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Heterosis Analysis for Yield and its Components Traits in Pearl Millet [*Pennisetum glaucum* (L.) R. Br.]

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A B S T R A C T

Pearl millet is the most important drought tolerant crop of tropical and subtropical region of the world. Pearl millet has balanced genetic load and show considerable inbreeding depression. Therefore, the varieties aimed to be developed in pearl millet should have heterozygous nature to be heterotic and at the same time homogenous constitution to be synchronous and uniformly productive. Therefore, breeding efforts are directed towards developing hybrids, synthetic and composite populations. The mid parent, better parent and standard heterosis were estimated for 10 yield and its contributing characters in pearl millet [*Pennisetum glaucum* (L.) R. Br.]. The analysis of variance disclose significant differences among treatments, parents and crosses for all characters studied, indicated the substantial amount of genetic variability among the treatments, parents and crosses in the experimental material used in present study. The crosses S-16/704 A x S-19/12, S-16/769 A x S-19/13, S-16/769 A x S-19/11, S-16/704 A x S-19/13 and DHLB-23 A x S-19/04 had significant average heterosis, heterobeltosis and standard heterosis over both standard checks *viz*., Aadishakti and AHB-1200 (Fe) for grain yield and most of the yield contributing traits. Hence, these crosses could be checked for their stable performance in multi location trials over environment.

Introduction

Pearl millet is the most important cereal crop of tropical and subtropical region of the world. It is predominantly consumed as a basic food grain and source of feed and fodder. It is staple food for billions of people living in harsh environments characterized by erratic rainfall and nutrient- poor soil and nutritionally superior. In fact, Pearl millet is the only suitable and efficient crop for arid and semi-arid conditions because of its efficient utilization of soil moisture and higher level of heat tolerance than sorghum and maize. Pearl millet grains contain 9-15% protein, 5% fat and 2-7 % minerals and impart substantial energy to the body with easy digestibility. India is a major pearl millet producing country with 43.3 per cent of the world area and 42 per cent of world production. In the states of Rajasthan, Maharashtra, Gujarat, Madhya Pradesh, Karnataka, Andhra Pradesh, Uttar Pradesh and Tamil Nadu it is mainly cultivated. In

terms of both area) 7.50 million ha) and production) 9.73 million ton), India is the largest producer of pearl millet with an average productivity is 850 kg/ha) Anonymous, 2018). Maharashtra is the fifth largest producer of pearl millet in India with 11.04 % area and 8.21 % production. Pearl millet shows considerable inbreeding depression therefore, the varieties aimed to be developed in pearl millet should have heterozygous nature to be heterotic and at the same time homogenous constitution to be synchronous and uniformly productive.

Therefore, breeding efforts are directed towards developing hybrids, synthetic and composite populations. For the development of effective heterosis breeding programme in pearl millet, having information about genetic architecture and estimated prepotency of parents in hybrid combinations is essential. This knowledge in fact helps in exploiting heterosis for commercial purpose.

Materials and Methods

The experimental material comprised of four male sterile lines S-16/760A, S-16/769A, S-16/704A, DHLB-23A and ten restorers S-19/03, S-19/04, S-19/05, S-19/08, S-19/09, S-19/10, S-19/11, S-19/12, S-19/13, S-19/14 with two checks Aadishakti and AHB 1200) Fe). Crosses were done in line x tester fashion to obtain 40 hybrids. All experimental material evaluated in randomized block design with two replication during *Kharif* 2019. Five competitive plants were selected randomly from each treatment in each replication for grain yield per plant and its component traits *viz*., Days to 50% flowering, Days to maturity, Number of effective tillers per plant, Plant height, Earhead length, Earhead girth, 1000 seed weight, Grain yield per plant, Fodder yield per plant, Harvest index and averages were worked out. The mean data was utilized for estimating the heterosis as per cent increase or decrease in mean value of F_1 hybrids over better parent and standard checks as per Fonseca and Patterson) 1968).

