620481 and EC 620452 was crossed with three testers *viz.*, AVTO 1219, AVTO 1314 and Money Maker in line x tester mating design to obtain twenty one cross combinations. The 21 hybrids along with parents and three standard checks (ArkaRakshak, ArkaVikas and PKM-1) were evaluated during early *Summer* 2019 at PG students Research farm, College of Horticulture, Sri kondaLaxman Telangana State Horticultural University, Rajendranagar, Hyderabad-30. The experiment was laid out in a Randomized Block Design with three replications. Crosses were made manually using the standard procedure of hand emasculation and pollination.

### Traits evaluated

F<sub>1</sub>s were evaluated along with their parents and standard checks to study estimates of average heterosis, heterobeltiosis and standard heterosis for leaven yield and yield related traits *viz.*, plant height (cm), number of flowers per cluster, days to first flowering, days to 50% flowering, days to first harvest, days to last harvest, number of marketable fruits per plant, fruit length (cm), fruit width (cm), average fruit weight (gm), fruit yield per plant (kg).

### Results and Discussion

Analysis of variance indicated significant differences among parents and hybrids for all the characters under study. Percentheterosis for each character over mid parent, better parent and three standard checks for yield and yields components are presented in Table 1 to 6.

#### Plant height

Taller plants in tomato had added advantage due to increase in yield. Hence, positive heterosis is desirable for plant height. The results of heterosis for plant height are presented in Table 1. The observed range of mid parental heterosis and heterobeltiosis among hybrids was -4.92% (EC 914093 x Money Maker) to 9.80% (EC 914093 x AVTO 1314) and -24.26% (EC 914093 x Money Maker) to 4.95% (EC 620481 x AVTO 1314), respectively. Seven hybrids were exhibited significant and positive average heterosis and three hybrids were exhibited significant and negative average heterosis. When compared with hybrid check ArkaRakshak the standard heterosis ranged from 1.34% in EC 914090 x AVTO 1314 to 51.56% in EC 620441 x Money Maker. Among twenty one hybrids twenty were registered significant positive standard heterosis.

#### Number of flowers per cluster

Number of flowers per cluster directly affected the total fruit yield per plant, so this character is very important for fruit yield. The results of three kinds of heterosis for number of flowers per cluster are presented in Table 1. The hybrids were registered a relative heterosis ranged from -34.22% in EC 914093 x AVTO 1314 to 40.93% in EC 914090 x Money Maker and from 34.22% in EC 914093 x AVTO 1314 to 30.23% in EC 620481 x AVTO 1219 for heterobeltiosis. Fourteen hybrids were significantly superior over their mid parents. Seven hybrids *viz.*, EC 620481 x AVT 1219 (30.23%), EC 914090 x Money Maker (27.74%), EC 620481 x Money Maker (26.19%), EC 914090 x AVTO 1314

(21.52%), EC 620452 x AVTO 1219 (20.45%), EC 914100 x AVTO 1314 (18.99%) and EC 914100 x Money Maker (18.79%). Five hybrids *viz.*, EC 914090 x Money Maker (22.98%), EC 914090 x AVTO 1314 (19.25%), EC 914100 x AVTO 1314 (16.77%), EC 914090 x Money Maker (15.53%) and EC 914100 x Money Maker (9.94%) manifested significant and positive standard heterosis over ArkaRakshak. The range varied from -23.60 in EC 914093 x AVTO 1314 to 22.98% in EC 914090 x Money Maker. Heterosis over ArkaVikas ranged from -3.91% in EC 914093 x AVTO 1314 to 54.69% in EC 914090 x Money Maker and ten hybrids ranged from 54.69% in EC 914090 x Money Maker to 3.25% in EC 620481 x AVTO 1219 were showed significant and positive standard heterosis. Seventeen hybrids showed significant increase in number of flowers per cluster over PKM-1.

#### Days to first flowering

For the development of early fruiting genotypes, negative heterosis for days to first flowering is desirable. Early flowering leads to earliness and also early supply of the produce in the market and enables it to fetch a remunerative price. Thus, heterosis for days to first flowering had been estimated in terms of earliness. The results pertaining to days to first flowering are presented in Table 2. Six hybrids showed significantly superior over the mid parents and respective better parents. Average heterosis in respect of days to first flowering ranged from -5.84% in EC 914100 x Money Maker to 9.11% in Pusa Ruby x AVTO 1314. For heterobeltiosis, it was ranged from -8.43% in EC 620452 x AVTO 1219 to 7.48% in Pusa Ruby x AVTO 1314. Four hybrids registered significant heterosis for earliness with respect to days to first flowering over ArkaRakshak. Fourteen hybrids exhibited significant and negative heterosis over check Arka Vikas and PKM-1

