Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2320-7051.5693

ISSN: 2320 – 7051

Int. J. Pure App. Biosci. **5 (4):** 1677-1685 (2017)

Research Article

International Journal of Pure & Applied Bioscience

OPEN ACCESS

Studies on Heterosis for Yield and Yield Contributing Traits in Tomato (*Solanum lycopersicum* L.)

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Received: 30.07.2017 | Revised: 9.08.2017 | Accepted: 10.08.2017

ABSTRACT

Seven diverse lines of tomato crossed with three testers in line x tester mating design to study the estimates of average heterosis, heterobeltiosis and standard heterosis for fourteen yield and yield contributing traits in tomato. The parent material was sown to generate F_1 s during Rabi season 2016-17 and the parents along with F_1s were raised in early Summer 2017 in Randomized Block Design with three replications at college of horticulture, SKLTSHU, 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. The two cross combinations EC 620494 x Arka Vikas and EC 620494 x Pusa Ruby were found to be promising for fruit yield per plant. These heterotic hybrids found superior over better parent and three standard checks have the potential to be exploited commercially.

Key words: *Tomato, Heterosis, yield.*

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crop belongs to the family solanaceae and chromosome number 2n=2x=24. It acquired the status of world's most popular vegetable crop due to its wider adaptability to various agro climatic conditions[9]. Tomato is a perennial plant but commonly cultivated as an annual[13]. It is considered as a protective food because it has rich source of minerals, vitamins and organic acids. Tomato is one of the rich sources of lycopene, which imparts red colour to ripe tomatoes, reported to possess anticancerous properties and it is powerful natural antioxidant (most efficient quencher of singlet oxygen) used in pharmaceuticals[18]. Although tomato is a self pollinated crop, heterosis is being commercially exploited on large scale. Tomato is a potential vegetable crop and has a plenty of scope for its improvement in India because of having varied agro climatic conditions.

Cite this article: Triveni, D., Saidaiah, P., Reddy, K.R. and Pandravada, S.R., Studies on Heterosis for Yield and Yield Contributing Traits in Tomato (*Solanum lycopersicum* L.), *Int. J. Pure App. Biosci.* **5(4):** 1677-1685 (2017). doi: http://dx.doi.org/10.18782/2320-7051.5693

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

Experimaental material

The experimental material consists of seven diverse genotypes of tomato *viz.,* EC 620408, EC 620494, EC 654289, EC 620639, EC 631410, EC 631407 and LA 3667 was crossed with three testers *viz.,* Pusa Ruby, Arka Vikas and Arka Megahli in line x tester mating design to obtain twenty one cross combinations .The 21 hybrids along with parents and three standard checks (Arka Rakshak, US 440 and Punjab Chhuhara) were evaluated during early *Summer* 2017 at PG students Research farm, College of Horticulture, Sri konda Laxman Telangana State Hortcultural 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_1s were evaluated along with their parents and standard checks to study estimates of average heterosis , heterobeltiosis and standard heterosis for fourteen yield and yield related traits *viz.*, number of flower clusters per plant, number of flowers per cluster, days to first flowering, days to 50% flowering, days to first harvest, days to last harvest, number of fruits per cluster, number of fruits per plant, number of marketable fruits per plant, fruit length (cm), fruit width (cm), fruit weight (gm), fruit yield per plant (kg) and yield per hectare (tons).

RESULTS AND DISCUSSION

Analysis of variance indicated significant differences among parents and hybrids for all the characters under study. Percent heterosis for each character over mid parent, better parent and three standard checks for yield and yields components are presented in Table 1 to 7.

For character number of flowers per plant, the hybrids registered a relative heterosis ranged from -44.44% in EC 620408 x Pusa Ruby to 77.09 % in EC 654289 x Arka Meghali. Out of 21 hybrids 10 hybrids showed significant and positive and 6 hybrids showed significant and negative average heterosis. The range for heterobeltiosis for the 21 crosses was from -49.17% in EC 631410 x Pusa Ruby to 59.52% in EC 654289 x Arka Meghali. Six hybrids showed significantly superior to their better parent. standard heterosis was ranged from 29.27 % in EC 620639 x Arka Vikas to 71.54 % in EC 620639 x Pusa Ruby over Arka Rakshak. Seven hybrids registered significant and positive heterosis over check US 440 [4,8,6].

Number of flowers per cluster directly affected the total fruit yield per plant, so this character is very important for fruit yield. Twelve hybrids manifested significant and positive standard heterosis over Arka Rakshak. The range varied from -8.76% in EC 631410 X Arka Meghali to 97.53% in EC 654289 x Arka Vikas. Heterosis over US 440 ranged from -31.65% in EC 631410 x Arka Meghali to 47.98% in EC 654289 x Arka Vikas[7,16].

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. Average

heterosis in respect of days to first flowering ranged from -7.31 % in EC 620494 x Arka Meghali to 4.42% in EC 620408 x Arka Vikas. Similar findings are shown by Hannan *et al.* for relative heterosis. For heterobeltiosis, it was ranged from -8.37 % in EC 620639 x Arka Meghali to 3.67% in EC 620408 x Arka Vikas[7,11].