Results and Discussion

To test the significance of differences among the treatments analysis of variance of mean was carried out. The data pertaining to the analysis of variance) Table 1) revealed significant differences among treatment, parents and crosses for all the characters) except plant height for parent *v/s* crosses) indicated the substantial amount of genetic variability among the treatments, parents and crosses in the experimental material used in present study.

Negative heterosis is desirable for days to 50% flowering. The hybrid S-16/760 A x S-19/08) -10.53%) exhibited highest significant and negative heterosis over mid parent and over better parent) 16.39%). The crosses, DHLB-23 A x S-19/09 and DHLB-23 A x S-19/10 recorded highest percentage of heterosis over standard checks; Aadishakti) -7.55%) and AHB-1200) Fe)) -9.26%)) Table 2.). For the character days to maturity S-16/760 A x S-19/09) -8.99%) followed by S-16/760 A x S-19/08) -8.79%) and S-16/769 A x S-19/09) -7.43) exhibited highest negative heterosis in desirable direction over mid parent. The cross, S-16/760 A x S-19/08) -11.7) manifested highest percentage of negative heterosis over better parent. As regards to standard checks, the crosses S-16/760 A x S-19/09, S-16/769 A x S-19/09 and DHLB-23 A x S-19/09 had exhibited highest negatively significant heterosis over Aadishakti) -8.99%) and AHB-1200) Fe)) -7.95) respectively. These findings in which negative heterosis is desirable are in accordance with Pawar *et al*., (2015), Bhaskar *et al*., (2017).

The heterosis over mid parent and better parent for number of effective tillers per plant ranged from -29.03) S-16/704 A x S-19/09) to 64.52 per cent) DHLB-23 A x S-19/13) and -38.89) S-16/704 A x S-19/09) to 59.37 per cent) DHLB-23 A x S-19/13), respectively. The cross DHLB-23 A x S-19/13 exhibited highest percentage of heterosis over mid parent) 64.52%) and better parent) 59.37%) followed by DHLB-23 A x S-19/05) 54.29% and 42.11%) respectively. The hybrids, DHLB-23 A x S-19/05) 42.11% and 80.00%) followed by DHLB-23 A x S-19/13) 34.21% and 70.00%) and S-16/769 A x S-19/04) 31.58% and 66.67%) had shown highest standard heterosis over both checks; Aadishakti and AHB-1200) Fe), respectively. Similar results has been reported by several workers *viz*., Mungra *et al*.,) 2014), Patel *et al*.,) 2016). With respect to the character plant height, not a single hybrid shown significant heterosis in desired direction over better parent. The hybrids *viz*., S-16/704 A x S-19/14) 17.94% and 19.39%) and S-16/704 A x S-19/03) 16.47% and 18.37%) had recorded the highest magnitude of heterosis in desired direction over the standard checks; Aadishakti and AHB-1200) Fe), correspondingly. These results are in accordance with Chittora *et al*., (2017), Karvar *et al*., (2017) and Badhe *et al*., (2018).

Table.1 Analysis of variance for different characters in pearl millet

Source	d.f	DF	DM	NET	PH	EL	EG	TW	GYP	FYP	HI
Replication	1	0.59	0.59	0.018	22.41	0.06	0.08	0.92	5.24	0.78	0.12
Treatment	53	19.93**	27.03**	0.23**	599.3**	8.08**	1.30**	9.61**	314.2**	568.4**	78.18**
Parents	13	28.18**	23.21**	0.09**	1514.6**	14.24**	1.18**	3.31**	73.34**	604.7**	76.94**
Crosses	39	13.84**	26.29**	0.23**	307.8**	5.59**	0.93**	4.11**	162.0**	474.9**	42.23**
Parents v/s Crosses	1	150.4**	105.3**	1.94**	70.38	24.99**	17.22**	306.0**	9381.4**	3744.0**	1496.5**
Error	53	1.34	1.95	0.005	38.38	0.67	0.14	0.30	8.30	46.03	2.64

* and ** Significant at 5 and 1 per cent level, respectively.