#### Days to 50% flowering

With regard to days to 50 per cent flowering, heterosis in negative direction is considered as desirable since earliness is preferred over late flowering. The hybrids recorded a relative heterosis ranged from -7.20% in EC 914100 x Money Maker to 3.53% in EC 620441 x AVTO 1219, while the range of heterobeltiosis was from -7.73% in EC 914100 x Money Maker to 2.47% in Pusa Ruby x AVTO 1314. Six hybrids showed early flowering over their mid parents and seven hybrids showed early flowering over their respective better parents (Table 2). Standard heterosis over ArkaRakshak were ranged from -9.38% in EC 914100 x Money Maker to -0.26% in EC 620452 x AVTO 1314. Over ArkaVikas it was ranged from -2.30% in EC 914100 x Money Maker to 7.72% in EC 620441 x AVTO 1219, respectively. Ten hybrids exhibited significant and negative heterosis for earliness in flowering over ArkaRakshak and none of the hybrids showed significant and negative heterosis for earliness in flowering over ArkaVikas. Five hybrids showed lesser days to fifty percent flowering when compared to check PKM-1.

#### Days to first harvest

Earliness is required for realizing the potential economic yield, which is an important consideration for a tomato growers. An early flowering is not always a vital criterion for determining earliness, as some hybrids which exhibited early flowering could not show earliness in harvest. Therefore, days taken to first harvest are equally important in determining the

earliness of the hybrids. In case of days to first harvest, the negative heterosis was desirable. The results for days to first harvest are presented in Table 3. The observed range of mid parental heterosis and heterobeltiosis among hybrids was from -4.64% in EC 914090 x AVTO 1314 to 0.78% in EC 620452 x Money Maker and -7.03% in EC 914093 x AVTO1219 to 0.47% in EC 620481 x Money Maker. Eight hybrids were earlier than their mid parents, while thirteen hybrids were early to harvest compared to their respective better parents. For days to first harvest, seven hybrids ranged from -0.96% in EC 620441 x AVTO 1314 to 4.42% in Pusa Ruby x AVTO 1314 over standard check ArkaRakshak. One hybrid showed early harvest when compared to ArkaVikas. Eleven hybrids ranged from 2.42% in EC 620441 x AVTO 1219 and EC 914090 x Money Maker to 5.02% in Pusa Ruby x AVTO 1314 over check PKM-1.

#### Days to last harvest

Longer harvest span can directly enhances the production. Longer harvest duration is preferred in the present marketing system because it not only avoids the glut in the market but also off season nature of the crop is maintained. For days to last harvest, relative heterosis varied from -7.20% in EC 914100 x Money Maker to 3.63% in EC 620452 x AVTO 1314. Heterobeltiosis was ranged from -7.73% in EC 914100 x Money Maker to 2.47% in Pusa Ruby x AVTO 1314. Seven hybrids exhibited significantly superior over their mid parents and respective better parents (Table 3). Heterosis over standard check, ArkaRakshak was in the range of -9.38% in EC 914100 x Money Maker to -0.09% in EC 620441 x AVTO 1219. Eleven hybridsshowed negative and significant heterosis over ArkaRakshak, nine hybrids exhibited positive and significant heterosis over ArkaVikas and Five hybrids showed positive and significant heterosis over PKM-1.

#### Number of marketable fruits per plant

The hybrids were in the range from -30.85% in EC 914090 x Money Maker to 43.86% in EC 620441 x AVTO 1219 for average heterosis and from 52.23% in EC 914090 x Money Maker to 27.49% in Pusa Ruby x AVTO 1219 for heterobeltiosis. As many as ten hybrids registered significant and positive relative heterosis over their mid parents and eight hybrids registered significant and positive heterobeltiosis over their respective better parents (Table 4). Four hybrids viz., Pusa Ruby x Money Maker (16.05%), EC 620441 x AVTO 1219 (11.88%), EC 620441 x Money Maker (9.47%) and EC 620481 x Money Maker (8.99%) were recorded significant and positive standard heterosis over ArkaRakshak. Eleven hybrids ranged from 10.44% in Pusa Ruby x AVTO 1314 to 37.19% in Pusa Ruby x Money Maker showed significant and positive standard heterosis over ArkaVikas. Twenty hybrids out of twenty one hybrids exhibited significant standard heterosis over PKM-1. It was ranged from -35.56% in EC 914100 x AVTO 1219 to 51.26% in Pusa Ruby x Money Maker, respectively.

