RESEARCH ARTICLE

Heterosis and Inbreeding Depression for Yield and Quality Traits in Tomato (*Lycopersicon esculentum* Mill.)

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Abstract

Ten parental lines of tomato (*Lycopersicon esculantum* Mill.) were crossed in 10 x 10 diallel mating plan barring reciprocals. The 45 F_1 hybrids, along with their parents and one standard check (Pusa Ruby) were evaluated in a randomized block design with three replications during the years (2020–2021). This study is relevant that heterosis over the better parent, mid-parent, standard check and inbreeding depression were observed for all the traits under study. Highly significant heterosis was observed for days to first flowering (-18.35, -14.42 and -3.30%), days to 50% fruiting (-13.41, -12.30 and -6.71%), fruit diameter (41.20, 46.07 and 35.57%), fruits length (49.20, 63.23 and 5.98%), average fruit weight (59.26, 66.89 and 26.72%), number of fruits per plant (135.19, 159.63 and 80.67%), number of fruits per cluster (54.55, 54.55 and 80.02%) and total yield per plant (123.71, 146.41 and 99.13%) over the better, mid and standard parents, respectively along with considerable inbreeding depression. The most promising cross EC-165700 × EC-164563 have better yield per plant as compared to the parent and standard check. Thus, these heterotic hybrids found superior over better parents and one standard check have the potential to be exploited commercially.

Keywords: Tomato, F_1 hybrids, F_2 hybrids, Heterosis, Inbreeding depression, Standard heterosis,

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Introduction

Tomato is one of the foremost imperative natural product vegetables. It's fundamental to a well-balanced count of calories since they give not as it were vitality but too basic defensive substances such as vitamins, minerals, and antioxidants. Since phytochemicals such as carotenoids, inositol phosphate, phytosterols, and others are shown in vegetables, it could be an all-inclusive reality that "a plateful of veggies keeps the specialist absent" (Vekariya *et al.*, 2019). The sustenance significance of the tomato demonstrates there's need to be compelled to define the breeding program and create cultivars wealthy in vitamins, nutrients and oxidants, handling characteristics with tall quality of the natural product as well as surrender (Dagade, *et al.*, 2015). Vegetables play a vital part in the balanced count of calories by giving not as it were vitality but too could be a rich source of minerals (Press and phosphorus), vitamins (Vitamin A and C), natural corrosive, fundamental amino acids, dietary strands, etc. advance natural product gives 3–4% add up to sugar, 4–7% add up to solids, 15–30 mg/100g ascorbic corrosive, 7.5–10 mg/100ml titratable corrosiveness and 20–50 mg/100g natural product weight of lycopene. Tomato and its items have been related to a lower chance of creating stomach-related tract and prostate cancers (Giovannucci *et al.*, 2002). Investigating common differences as a source of novel alleles to move forward the efficiency, quality and nutritional esteem of the edit is the baseline of any breeding program. Effective misuse of heterosis in tomatoes is temperate since each natural product contains more seeds than other vegetables (Kumari and Sharma, 2011). Presently a day, agriculturists are exceptionally much slanted to develop hybrid assortment for having tall yielding and to induce great quality natural products. But there's a great missing hybrid. So, the advancement of the hybrid assortment of tomatoes is required to back agriculturists intrigued. Creating hybrid seeds each year by manufactured emasculation and pollination is exorbitant. In any case, the advance within the hereditary advancement of surrender potential has been restricted and the moved-forward cultivars fizzled to improve the efficiency of the trim. Contract differing hereditary qualities in developed genotypes have advance hampered the fruitful abuse of conventional breeding; in this manner, an elective breeding approach such as hybrid innovation is pivotal to expand the abdicate of tomatoes for guaranteeing nourishment and nutritional security. The greatness of heterosis serves as a direct for the choice of alluring guardians and is additionally a premise for deciding the differing hereditary qualities (Swindell and Poehlman, 1976). Abusing heterosis and hybrid vigor in tomato can enhance Abdicate enhancement by impressive additive and non-additive quality activity in heterosis breeding (Saxena and Sharma, 1990).