Where,

DF = Days to 50 % flowering
DM = Days to maturity
NET = No. of effective tillers per plant
PH = Plant height (cm)
EL = Earhead length
EG = Earhead girth
TW = 1000-seed weight (g)
GYP = Grain yield per plant (g)
FY = Fodder yield per plant (g)
HI = Harvest index (%)

Table.2 The estimates of heterosis over mid parent (MP), better parent (BP) and standard check (SC) for different characters in pearl millet

Sr. No.	Crosses	Days to 50% flowering				Days to maturity			
		M.P.(%)	B.P. (%)	SC-1	SC-2	M.P.(%)	B.P. (%)	SC-1	SC-2
1	760 A x S-19/03	-7.83 **	-14.52 **	0.00	-1.85	-4.40 **	-7.45 **	-2.25	-1.14
2	760 A x S-19/04	-7.83 **	-14.52 **	0.00	-1.85	-6.01**	-9.47 **	-3.37 *	-2.27
3	760 A x S-19/05	-7.96 **	-13.33 **	-1.89	-3.70	-6.67 **	-8.70 **	-5.62 **	-4.55 **
4	760 A x S-19/08	-10.53 **	-16.39 **	-3.77	-5.56 *	-8.79 **	-11.7 **	-6.74 **	-5.68 **
5	760 A x S-19/09	-8.26 **	-10.71 **	-5.66 *	-7.41 **	-8.99 **	-10.0 **	-8.99 **	-7.95 **
6	760 A x S-19/10	-4.59 *	-7.14 **	-1.89	-3.70	-5.62 **	-6.67 **	-5.62 **	-4.55 **
7	760 A x S-19/11	-0.92	-3.57	1.89	0.00	-1.69	-2.25	-2.25	-1.14
8	760 A x S-19/12	-0.90	-5.17 *	3.77	1.85	-2.79 *	-4.40 **	-2.25	-1.14
9	760 A x S-19/13	-1.82	-5.26 *	1.89	0.00	-2.25	-3.33 *	-2.25	-1.14
10	760 A x S-19/14	-1.82	-5.26 *	1.89	0.00	-6.15 **	-7.69 **	-5.62 **	-4.55 **