With regard to days to 50 per cent flowering, heterosis in negative direction is considered as desirable since earliness is preferred over late flowering. Standard heterosis over Arka Rakshak and US440 were ranged from -3.09 % in EC 620494 x Arka Vikas to 10.31% in LA 3667 x Arka Meghali and -1.05 % in EC 620494 x Arka Vikas to 12.63 % in LA 3667 x Arka Meghali respectively. None of the hybrids exhibited significant and negative heterosis for earliness in flowering over Arka Rakshak and US 440 [(2)]. For days to first harvest 85.71 of the hybrids showed early harvest compared to standard check, Arka Rakshak. All hybrids were showed early harvest when compared to standard check, Punjab Chhuhara[5, 16,17].

For days to last harvest only one hybrid, LA 3667 x Arka Meghali exhibited negative heterosis over Arka Rakshak, US 440 and Punjab Chhuhara. Most of the hybrids were not exhibited superior performance with respect to days to last harvest over three standard checks.

Number of fruits per cluster indicate the per cent fruit set. Six hybrids were positive and significantly superior over the standard check Arka Rakshak. The range of standard heterosis over Arka Rakshak was ranged from -33.15 % in LA 3667 x Arka Meghali to 46.30 % in EC 654289 x Arka Vikas. Six hybrids registered positive and significant standard heterosis over check US440. [(6,7,16).] For number of fruits per plant as many as sixteen out of twenty one hybrids showed significant and positive heterosis over their mid parents and respective better parents. Nine hybrids were positive and significantly superior over the standard check Arka Rakshak. The range of standard heterosis over Arka Rakshak was ranged from -31.38 % in EC 631408 x Arka Vikas to 36.95 % in EC 620639 x Pusa Ruby. Only five hybrids registered positive and significant standard heterosis over check US440[7,19].

As many as seventeen hybrids registered significant and positive relative heterosis over their mid parents and fourteen hybrids registered significant and positive relative heterosis over their respective better parents for number of marketable fruits per plant. Six recorded significant and positive standard heterosis over Arka Rakshak. Six showed significant and positive standard heterosis over US 440.

Fruit length is a growth attribute directly associated with yield, for which positive heterosis is desirable. Average heterosis for this trait ranged from -23.43 % in EC 654289 x Pusa Ruby to 30.15 % in EC 631407 x Arka Vikas and heterobeltiosis was ranged from -25.38 % in EC 654289 x Arka Vikas to 28.91% in EC 631407 x Arka Vikas. These findings are in agreement with Nadeem *et al.* (2014). None of the hybrids registered significant superior heterosis for character fruit length over three standard checks. For fruit length seven hybrids showed significant and positive average heterosis over their mid parents. Only two hybrids, LA 3667 x Pusa Ruby and LA 3667 x Arka Vikas exhibited superior heterosis over their better parents. Over Arka Rakshak four hybrids manifested superior heterosis. Eight hybrids showed significant and positive standard heterosis over Punjab Chhuhara[2,7,13].

Average fruit weight directly affects the total fruit yield, so this character is very important so far fruit yield is concerned. When compared to Arka Rakshak three hybrids *viz.*, EC 620494 x Arka Vikas (21.37%), EC 620494 x Pusa Ruby (18.51%) and EC 620408 x Arka Meghali (4.74%) registered positive and significant standard heterosis[1,2,20].

High fruit yield per plant is the ultimate goal of any breeding programme, so requires higher consideration. Average heterosis ranged from -33.37 % in EC 654289 x Arka Vikas to 117.06 % in EC 620494 x Pusa Ruby and heterobeltiosis ranged from -

43.48 % in EC 654289 x Arka Vikas to 90.76 % in EC 620494 x Pusa Ruby. Standard heterosis was ranged from -65.71% in EC 654289 x Arka Vikas to 12.71% in EC 620494 x Arka Vikas. Two hybrids, EC 620494 x Arka Vikas (12.71%), EC 620494 x Pusa Ruby (11.39%), showing significant and positive heterosis over the Arka Rakshak. Only one hybrid EC 620494 x Arka Vikas (10.46%) showed significant and positive heterosis over check US 440[2, 9].

For fruit yield per hectare fifteen hybrids scored significant positive relative heterosis and ten hybrids were significantly positive and superior over their respective better parents. The range of standard heterosis varied from -69.05 % in EC 654289 x Arka Vikas to 9.8 % in EC 620494 x Pusa Ruby. None of the hybrids showed significant and positive heterosis over Arka Rakshak and US 440 with respect to fruit yield per hectare[1,6,19].

