

HETEROSIS STUDIES IN TOMATO (*LYCOPERSICON ESCULENTUM* MILL.) FOR YIELD AND YIELD ATTRIBUTING TRAITS FOR FURTHER IMPLICATIONS IN CROP IMPROVEMENT

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ABSTRACT

The present investigation entitled "Studies on heterosis and combining ability in tomato (*Solanum lycopersicum* L.) for important horticultural traits was carried out at Research and Demonstration Block, Department of Vegetable Science of College of Horticulture, VCSG Uttarakhand University of Horticulture and Forestry, Bharsar, during *Kharif*, 2014. The six diverse parental lines of tomato were crossed in a 6 × 6 diallel mating design excluding reciprocals. The 15 F₁ hybrids and two standard checks (HYB-Roop-666 and TS-15) along with their parents were evaluated in a Randomized Complete Block Design (RCBD) with three replications. Significant differences were observed among genotypes for all the traits studied. Significant positive heterosis over mid parent, heterobeltiosis including standard heterosis for both the check was observed in desirable direction for most of the traits. Seven cross combination over the mid parent, five crosses over better parent, two cross over commercial check (HYB-Roop-666) and six crosses over the commercial check (TS-15) exhibited positive and significant heterosis for fruit yield per plant. The cross Punjab Chuhara x Best of All exhibited maximum heterosis over the mid parent (34.73%), better parent (31.82%), the cross Arka Abha x Punjab Chuhara over commercial check HYB-Roop-666 (19.03%) and over commercial check TS-15 (34.44%) for fruit yield per plant. Some hybrids combinations have performed better for yield & quality traits that opened the ways for further evaluation & release as hybrids or for making selection in the segregating generation in search of transgressive segregants.

No: of Figures: 8

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INTRODUCTION

Tomato (*Solanumly copersicum* L.) $2n=2x=24$ is one of the most important vegetable crop grown widely all over the world. It is a member of *Solanaceae* family and is native to Central and South America (Vavilov, 1951). In the world, it ranks second in importance after potato but tops the list of processed vegetables (Chaudhary, 1996). It is a very good source of income for small and marginal farmers and also contributes to the nutrition of the consumer (Singh *et al.*, 2010). The ripe fruits are taken as raw or made into salads, soups, preserve, pickles, ketchup, puree, paste and many other products (Chadha, 2001).

Tomato is grown as autumn-winter, winter and spring-summer crop in many parts of country but owing to high temperature and rains, tomato cannot be grown commercially in the North Indian plains from May to October. In India, it occupied an area of 8.82 lakh hectares with a production of 18.73 million metric tonnes with an average productivity of 21.23 metric tonnes per hectare (NHB 2013-14). It occupied second position among the vegetable crops in terms of production after potato. Uttarakhand is one of the tomato growing state covering an area of 9.08 thousand hectare with a production of 113.65 thousand metric tonnes and an average productivity of 12.51 metric tonnes per hectares (NHB 2013-14). The productivity level of the state is much lower to nation which further raised the need to develop location specific superior cultivars adapted for the region to meet the ever-increasing demand for this vegetable in fresh market and

processing industries, it is imperative to develop such hybrids which are good in both yield and quality of the produce.

Heterosis in tomato was first observed by Hedrick and Booth (1907) for higher yield and more number of fruits per plant. Subsequently, heterosis for yield and its component traits has been demonstrated by many workers (Wellington, 1912; Burdick, 1954; Daskalefet *al.*, 1967). Larson and Currence (1944) observed that average yield of all tested F_1 hybrids was 39 % above the average yield of the parental lines. Power (1945) found that the mean value of total yield of red fruits of the hybrid surpassed by 60% of the mean value of the parental lines. It manifests in tomato in form of greater vigour, faster growth and development, earliness in maturity, increased productivity and higher levels of resistance to biotic and abiotic stresses. Tomato is a self-pollinated crop, the unusual high heterosis observed in it has been attributed to the fact that originally tomato was a highly cross pollinated genus which has later evolved into a self-pollinated one (Rick 1965).

Identification and selection of potential parental lines is required, which can be used in any hybridization programme to produce genetically improved and potentially rewarding germplasm by assembling fixable gene effects in a homozygous line. Exploitation of heterosis is primarily dependent on the screening and selection of available germplasm that could produce better combinations of important agronomic characters. The present study was undertaken to estimate the extent of heterosis for quality traits like lycopene content, TSS

and pericarp thickness in order to get better quality hybrids along with improved yield.