11	769 A x S-19/03	-1.75	-9.68 **	5.66 *	3.70	1.68	-3.19 *	2.25	3.41 *
12	769 A x S-19/04	-7.02 **	-14.52 **	0.00	-1.85	-1.11	-6.32 **	0.00	1.14
13	769 A x S-19/05	-5.36 **	-11.67 **	0.00	-1.85	-0.56	-4.35 **	-1.12	0.00
14	769 A x S-19/08	-2.65	-9.84 **	3.77	1.85	0.56	-4.26 **	1.12	2.27
15	769 A x S-19/09	-7.41 **	-10.71 **	-5.66 *	-7.41 **	-7.43 **	-10.0 **	-8.99 **	-7.95 **
16	769 A x S-19/10	-7.41 **	-10.71 **	-5.66 *	-7.41 **	-6.29 **	-8.89 **	-7.87 **	-6.82 **
17	769 A x S-19/11	9.26 **	5.36 *	11.32 **	9.26 **	5.75 **	3.37 *	3.37 *	4.55 **
18	769 A x S-19/12	5.45 **	0.00	9.43 **	7.41 **	4.55 **	1.10	3.37 *	4.55 **
19	769 A x S-19/13	6.42 **	1.75	9.43 **	7.41 **	5.14 **	2.22	3.37 *	4.55 **
20	769 A x S-19/14	6.42 **	1.75	9.43 **	7.41 **	5.68 **	2.20	4.49 **	5.68 **
21	704 A x S-19/03	-2.61	-9.68 **	5.66 *	3.70	0.55	-3.19 *	2.25	3.41 *
22	704 A x S-19/04	-4.35 *	-11.29 **	3.77	1.85	-2.20	-6.32 **	0.00	1.14
23	704 A x S-19/05	-4.42 *	-10.00 **	1.89	0.00	-0.56	-3.26 *	0.00	1.14
24	704 A x S-19/08	-5.26 **	-11.48 **	1.89	0.00	-2.76 *	-6.38 **	-1.12	0.00
25	704 A x S-19/09	-2.75	-5.36 *	0.00	-1.85	-0.56	-2.22	-1.12	0.00
26	704 A x S-19/10	-8.26 **	-10.71 **	-5.66 *	-7.41 **	-3.95 **	-5.56 **	-4.49 **	-3.41 *
27	704 A x S-19/11	-0.92	-3.57	1.89	0.00	2.27	1.12	1.12	2.27
28	704 A x S-19/12	0.90	-3.45	5.66 *	3.70	2.25	0.00	2.25	3.41 *
29	704 A x S-19/13	5.45 **	1.75	9.43 **	7.41 **	5.08 **	3.33 *	4.49 **	5.68 **
30	704 A x S-19/14	5.45 **	1.75	9.43 **	7.41 **	5.62 **	3.30 *	5.62 **	6.82 **
31	23 A x S-19/03	0.00	-9.68 **	5.66 *	3.70	2.82 *	-3.19 *	2.25	3.41 *
32	23 A x S-19/04	0.00	-9.68 **	5.66 *	3.70	1.12	-5.26 **	1.12	2.27
33	23 A x S-19/05	-5.45 **	-13.33 **	-1.89	-3.70	-4.00 **	-8.70 **	-5.62 **	-4.55 **
34	23 A x S-19/08	-2.70	-11.48 **	1.89	0.00	-1.69	-7.45 **	-2.25	-1.14
35	23 A x S-19/09	-7.55 **	-12.50 **	-7.55 **	-9.26 **	-6.36 **	-10.00 **	-8.99 **	-7.95 **
36	23 A x S-19/10	-7.55 **	-12.50 **	-7.55 **	-9.26 **	-5.20 **	-8.89 **	-7.87 **	-6.82 **
37	23 A x S-19/11	0.00	-5.36 *	0.00	-1.85	2.33	-1.12	-1.12	0.00
38	23 A x S-19/12	0.00	-6.90 **	1.89	0.00	2.30	-2.20	0.00	1.14
39	23 A x S-19/13	0.93	-5.26 *	1.89	0.00	0.58	-3.33 *	-2.25	-1.14
40	23 A x S-19/14	2.80	-3.51	3.77	1.85	3.45 *	-1.10	1.12	2.27
	SE (d) (±)	1.005	1.160	1.160	1.160	1.209	1.396	1.396	1.396
	CD @ 95 %	2.033	2.347	2.347	2.347	2.446	2.825	2.825	2.825
	CD @ 99 %	2.722	3.143	3.143	3.143	3.275	3.782	3.782	3.782

		Number of effective tillers per plant				**Plant height (cm)**			
Sr. No.	**Crosses**	**M.P.(%)**	**B.P. (%)**	**SC-1**	**SC-2**	**M.P.(%)**	**B.P. (%)**	**SC-1**	**SC-2**
1	760 A x S-19/03	53.33 **	27.78 **	21.05 **	53.33 **	4.63	-13.63 **	5.22	6.94
2	760 A x S-19/04	40.00 **	16.67 **	10.53 **	40.00 **	-1.26	-17.39 **	-2.68	-1.09
3	760 A x S-19/05	5.48 **	10.53 **	10.53 **	40.00 **	3.29	-13.62 **	1.87	3.54
4	760 A x S-19/08	16.13 **	-5.26	-5.26	20.00 **	-1.08	-15.65 **	-5.15	-3.61
5	760 A x S-19/09	0.00 **	15.38 **	-21.05 **	0.00	4.69	-2.48	-10.37 *	-8.91 *
6	760 A x S-19/10	26.67 **	5.56	0.00	26.67 **	7.34	-7.15	0.87	2.52
7	760 A x S-19/11	33.33 **	20.00 **	-5.26	20.00 **	4.16	-12.55 **	2.14	3.81
8	760 A x S-19/12	21.43 **	6.25	-10.53 **	13.33 **	2.50	-13.64 **	0.00	1.63
9	760 A x S-19/13	40.74 **	26.67 **	0.00	26.67 **	6.64	-7.91*	0.47	2.11
10	760 A x S-19/14	20.00 **	0.00	-5.26	20.00 **	-5.32	-19.13 **	-9.44 *	-7.96
11	769 A x S-19/03	33.33 **	22.22 **	15.79 **	46.67 **	8.85 *	-16.87 **	1.27	2.93
12	769 A x S-19/04	51.52 **	38.89 **	31.58 **	66.67 **	3.01	-20.40 **	-6.22	-4.69
13	769 A x S-19/05	23.53 **	10.53 **	10.53 **	40.00 **	9.11 *	-15.72 **	-0.60	1.02
14	769 A x S-19/08	17.65 **	5.26	5.26	33.33 **	11.14 **	-12.68 **	-1.81	-0.20