Table 1: Average heterosis (%), heterobeltiosis (%) and standard heterosis (%) for number of clusters per plant and number of flowers per cluster in Tomato

Crosses	Number of flower clusters per plant					Number of flowers per cluster				
	Average heterosis (%)	Hetero-beltiosis (%)	Standard heterosis (%) over			Average heterosis (%)	Hetero-beltiosis (%)	Standard heterosis (%) over		
			Arka Rakshak	US440	Punjab Chhuhara			Arka Rakshak	US 440	Punjab Chhuhara
EC 620408 x Pusa Ruby	-44.44 **	-47.51 **	-22.76 **	-31.16 **	-5	8.11	-6.3	4.79	-21.49 **	-2.95
EC 620408 x ArkaVikas	-7.64	-9.94	17.89 *	5.07	45.00 **	0.25	-5.3	19.10 **	-10.77 *	10.3
EC 620408 x Arka Meghali	6.87	-13.04 *	13.82	1.45	40.00 **	11.11 *	-2.85	8.65	-18.60 **	0.62
EC 620494 x Pusa Ruby	16.61 **	-8.84	34.15 **	19.57 **	65.00 **	10.05	-4.62	6.67	-20.09 **	-1.21
EC 620494 x ArkaVikas	31.76 **	9.8	36.59 **	21.74 **	68.00 **	0.06	-5.48	18.88 **	-10.94 *	10.09
EC 620494 x Arka Meghali	23.15 **	22.55 *	1.63	-9.42	25.00 **	4.48	-8.64	2.17	-23.46 **	-5.38
EC 654289 x Pusa Ruby	32.90 **	12.71 *	65.85 **	47.83 **	104.00 **	5.06	-23.96 **	39.33 **	4.38	29.03 **
EC 654289 x ArkaVikas	44.80 **	32.03 **	64.23 **	46.38 **	102.00 **	27.85 **	7.81 *	97.53 **	47.98 **	82.93 **
EC 654289 x Arka Meghali	77.09 **	59.52 **	63.41 **	45.65 **	101.00 **	19.92 **	-12.63 **	60.07 **	19.92 **	48.25 **
EC 620639 x Pusa Ruby	29.85 **	16.57 **	71.54 **	52.90 **	111.00 **	9.94 *	-16.85 **	33.03 **	-0.34	23.20 **
EC 620639 x ArkaVikas	-41.41 **	-43.14 **	-29.27 **	-36.96 **	-13	-15.81 **	-24.81 **	20.30 **	-9.88 *	11.41 *
EC 620639 x Arka Meghali	1.22	-13.89 *	0.81	-10.14	24.00 **	-19.98 **	-39.04 **	-2.47	-26.94 **	-9.68
EC 631407 x Pusa Ruby	-40.88 **	-40.88 **	-13.01	-22.46 **	7	-4.01	-19.10 **	-3.22	-27.50 **	-10.37
EC 631407 x ArkaVikas	-34.73 **	-39.78 **	-11.38	-21.01 **	9	-7.33	-9.59 *	13.71 *	-14.81 **	5.31
EC 631407 x Arka Meghali	0.71	-21.55 **	15.45 *	2.9	42.00 **	55.51 **	32.19 **	58.13 **	18.46 **	46.44 **
EC 631410 x Pusa Ruby	-40.65 **	-49.17 **	-25.20 **	-33.33 **	-8	12.46 *	0.72	4.42	-21.77 **	-3.3
EC 631410 x ArkaVikas	39.01 **	28.10 **	59.35 **	42.03 **	96.00 **	5	-4.23	20.45 **	-9.76 *	11.55 *
EC 631410 x Arka Meghali	14.78 *	2.33	7.32	-4.35	32.00 **	-2.64	-11.99 *	-8.76	-31.65 **	-15.50 **
LA 3667 x Pusa Ruby	-23.44 **	-45.86 **	-20.33 **	-28.99 **	-2	9.21	2.06	-3.67	-27.83 **	-10.79
LA 3667 x ArkaVikas	7.02	-20.26 **	-0.81	-11.59	22.00 *	26.17 **	10.42 *	38.88 **	4.04	28.62 **
LA 3667 x Arka Meghali	29.89 **	13.17	-7.07	-17.17 **	14.3	55.00 **	46.27 **	38.05 **	3.42	27.85 **