Materials and Methods

Six diverse tomato cultivars/lines viz, ArkaSaurabh, ArkaAbha, ArkaMeghali, Punjab Chhuhara, Best of All and Sioux were selected on the basis of high yield coupled with high quality, and crossed in a half diallel fashion to obtain fifteen cross combinations. The seedlings of parents were raised in November, 2013 and further transplanted in polyhouse to attempt crossing and generate F1. The seeds of crosses were harvested in April-June, 2014. The F1 seeds along with parents and two check hybrid varieties TS-15 and HYB-Roop-666 (Both commercial F1 hybrids from Ocean Crop Sciences) were planted during August, 2014 for their evaluation and generation of data. Two checks were taken to get maximum accuracy in estimation of heterosis which is commercially utilizable. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The

seedlings were raised in August-2014 and transplanting of each entry in the block was done on 25th August-2014. There were twelve plants of each entry in each replication in a plot of 1.8 x 1.8 m² with a spacing of 60 cm x 45 cm. The standard cultural practices were followed to raise the tomato crop. Analysis of variance (ANOVA) was performed as explained by Gomez and Gomez (1983) while the heterosis was analysed and tested for significance as explained by Nadarajan & Gunasekaran (2012).

Result and Discussion

The analysis of variance for all the traits under study showed significant differences among parents and crosses. The magnitude of heterosis of fifteen F1 over mid parent, over better parent and percent increase or decrease over the two check cultivars HYB-Roop-666 and TS-15 designated as Check-1 and Check-2, respectively has been presented character-wise in Table 1-4. The results obtained for different traits are described below:

Table 1: Number of fruits per plant

Cross	MP	BP	Check-1	Check-2
ArkaSaurabh x ArkaAbha	-5.26	-9.52	-19.96*	-10.78
ArkaSaurabh x ArkaMeghali	3.07	2.78	-8.58	1.91
ArkaSaurabh x Punjab Chhuhara	17.14*	11.45*	-1.40	9.91
ArkaSaurabh x Best of All	12.50*	4.76	-7.33	3.30
ArkaSaurabh x Sioux	-4.42	-4.76	-15.75*	-6.08
ArkaAbha x ArkaMeghali	-7.18	-11.57*	-21.37*	-12.34*
ArkaAbha x Punjab Chhuhara	7.19	6.77	-14.04*	-4.17
ArkaAbha x Best of All	2.88	0.17	-19.34*	-10.08
ArkaAbha x Sioux	-7.50	-11.37*	-22.15*	-13.21*
ArkaMeghali x Punjab Chhuhara	4.25	-1.05	-12.01*	-1.91
ArkaMeghali x Best of All	2.17	-5.10	-15.60*	-5.91
ArkaMeghali x Sioux	-4.32	-4.92	-15.44*	-5.73
Punjab Chhuhara x Best of All	18.48*	15.82*	-7.48	3.13
Punjab Chhuhara x Sioux	-3.62	-7.99	-19.18*	-9.91

Best of All x Sioux	6.46	-0.53	-12.63*	-2.60
SE(d) \pm	1.79	2.07	2.07	2.07

* Significant at 5% level

Number of Fruits per Plant

The heterosis over mid parent ranged from -7.50 to 18.48 per cent, with maximum in Punjab Chhuhara x Best of All. Out of fifteen cross combinations, three crosses viz, Punjab Chhuhara x Best of All (18.48 %) ArkaSaurabh x Punjab Chhuhara (17.14 %) and ArkaSaurabh x Best of All (12.50 %) exhibited significant positive heterosis over mid parent for this trait.

The heterosis over better parent ranged from -11.57 to 15.82 percent, with maximum in Punjab Chhuhara x Best of All. Only two crosses viz, Punjab Chhuhara x Best of All (15.82 %) and ArkaSaurabh x Punjab Chhuhara (11.45 %) exhibited significant positive heterosis over better parent for this trait. None of the cross combination showed significant standard heterosis over the standard Check-1 and Check-2.

Number of fruits per plant is the most important component trait, which is directly related with increased fruit yield per plant. Out of fifteen cross combinations, two crosses, viz., ArkaSaurabh x Punjab Chhuhara and

Punjab Chhuhara x Best of All resulted in significant positive heterosis over mid parent and better parent. But both of them failed to report any economic heterosis over the check-1.