#### Fruit length (cm)

Fruit length is a growth attribute directly associated with yield, for which positive heterosis is desirable. It is a vital character influencing fruit quality. Fruits with more length and diameter are preferable both for consumption and for processing purpose. The results for fruit length (cm) are presented in Table 4. Average heterosis for this trait ranged from -22.60% in EC 914090 x AVTO 1314 to 74.96% in Pusa

Ruby x AVTO 1314 and heterobeltiosis was ranged from -36.81% in EC 914090 x AVTO 1314 to 46.73% in Pusa Ruby x AVTO1314. Number of hybrids exhibited significant superior heterosis over their mid parents and respective better parents were eleven and six respectively. Five hybrids registered significant superior heterosis for character fruit length over standard check ArkaRakshak. Standard heterosis over ArkaRakshak was ranged from -36.77% in EC 620441 x Money Maker to 21.10% in Pusa Ruby x AVTO 1314. Nineteen hybrids ranged from -4.05% in EC 620441 x Money Maker to 83.76% showed positive heterosis in check ArkaVikas. All hybrids showed significant and positive heterosis in PKM-1.

#### Fruit width (cm)

The range of average heterosis and heterobeltiosis among the hybrids was from -24.62% in EC 914090 x AVTO 1314 to 52.39% in Pusa Ruby x AVTO 1314 and -36.24% in EC 914090 x AVTO 1314 to 29.34% in Pusa Ruby x AVTO 1314. Six hybrids showed significant and positive average heterosis over their mid parents. Five hybrids exhibited superior heterosis over their better parents (Table 5). Standard heterosis over ArkaRakshak was ranged from 0.98% in EC 620481 x Money Maker to 63.51% in Pusa Ruby x AVTO 1314. Eighteen hybrids exhibited significant and positive standard heterosis over ArkaRakshak. Eighteen hybrids ranged from 10.26% in EC 620452 x AVTO 1314 to 60.97% in Pusa Ruby x AVTO 1314 showed positive and significant standard heterosis over ArkaVikas. Twenty hybrids ranged from 3.68% in EC 620452 x Money Maker to 65.97% in Pusa Ruby x AVTO 1314 showed significant and positive standard heterosis over PKM-1.

#### Average fruit weight (g)

Average fruit weight directly affects the total fruit yield, so this character is very important as fruit yield is concerned. High average fruit weight is of prime importance in breeding high yielding cultivars. For average fruit weight, mid parental heterosis was ranged from -20.45% in EC 914093 x Money Maker to 125.82% in Pusa Ruby x Money Maker and heterobeltiosis ranged from -42.70% in EC 914093 x Money Maker to 120.78% in Pusa Ruby x Money Maker. Fourteen hybrids recorded positive and significant average heterosis, while eight hybrids registered significant and positive heterobeltiosis (Table 5). When compared to ArkaRakshak, fifteen hybrids ranged from 17.94% in EC 914090 x Money Maker to 65.43% in Pusa Ruby x AVTO 1314 registered positive and significant standard heterosis over varietal check ArkaVikas, it ranged from -14.55% in EC 914093 x Money Maker to 101.87% in Pusa Ruby x AVTO 1314. Nineteen hybrids showed significant and positive heterosis over ArkaVikas. Twenty hybrids ranged from 10.66% in EC 914090 x Money Maker to 126.0% in Pusa Ruby x AVTO 1314 registered positive and significant standard heterosis over PKM-1.

#### Fruit yield per plant (Kg)

High fruit yield per plant is the ultimate goal of any breeding programme, hence requires higher consideration. The results are presented in Table 6. With respect to fruit yield per plant, heterosis ranged from 4.31% in EC 620481 x AVTO 1219 to 66.55% in EC 914090 x Money Maker and heterobeltiosis ranged from -9.91% in EC 914100 x AVTO 1219 to 51.32% in Pusa Ruby x AVTO 1219. All 21 hybrids were exhibited

significant and positive average heterosis, top ten hybrids with highest fruit yield per plant viz., EC 914090 x Money Maker (66.55%), Pusa Ruby x AVTO 1219 (63.26%), Pusa Ruby x Money Maker (61.28%), Pusa Ruby x AVTO 1314 (60.72%), EC 620441 x AVTO 1314 (48.51%), EC 620452 x Money Maker (44.81%), EC 914090 x AVTO 1314 (34.45%), EC 914100 x AVTO 1314 (31.66%), EC 620481 x AVTO 1314 (30.78%) and EC 620481 x Money Maker (30.12%). Twelve hybrids exhibited significant and positive heterobeltiosis.