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Material And Methods

The study was conducted during three seasons (10 Feb.2020, 12 Aug-2020 and 17 Feb-2021) at the Agriculture research farm of C.C.R (PG) College Muzaffarnagar, U.P. The material for the present study comprised ten parents of tomatoes namely EC-620406, EC-163605, EC-165700, EC-631364, EC-164563, EC-521067, EC-528360, EC-145057, Floradade, and Arka Meghali and forty-five hybrids were produced through half diallel mating design. The experiments were laid out in three replication and randomized block design, each line consisting of ten plants in spacing at 60 x 45 cm. All the recommended packages of practices were adopted for raising a healthy crop. The observations were recorded randomly on 5 plants in each parent and F_{1s} and 10 plants in each F_{2s} population on each replication. The chosen pants were tagged and legitimately leveled some time recently blooming and for recording the eight characteristics viz., days to first flowering, days to 50% fruiting, fruit diameter (mm), fruit length (mm), average fruit weight (g), number of fruits/plant, number of fruit/cluster, and total yield/plant (g). Heterosis and inbreeding depression for each characteristic were worked out by utilizing the overall cruel of each hybrid over replications for each characteristic. Heterosis was examined over the better parent (heterobeltiosis), over the mid parent and the standard variety, i.e., Standard checks (economic heterosis), following the method described by Kempthorne (1957):-

Mid parent =

Heteroeltiosis

Economic check =

Where,

= Mean value of the F_{1s} generation

MP = Mean performance of mid parent

= Mean value of the better parent (Heteroeltiosis)

= Mean value of the economic cultivar (check).

Inbreeding Depression

Inbreeding depression in F_2 generation was assessed as the cruel contrast between the F_1- F_2 populaces.

Inbreeding depression (%)

Where,

= Mean value of the F_1 Hybrid

= Mean value of the F_2 generation

Gauge of inbreeding depression from F_2 over F_1 were calculated in term of rate.

Result And Discussion

Analysis of variance revealed (Table 1) that parents and hybrids were highly significant for all the characters except days to first flowering, indicating the presence of a wide range variation among the parents as well as crosses studied. This emphasized the need to select parents for maximization of hybrid vigor with, respectively total yield and its related characteristics. Many workers have reported similar results for different characteristics (Dagade *et al*., 2015 Shankar *et al*., 2014). The enhancement of totally different quantitative and qualitative characteristics in tomatoes through heterosis breeding was observed by Tiwari and Lal, (2004), and detailed significance heterosis was recorded in EC- 165700 x EC- 164563 (123.71 over better parent and 66.89 over mid-parent) for total yield per plant. Heterosis was evaluated as the percent increment or diminishes of F_1 hybrid over the better parent (BP), mid parent (MP) and standard variety (SV) as well as inbreeding depression. The degree of heterosis and inbreeding depression for different characters is presented in Tables 1 to 5.

Table 1: Analysis of variance for parent and F_1S and F_2S in tomato

Sourced of variation	*d.f*	*Days to First flowering*	*Days to 50 % fruiting*	*Fruit diameter*	*Fruits length*
REPLICATION	2	1.36	3.45	12.17	18.82
PARENTS	9	10.65**	11.91**	198.41**	383.90**
F1 Hybrid	44	11.41**	20.23**	156.46**	153.43**
Parents verses F1Hybrid	1	1.95	21.72**	122.35**	793.88**
F2 Hybrid	44	8.90**	21.33**	154.95**	139.50**
Parents verses F2Hybrid	1	0.16	38.46**	90.39**	904.74**
ERROR	198	1.51	3.40	16.78	5.02

Sourced of variation	d.f	Average fruit weight (g)	Number of fruits /plant	Number of fruits /cluster	Total yield/plant
REPLICATION	2	15.32	4.48	0.63	4007.98
PARENTS	9	1453.63**	796.98**	1.24**	1712692.40**
F1 Hybrid	44	284.81**	703.78**	1.55**	726066.68**
Parents verses F1Hybrid	1	1393.27**	1501.87**	6.41**	190572.28**
F2 Hybrid	44	275.30**	706.19**	1.37**	709849.37**
Parents verses F2Hybrid	1	1471.04**	1629.91**	5.18**	188543.53**
ERROR	198	9.70	8.12	0.30	3423.16

*, ** significant at 5% and 1% level of significance, respectively

Table 2. Heterotic effect for days to first flowering and days to 50 % fruiting in tomato