** 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 in Tomato

Crosses	Days to first flowering					Days to 50% flowering				
	Average heterosis (%)	Hetero-beltiosis (%)	Standard heterosis (%) over			Average heterosis (%)	Hetero-beltiosis (%)	Standard heterosis (%)		
			Arka Rakshak	US440	Punjab Chhuhara			Arka Rakshak	US 440	Punjab Chhuhara
EC 620408 x Pusa Ruby	0.62	-0.41	1.88	5.86	-4.13	0	-1.96	3.09	5.26	-3.85
EC 620408 x ArkaVikas	4.42	3.67	6.05	10.20 **	-0.2	-1	-2.94	2.06	4.21	-4.81
EC 620408 x Arka Meghali	-2.62	-3.78	0.84	4.77	-5.11	-1.96	-1.96	3.09	5.26	-3.85
EC 620494 x Pusa Ruby	-5.63 *	-7.24 *	-3.76	0	-9.43 **	-7.32 **	-11.21 **	-2.06	0	-8.65 **
EC 620494 x ArkaVikas	-6.12 *	-7.44 *	-3.97	-0.22	-9.63 **	-8.29 **	-12.15 **	-3.09	-1.05	-9.62 **
EC 620494 x Arka Meghali	-7.31 **	-7.77 *	-3.34	0.43	-9.04 **	-5.26 *	-7.48 **	2.06	4.21	-4.81
EC 654289 x Pusa Ruby	-2.37	-3.46	-1.04	2.82	-6.88 *	-0.99	-3.85	3.09	5.26	-3.85
EC 654289 x ArkaVikas	-2.05	-2.85	-0.42	3.47	-6.29 *	-4.95 *	-7.69 **	-1.03	1.05	-7.69 **
EC 654289 x Arka Meghali	-6.14 *	-7.17 *	-2.71	1.08	-8.45 **	-3.88	-4.81	2.06	4.21	-4.81
EC 620639 x Pusa Ruby	-2.19	-2.29	-2.09	1.74	-7.86 **	-1	-2.94	2.06	4.21	-4.81
EC 620639 x ArkaVikas	-0.83	-1.24	-0.42	3.47	-6.29 *	-1	-2.94	2.06	4.21	-4.81
EC 620639 x Arka Meghali	-6.22 *	-8.37 **	-3.97	-0.22	-9.63 **	-2.94	-2.94	2.06	4.21	-4.81
EC 631407 x Pusa Ruby	-0.21	-0.62	0.42	4.34	-5.5	-2	-3.92	1.03	3.16	-5.77 *
EC 631407 x ArkaVikas	1.14	1.03	2.09	6.07	-3.93	-2	-3.92	1.03	3.16	-5.77 *
EC 631407 x Arka Meghali	-5.48 *	-7.17 *	-2.71	1.08	-8.45 **	-3.92	-3.92	1.03	3.16	-5.77 *
EC 631410 x Pusa Ruby	-0.28	-2.35	2.09	6.07	-3.93	-2.46	-5.71 *	2.06	4.21	-4.81
EC 631410 x ArkaVikas	-4.04	-5.74	-1.46	2.39	-7.27 *	-0.49	-3.81	4.12	6.32 *	-2.88
EC 631410 x Arka Meghali	-0.87	-1	3.76	7.81 *	-2.36	0.48	-0.95	7.22 *	9.47 **	0
LA 3667 x Pusa Ruby	1.11	-1.58	4.18	8.24 *	-1.96	1.94	-2.78	8.25 **	10.53 **	0.96
LA 3667 x Arka Vikas	0.2	-2.17	3.55	7.59 *	-2.55	1.94	-2.78	8.25 **	10.53 **	0.96
LA 3667 x Arka Meghali	1.63	1.12	7.04 *	11.21 **	0.73	1.9	-0.93	10.31 **	12.63 **	2.88

** 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 in Tomato

Crosses	Days to First harvest					Days to last harvest				
	Average heterosis (%)	Hetero-beltiosis (%)	Standard heterosis (%) over			Average heterosis (%)	Hetero-beltiosis (%)	Standard heterosis (%) over		
			Arka Rakshak	US440	Punjab Chhuhara			Arka Rakshak	US 440	Punjab Chhuhara
EC 620408 x Pusa Ruby	-4.13 **	-6.34 **	-10.00 **	-0.15	-22.00 **	1.98	1.54	-12.36	-11.04	-9.09
EC 620408 x ArkaVikas	-3.90 **	-5.20 **	-8.90 **	1.06	-21.05 **	2.99	0.82	-9.93	-8.58	-6.58
EC 620408 x Arka Meghali	-5.36 **	-6.14 **	-9.80 **	0.06	-21.83 **	5.26	5.17	-10	-8.65	-6.64
EC 620494 x Pusa Ruby	-1.61 *	-3.78 **	-7.72 **	2.37 **	-20.02 **	8.01	4.31	-3.34	-1.89	0.26
EC 620494 x ArkaVikas	-5.01 **	-6.20 **	-10.04 **	-0.21	-22.04 **	6.16	4.26	-3.39	-1.94	0.21
EC 620494 x Arka Meghali	-5.52 **	-6.20 **	-10.04 **	-0.21	-22.04 **	8.74	4.49	-3.17	-1.72	0.44
EC 654289 x Pusa Ruby	-1	-1.83 *	-10.00 **	-0.15	-22.00 **	-1.8	-5.21	-12.08	-10.76	-8.81
EC 654289 x Arka Vikas	-6.23 **	-7.91 **	-13.90 **	-4.49 **	-25.38 **	0.59	-1.26	-8.43	-7.05	-5.01
EC 654289 x Arka Meghali	-5.62 **	-7.81 **	-12.86 **	-3.34 **	-24.48 **	-1.07	-4.97	-11.87	-10.54	-8.58
EC 620639 x Pusa Ruby	-4.66 **	-5.47 **	-11.84 **	-2.20 **	-23.59 **	2.94	2.24	-10.54	-9.2	-7.2
EC 620639 x Arka Vikas	-5.00 **	-5.12 **	-11.30 **	-1.60 *	-23.12 **	-0.9	-1.92	-12.38	-11.07	-9.12
EC 620639 x Arka Meghali	-7.08 **	-7.69 **	-12.76 **	-3.22 **	-24.39 **	0.48	-0.71	-13.13	-11.82	-9.89
EC 631407 x Pusa Ruby	-5.13 **	-6.74 **	-14.50 **	-5.16 **	-25.90 **	8.06	5.97	-4.86	-3.43	-1.31
EC 631407 x Arka Vikas	-1.58 *	-4.18 **	-10.41 **	-0.62	-22.36 **	4.18	3.92	-6.7	-5.3	-3.22
EC 631407 x Arka Meghali	-1.57 *	-4.67 **	-9.90 **	-0.05	-21.91 **	6.57	3.99	-6.63	-5.23	-3.15
EC 631410 x Pusa Ruby	-1.18	-1.93 *	-10.09 **	-0.26	-22.08 **	5.29	1.51	-5.6	-4.18	-2.08
EC 631410 x Arka Vikas	-0.73	-2.44 **	-8.79 **	1.19	-20.95 **	-3.3	-5.2	-11.84	-10.52	-8.56
EC 631410 x Arka Meghali	3.70 **	1.38	-4.18 **	6.29 **	-16.96 **	-2.07	-6.05	-12.63	-11.32	-9.37
LA 3667 x Pusa Ruby	5.84 **	0.92	2.00 **	13.15 **	-11.60 **	7.37	1.6	-12.3	-10.99	-9.03
LA 3667 x Arka Vikas	7.72 **	3.68 **	4.79 **	16.25 **	-9.18 **	7.97	0.54	-10.18	-8.83	-6.83
LA 3667 x Arka Meghali	2.41 **	-0.91	0.15	11.10 **	-13.20 **	-24.91 **	-28.59 **	-39.00 **	-38.08 **	-36.72 **