Standard heterosis was ranged from -17.38% in EC 914100 x AVTO 1219 to 30.48% in EC 620452 x Money Maker. Eight hybrids viz., EC 914100 x AVTO 1314 (30.48%), Pusa Ruby x Money Maker (28.07%), EC 914090 x Money

Maker(27.81%), EC 620441 x AVTO 1314 (26.47%), Pusa Ruby x AVTO 1219 (25.94%), EC 620441 x Money Maker (24.06%), EC 620481 x Money Maker (12.03%) and Pusa Ruby x AVTO 1314 (60.72%) recorded positive and significant heterosis over the check ArkaRakshak. Eleven hybrids recorded negative and significant heterosis over the check ArkaRakshak. Standard heterosis was ranged from 17.05% in EC 914100 x AVTO 1219 to 84.85% in EC 620452 x Money Maker over ArkaVikas. All hybrids recorded positive and significant heterosis over the check ArkaVikas. Standard heterosis was ranged from 36.12% in EC 914100 x AVTO 1219 to 114.98% in EC 620452 x Money Maker over PKM-1. All hybrids recorded positive and significant heterosis over the check over PKM-1.

**Table 1:** Average heterosis (%), heterobeltiosis (%) and standard heterosis (%) for plant height (cm) and number of flowers per cluster

Crosses	Plant height (cm)					Number of flowers per cluster				
	Average heterosis (%)	Heterobeltiosis (%)	Standard heterosis (%) over			Average heterosis (%)	Heterobeltiosis (%)	Standard heterosis (%) over		
			Arka Rakshak	Arka Vikas	PKM-1			Arka Rakshak	Arka Vikas	PKM-1
Pusa Ruby x AVTO 1219	3.12**	-7.62**	34.97**	5.19**	33.70**	9.32*	0.00	-19.88**	0.78	8.40
Pusa Ruby x AVTO 1314	4.01**	-0.81	14.73**	-10.59**	13.65**	-4.92	-20.25**	-21.74**	-1.56	5.88
Pusa Ruby x Money Maker	-0.80	-14.00**	35.52**	5.62**	34.25**	13.30**	4.76	-18.01**	3.13	10.92*
EC620441 x AVTO1219	-0.20	-0.71	45.07**	13.06**	43.71**	10.84**	6.98	-14.29**	7.81	15.97**
EC620441 x AVTO1314	2.73*	-11.35**	28.19**	-0.09	26.99**	-6.47*	-17.72**	-19.25**	1.56	9.24*
EC 620441 x Money Maker	0.31	-3.82**	51.56**	18.12**	50.14**	3.25	0.79	-21.12**	-0.78	6.72
EC914100 x AVTO1219	-2.39*	-11.05**	29.97**	1.29	28.75**	13.67**	6.04	-1.86	23.44**	32.77**
EC914100 x AVTO1314	1.89	-4.57**	14.70**	-10.61**	13.62**	22.48**	18.99**	16.77**	46.88**	57.98**
EC914100 x Money Maker	-2.12	-13.74**	35.93**	5.94**	34.66**	28.73**	18.79**	9.94**	38.28**	48.74**
EC914093 x AVTO1219	-3.47**	-20.85**	15.64**	-9.87**	14.56**	-17.72**	-30.48**	-19.25**	1.56	9.24*
EC914093 x AVTO1314	9.80**	3.80*	8.94**	-15.10**	7.92**	-28.70**	-34.22**	-23.60**	-3.91	3.36
EC914093 x MoneyMaker	-4.92**	-24.26**	19.35**	-6.98**	18.23**	18.85**	-0.53	15.53**	45.31**	56.30**
EC914090 x AVTO1219	-1.09	-19.27**	17.95**	-8.07**	16.84**	-2.82	-10.97**	-14.29**	7.81	15.97**
EC914090 x AVTO1314	2.71	-3.44*	1.34	-21.02**	0.39	22.68**	21.52**	19.25**	50.00**	61.34**
EC914090 x MoneyMaker	-0.88	-21.38**	23.89**	-3.45*	22.73**	40.93**	27.74**	22.98**	54.69**	66.39**
EC620481 x AVTO1219	0.65	-13.62**	26.21**	-1.64	25.03**	38.84**	30.23**	4.35	3.25**	41.18**
EC620481 x AVTO1314	5.08**	4.95**	10.15**	-14.16**	9.11**	15.13**	-1.27	-3.11	21.88**	31.09**
EC620481 x MoneyMaker	2.18	-14.96**	34.00**	4.44**	32.74**	33.05**	26.19**	-1.24	24.22**	33.61**
EC620452 x AVTO1219	2.34*	-4.40**	39.68**	8.86**	38.37**	21.84**	20.45**	-1.24	24.22**	33.61**
EC620452 x AVTO1314	2.38	-6.47**	18.66**	-7.52**	17.54**	9.66**	0.63	-1.24	24.22**	33.61**
EC620452 x Money Maker	2.89**	-7.14**	46.32**	14.04**	44.95**	2.33	0.00	-18.01**	3.13	10.92*

\*\* Significant at 1% level, \* Significant at 5% level

**Table 2:** Average heterosis (%), heterobeltiosis (%) and standard heterosis (%) for days to first flowering and days to 50% flowering