S. No	*Cross*	*Days to first flowering*		*Days to 50 % fruiting*	
		Heterosis (%) over BP	*Inbreeding depression*	*Heterosis (%) over BP*	*Inbreeding depression*
1.	EC-620406 x EC-163605	-8.00 **	-1.09	-0.63	-5.70**
2.	EC-620406 x EC-165700	-2.13	-2.17	-11.87 **	1.42
3.	EC-620406 x EC-164563	5.15	3.91	-13.41 **	0.71
4.	EC-620406 x EC-631364	6.06 *	-6.67	-12.58 **	-0.72
5.	EC-620406 x EC-521067	-10.09 **	9.19**	-11.32 **	1.42
6.	EC-620406 x EC-528360	10.42 **	-1.88	-12.58 **	-2.16
7.	EC-620406 x EC-145057	-3.19	-1.10	-8.81 **	-0.69
8.	EC-620406 x floradade	4.04	-1.94	-5.03 *	-1.32
9.	EC-620406 x ArkaMeghali	9.09 **	-3.69	-11.32 **	-1.42
10.	EC-163605 x EC-165700	1.00	-0.99	-7.50 **	-1.35
11.	EC-163605 x EC-164563	-7.00 *	-1.07	-7.93 **	3.99
12.	EC-163605 x EC-631364	10.00 **	-5.45	-7.59 **	-2.74
13.	EC-163605 x EC-521067	-7.34 **	-7.12*	-3.21	3.97
14.	EC-163605 x EC-528360	-6.00 *	-1.06	-4.55	-1.36
15.	EC-163605 x EC-145057	-9.00 **	-1.10	-3.90	-5.40
16.	EC-163605 x Floradade	-2.00	-1.02	-2.60	-0.67
17.	EC-163605 x ArkaMeghali	1.00	1.97	-5.19 *	-1.37
18.	EC-165700 x EC-164563	-3.09	-1.06	-5.49 *	-1.29
19.	EC-165700 x EC-631364	-11.11 **	-2.26	-5.63 *	2.66
20.	EC-165700 x EC-521067	-13.76 **	-1.06	3.13	-1.21
21.	EC-165700 x EC-528360	9.38 **	-0.95	-10.00 **	4.17*
22.	EC-165700 x EC-145057	14.44 **	-6.80*	-4.37	5.88**
23.	EC-165700 x Floradade	-3.03	-1.04	8.13 **	5.21**
24.	EC-165700 x ArkaMeghali	-8.08 **	1.10	-5.63 *	-4.64**
25.	EC-164563 x EC-631364	6.06 *	-2.43	0.00	1.16
26.	EC-164563 x EC-521067	-9.17 **	6.39*	-4.88 *	3.85
27.	EC-164563 x EC-528360	-6.19 *	1.10	-9.76 **	6.08**
28.	EC-164563 x EC-145057	3.09	6.02	4.27	-4.35*
29.	EC-164563 x Floradade	-7.07 *	-4.10	-10.37 **	4.08
30.	EC-164563 x ArkaMeghali	0.00	-5.06	-8.54 **	4.00
31.	EC-631364 x EC-521067	-18.35 **	1.97	-3.16	5.88
32.	EC-631364 x EC-528360	1.01	2.00	-0.63	-3.83
33.	EC-631364 x EC-145057	-3.03	2.09	-3.80	-3.94
34.	EC-631364 x Floradade	7.07 *	-3.77	-3.80	3.28
35.	EC-631364 x ArkaMeghali	11.11 **	-6.37*	-1.90	4.94*
36.	EC-521067 x EC-528360	-8.26 **	3.23	2.56	-4.37*
37.	EC-521067 x EC-145057	-15.60 **	2.78	3.21	3.73
38.	EC-521067 x Floradade	-11.93 **	-5.59	3.21	-3.11
39.	EC-521067x ArkaMeghali	-13.76 **	-3.20	-3.21	3.97
40.	EC-528360 x EC-145057	-2.08	4.27	-1.96	8.00**
41.	EC-528360 x Floradade	5.05	-3.86	0.00	-5.88**
42.	EC-528360 x ArkaMeghali	-7.07 *	3.26	5.23 *	-3.11
43.	EC-145057 x Floradade	0.00	1.01	-2.61	1.33
44.	EC-145057 x ArkaMeghali	3.03	2.94	8.22 **	2.53
45.	Floradade x ArkaMeghali	-4.04	3.16	0.65	4.32