Positive heterosis over better parent for this trait has also been reported by Ahmed *et al.* (1988), Dev *et al.* (1994), Singh *et al.* (1995), Dharmatti *et al.* (1997), Srivastava *et al.* (1998), Gunasekera and Parera (1999), Bhatt *et al.* (2001), Thakur *et al.* (2004), Singh *et al.* (2005a), Premalakshmi *et al.* (2005), Mirshamssi *et al.* (2006), Hannan *et al.* (2007), Rani and Veeraragavathatham (2008), Kumar *et al.* (2009), Kumari *et al.* (2010), Kumari and Sharma (2011), Ahmed *et al.* (2011) and Singh and Sastry (2011).

For number of fruits per plant, significant positive heterosis over commercial checks were also achieved by Tiwari and Lal (2004), Kulkarni (2003), Duhan *et al.* (2005) and Yashavantakumar (2008).

Table 2: Heterotic response for number of fruits per cluster in tomato.

Cross	MP	BP	Check-1	Check-2
ArkaSaurabh x ArkaAbha	2.67	-3.49	5.78	13.07*
ArkaSaurabh x ArkaMeghali	-6.54*	-14.22*	-5.97	0.49
ArkaSaurabh x Punjab Chhuhara	0.04	-2.42	12.51*	20.25*
ArkaSaurabh x Best of All	8.99*	0.08	9.71*	17.26*
ArkaSaurabh x Sioux	11.12*	3.40	13.35*	21.15*
ArkaAbha x ArkaMeghali	14.20*	11.32*	7.37	14.77*
ArkaAbha x Punjab Chhuhara	-2.02	-10.04*	3.73	10.87*
ArkaAbha x Best of All	-0.64	-3.09	-6.53	-0.09

ArkaAbha x Sioux	0.68	-0.38	-3.92	2.69
ArkaMeghali x Punjab Chhuhara	-3.24	-13.19*	0.09	6.98
ArkaMeghali x Best of All	6.67	6.61	-2.24	4.49
ArkaMeghali x Sioux	5.22	3.65	-2.14	4.59
Punjab Chhuhara x Best of All	6.08	-4.77	9.80*	17.36*
Punjab Chhuhara x Sioux	11.30*	1.21	16.71*	24.75*
Best of All x Sioux	13.89*	12.26*	5.97	13.27*
SE(d)±	0.11	0.13	0.13	0.13

* Significant at 5% level

Number of fruits per cluster

Among the fifteen cross combination six crosses showed significant positive heterosis over mid parent. The heterosis over mid parent ranges from -6.54 to 14.20 percent, minimum being in ArkaSaurabh x ArkaMeghali and maximum in ArkaAbha x ArkaMeghali. The significant positive heterosis will be observed in the cross viz, ArkaAbha x ArkaMeghali (14.20 %), Best of All x Sioux (13.89 %), Punjab Chhuhara x Sioux (11.30%), ArkaSaurabh x Sioux (11.12 %) and ArkaSaurabh x Best of All (8.99 %)

The heterosis over better parent ranged from -14.22% (ArkaSaurabh x ArkaMeghali) to 12.26% (Best of All x Sioux). Three cross combinations viz, Best of All x Sioux (12.26%) and ArkaAbha x

ArkaMeghali (11.32%) showed significant positive heterosis over better parent.

The heterosis over Check-1 ranged from -6.53% (ArkaAbha x Best of All) to 16.71% (Punjab Chhuhara x Sioux) five cross combinations viz, Punjab Chhuhara x Sioux (16.71%), ArkaSaurabh x Sioux (13.35%), ArkaSaurabh x Punjab Chhuhara (12.51%), Punjab Chhuhara x Best of All (9.80%) and ArkaSaurabh x Best of All (9.71%) was found to surpass the Check-1 with regard to heterosis for this trait. The heterosis over Check-2 ranged from -0.09% (ArkaAbha x Best of All) to 24.75% (Punjab Chhuhara x Sioux) nine cross combinations was found to sufficiently surpass the Check-2 with regard to heterosis for this trait.

Table 3: Heterotic response for average fruits weight in tomato

Cross	MP	BP	Check-1	Check-2
ArkaSaurabh x ArkaAbha	7.90	5.05	19.25*	29.87*
ArkaSaurabh x ArkaMeghali	2.85	-1.23	6.18	15.64
ArkaSaurabh x Punjab Chhuhara	-7.06	-9.47	-2.67	5.99
ArkaSaurabh x Best of All	2.62	1.37	8.99	18.70*
ArkaSaurabh x Sioux	9.19	8.52	16.67	27.06*
ArkaAbha x ArkaMeghali	29.95*	21.63*	38.06*	50.36*
ArkaAbha x Punjab Chhuhara	16.85*	10.90	25.87*	37.09*
ArkaAbha x Best of All	17.49*	13.04	28.31*	39.74*
ArkaAbha x Sioux	11.20	7.61	22.16*	33.04*
ArkaMeghali x Punjab Chhuhara	28.57*	26.70*	29.15	40.65*
ArkaMeghali x Best of All	2.87	-0.03	4.85	14.19
ArkaMeghali x Sioux	12.71	8.87	15.62	25.92*