Crosses	Days to first flowering					Days to 50% flowering				
	Average heterosis (%)	Heterobeltiosis (%)	Standard heterosis (%) over			Average heterosis (%)	Heterobeltiosis (%)	Standard heterosis (%) over		
			ArkaRakshak	ArkaVikas	PKM-1			ArkaRakshak	ArkaVikas	PKM-1
Pusa Ruby x AVTO 1219	1.58	0.21	1.05	-1.63	1.90	-1.93	-4.62*	-6.65**	0.64	-0.54
Pusa Ruby x AVTO 1314	9.11**	7.48**	5.45**	2.65	6.34**	2.80	2.47	-4.60/	2.85	1.63
Pusa Ruby xMoney Maker	4.88**	3.42	1.47	-1.22	2.33	2.34	-0.09	-2.98	4.60*	3.36
EC620441 x AVTO1219	-1.80	-3.74	-2.94	-5.51**	-2.11	3.53*	2.09	-0.09	7.72**	6.45**
EC620441 x AVTO1314	3.49	2.60	-0.63	-3.27	0.21	2.81	1.70	-3.24	4.32*	3.09
EC 620441 x Money Maker	2.51	1.73	-1.47	-4.08*	-0.63	1.82	0.79	-2.13	5.51**	4.27*
EC914100 x AVTO1219	-1.05	-2.29	-1.47	-4.08*	-0.63	-3.83*	-3.99*	-5.71**	1.65	0.45
EC914100 x AVTO1314	-5.74**	-7.25**	-8.81**	-11.22**	-8.03**	-1.96	-4.51*	-6.22**	1.10	-0.09
EC914100 x Money Maker	-5.84**	-7.25**	-8.81**	-11.22**	-8.03**	-7.20**	-7.73**	-9.38**	-2.30	-3.45
EC914093 x AVTO1219	-2.41	-3.33	-2.52	-5.10**	-1.69	-5.32**	-6.97**	-8.95**	-1.84	-3.00
EC914093 x AVTO1314	0.65	-1.27	-2.31	-4.90*	-1.48	1.27	0.54	-5.03*	2.39	1.18
EC914093 x MoneyMaker	-0.11	-1.91	-2.94	-5.51**	-2.11	1.74	0.35	-2.56	5.06*	3.81
EC914090 x AVTO1219	-4.39*	-4.99*	-4.19*	-6.73**	-3.38	-0.53	-1.74	-3.84*	3.68	2.45
EC914090 x AVTO1314	0.11	-2.11	-2.52	-5.10**	-1.69	-3.07	-4.29*	-8.61**	-1.47	-2.63
EC914090 x MoneyMaker	-1.51	-3.58	-3.98*	-6.53**	-3.17	-5.44**	-6.23**	-8.95**	-1.84	-3.00
EC620481 x AVTO1219	-2.31	-3.12	-2.31	-4.90*	-1.48	1.63	0.35	-1.79	5.88**	4.63*
EC620481 x AVTO1314	0.11	-1.90	-2.73	-5.3**	-1.90	-0.50	-1.70	-6.22**	1.10	-0.09
EC620481 x MoneyMaker	-0.43	-2.33	-3.14	-5.71**	-2.33	0.00	-0.88	-3.75	3.77	2.54
EC620452 x AVTO1219	-4.69**	-8.43**	0.21	-2.45	1.06	-1.47	-2.23	-2.81	4.78*	3.54

EC620452 x AVTO1314	-0.82	-7.28**	1.47	-1.22	2.33	3.63*	0.34	-0.26	7.54**	6.27**
EC620452 x Money Maker	-2.76	0.01	-0.42	-3.06	0.42	-0.48	-1.63	-2.22	5.42*	4.18*

\*\* Significant at 1% level, \* Significant at 5% level

**Table 3:** Average heterosis (%), heterobeltiosis (%) and standard heterosis (%) for days to first harvest and days to last harvest