Table 3: Heterotic effect for fruit diameter and fruit length in tomato

S. No	*Cross*	*Fruit diameter (mm)*		*Fruits length (mm)*	
		Heterosis (%) over BP	*Inbreeding depression*	*Heterosis (%) over BP*	*Inbreeding depression*
1.	EC-620406 x EC-163605	-8.59	-2.98	-1.41	-6.50*
2.	EC-620406 x EC-165700	11.02	-6.18*	-21.97 **	-16.38**
3.	EC-620406 x EC-164563	4.13	-1.27	-39.97 **	-2.66
4.	EC-620406 x EC-631364	-0.26	-1.81	-25.49 **	-0.85
5.	EC-620406 x EC-521067	-9.58	-8.90**	-14.28 **	4.05
6.	EC-620406 x EC-528360	-20.41 **	-0.91	-46.06 **	-1.56
7.	EC-620406 x EC-145057	10.12	-1.50	-43.85 **	-2.16
8.	EC-620406 x floradade	-16.82 *	-3.18	-44.77 **	-1.87
9.	EC-620406 x ArkaMeghali	-3.40	-1.37	-43.70 **	7.33*
10.	EC-163605 x EC-165700	12.36	-0.91	-10.52	3.07
11.	EC-163605 x EC-164563	-37.28 **	-1.93	-35.31 **	-2.31
12.	EC-163605 x EC-631364	-10.10	-3.73	-47.22 **	-2.42
13.	EC-163605 x EC-521067	5.43	-1.40	-2.73	-0.33
14.	EC-163605 x EC-528360	36.58 **	-1.50	49.20 **	-1.69
15.	EC-163605 x EC-145057	-8.57	6.95*	-30.60 **	-1.66
16.	EC-163605 x Floradade	-30.77 **	-1.92	-56.62 **	-0.19
17.	EC-163605 x ArkaMeghali	-5.45	-1.55	-56.76 **	-1.67
18.	EC-165700 x EC-164563	-23.16 **	-0.96	-1.12	-0.91
19.	EC-165700 x EC-631364	0.09	-0.84	-23.43 **	-0.33
20.	EC-165700 x EC-521067	2.95	-0.90	-16.81 **	-2.25
21.	EC-165700 x EC-528360	41.20 **	-1.42	10.60	7.66**
22.	EC-165700 x EC-145057	41.04 **	-3.13	-3.16	15.95**
23.	EC-165700 x Floradade	-2.12	4.27	-31.54 **	-2.37
24.	EC-165700 x ArkaMeghali	-5.42	-0.39	-34.60 **	4.30
25.	EC-164563 x EC-631364	0.45	-2.32	-51.17 **	3.47
26.	EC-164563 x EC-521067	-10.12	4.23	-18.77 **	11.58**
27.	EC-164563 x EC-528360	22.34 **	-9.48**	-25.73 **	9.62**
28.	EC-164563 x EC-145057	5.75	1.03	-42.34 **	-8.46**
29.	EC-164563 x Floradade	-11.73	-7.53**	-35.76 **	3.85
30.	EC-164563 x ArkaMeghali	-17.50 *	-7.89**	-41.93 **	4.72
31.	EC-631364 x EC-521067	-15.35	-10.20**	-15.73 **	-8.28**
32.	EC-631364 x EC-528360	-15.34	-6.44*	-27.18 **	-4.35
33.	EC-631364 x EC-145057	-11.63	2.67	-20.40 **	-7.46
34.	EC-631364 x Floradade	-32.93 **	2.49	-31.01 **	3.94
35.	EC-631364 x ArkaMeghali	7.73	2.47	-34.83 **	6.23*
36.	EC-521067 x EC-528360	-2.14	-4.53	-9.18	6.64*
37.	EC-521067 x EC-145057	-9.84	5.09	-15.81 **	10.31**
38.	EC-521067 x Floradade	-28.72 **	0.89	-35.41 **	8.68**
39.	EC-521067x ArkaMeghali	-24.32 **	8.03**	-31.33 **	4.65
40.	EC-528360 x EC-145057	-3.43	2.70	-9.85	4.02
41.	EC-528360 x Floradade	-28.05 **	-7.23*	-33.93 **	6.28*
42.	EC-528360 x ArkaMeghali	3.27	-9.32**	-42.14 **	2.52
43.	EC-145057 x Floradade	-18.03 **	-3.57	-30.37 **	6.84**
44.	EC-145057 x ArkaMeghali	1.67	3.10	-41.01 **	6.82**
45.	Floradade x ArkaMeghali	-5.53	-3.84	-37.48 **	4.33

Table 4: Heterotic effect for average fruit weight and number of fruit /plant in tomato