Punjab Chhuhara x Best of All	12.75	11.16	16.60	26.99*
Punjab Chhuhara x Sioux	-5.00	-6.90	-1.14	7.65
Best of All x Sioux	-1.98	-2.58	3.45	12.66
SE(d)±	3.56	4.11	4.11	4.11

* Significant at 5% level

Average fruits weight (g)

Out of fifteen cross combinations, thirteen crosses showed positive relative heterosis and out of them only four crosses showed significant positive heterosis over mid parent for average fruit weight (g). The heterosis over mid parent ranges from -7.06% (ArkaSaurabh x Punjab Chhuhara) to 29.95% (ArkaAbha x ArkaMeghali). The significant positive heterosis over mid parent was observed in the cross ArkaAbha x ArkaMeghali (29.95%), ArkaMeghali x Punjab Chhuhara (28.57%), ArkaAbha x Best of All (17.49%) and ArkaAbha x Punjab Chhuhara (16.85%).

Among the fifteen cross combinations, eleven crosses showed positive heterobeltiosis and out of them only two crosses showed significant positive heterobeltiosis for average fruit weight (g). The heterosis over better parent ranged from -9.47 to 26.70 percent, being lowest in ArkaSaurabh x Punjab Chhuhara and highest in ArkaMeghali x Punjab Chhuhara. The maximum significant positive heterobeltiosis was exhibited by the cross ArkaMeghali x Punjab Chhuhara (26.70%) and ArkaAbha x ArkaMeghali (21.63%).

The heterosis over Check-1 ranged from -2.67% (ArkaSaurabh x Punjab Chhuhara) to 38.06% (ArkaAbha x ArkaMeghali). Five cross combinations performed significantly better over the Check-1 viz, ArkaAbha x ArkaMeghali

(38.06 %), ArkaAbha x Best of All (28.31%), ArkaAbha x Punjab Chhuhara (25.87%), ArkaAbha x Sioux (22.16 %) and ArkaSaurabh x ArkaAbha (19.25%).

The standard heterosis varied from 5.99 % (ArkaSaurabh x Punjab Chhuhara) to 50.36% (ArkaAbha x ArkaMeghali) in case of Check-2. Eleven cross combinations expressed significant positive heterosis over the Check-2.

Average fruit weight is also a direct contributing trait to yield. The significant relative heterotic effect was observed in four crosses, viz., ArkaAbha x ArkaMeghali, ArkaAbha x Punjab Chhuhara, ArkaAbha x Best of All and ArkaMeghali x Punjab Chhuhara, which was also proved again in two cross combinations for heterobeltiosis and standard heterosis over both the checks too. e.g. ArkaAbha x ArkaMeghali and ArkaMeghali x Punjab Chhuhara.

For average fruit weight, expression of significant positive heterosis over mid, better parent and check parents corroborate with the findings of Singh *et al.* 2008, Ahmed *et al.* (1988), Pujari and Kale (1994), Dev *et al.* (1994), Singh *et al.* (1995), Gunasekera and Parera (1999), Tiwari and Lal (2004), Thakur *et al.* (2004), Premalakshme *et al.* (2005), Anita *et al.* (2005), Singh *et al.* (2005a), Mirshamssi *et al.* (2006), Hannan *et al.* (2007a), Rani and Veeraragavathatham (2008), Kumar *et al.* (2009), Kumari *et al.* (2010), Gul *et al.* (2010), Ahmed *et al.* (2011), Singh and

Sastry (2011) and Kumari and Sharma (2011).