Crosses	Days to first harvest					Days to last harvest				
	Average heterosis (%)	Heterobeltiosis (%)	Standard heterosis (%) over			Average heterosis (%)	Heterobeltiosis (%)	Standard heterosis (%) over		
			Arka Rakshak	Arka Vikas	PKM-1			Arka Rakshak	Arka Vikas	PKM-1
Pusa Ruby x AVTO 1219	-3.59**	-5.52**	1.92	0.14	2.51*	-1.93	-4.62*	-6.65**	0.64	-0.54
Pusa Ruby x AVTO 1314	0.18	-0.46	4.42**	2.60*	5.02**	2.80	2.47	-4.60*	2.85	1.63
Pusa Ruby x MoneyMaker	-1.45	-2.55*	0.91	-0.85	1.50	2.34	-0.09	-2.98	4.60*	3.36
EC620441 x AVTO1219	-1.30	-5.61**	1.83	0.05	2.42*	3.53*	2.09	-0.09	7.72**	6.45**
EC620441 x AVTO1314	-2.60*	-5.59**	-0.96	-2.69*	-0.39	2.81	1.70	-3.24	4.32*	3.09
EC 620441 x Money Maker	0.29	-1.09	0.14	-1.60	0.72	1.82	0.79	-2.13	5.51**	4.27*
EC914100 x AVTO1219	-3.59**	-6.14**	1.25	-0.52	1.84	-3.82*	-3.99*	-5.71**	1.65	0.45
EC914100 x AVTO1314	-1.37	-2.66*	2.11	0.33	2.71*	-1.96	-4.51*	-6.22**	1.10	-0.09
EC914100 x Money Maker	-1.63	-2.07	0.05	-1.70	0.63	-7.20**	-7.73**	-9.38**	-2.30	-3.45
EC914093 x AVTO1219	-3.65**	-7.03**	0.29	-1.46	0.87	-5.32**	-6.97**	-8.95**	-1.84	-3.00
EC914093 x AVTO1314	-2.69*	-4.53**	0.14	-1.60	0.72	1.27	0.54	-5.03*	2.39	1.18
EC914093 x MoneyMaker	0.38	-0.09	1.15	-0.61	1.74	1.74	0.35	-2.56	5.06*	3.81
EC914090 x AVTO1219	-2.49*	-4.19**	3.36**	1.56	3.96**	-0.53	-1.74	-3.84*	3.68	2.45
EC914090 x AVTO1314	-4.64**	-4.99**	-0.34	-2.08	0.24	-3.07	-4.29*	-8.61**	-1.47	-2.63
EC914090 x MoneyMaker	-0.84	-2.21*	1.83	0.05	2.42*	-5.44**	-6.23**	-8.95**	-1.84	-3.00
EC620481 x AVTO1219	-2.24*	-4.99**	2.50*	0.71	3.09**	1.63	0.35	-1.79	5.88**	4.63*
EC620481 x AVTO1314	0.74	-0.73	4.13**	2.31*	4.73**	-0.50	-1.70	-6.22**	1.10	-0.09
EC620481 x MoneyMaker	0.76	0.47	2.31*	0.52	2.90*	0.00	0.88	-3.75	3.77	2.54
EC620452 x AVTO1219	-1.58	-4.41**	3.12**	1.32	3.72**	-1.47	-2.23	-2.81	4.78*	3.54
EC620452 x AVTO1314	-0.16	-1.69	3.12**	1.32	3.72**	3.63*	0.34	-0.26	7.54**	6.27**
EC620452 x Money Maker	0.78	-0.99	0.67	-1.09	1.26	-0.48*	-1.63	-2.22	5.42*	4.18*

\*\* Significant at 1% level, \* Significant at 5% level

**Table 4:** Average heterosis (%), heterobeltiosis (%) and standard heterosis (%) for number of marketable fruits per plant and fruit length (cm)