15	769 A x S-19/09	0.00	-6.67	-26.32 **	-6.67	9.64 *	-6.85	-14.39 **	-12.99 **
16	769 A x S-19/10	9.09 *	0.00	-5.26	20.00 **	15.91 **	-7.76 *	0.20	1.84
17	769 A x S-19/11	26.67 **	26.67 **	0.00	26.67 **	23.11 **	-4.58	11.45 **	13.27 **
18	769 A x S-19/12	3.23	0.00	-15.79 **	6.67	25.28 **	-2.60	12.78 **	14.63 **
19	769 A x S-19/13	20.00 **	20.00 **	-5.26	20.00 **	27.03 **	0.92	10.11 *	11.90 **
20	769 A x S-19/14	27.27 **	16.67 **	10.53 **	40.00 **	30.19 **	2.45	14.73 **	16.60 **
21	704 A x S-19/03	11.11 **	11.11 **	5.26	33.33 **	10.83 **	-4.40	16.47 **	18.37 **
22	704 A x S-19/04	5.56	5.56	0.00	26.67 **	6.36	-6.93	9.64 *	11.43 **
23	704 A x S-19/05	29.73 **	26.32 **	26.32 **	60.00 **	2.79	-10.10 **	6.02	7.76
24	704 A x S-19/08	-18.92 **	-21.05 **	-21.05 **	0.00	10.20 **	-1.61	10.64 *	12.45 **
25	704 A x S-19/09	-29.03 **	-38.89 **	-42.11 **	-26.67 **	10.21 *	8.08	-0.67	0.95
26	704 A x S-19/10	5.56	5.56	0.00	26.67 **	8.87 *	-1.29	7.23	8.98 *
27	704 A x S-19/11	15.15 **	5.56	0.00	26.67 **	9.62 **	-3.72	12.45 **	14.29**
28	704 A x S-19/12	35.29**	27.78 **	21.05 **	53.33 *	10.49 **	-2.60	12.78 **	14.63 **
29	704 A x S-19/13	27.27 **	16.67 **	10.53 **	40.00**	14.58 **	3.68	13.12 **	14.97 **
30	704 A x S-19/14	-27.78 **	-27.78 **	-31.58 **	-13.33 **	17.74 **	5.32	17.94 **	19.86 **
31	23 A x S-19/03	17.65 **	11.11 **	5.26	33.33 **	15.91 **	-4.95	15.80 **	17.69 **
32	23 A x S-19/04	35.29 **	27.78 **	21.05 **	53.33 **	20.00 **	-0.28	17.47 **	19.39 **
33	23 A x S-19/05	54.29 **	42.11 **	42.11 **	80.00 **	11.72 **	-7.21 *	9.44 *	11.22 *
34	23 A x S-19/08	20.00 **	10.53 **	10.53 **	40.00 **	8.54 *	-8.10 *	3.35	5.03
35	23 A x S-19/09	3.45	-6.25	-21.05 **	0.00	16.23 **	7.43	-1.27	0.34
36	23 A x S-19/10	29.41 **	22.22 **	15.79 **	46.67 **	4.81	-9.98 *	-2.21	-0.61
37	23 A x S-19/11	29.03 **	25.00 **	5.26	33.33 **	3.09	-19.20 **	-5.62	-4.08
38	23 A x S-19/12	6.25	6.25	-10.53 **	13.33 **	-1.90	-17.92 **	-4.95	-3.40
39	23 A x S-19/13	64.52 **	59.37 **	34.21 **	70.00 **	5.76	-9.33 *	-1.07	0.54
40	23 A x S-19/14	29.41 **	22.22 **	15.79 **	6.67 **	5.14	-10.82 **	-0.13	1.50
	SE (d) (±)	0.063	0.072	0.072	0.072	5.365	6.195	6.195	6.195
	CD @ 95 %	0.127	0.147	0.147	0.147	10.852	12.531	12.531	12.531
	CD @ 99 %	0.171	0.197	0.197	0.197	14.528	16.776	16.776	16.776