S. No	*Cross*	*Average fruit weight (g)*		*Number of fruit /plant*	
		Heterosis (%) over BP	*Inbreeding depression*	*Heterosis (%) over BP*	*Inbreeding depression*
1.	EC-620406 x EC-163605	-19.05 **	-4.07	-64.32 **	-9.21**
2.	EC-620406 x EC-165700	-42.32 **	-3.43	-1.23	5.45
3.	EC-620406 x EC-164563	-37.63 **	-1.06	135.19 **	-2.82
4.	EC-620406 x EC-631364	-47.75 **	-9.80**	-12.50	6.73*
5.	EC-620406 x EC-521067	-24.35 **	0.38	48.10 **	5.64
6.	EC-620406 x EC-528360	-10.55 *	-1.47	-13.14 **	-0.49
7.	EC-620406 x EC-145057	-22.39 **	-8.20**	-3.37	2.93
8.	EC-620406 x floradade	-44.85 **	-5.46	21.24 **	-6.19**
9.	EC-620406 x ArkaMeghali	-25.42 **	-1.77	-1.39	5.63*
10.	EC-163605 x EC-165700	-32.72 **	1.29	-11.74 **	2.13
11.	EC-163605 x EC-164563	-77.94 **	5.13	-11.27 **	2.65
12.	EC-163605 x EC-631364	-21.91 **	-3.59	-45.07 **	-2.56
13.	EC-163605 x EC-521067	-40.34 **	-3.67	-23.47 **	2.46
14.	EC-163605 x EC-528360	14.01	-11.57**	-51.64 **	6.80*
15.	EC-163605 x EC-145057	2.68	-1.31	-41.78 **	10.49**
16.	EC-163605 x Floradade	-79.72 **	-10.01**	-7.51 *	2.03
17.	EC-163605 x ArkaMeghali	-69.58 **	-1.36	-12.68 **	-9.14**
18.	EC-165700 x EC-164563	-18.27 **	-2.05	76.54 **	-1.40
19.	EC-165700 x EC-631364	-65.64 **	-1.76	34.57 **	6.42*
20.	EC-165700 x EC-521067	-23.42 **	-1.15	9.88	-4.50
21.	EC-165700 x EC-528360	59.26 **	1.06	-28.47 **	-1.02
22.	EC-165700 x EC-145057	17.26	-4.67	29.21 **	3.48
23.	EC-165700 x Floradade	-62.27 **	7.66*	-13.27 *	-1.02
24.	EC-165700 x ArkaMeghali	-28.82 **	-5.44	39.51 **	-6.76*
25.	EC-164563 x EC-631364	-2.30	4.31	-17.19	17.00**
26.	EC-164563 x EC-521067	-19.30 **	-7.71*	0.00	7.60**
27.	EC-164563 x EC-528360	-10.06	-2.82	-61.31 **	1.88
28.	EC-164563 x EC-145057	-36.04 **	-3.07	30.34 **	4.51
29.	EC-164563 x Floradade	-61.56 **	6.03*	57.52 **	9.55**
30.	EC-164563 x ArkaMeghali	-2.46	4.63	75.00 **	7.94**
31.	EC-631364 x EC-521067	-10.37	-5.79*	-13.92	12.10**
32.	EC-631364 x EC-528360	-39.82 **	-7.62*	1.46	4.32
33.	EC-631364 x EC-145057	-14.74 **	-5.19	-21.35 **	4.27
34.	EC-631364 x Floradade	-66.63 **	-15.11**	27.43 **	4.42
35.	EC-631364 x ArkaMeghali	-15.35 **	13.45**	9.72	7.60**
36.	EC-521067 x EC-528360	-23.38 **	-13.78**	-63.50 **	-8.98**
37.	EC-521067 x EC-145057	-38.11 **	13.50**	-16.85 *	13.51**
38.	EC-521067 x Floradade	-68.19 **	-10.90**	-28.32 **	-7.41**
39.	EC-521067x ArkaMeghali	-27.37 **	12.16**	35.44 **	-13.08**
40.	EC-528360 x EC-145057	-14.96	3.13	-1.46	4.44
41.	EC-528360 x Floradade	-77.01 **	3.14	0.73	4.35
42.	EC-528360 x ArkaMeghali	-29.75 **	-9.06**	-12.41 *	-5.00
43.	EC-145057 x Floradade	-62.78 **	-6.06	90.27 **	-1.91
44.	EC-145057 x ArkaMeghali	-29.76 **	12.56**	134.83 **	-2.87
45.	Floradade x ArkaMeghali	-60.63 **	-13.09**	89.38 **	-4.10

Table 5: Heterotic effect for number of fruit/cluster and total yield/plant in tomato