	Number of marketable fruits per plant					Fruit length (cm)				
	Average heterosis (%)	Heterobeltiosis (%)	Standard heterosis (%) over			Average heterosis (%)	Heterobeltiosis (%)	Standard heterosis (%) over		
			Arka Rakshak	Arka Vikas	PKM-1			Arka Rakshak	Arka Vikas	PKM-1
Pusa Ruby x AVTO 1219	41.47**	27.49**	0.48	18.79**	30.96**	-7.64**	-26.01**	-31.33**	4.20	16.57**
Pusa Ruby x AVTO 1314	20.62**	18.53**	-6.58**	10.44**	21.76**	74.96**	46.73**	21.10**	83.76**	105.58**
Pusa Ruby x Money Maker	17.56**	-2.17	16.05**	37.19**	51.26**	35.25**	33.57**	-23.43**	16.18**	29.98**
EC620441 x AVTO1219	43.86**	21.22**	11.88**	32.26**	45.82**	19.85**	1.55	-5.76**	43.00**	59.98**
EC620441 x AVTO1314	21.07**	10.43**	1.93	20.49**	32.85**	28.13**	14.11**	-5.82**	42.91**	59.87**
EC 620441 x Money Maker	3.81	-7.71**	9.47**	29.41**	42.68**	3.84	-1.91	-36.77**	-4.05	7.34**
EC914100 x AVTO1219	-7.65	-21.83**	-50.56**	-41.56**	-35.56**	8.99**	-0.35	11.60**	69.34**	89.44**
EC914100 x AVTO1314	-11.65**	-30.38**	-47.03**	-37.38**	-30.96**	-3.90**	-16.54**	-6.53**	41.83**	58.66**
EC914100 x Money Maker	-29.25**	-51.56**	-42.54**	-32.07**	-25.10**	15.18**	-12.93**	-2.49	47.96**	65.52**
EC914093 x AVTO1219	1.39	-12.18**	-44.46**	-34.35**	-27.62**	-5.74**	-16.42**	0.28	52.16**	70.23**
EC914093 x AVTO1314	-6.36	-24.68**	-42.70**	-32.36**	-25.31**	-2.84*	-18.00**	-1.62	49.29**	67.01**
EC914093 x MoneyMaker	-27.59**	-49.66**	-40.29**	-29.41**	-22.18**	5.74**	-21.87**	-6.26**	42.25**	59.13**
EC914090 x AVTO1219	-2.07	-15.99**	-46.87**	-37.19**	-30.75**	-15.99**	-28.10**	-6.23**	42.28**	59.18**
EC914090 x AVTO1314	-12.17**	-29.96**	-46.71**	-37.00**	-30.54**	-22.60**	-36.81**	-17.59**	25.05**	39.90**
EC914090 x MoneyMaker	-30.85**	-52.23**	-43.34**	-33.02**	-26.15**	-0.79	-28.59**	-6.87**	41.31**	58.09**
EC620481 x AVTO1219	20.15**	3.58	-9.55**	6.93*	17.89	21.52**	20.93**	12.22**	70.29**	90.51**
EC620481 x AVTO1314	15.62**	8.18**	-5.54*	11.67**	23.12**	27.79**	21.28**	11.45**	69.12**	89.19**
EC620481 x MoneyMaker	5.85**	-8.12**	8.99**	28.84**	42.05**	49.31**	21.23**	11.40**	69.04**	89.11**
EC620452 x AVTO1219	31.34**	14.95**	-3.13	14.52**	26.26**	-10.64**	-13.93**	-20.12**	21.21**	35.60**
EC620452 x AVTO1314	21.32**	15.43**	-2.73	14.99**	26.78**	-3.87**	-5.79**	-19.01**	22.89**	37.48**
EC620452 x Money Maker	-1.58	-15.83**	-0.16	18.03**	30.13**	7.02**	-10.81**	-23.32**	16.35**	30.16**

\*\* Significant at 1% level, \* Significant at 5% level

**Table 5:** Average heterosis (%), heterobeltiosis (%) and standard heterosis (%) for fruit width (cm) and average fruit weight (g)

Crosses	Fruit width (cm)					Average fruit weight (g)				
	Average heterosis (%)	Heterobeltiosis (%)	Standard heterosis(%)over			Average heterosis (%)	Heterobeltiosis (%)	Standard heterosis(%)over		
			Arka Rakshak	Arka Vikas	PKM-1			Arka Rakshak	Arka Vikas	PKM-1
Pusa Ruby x AVTO 1219	27.80**	10.36**	33.83**	31.75**	35.84**	69.26**	25.52**	46.39**	78.64**	100.00**
Pusa Ruby x AVTO 1314	52.39**	29.34**	63.51**	60.97**	65.97**	110.66**	64.26**	65.43**	101.87**	126.01**
Pusa Ruby x Money Maker	34.86**	26.65**	27.15**	25.17**	29.07**	125.82**	120.78**	24.40**	51.80**	69.96**
EC620441 x AVTO1219	16.37**	6.23**	28.81**	26.81**	30.75**	16.20**	2.25	19.26**	45.53**	62.93**
EC620441 x AVTO1314	20.38**	7.86**	36.36**	34.24**	38.41**	60.18**	50.57**	51.64**	85.05**	107.17**
EC 620441 x Money Maker	2.43	2.29	2.69	1.10	4.24**	29.03**	3.70*	-8.10**	12.15**	25.56**
EC914100 x AVTO1219	-4.11**	-13.77**	30.95**	28.91**	32.92**	13.92**	0.87	52.63**	86.25**	108.52**
EC914100 x AVTO1314	-2.41**	-10.58**	35.80**	33.68**	37.84**	13.13**	-5.78**	42.56**	73.97**	94.77**
EC914100 x Money Maker	-1.32	-18.04**	24.46**	22.53**	26.34**	25.44**	-14.97**	28.67**	57.01**	75.78**
EC914093 x AVTO1219	-11.91**	-23.99**	27.01**	25.04**	28.93**	10.22**	7.70**	31.62**	60.61**	79.82**
EC914093 x AVTO1314	-12.84**	-23.45**	27.92**	25.93**	29.85**	14.65**	4.57**	27.79**	55.94**	74.59**
EC914093 x MoneyMaker	-11.09**	-28.83**	18.92**	17.07**	20.71**	-20.45**	-42.70**	-29.98**	-14.55**	-4.33**
EC914090 x AVTO1219	-22.40**	-35.45**	17.95**	16.12**	19.73**	-4.99**	-11.62**	19.80**	46.19**	63.68**
EC914090 x AVTO1314	-24.62**	-36.24**	16.52**	14.71**	18.27**	-0.16	-12.99**	17.94**	43.93**	61.14**
EC914090 x MoneyMaker	-7.89**	-28.65**	30.39**	28.36**	32.36**	-14.85**	-40.52**	-19.37**	-1.60	10.16**
EC620481 x AVTO1219	8.88**	1.77	41.94**	39.73**	44.08**	11.70	8.91**	33.70**	63.15**	82.66**
EC620481 x AVTO1314	-4.82**	-9.28**	26.54**	24.57**	28.44**	8.49**	-1.25	21.23**	47.93**	65.62**
EC620481 x MoneyMaker	-15.80**	-27.60**	0.98	-0.59	2.51	36.93**	-1.52	20.90**	47.53**	65.17**
EC620452 x AVTO1219	-2.54*	-6.17**	13.78**	12.01**	15.49**	-5.52**	-12.57**	1.97	24.43**	39.31**
EC620452 x AVTO1314	-6.13**	-11.41**	12.00**	10.26**	13.69**	-0.41	-1.14	-0.44	21.50**	36.02**
EC620452 x Money Maker	-3.91**	-8.97**	2.15	0.56	3.68*	22.09**	-5.84**	-6.56**	14.02**	27.65**