		Earhead length (cm)				**Earhead girth (cm)**			
Sr. No.	**Crosses**	**M.P.(%)**	**B.P. (%)**	**SC-1**	**SC-2**	**M.P.(%)**	**B.P. (%)**	**SC-1**	**SC-2**
1	760 A x S-19/03	5.09	-7.31 *	4.47	5.46	5.07	-1.44	-3.05	-11.58 **
2	760 A x S-19/04	8.80 *	-1.55	4.71	5.70	8.44 *	-0.05	-1.69	-10.34 **
3	760 A x S-19/05	2.13	-10.00 **	1.65	2.61	9.31 *	0.57	-1.08	-9.78 **
4	760 A x S-19/08	-5.80	-19.30 **	-2.59	-1.66	9.88 **	4.42	2.71	-6.33
5	760 A x S-19/09	10.31 **	4.39	0.71	1.66	0.81	-2.30	2.41	-6.60
6	760 A x S-19/10	15.99 **	8.29 *	7.53	8.55 *	6.30	4.58	2.86	-6.19
7	760 A x S-19/11	14.76 **	1.04	14.35 **	15.44 **	9.48 **	9.28 *	7.88	-1.61
8	760 A x S-19/12	3.11	-10.93 **	5.41	6.41	7.77 *	4.45	9.49 *	-0.15
9	760 A x S-19/13	6.60	-7.44 *	8.24 *	9.26 *	6.48	5.44	5.78	-3.52
10	760 A x S-19/14	8.57 *	-3.80	7.29	8.31 *	4.35	2.36	4.66	-4.55
11	769 A x S-19/03	10.15 **	0.84	13.65 **	14.73 **	-1.10	-2.01	-13.98 **	-21.55 **
12	769 A x S-19/04	4.24	-1.99	4.24	5.23	6.59	3.66	-9.00 *	-17.01 **
13	769 A x S-19/05	9.11 **	-0.21	2.71 **	13.78 **	12.08 **	8.79	-4.50	-12.9 **
14	769 A x S-19/08	9.33**	-2.92	17.18 **	18.29 **	17.05 **	16.52 **	3.22	-5.87
15	769 A x S-19/09	15.35 **	13.66 **	9.65 *	10.69 **	9.02 *	0.15	4.98	-4.25
16	769 A x S-19/10	20.98 **	17.54 **	16.71 **	17.81 **	12.65 **	8.28	3.05	-6.01
17	769 A x S-19/11	16.50 **	6.44	20.47 **	21.62 **	19.66 **	13.03 **	11.58 **	1.76
18	769 A x S-19/12	15.21 **	3.18	22.12 **	23.28 **	13.86 **	4.60	9.65 *	0.00