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

Table 4: Average heterosis (%), heterobeltiosis (%) and standard heterosis (%) for number of fruits per cluster and number of fruits per plant in Tomato

Crosses	Number of fruits per cluster					Number of fruits per plant				
	Average heterosis (%)	Hetero-beltiosis (%)	Standard heterosis (%) over			Average heterosis (%)	Hetero-beltiosis (%)	Standard heterosis (%) over		
			Arka Rakshak	US440	Punjab Chhuhara			Arka Rakshak	US 440	Punjab Chhuhara
EC 620408 x Pusa Ruby	11.33 *	4.55	2.5	-2.18	44.63 **	-5.47	-9.04 *	-27.17 **	-32.87 **	-19.07 **
EC 620408 x ArkaVikas	-13.81 *	-14.14 *	-26.09 **	-29.46 **	4.29	0.41	-1.7	-24.04 **	-29.99 **	-15.60 **
EC 620408 x Arka Meghali	0.38	0.25	-13.70 *	-17.63 **	21.78 **	34.72 **	31.52 **	2.21	-5.8	13.56 **
EC 620494 x Pusa Ruby	21.25 **	3.1	1.09	-3.53	42.64 **	22.39 **	15.96 **	-7.15 *	-14.43 **	3.16
EC 620494 x ArkaVikas	2.4	-7.63	-21.09 **	-24.69 **	11.35	23.66 **	19.17 **	-7.91 *	-15.13 **	2.32
EC 620494 x Arka Meghali	60.62 **	44.56 **	24.13 **	18.46 **	75.15 **	18.09 **	13.49 **	-11.81 **	-18.72 **	-2.01
EC 654289 x Pusa Ruby	27.36 **	12.61 **	43.70 **	37.14 **	102.76 **	38.91 **	20.98 **	30.58 **	20.35 **	45.09 **
EC 654289 x ArkaVikas	37.35 **	14.65 **	46.30 **	39.63 **	106.44 **	4.46	-10.38 **	-3.26	-10.84 **	7.48 *
EC 654289 x Arka Meghali	20.37 **	0.68	28.48 **	22.61 **	81.29 **	3.32	-11.15 **	-4.1	-11.61 **	6.56
EC 620639 x Pusa Ruby	46.02 **	45.70 **	43.48 **	36.93 **	102.45 **	45.44 **	26.51 **	36.95 **	26.22 **	52.16 **
EC 620639 x ArkaVikas	2.36	-4.42	-5.87	-10.17	32.82 **	18.75 **	1.76	10.16 **	1.53	22.40 **
EC 620639 x Arka Meghali	-14.62 **	-20.09 **	-21.30 **	-24.90 **	11.04	16.81 **	0.33	8.61 *	0.1	20.68 **
EC 631407 x Pusa Ruby	-18.13 **	-19.79 **	-18.04 **	-21.78 **	15.64 *	28.07 **	17.77 **	-5.7	-13.09 **	4.78
EC 631407 x Arka Vikas	12.86 *	3.62	5.87	1.04	49.39 **	-5	-11.19 **	-31.38 **	-36.75 **	-23.75 **
EC 631407 x Arka Meghali	41.04 **	29.79 **	32.61 **	26.56 **	87.12 **	18.99 **	10.94 *	-13.79 **	-20.54 **	-4.21
EC 631410 x Pusa Ruby	-13.41 **	-27.12 **	4.57	-0.21	47.55 **	51.92 **	48.11 **	24.85 **	15.07 **	38.73 **
EC 631410 x Arka Vikas	-30.67 **	-44.70 **	-20.65 **	-24.27 **	11.96	27.75 **	22.43 **	3.2	-4.88	14.67 **
EC 631410 x Arka Meghali	-17.73 **	-34.24 **	-5.65	-9.96	33.13 **	38.34 **	32.94 **	12.06 **	3.28	24.52 **
LA 3667 x Pusa Ruby	12.87	-19.29 **	-20.87 **	-24.48 **	11.66	41.73 **	38.94 **	15.81 **	6.73 *	28.68 **
LA 3667 x Arka Vikas	12.1	-16.28 *	-28.48 **	-31.74 **	0.92	49.93 **	44.47 **	20.42 **	10.98 **	33.80 **
LA 3667 x Arka Meghali	4.41	-22.15 **	-33.15 **	-36.20 **	-5.67	38.92 **	34.22 **	11.87 **	3.11	24.30 **