\*\* Significant at 1% level, \* Significant at 5% level

**Table 6:** Average heterosis (%), heterobeltiosis (%) and standard heterosis (%) for fruit yield per plant (kg)

Crosses	Fruit yield per plant(kg)				
	Average Heterosis(%)	Heterobeltiosis (%)	Standard heterosis (%) over		
			ArkaRakshak	ArkaVikas	PKM-1
Pusa Ruby x AVTO 1219	63.26**	37.32**	25.94**	78.41**	107.49**
Pusa Ruby x AVTO 1314	60.72**	51.32**	7.22**	51.89**	76.65**
Pusa Ruby x Money Maker	61.28**	33.06**	28.07**	81.44**	111.01**
EC620441 x AVTO1219	4.34**	0.27	-0.27	41.29**	64.32**
EC620441 x AVTO1314	48.51**	27.15**	26.47**	79.17**	108.37**
EC 620441 x Money Maker	26.78**	24.73**	24.06**	75.76**	104.41**
EC914100 x AVTO1219	11.35**	-9.91**	-17.38**	17.05**	36.12**
EC914100 x AVTO1314	31.66**	18.49**	-16.04**	18.94**	38.33**
EC914100 x Money Maker	25.52**	-0.28	-4.01*	35.98**	58.15**
EC914093 x AVTO1219	14.49**	-4.37*	-12.30**	24.24**	44.49**
EC914093 x AVTO1314	26.06**	17.74*	-16.58**	18.18**	37.44**
EC914093 x MoneyMaker	22.37**	0.28	-3.48	36.74**	59.03**
EC914090 x AVTO1219	20.29**	-2.33	-10.43**	26.89**	47.58**
EC914090 x AVTO1314	34.45**	21.51**	-13.90**	21.97**	41.85**
EC914090 x MoneyMaker	66.55**	32.78**	27.81**	81.06**	110.57**
EC620481 x AVTO1219	4.31*	-4.66*	-12.57**	23.86**	44.05**
EC620481 x AVTO1314	30.78**	35.47**	-4.01*	35.98**	58.15**
EC620481 x MoneyMaker	30.12**	16.39**	12.03**	58.71**	84.58**
EC620452 x AVTO1219	6.85**	2.33	-6.15**	32.95**	54.63**
EC620452 x AVTO1314	14.34**	24.91**	-11.50**	25.38**	45.81**
EC620452 x Money Maker	44.81**	35.56**	30.48**	84.85**	114.98**

\*\* Significant at 1% level, \* Significant at 5% level

**Conclusion**

The overall results of average heterosis, heterobeltiosis and standard heterosis indicated that the parents involved in the crossing should have one high per se performing parent. The main reason ascribed is diversified parents involved in the cross combinations or uncommon genes for a trait is the cause to exploit the maximum exploitable level of heterosis in tomato. Based on heterotic results it can be emphasized that significant and higher standard heterosis over better check ArkaRakshak for fruit yield per plant was recorded in EC 914100 x AVTO 1314 (30.48%), Pusa Ruby x Money Maker (28.07%), EC 914090 x Money Maker (27.81%), EC 620441 x AVTO 1314 (26.47%), Pusa Ruby x AVTO 1219 (25.94%),

EC 620441 x Money Maker (24.06%), EC 620481 x Money Maker (12.03%) and Pusa Ruby x AVTO 1314 (60.72%) recorded positive and significant heterosis over the check ArkaRakshak. The superior hybrids can be selected for the exploitation of hybrid vigour and commercialization.

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