19	769 A x S-19/13	16.20 **	4.63	22.35 **	23.52 **	18.29 **	10.90 **	11.25 **	1.47
20	769 A x S-19/14	17.89 **	8.44 *	20.94 **	22.09 **	16.07 **	7.86 *	10.29 *	0.59
21	704 A x S-19/03	9.30 **	0.63	13.41 **	14.49 **	9.70 *	3.69	0.35	-8.47 *
22	704 A x S-19/04	12.05 **	5.97	12.71 **	13.78 **	10.35 **	2.47	-0.82	-9.55 *
23	704 A x S-19/05	7.81 *	-0.83	12.00 **	13.06 **	5.38	-2.33	-5.47	-13.78 **
24	704 A x S-19/08	7.64 *	-3.90	16.00 **	17.10 **	15.52 **	10.63 *	7.07	-2.35
25	704 A x S-19/09	18.57 **	17.56 **	13.41 **	14.49 **	6.70	2.61	7.56	-1.91
26	704 A x S-19/10	14.18 **	11.61 **	10.82 **	11.88 **	10.22 **	9.30 *	5.79	-3.52
27	704 A x S-19/11	5.88	-2.70	10.12 *	11.16 **	15.95 **	14.82 **	13.34 **	3.37
28	704 A x S-19/12	11.26 **	0.20	18.59 **	19.71 **	16.43 **	11.96 **	17.36 **	7.04
29	704 A x S-19/13	15.11 **	4.23	21.88 **	23.04 **	12.72 **	10.74 **	11.09 **	1.32
30	704 A x S-19/14	17.90 **	9.07 *	21.65 **	22.80 **	15.67 **	12.58 **	15.11 **	4.99
31	23 A x S-19/03	15.88 **	-0.21	12.47 **	13.54 **	12.03 **	3.82	4.82	-4.40
32	23 A x S-19/04	14.54 **	1.11	7.53	8.55 *	13.99 **	3.82	4.82	-4.40
33	23 A x S-19/05	2.66	-11.67 **	-0.24	0.71	0.39	-8.72 *	-7.84	-15.95 **
34	23 A x S-19/08	7.57 *	-9.94 **	8.71 *	9.74 *	13.32 **	6.37	7.40	-2.05
35	23 A x S-19/09	12.43 **	3.66	0.00	0.95	7.34 *	5.37	10.45 *	0.73
36	23 A x S-19/10	3.39	-5.92	-6.59	-5.70	-2.37	-5.17	-4.25	-12.68 **
37	23 A x S-19/11	-3.26	-16.84 **	-5.88	-4.99	-0.51	-1.62	-0.67	-9.41 *
38	23 A x S-19/12	1.06	-14.71 **	0.94	1.90	8.44 *	6.44	11.58**	1.76
39	23 A x S-19/13	10.08 **	-6.64	9.18 *	10.21 *	9.58 **	9.24 *	10.29 *	0.59
40	23 A x S-19/14	6.10	-8.23 *	2.35	3.33	8.07 *	7.39	9.81 *	0.15
	SE (d) (±)	0.713	0.823	0.823	0.823	0.332	0.384	0.384	0.384
	CD @ 95 %	1.442	1.665	1.665	1.665	0.672	0.770	0.777	0.777
	CD @ 99 %	1.931	2.229	2.229	2.229	0.900	1.040	1.040	1.040