Table 4: Heterotic response for fruit yield per plants in tomato

Cross	MP	BP	Check-1	Check-2
ArkaSaurabh x ArkaAbha	1.87	-0.40	-3.96	8.46
ArkaSaurabh x ArkaMeghali	8.26	4.37	0.63	13.67
ArkaSaurabh x Punjab Chhuhara	10.57	3.83	0.12	13.08
ArkaSaurabh x Best of All	13.64*	4.55	0.81	13.87
ArkaSaurabh x Sioux	4.03	3.28	-0.41	12.48
ArkaAbha x ArkaMeghali	22.58*	20.83*	11.29	25.70*
ArkaAbha x Punjab Chhuhara	34.67*	29.23*	19.03*	34.44*
ArkaAbha x Best of All	21.70*	14.37	5.34	18.98*
ArkaAbha x Sioux	8.72	7.06	1.72	14.89
ArkaMeghali x Punjab Chhuhara	34.62*	30.99*	17.21*	32.39*
ArkaMeghali x Best of All	23.32*	17.47*	5.12	18.73*
ArkaMeghali x Sioux	-8.45	-11.11	-15.54*	-4.61
Punjab Chhuhara x Best of All	34.73*	31.82*	11.60	26.05*
Punjab Chhuhara x Sioux	-11.63	-16.44*	-20.61*	-10.33
Best of All x Sioux	9.05	1.01	-4.02	8.40
SE(d)±	173.30	200.11	200.11	200.11

* Significant at 5% level

Fruit yield per plant (g)

The range of heterosis over mid parent for yield per plant varied from -11.63% (Punjab Chhuhara x Sioux) to 34.73% (Punjab Chhuhara x Best of All). Over all, seven cross combinations resulted in significant positive heterosis over mid parent.

The range of heterobeltiosis for yield per plant varied from -16.44% (Punjab Chhuhara x Sioux) to 31.82% (Punjab Chhuhara x Best of All). Out of fifteen cross combinations, five crosses viz, Punjab Chhuhara x Sioux (31.82%), ArkaMeghali x Punjab Chhuhara (30.99%), ArkaAbha x Punjab Chhuhara (29.23%), ArkaAbha x ArkaMeghali (20.83%) and ArkaMeghali x Best of All (17.47%) resulted in significant positive heterosis over better parent.

For Check-1, standard heterosis varied from -20.61% (Punjab Chhuhara x

Sioux) to 19.03% (ArkaAbha x Punjab Chhuhara). The only two cross combinations viz, ArkaAbha x Punjab Chhuhara (19.03%) and ArkaMeghali x Punjab Chhuhara (17.21%) revealed significant positive heterosis over the Check-1.

The standard heterosis for Check-2 varied from -10.33% (Punjab Chhuhara x Sioux) to 34.44% (ArkaAbha x Punjab Chhuhara). Out of fifteen cross combinations, six crosses revealed significant positive heterosis over the Check-2.

The ultimate goal of any breeding programme is target to achieve maximization of yield. This is also the key factor in adoption or rejection of a variety or hybrid by the farmer.

In the present studies, among the fifteen cross combinations, five crosses, viz., ArkaAbha x ArkaMeghali, ArkaAbha

x Punjab Chhuhara, ArkaMeghali x Punjab Chhuhara, ArkaMeghali x Best of All and Punjab Chhuhara x Best of All resulted in significant positive heterosis over mid and better parent. But only two cross combinations, viz., ArkaAbha x Punjab Chhuhara and ArkaMeghali x Punjab Chhuhara were found to have significant positive standard heterosis over check-1 and check-2.

Positive heterosis for fruit yield per plant has also been reported by Bhatt *et al.* (2001), Sharma *et al.* (2001), Chaudhary and Malhotra (2001), Fageria *et al.* (2001),

Thakur *et al.* (2004), Tiwari and Lal (2004), Mahendrakaret *al.* (2005), Premalakshmeet *al.* (2005), Singh *et al.* (2005a), Anita *et al.* (2005) Mirshamssi *et al.* (2006), Hannan *et al.* (2007a), Rani and Veeraragavathatham (2008), Kumar *et al.* (2009), Gul *et al.* (2010), Kumari *et al.* (2010), Kumari and Sharma (2011), Singh and Shastri (2011), Ahmad *et al.* (2011).

For fruit yield per plant, significant positive heterosis over mid parent, better parent and commercial checks were also reported by Sharma and Thakur (2008).