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

Table 5: Average heterosis (%), heterobeltiosis (%) and standard heterosis (%) for number of marketable fruits per plant and fruit length in Tomato

Crosses	Number of marketable fruits per plant					Fruit length (cm)				
	Average heterosis (%)	Hetero-beltiosis (%)	Standard heterosis (%) over			Average heterosis (%)	Hetero-beltiosis (%)	Standard heterosis (%) over		
			Arka Rakshak	US440	Punjab Chhuhara			Arka Rakshak	US 440	Punjab Chhuhara
EC 620408 x Pusa Ruby	-7.59 **	-12.25 **	-33.38 **	-34.14 **	-20.69 **	-5.01	-12.70 **	-33.42 **	-10.54 **	-23.21 **
EC 620408 x ArkaVikas	-1.66	-4.09 *	-31.13 **	-31.91 **	-18.00 **	1.86	-9.29 *	-30.82 **	-7.06	-20.22 **
EC 620408 x Arka Meghali	35.64 **	33.67 **	-6.02 **	-7.09 **	11.89 **	-2.86	-6.97	-29.05 **	-4.68	-18.18 **
EC 620494 x Pusa Ruby	22.47 **	14.31 **	-13.22 **	-14.21 **	3.32 *	-2.76	-11.65 **	-30.89 **	-7.14	-20.29 **
EC 620494 x ArkaVikas	22.60 **	17.46 **	-15.64 **	-16.61 **	0.43	6.66	-6.07	-26.52 **	-1.28	-15.26 **
EC 620494 x Arka Meghali	20.25 **	16.38 **	-18.17 **	-19.10 **	-2.57	-19.03 **	-23.38 **	-40.06 **	-19.47 **	-30.88 **
EC 654289 x Pusa Ruby	35.24 **	18.58 **	19.45 **	18.09 **	42.22 **	-23.43 **	-25.38 **	-49.75 **	-32.48 **	-42.04 **
EC 654289 x ArkaVikas	3.17 *	-11.64 **	-10.99 **	-12.01 **	5.97 **	2.84	-3.1	-34.75 **	-12.33 **	-24.74 **
EC 654289 x Arka Meghali	2.16	-13.27 **	-12.63 **	-13.63 **	4.02 **	-10.20 **	-11.79 **	-38.42 **	-17.26 **	-28.98 **
EC 620639 x Pusa Ruby	43.71 **	25.34 **	27.85 **	26.39 **	52.22 **	-4.3	-11.88 **	-43.67 **	-24.32 **	-35.04 **
EC 620639 x ArkaVikas	16.41 **	-0.81	1.17	0.02	20.46 **	9.77 *	4.46	-37.78 **	-16.41 **	-28.25 **
EC 620639 x Arka Meghali	15.47 **	-2.47 *	-0.51	-1.65	18.45 **	5.89	-6.26	-34.56 **	-12.07 **	-24.53 **
EC 631407 x Pusa Ruby	22.79 **	14.65 **	-12.96 **	-13.95 **	3.63 *	1.4	-2.97	-37.97 **	-16.67 **	-28.47 **
EC 631407 x ArkaVikas	-4.01 *	-7.99 **	-33.93 **	-34.68 **	-21.33 **	30.15 **	28.91 **	-23.23 **	3.15	-11.46 **
EC 631407 x Arka Meghali	21.62 **	17.77 **	-17.20 **	-18.14 **	-1.41	9.48 *	0.54	-29.81 **	-5.7	-19.05 **
EC 631410 x Pusa Ruby	36.55 **	34.42 **	5.33 **	4.13 **	25.41 **	9.76 *	5.25	-32.72 **	-9.61 *	-22.41 **
EC 631410 x ArkaVikas	31.01 **	25.54 **	-1.63	-2.75 *	17.12 **	14.88 **	14.03 **	-32.09 **	-8.76 *	-21.68 **
EC 631410 x Arka Meghali	41.16 **	33.91 **	4.94 **	3.74 **	24.94 **	19.90 **	10.34 *	-22.97 **	3.49	-11.17 **
LA 3667 x Pusa Ruby	41.60 **	40.42 **	8.42 **	7.18 **	29.08 **	16.79 **	12.71 **	-22.53 **	4.08	-10.66 **
LA 3667 x Arka Vikas	51.70 **	46.40 **	13.04 **	11.75 **	34.58 **	-1.13	-7.73	-36.58 **	-14.80 **	-26.86 **
LA 3667 x Arka Meghali	38.81 **	32.60 **	2.38	1.21	21.90 **	-11.19 **	-11.88 **	-38.48 **	-17.35 **	-29.05 **