S. No	*Cross*	*Number of fruit/cluster*		*Total yield/plant (g)*	
		Heterosis (%) over BP	*Inbreeding depression*	*Heterosis (%) over BP*	*Inbreeding depression*
1.	EC-620406 x EC-163605	-13.33	-15.37**	23.89 **	-10.54**
2.	EC-620406 x EC-165700	30.00 *	-7.69**	-2.30	20.55**
3.	EC-620406 x EC-164563	9.09	-8.33**	51.96 **	1.02
4.	EC-620406 x EC-631364	-10.00	11.10**	-48.22 **	-27.18**
5.	EC-620406 x EC-521067	16.67	-7.22*	94.73 **	2.12
6.	EC-620406 x EC-528360	30.77 **	-17.65**	75.33 **	-6.57
7.	EC-620406 x EC-145057	27.27 *	-7.16*	18.94 **	9.47**
8.	EC-620406 x floradade	18.18	-15.37**	-38.66 **	-7.35*
9.	EC-620406 x ArkaMeghali	-13.33	7.78**	9.90 *	-6.73
10.	EC-163605 x EC-165700	20.00 *	-22.22**	28.23 **	-2.34
11.	EC-163605 x EC-164563	-13.33	-15.37**	-19.68 **	7.56*
12.	EC-163605 x EC-631364	13.33	-11.77**	63.59 **	-5.61
13.	EC-163605 x EC-521067	-26.67 **	18.16**	30.97 **	-2.37
14.	EC-163605 x EC-528360	-13.33	3.85	-6.40	-16.16**
15.	EC-163605 x EC-145057	-26.67 **	9.08**	33.25 **	-5.92
16.	EC-163605 x Floradade	-13.33	-15.37**	-61.97 **	0.89
17.	EC-163605 x ArkaMeghali	13.33	-5.89	-44.72 **	-1.73
18.	EC-165700 x EC-164563	18.18	7.71**	123.71 **	-2.77
19.	EC-165700 x EC-631364	40.00 **	7.14*	-37.09 **	0.80
20.	EC-165700 x EC-521067	8.33	7.78**	-21.54 **	-0.14
21.	EC-165700 x EC-528360	7.69	-7.22**	11.06 *	-9.29**
22.	EC-165700 x EC-145057	27.27 *	21.43**	30.32 **	-5.22
23.	EC-165700 x Floradade	-9.09	-9.99**	-66.44 **	2.99
24.	EC-165700 x ArkaMeghali	-26.67 **	9.08**	-8.91 *	-10.66**
25.	EC-164563 x EC-631364	45.45 **	-6.24	-8.45	6.46
26.	EC-164563 x EC-521067	0.00	8.33**	22.36 **	6.64
27.	EC-164563 x EC-528360	7.69	-7.22	-22.30 **	-16.76**
28.	EC-164563 x EC-145057	-9.09	10.11**	42.62 **	-17.07**
29.	EC-164563 x Floradade	36.36 **	6.66	-40.40 **	-0.41
30.	EC-164563 x ArkaMeghali	-13.33	-7.69**	87.21 **	-3.47
31.	EC-631364 x EC-521067	25.00 *	6.66	19.42 **	8.75**
32.	EC-631364 x EC-528360	-15.38	-9.19**	33.31 **	-4.17
33.	EC-631364 x EC-145057	9.09	-8.33**	-0.45	-11.45**
34.	EC-631364 x Floradade	0.00	9.08**	-54.19 **	-2.23
35.	EC-631364 x ArkaMeghali	-26.67 **	18.16**	15.83 **	19.27**
36.	EC-521067 x EC-528360	-7.69	-8.25	-51.00 **	7.89*
37.	EC-521067 x EC-145057	0.00	33.33**	-11.86 *	-6.05
38.	EC-521067 x Floradade	-8.33	9.08**	-77.32 **	9.27**
39.	EC-521067x ArkaMeghali	0.00	-6.66	-9.51 *	0.33
40.	EC-528360 x EC-145057	7.69	-7.22**	-6.76	-7.42*
41.	EC-528360 x Floradade	0.00	7.55**	-70.20 **	3.54
42.	EC-528360 x ArkaMeghali	-13.33	7.78**	3.10	9.45**
43.	EC-145057 x Floradade	54.55 **	-5.89	-25.61 **	-12.86**
44.	EC-145057 x ArkaMeghali	6.67	-6.24	77.63 **	1.82

Days to first flowering: A perusal of data presented in Table 2 revealed that the magnitude of heterosis over better parent ranged varies from nine cross combination EC-165700 x EC-145057 (14.44) to EC- 631364 x Floradade (7.07) shows significant positive heterosis over the better parent. Eighteen of the cross combination range varies from EC-631364 x EC-521067 (-18.35) to EC-163605 x EC- 528360 (-6.00), showing a negative magnitude of heterosis over a better parent for this trait. The magnitude of inbreeding depression ranged varies from EC-620406 x EC-521067 (9.19) to EC-164563 x EC-521067 (6.39). The negative magnitude heterosis range varies from EC-163605 x EC- 521067 (-7.12) to EC-631364 x Arka Meghali (-6.37). Negative heterosis for earliness days to first flowering was more over-observed by Asati *et al*. (2007), Singh *et al*. (2008), Kumari and Sharma (2011) and Shankar *et al*. (2014) indicated that heterosis over superior, mid and standard parent were the negative course which back our finding.