Table 4.1.8: Heterotic response for plant height at last harvest (cm) in tomato

Cross	MP	BP	Check-1	Check-2
ArkaSaurabh x ArkaAbha	11.68	11.23	21.51*	17.56*
ArkaSaurabh x ArkaMeghali	22.46*	20.72*	35.73*	31.32*
ArkaSaurabh x Punjab Chhuhara	44.47*	35.88*	48.56*	43.73*
ArkaSaurabh x Best of All	-2.09	-8.70	15.30	11.55
ArkaSaurabh x Sioux	14.04*	6.31	16.14*	12.36
ArkaAbha x ArkaMeghali	15.08*	13.00	27.05*	22.92*
ArkaAbha x Punjab Chhuhara	21.01*	14.34	23.91*	19.88*
ArkaAbha x Best of All	51.24*	40.50*	77.45*	71.68*
ArkaAbha x Sioux	17.86*	10.29	19.51*	15.63*
ArkaMeghali x Punjab Chhuhara	19.15*	10.66	24.42*	20.37*
ArkaMeghali x Best of All	0.74	-4.77	20.25*	16.34*
ArkaMeghali x Sioux	21.22*	11.52	25.38*	21.30*
Punjab Chhuhara x Best of All	28.83*	13.59*	43.46*	38.79*
Punjab Chhuhara x Sioux	13.06	11.91	7.89	4.38
Best of All x Sioux	26.02*	10.22	39.08*	34.56*
SE(d)±	8.40	9.70	9.70	9.70

* Significant at 5% level

Plant height at last harvest (cm)

The relative heterosis effects ranges from -2.09% (ArkaSaurabh x Best of All) to 44.47% (ArkaSaurabh x Punjab Chhuhara) for plant height at last harvest. Out of fifteen cross combination, fourteen crosses showed positive heterosis over

mid parent, out of which ten crosses showed significant positive heterosis.

Further, heterosis over better parent for plant height at last harvest ranged from -8.70% (ArkaSaurabh x Best of All) to 35.99% (ArkaSaurabh x Punjab Chhuhara). The only three cross combinations viz., ArkaSaurabh x Punjab Chhuhara (35.99%), ArkaSaurabh x

ArkaMeghali (20.72%) and ArkaAbha x Best of All (19.19%) revealed significant positive heterosis over better parent.

For Check-1, standard heterosis varied from 15.30% (ArkaSaurabh x Best of All) to 50.53% (ArkaAbha x Best of All). Significant positive heterosis over the Check-1 was revealed by ten cross combination.

The standard heterosis varied from 11.55% (ArkaSaurabh x Best of All) to 45.63% (ArkaAbha x Best of All). The five cross combination significant positive heterosis was revealed by over the Check-2.

Taller plant is considered to be desirable because it leads to more number of branches and ultimately result in increased productivity. Ten, three, ten and six crosses out of fifteen, showed significantly positive heterosis over mid, better, check-1 and check-2 parents.

Positive heterosis for this trait has also been reported by Dev *et al.*, (1994), Srivastava *et al.*, (1998), Thakur *et al.*, (2004), Mirshamsiet *et al.*, (2006); Rani and Veeraragavathatham, (2008), Sharma and Thakur (2008), Kumari *et al.* (2010), Singh and Asati (2011), Singh and Sastry (2011), Kumari and Sharma (2011) and Ahmed *et al* (2011).

Table 4.1.10: Heterotic response for Fruit length (mm) in tomato

Cross	MP	BP	Check-1	Check-2
ArkaSaurabh x ArkaAbha	6.05	5.71	14.36*	19.55*
ArkaSaurabh x ArkaMeghali	11.63*	8.16	17.01*	22.31*
ArkaSaurabh x Punjab Chhuhara	10.06*	-4.31	40.15*	46.51*
ArkaSaurabh x Best of All	4.94	3.79	12.28*	17.37*
ArkaSaurabh x Sioux	1.92	1.33	10.88*	15.91*
ArkaAbha x ArkaMeghali	-1.58	-4.34	2.81	7.47
ArkaAbha x Punjab Chhuhara	4.70	-9.23*	32.95*	38.98*
ArkaAbha x Best of All	7.58	6.75	14.74*	19.94*
ArkaAbha x Sioux	-1.80	-2.67	6.48	11.31*
ArkaMeghali x Punjab Chhuhara	1.66	-13.96*	26.02*	31.74*
ArkaMeghali x Best of All	13.75*	11.47*	17.89*	23.23*
ArkaMeghali x Sioux	2.26	-1.45	7.81	12.70*
Punjab Chhuhara x Best of All	-3.86	-17.20*	21.28*	26.77*
Punjab Chhuhara x Sioux	-3.39	-15.61*	23.60*	29.21*
Best of All x Sioux	1.98	0.30	9.74*	14.72*
SE(d)±	1.58	1.83	1.83	1.83

* Significant at 5% level

4.1.10 Fruit length (mm)

For fruit length (mm) only three crosses out of the fifteen cross combinations, viz., ArkaMeghali x Best of All (13.75%), ArkaSaurabh x ArkaMeghali (11.63%) and ArkaSaurabh x Punjab

Chhuhara (10.06%) showed significantly positive mid parent heterosis. It ranges from -3.86% (Punjab Chhuhara x Best of All) to 13.75 % (ArkaMeghali x Best of All).