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

Table 6: Average heterosis (%), heterobeltiosis (%) and standard heterosis (%) for fruit width and average fruit weight in Tomato

Crosses	Fruit width (cm)					Average fruit weight (g)				
	Average heterosis (%)	Hetero-Beltiosis (%)	Standard heterosis (%) over			Average heterosis (%)	Hetero-beltiosis (%)	Standard heterosis (%) over		
			Arka Rakshak	US440	Punjab Chhuhara			Arka Rakshak	US 440	Punjab Chhuhara
EC 620408 x Pusa Ruby	-14.67 **	-14.90 **	-12.89 **	-15.03 **	-4.34	-7.39 **	-19.29 **	-43.80 **	-39.51 **	-32.74 **
EC 620408 x ArkaVikas	-3.52	-7.45 **	-5.77 *	-8.10 **	3.47	-0.33	-12.14 **	-40.42 **	-35.87 **	-28.69 **
EC 620408 x Arka Meghali	-0.15	-5.42 *	7.67 **	5.01 *	18.23 **	67.76 **	43.22 **	4.74 **	12.74 **	25.35 **
EC 620494 x Pusa Ruby	5.82 *	1.85	4.27	1.7	14.50 **	75.43 **	70.20 **	18.51 **	27.56 **	41.83 **
EC 620494 x ArkaVikas	4.49	3.84	-1.66	-4.09	7.99 **	82.11 **	78.96 **	21.37 **	30.64 **	45.26 **
EC 620494 x Arka Meghali	-27.75 **	-33.82 **	-24.66 **	-26.52 **	-17.27 **	-8.93 **	-13.70 **	-36.89 **	-32.07 **	-24.46 **
EC 654289 x Pusa Ruby	-16.76 **	-28.88 **	-27.19 **	-28.99 **	-20.05 **	25.51 **	-9.58 **	-37.04 **	-32.24 **	-24.65 **
EC 654289 x ArkaVikas	-19.56 **	-28.57 **	-33.20 **	-34.85 **	-26.65 **	-33.21 **	-51.50 **	-67.10 **	-64.59 **	-60.63 **
EC 654289 x Arka Meghali	-39.86 **	-50.76 **	-43.95 **	-45.34 **	-38.45 **	21.82 **	-13.53 **	-36.76 **	-31.93 **	-24.32 **
EC 620639 x Pusa Ruby	-1.63	-18.69 **	-16.76 **	-18.81 **	-8.59 **	3.2	-23.62 **	-46.81 **	-42.75 **	-36.35 **
EC 620639 x ArkaVikas	7.84 **	-7.52 **	-13.52 **	-15.65 **	-5.03	28.84 **	-3.81 *	-34.77 **	-29.79 **	-21.93 **
EC 620639 x Arka Meghali	2.8	-18.40 **	-7.11 **	-9.41 **	2	19.79 **	-12.71 **	-36.16 **	-31.29 **	-23.60 **
EC 631407 x Pusa Ruby	6.99 **	-10.73 **	-8.62 **	-10.87 **	0.35	2.28	-0.4	-30.65 **	-25.35 **	-17.00 **
EC 631407 x ArkaVikas	20.55 **	4.4	-2.37	-4.78	7.20 *	-11.35 **	-12.55 **	-40.69 **	-36.16 **	-29.02 **
EC 631407 x Arka Meghali	-19.34 **	-35.42 **	-26.48 **	-28.30 **	-19.27 **	-37.87 **	-40.91 **	-56.78 **	-53.48 **	-48.28 **
EC 631410 x Pusa Ruby	-7.80 **	-10.50 **	-8.38 **	-10.64 **	0.61	15.36 **	15.25 **	-19.59 **	-13.45 **	-3.76 **
EC 631410 x Arka Vikas	-1.58	-3.04	-6.56 *	-8.87 **	2.6	25.92 **	24.16 **	-13.37 **	-6.75 **	3.68 **
EC 631410 x Arka Meghali	10.42 **	1.94	16.05 **	13.18 **	27.43 **	19.59 **	16.84 **	-14.55 **	-8.03 **	2.26
LA 3667 x Pusa Ruby	14.30 **	13.90 **	16.60 **	13.72 **	28.04 **	-6.16 **	-10.49 **	-37.68 **	-32.92 **	-25.41 **
LA 3667 x Arka Vikas	17.05 **	12.36 **	14.23 **	11.41 **	25.43 **	3.48 *	-0.04	-32.21 **	-27.03 **	-18.87 **
LA 3667 x Arka Meghali	-9.83 **	-14.65 **	-2.85	-5.24 *	6.68 *	-2.99 *	-9.58 **	-33.87 **	-28.82 **	-20.86 **