Days to 50% fruiting: The magnitude of heterosis (Table 2) over better parent ranged varies from three cross combination EC- 145057 x Arka Meghali (8.22) to EC- 528360 x Arka Meghali (5.23) shows significant positive heterosis over the better parent. Twenty of the cross combinations range varies from EC-620406 x EC- 164563 (-13.41) to EC- 620406 x Floradade (-5.03) showing a negative magnitude of heterosis over better parent for this trait. The magnitude of inbreeding depression ranged varies from EC-528360 x EC- 145057 (8.00) to EC-631364 x Floradade (4.94). The negative magnitude heterosis range varies from EC-528360 x Floradade (-5.88) to EC-164563 x EC- 145057 (-4.35). Heterosis for days to 50 % fruiting was moreover indicated by Premalakshme *et al*. (2006) and Singh *et al*. (2008).

Fruit diameter: The magnitude of heterosis (Table 3) over better parent ranged varies from Four cross combinations varies from EC- 165700 x EC-528360 (41.20) to EC- 164563 x EC-528360 (22.34) shows significant positive heterosis over the better parent. Eleven of the cross combinations range varies from EC-163605 x EC- 164563 (-37.28) to EC- 145057 x Floradade (-16.82) showing a negative magnitude of heterosis over better parent for this trait. The magnitude of inbreeding depression ranged varies from EC-521067 x Arka Meghali (8.03) to EC- 163605 x EC-145057 (6.95). The negative magnitude heterosis range varies from EC-631364 x EC-521067 (-10.20) to EC-620406 x EC-165700 (-6.18). The comes about of heterosis for fruit diameter is in close understanding with the similar findings of Asati *et al*. (2007), Shankar *et al*. (2014), Dagade *et al*. (2015) and Soresa *et al*. (2020). they appeared noteworthy heterosis in F_1 and tall inbreeding depression in the F_2 era revealing nearness of non-additive quality.

Fruit length: The magnitude of heterosis (Table 3) over better parent ranged varies from one cross combinations EC-163605 × EC-528360 (49.20). The magnitude of heterosis over better parent ranged varies from Thirty-six cross combination varies from EC- 163605 x Arka Meghali (-56.76) to EC- 620406 x EC- 521067 (-14.28) shows significant negative heterosis over the better parent. The magnitude of inbreeding depression ranged varies from EC- 165700 x EC- 145057 (15.95) to EC- 631364 x Arka Meghali (6.23). The negative magnitude heterosis range varies from EC-620406 x EC-165700 (-16.38) to EC-620406 x EC- 163605(-6.50). Fruit length could be a crucial character impacting natural product quality. Fruits with more length and diameter are ideal for utilization and preparation. Noteworthy heterosis and both course inbreeding depression for fruit length were moreover detailed by Kurian *et al*. (2001), Dagade *et al*. (2015) and Soresa *et al*. (2020).

Average Fruit weight: The magnitude of heterosis (Table 4) over better parent ranged from one cross combination from EC- 165700 x EC-528360 (59.26). Thirty-six of the cross combination range varies from EC-163605 x Floradade (-79.72) to EC- 620406 x EC- 528360 (-10.55), showing a negative magnitude of heterosis over a better parent for this trait. The magnitude of inbreeding depression ranged varies from EC- 145057 x Arka Meghali (12.56) to EC- 164563 x Floradade (6.03). The negative magnitude heterosis range varies from EC-631364 x Floradade (-15.11) to EC-631364 x EC- 528360 (-5.79). Average fruit weight specifically influences the full abdicate, so this character is exceptionally imperative so distance adds up to surrender is concerned. Shankar *et al*. (2014) and Kumari and Sharma (2011) moreover detailed positive heterosis up to 10 to 40 percent for average fruit weight in tomatoes. High Average fruit weight is of prime significance in breeding high-yielding cultivars.