The heterosis over better parent for fruit length (mm) ranged from -17.20 %

(Punjab Chhuhara x Best of All) to 11.47% (ArkaMeghali x Best of All). Out of fifteen crosses, only one cross combination viz, ArkaMeghali x Best of All (11.47%) resulted in significantly positive heterosis over the better parent.

The increase or decrease over the standard heterosis for Check-1 ranged from 2.81 per cent (ArkaAbha x ArkaMeghali) to 40.15% (ArkaSaurabh x Punjab Chhuhara). On the other hand, among the fifteen cross combination twelve crosses exhibited significant positive heterosis over the Check-1.

The standard heterosis for Check-2 varied from 7.47% (ArkaAbha x ArkaMeghali) to 46.51% (ArkaSaurabh x Punjab Chhuhara). Among the fifteen cross combination fourteen crosses

exhibited significant positive heterosis over the Check-2.

Fruit length has been globally identified as an important component of direct contributing to yield in tomato. In the present studies three cross combinations, viz., ArkaMeghali x Best of All crossed expressed its superiority for all kinds of heterosis including both the checks.

Mahendrakar. (2004) also reported heterosis in fruit length in tomato. Significant positive heterosis over mid and better parent was also reported by Gul *et al.* (2010), Islam *et al.* (2012) and Singh *et al.* (2012).

Table 4.1.11: Heterotic response for Fruit breadth (mm) in tomato

Cross	MP	BP	Check-1	Check-2
ArkaSaurabh x ArkaAbha	-1.09	-5.80	17.47*	17.58*
ArkaSaurabh x ArkaMeghali	11.66*	7.85*	21.68*	21.79*
ArkaSaurabh x Punjab Chhuhara	15.37*	-1.43	11.19*	11.30*
ArkaSaurabh x Best of All	0.43	-5.53*	6.57*	6.67*
ArkaSaurabh x Sioux	15.44*	10.24*	24.37*	24.49*
ArkaAbha x ArkaMeghali	-3.93*	-11.47*	10.39*	10.50*
ArkaAbha x Punjab Chhuhara	7.28*	-11.97*	9.77*	9.87*
ArkaAbha x Best of All	4.56*	-6.04*	17.16*	17.28*
ArkaAbha x Sioux	-0.16	-8.99*	13.49*	13.60*
ArkaMeghali x Punjab Chhuhara	18.54*	4.34	9.69*	9.79*
ArkaMeghali x Best of All	7.44*	4.51	9.87*	9.98*
ArkaMeghali x Sioux	6.58*	5.33*	10.73*	10.84*
Punjab Chhuhara x Best of All	8.91*	-1.75	-2.34	-2.24
Punjab Chhuhara x Sioux	21.49*	8.05	10.91*	11.02*
Best of All x Sioux	2.17	0.56	3.22	3.32
SE(d)±	1.00	1.16	1.16	1.16

* Significant at 5% level

4.1.11 Fruit breadth (mm)

The heterosis over mid parent ranges from -3.93% (ArkaAbha x ArkaMeghali) to 21.49 % (Punjab

Chhuhara x Sioux) for fruit breadth (mm). Out of the fifteen cross combination ten crosses expressed significantly better mid parent heterosis.

The heterosis over better parent for fruit breadth (mm) ranged from -11.97 % (ArkaAbha x Punjab Chhuhara) to 10.24% (ArkaSaurabh x Sioux). Out of fifteen crosses, only four cross combination, viz., ArkaSaurabh x Sioux (10.24%), Punjab Chhuhara x Sioux (8.05%), ArkaSaurabh x ArkaMeghali (7.85%) and ArkaMeghali x Sioux (5.33%) resulted in significant positive heterosis over the better parent.

For check-1, the standard heterosis varied from -2.34% (Punjab Chhuhara x Best of All) to 24.37% (ArkaSaurabh x Sioux) while for Check-2, it varied from -2.24% (Punjab Chhuhara x Best of All) to 24.49% (ArkaSaurabh x Sioux). For both Check-1 & 2, out of fifteen cross combination, thirteen crosses performed significantly better over them.

Fruit length has been globally identified as an important component of direct contributing to yield in tomato. Out of fifteen crosses, ten crosses for relative, four crosses for better and thirteen crosses

for standard heterosis revealed significant positive values.