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

Table 7: Average heterosis (%), heterobeltiosis (%) and standard heterosis (%) for fruit yield per plant and fruit yield per hectare in Tomato

Crosses	Fruit yield per plant (kg)					Yield per hectare (tons)				
	Average heterosis (%)	Hetero-beltiosis (%)	Standard heterosis (%) over			Average heterosis (%)	Hetero-beltiosis (%)	Standard heterosis % over		
			Arka Rakshak	US440	Punjab Chhuhara			Arka Rakshak	US 440	Punjab Chhuhara
EC 620408 x Pusa Ruby	-16.61	-30.39 **	-59.35 **	-60.16 **	-33.00 **	-12.33	-26.72	-59.64 **	-59.84 **	-45.03 **
EC 620408 x ArkaVikas	-9.86	-25.89 **	-55.04 **	-55.93 **	-25.89 **	-0.99	-15.22	-55.98 **	-56.19 **	-40.04 **
EC 620408 x Arka Meghali	99.01 **	67.22 **	-3.96	-5.88	58.30 **	130.37 **	91.33 **	7.09	6.57	45.86 **
EC 620494 x Pusa Ruby	117.06 **	90.76 **	11.39 *	9.17	83.60 **	120.30 **	99.35 **	9.8	9.26	49.54 **
EC 620494 x ArkaVikas	114.86 **	85.77 **	12.71 *	10.46 *	85.77 **	59.91 **	48.63 **	-22.82 **	-23.20 **	5.12
EC 620494 x Arka Meghali	18.16 *	4.59	-39.93 **	-41.13 **	-0.99	9.18	-1.91	-45.10 **	-45.36 **	-25.22 *
EC 654289 x Pusa Ruby	57.24 **	35.52 **	-20.86 **	-22.44 **	30.43 **	87.42 **	48.29 **	-18.33 *	-18.72 *	11.24
EC 654289 x ArkaVikas	-33.37 **	-43.48 **	-65.71 **	-66.39 **	-43.48 **	-26.31	-40.39 *	-69.05 **	-69.20 **	-57.84 **
EC 654289 x Arka Meghali	19.78 *	3.97	-40.29 **	-41.48 **	-1.58	33.24 *	4.8	-41.34 **	-41.63 **	-20.11
EC 620639 x Pusa Ruby	38.04 **	24.44 **	-27.34 **	-28.79 **	19.76 *	57.11 **	32.92 *	-26.79 **	-27.15 **	-0.29
EC 620639 x ArkaVikas	20.18 *	6.52	-35.37 **	-36.66 **	6.52	53.65 **	33.21 *	-30.83 **	-31.16 **	-5.79
EC 620639 x Arka Meghali	28.97 **	17.12	-32.73 **	-34.08 **	10.87	43.11 **	20.28	-32.67 **	-33.00 **	-8.3
EC 631407 x Pusa Ruby	27.13 **	14.99	-32.85 **	-34.20 **	10.67	37.43 *	24.1	-31.65 **	-31.98 **	-6.91
EC 631407 x ArkaVikas	-22.22 **	-30.83 **	-58.03 **	-58.87 **	-30.83 **	-15.17	-21.33	-59.15 **	-59.35 **	-44.36 **
EC 631407 x Arka Meghali	-26.00 **	-32.57 **	-61.27 **	-62.04 **	-36.17 **	-25.67	-33.36 *	-62.70 **	-62.88 **	-49.20 **
EC 631410 x Pusa Ruby	44.91 **	43.12 **	-16.43 **	-18.10 **	37.75 **	62.07 **	60.54 **	-9.88	-10.32	22.75
EC 631410 x Arka Vikas	43.53 **	39.13 **	-15.59 **	-17.27 **	39.13 **	67.38 **	61.11 **	-9.56	-10	23.18 *
EC 631410 x Arka Meghali	51.36 **	50.73 **	-13.43 **	-15.16 **	42.69 **	65.84 **	65.61 **	-7.04	-7.49	26.61 *
LA 3667 x Pusa Ruby	31.73 **	24.02 **	-27.58 **	-29.02 **	19.37 *	32.88 *	30.36	-28.20 **	-28.55 **	-2.21
LA 3667 x Arka Vikas	49.15 **	37.94 **	-16.31 **	-17.98 **	37.94 **	55.30 **	53.74 **	-18.54 *	-18.93 *	10.95
LA 3667 x Arka Meghali	-16.61	-30.39 **	-59.35 **	-60.16 **	-33.00	32.55 *	29.01	-27.79 **	-28.14 **	-1.65

** 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 US 440 for fruit yield per plant was recorded in EC 620494 x Arka Vikas (10.46%). Over Arka Rakshak two hybrids, EC 620494 x Arka Vikas (12.71%) and EC 620494 x Pusa Ruby (11.39%) showed high and significant standard heterosis. Significant and high standard heterosis over Punjab Chhuhara was observed in ten crosses.

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