Number of fruits per plant: The magnitude of heterosis (Table 4) over better parent ranged varies from fourteen cross combination varies from EC- 620406 x EC-164563 (135.19) to EC-620406 x Floradade (21.24) shows significant positive heterosis over the better parent. Eighteen of the cross combination range varies from EC-620406 x EC- 145057 (-64.32) to EC- 163605 x Floradade (-7.51) showing a negative magnitude of heterosis over better parent for this trait. The magnitude of inbreeding depression ranged varies from EC- 164563 x EC- 631364 (17.00) to EC- 620406 x Arka Meghali (5.63). The negative magnitude heterosis range varies from EC-521067 x Arka Meghali (-13.08) to EC-165700 x Arka Meghali (-6.76). The number of fruits straight forwardly influences the whole number of fruit per plant, so this character is exceptionally vital for total yield per plant. These findings are in close assertion with Asati *et al*. (2007), Kumari and Sharma (2011) and Kumar *et al*. (2020).

Number of fruits per cluster: The magnitude of heterosis (Table 5) over better parent ranged varies from Ten cross combination varies from EC- 145057 x Floradade (54.55) to EC-163605 x EC- 165700 (20.00) shows significant positive heterosis over the better parent. Four of the cross combination range varies from EC-631364 x Arka Meghali (-26.67) shows a negative magnitude of heterosis over a better parent for this trait. The magnitude of inbreeding depression ranged varies from EC-521067 x EC- 145057 (33.33) to Floradade x Arka Meghali (5.88). The negative magnitude heterosis range varies from EC-163605 x EC-165700 (-22.22) to EC-620406 x EC-145057 (-7.16).

Total yield per plant: The magnitude of heterosis (Table 5) over better parent ranged varies from Nineteen cross combination varies from EC- 165700 x EC-164563 (123.71) to EC-165700 x EC-528360 (-11.06) shows significant positive heterosis over the better parent. Nineteen of the cross combination range varies from EC-521067 x Floradade (-77.32) to EC- 165700 x Arka Meghali (-8.91) showing a negative magnitude of heterosis over better parent for this trait. The magnitude of inbreeding depression ranged varies from EC- 620406 x EC-165700 (20.55.) to EC- 163605 x EC- 164563 (7.56). The negative magnitude heterosis range varies from EC-620406 x EC- 631364 (-27.18) to EC-620406 x Floradade (-7.35). These findings are in conformity with of Asati *et al.* (2007), Singh *et al.* (2008), Kurian *et al.* (2001), Kumari and Sharma (2011) and Kumar *et al.* (2020). Who have also observed various heterosis estimates? Positive and significant heterosis over mid-parent and the better parent along with positive inbreeding misery may be credited to the major commitment from dominance (h) and additive x additive (i) quality impacts. Hence, the determination will be successful as it was in afterward eras. Total yield per plant is controlled by polygenes. The positive and tall size of heterosis for total yield per plant standard plant taken note may be beneath the impact of one or more yield contributing characters (Chandrakala *et al.*, 2010). Within the show assessment, heterosis days to first flowering, days to 50% fruiting, fruit diameter (mm), fruit length (mm), average fruit weight (g), number of fruit /plant, number of fruit/cluster, and total yield/plant (g). The observed heterosis for total yield may be due to the genetic diversity of the parent used in hybrid combinations, the increase in fruit diameter, weight and the number of fruits. These findings are in close agreement with the findings of Asati *et al.* (2007), Singh *et al.* (2008), Kurian *et al.* (2001), Kumari and Sharma (2011) and Kumar *et al.* (2020).

Conclusion

Heterosis breeding has been utilized comprehensively in potential yield improvement through the advancement of hybrid cultivars in tomatoes. Heterosis for total yield per plant and other characters was revealed within the show examination. The critical heterosis watched for fruit length and average fruit weight comes about in higher yield of hybrids, which is in confirmation with prior works (Anuradha *et al.*, 2007; Satish *et al.*, 2006). Both additives, as well as non-additive quality impacts, were watched to be included in most of the cases. Heterosis breeding and populace advancement embracing *connect* mating among promising divergent genotypes and accomplishing concurrent determination like repetitive choice may demonstrate to be convenient. In expansion, biparental mating for days to first flowering, the number of fruits per plant and total yield per plant is recognized as the perfect breeding approach for tomato enhancement programme.

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Author's Contribution

Vijay kumar collected data and write the manuscript, Ravi Singh Thapa: edited the manuscript, Naresh kumar: edited the manuscript, Sunil kumar Singh: edited the manuscript and remove the plagiarism.

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