Mahendrakar. (2004) Baishya et al. (2001), Gul et al. (2010) and Islam et al. (2012) and Singh et al. (2012) also reported heterosis on fruit breadth in tomato.

4.1.14 Number of fruit clusters per plant

The heterosis over the mid parent ranges from -9.03% (ArkaSaurabh x Sioux) to 42.65% (ArkaMeghali x Punjab Chhuhara). Out of the fifteen crosses fourteen showed positive mid parent heterosis out of them only ten were significant.

The range of heterobeltiosis for number of fruit clusters per plant varied from -9.94 % (ArkaSaurabh x Sioux) to 32.66% (ArkaMeghali x Punjab Chhuhara) and six cross combinations resulted in significantly positive heterobeltiosis.

Table 4.1.14: Heterotic response for number of fruit clusters per plant in tomato

Cross	MP	BP	Check-1	Check-2
ArkaSaurabh x ArkaAbha	14.00*	12.11*	-0.56	8.69
ArkaSaurabh x ArkaMeghali	16.94*	16.60*	0	9.31
ArkaSaurabh x Punjab Chhuhara	23.57*	14.61*	-1.70	7.45
ArkaSaurabh x Best of All	26.24*	25.84*	7.95	18.01*
ArkaSaurabh x Sioux	-9.03	-9.94	-22.72*	-15.52*
ArkaAbha x ArkaMeghali	-3.92	-5.76	-16.47*	-8.69
ArkaAbha x Punjab Chhuhara	11.57*	1.92	-9.65*	-1.24
ArkaAbha x Best of All	1.96	0	-11.36*	-3.10
ArkaAbha x Sioux	25.00*	21.73*	7.95	18.01*
ArkaMeghali x Punjab Chhuhara	42.65*	32.66*	13.06*	23.60*
ArkaMeghali x Best of All	7.33	7.33	-8.52	0
ArkaMeghali x Sioux	10.73*	10.00	-6.25	2.48
Punjab Chhuhara x Best of All	14.69*	6.60	-9.09	-0.62
Punjab Chhuhara x Sioux	16.24*	8.82	-8.52	0
Best of All x Sioux	2.01	1.33	-13.63*	-5.59
SE(d)±	0.46	0.53	0.53	0.53

* Significant at 5% level

Standard heterosis for number of fruit clusters per plant ranged from -9.93% (ArkaSaurabh x Sioux) to 13.06% (ArkaMeghali x Punjab Chhuhara) for Check-1. Only one cross combination, i.e. ArkaMeghali x Punjab Chhuhara (13.06%) was found to surpass the Check-1 with regard to heterosis for this trait.

The standard heterosis for Check-2 ranged from -15.52% (ArkaSaurabh x Sioux) to 23.60% (ArkaMeghali x Punjab Chhuhara). Only three cross combinations, viz., ArkaMeghali x Punjab Chhuhara (23.60%), ArkaAbha x Sioux (18.01%) and ArkaSaurabh x Best of All (18.01%) were found to surpass sufficiently over the Check-2 with regard to heterosis for this trait.

Number of fruit clusters per plant is one of the important yield component. For average number of fruits cluster per plant, ArkaMeghali x Punjab Chhuhara has positively significant values for all types of heterosis including standard heterosis over both the checks.

Similar trend was noticed by Sajjan (2001), Kulkarni (2003) and Duhan *et al.* (2005). Exhibited positive heterosis over mid parent and better parent similarly trend was noticed by Sekharet *al.* (2010) and heterosis over better parent reported by Deepa and Sharma (2013).

Conclusion

Top three cross combinations for fruit yield per plant as per their *per se* performance, ArkaAbha x Punjab Chhuhara, ArkaMeghali x Punjab Chhuhara, Punjab Chhuhara x Best of All came out to be expressing significantly positive standard heterosis. Most of the

crosses manifested highly significant heterosis over both checks, for fruit length and Fruit breadth that reflect that hybrids have better chance of having bigger fruits in case of tomato. For average fruit weight, ArkaAbha x ArkaMeghali, ArkaMeghali x Punjab Chhuhara proved to be the best hybrids which has expressed significant positive results for all types of heterosis including over checks. Overall, hybrids have reported greater plant heights as compared to check and mid parents which indicate that heterosis can be exploited for further improving the plant heights. ArkaMeghali x Punjab Chhuhara found to be the best cross combination which have significant favourable heterosis, of all three types, for vitals yield attributing traits i.e. number of fruits per cluster and number of fruit clusters per plant

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