		1000 seed weight (g)				**Grain yield per plant (g)**			
Sr. No.	**Crosses**	**M.P.(%)**	**B.P. (%)**	**SC-1**	**SC-2**	**M.P.(%)**	**B.P. (%)**	**SC-1**	**SC-2**
1	760 A x S-19/03	35.98 **	29.06 **	17.93 **	20.89 **	61.09 **	46.69 **	-6.74	9.93
2	760 A x S-19/04	36.89 **	33.60 **	15.17 **	18.06 **	69.66 **	67.98 **	-10.53	5.46
3	760 A x S-19/05	45.73 **	39.92 **	14.83 **	17.71 **	62.29 **	39.31 **	1.47	19.60 *
4	760 A x S-19/08	46.98 **	32.77 **	8.97 *	11.70 **	78.15 **	51.21 **	-21.05 **	-6.95
5	760 A x S-19/09	37.16 **	25.63 **	3.10	5.69	37.91 **	17.34	-38.74 **	-27.79 **
6	760 A x S-19/10	18.90 **	11.85 **	4.14	6.75	36.05 **	11.28	-8.63	7.69
7	760 A x S-19/11	29.08 **	22.73 **	11.72 **	14.53 **	82.83 **	81.03 **	-3.58	13.65
8	760 A x S-19/12	25.34 **	16.13 **	11.72 **	14.53 **	58.59 **	53.79 **	-14.53 *	0.74
9	760 A x S-19/13	26.40 **	24.54 **	2.21	4.77	62.63 **	54.44 **	-19.37 **	-4.96
10	760 A x S-19/14	47.68 **	44.42 **	24.00 **	27.11 **	71.48 **	64.21 **	-6.32	10.42
11	769 A x S-19/03	20.38 **	18.57 **	8.34 *	11.06 **	64.89 **	38.41 **	-12.00	3.72
12	769 A x S-19/04	20.51 **	18.87 **	5.34	7.99 *	88.21 **	70.36 **	-9.26	6.95
13	769 A x S-19/05	34.50 **	24.55 **	10.38 **	13.15 **	67.70 **	33.53 **	-2.74	14.64
14	769 A x S-19/08	46.06 **	27.59 **	13.07 **	15.91 **	166.14**	145.37**	5.89	24.81 **
15	769 A x S-19/09	46.86 **	30.00 **	15.21 **	18.10 **	107.39**	91.71 **	-17.26 **	-2.48
16	769 A x S-19/10	24.40 **	21.41 **	13.03 **	15.87 **	84.20 **	40.51 **	15.37 *	35.98 **
17	769 A x S-19/11	42.80 **	40.91 **	28.28 **	31.50 **	172.05**	146.25**	31.16 **	54.59 **
18	769 A x S-19/12	31.27 **	26.09 **	21.31 **	24.35 **	135.39**	109.09**	16.21 *	36.97 **
19	769 A x S-19/13	39.47 **	32.41 **	17.34 **	20.29 **	200.47**	188.34**	35.37 **	59.55 **
20	769 A x S-19/14	35.73 **	33.62 **	18.41 **	21.39 **	131.51**	103.32**	16.00 *	36.72 **
21	704 A x S-19/03	38.15 **	32.68 **	21.24 **	24.28 **	44.79 **	44.55 **	-7.79	8.68
22	704 A x S-19/04	22.31 **	20.84 **	4.17	6.79	45.68 **	33.66 **	-14.74 *	0.50

23	704 A x S-19/05	6.91	1.43	-14.66 **	-12.51 **	-2.00	-8.09	-33.05 **	-21.09 **
24	704 A x S-19/08	26.42 **	12.95 **	-4.97	-2.58	66.81 **	31.02 **	-16.42 *	-1.49
25	704 A x S-19/09	43.35 **	29.84 **	9.24 *	11.98 **	24.53 *	-1.98	-37.47 **	-26.30 **
26	704 A x S-19/10	18.87 **	13.15 **	5.34	7.99 *	40.26 **	24.62 **	2.32	20.60 **
27	704 A x S-19/11	44.06 **	38.60 **	26.17 **	29.34 **	101.08**	84.49 **	17.68 **	38.71 **
28	704 A x S-19/12	36.67 **	28.10 **	23.24 **	26.33 **	147.97**	132.01**	48.00 **	74.44 **
29	704 A x S-19/13	41.56 **	37.79 **	15.93 **	18.84 **	133.08**	102.31**	29.05 **	52.11 **
30	704 A x S-19/14	42.11 **	40.68 **	20.79 **	23.82 **	65.16 **	56.44 **	-0.21	17.62 *
31	23 A x S-19/03	19.60 **	13.96 **	4.14	6.75	87.09 **	77.48 **	12.84 *	33.00 **
32	23 A x S-19/04	19.92 **	17.52 **	1.31	3.85	121.37**	114.02**	22.11 **	43.92 **
33	23 A x S-19/05	10.72 *	5.87	-12.38 **	-10.18 *	69.21 **	50.87 **	9.89	29.53 **
34	23 A x S-19/08	38.66 **	24.79 **	3.28	5.87	112.16**	73.80 **	-0.84	16.87*
35	23 A x S-19/09	44.89 **	32.21 **	9.41 *	12.16 **	90.56 **	56.46 **	-10.74	5.21
36	23 A x S-19/10	17.02 **	10.52 *	2.90	5.48	56.13 **	32.31 **	8.63	28.04 **
37	23 A x S-19/11	12.70 **	7.58	-2.07	0.39	91.98 **	85.61 **	5.89	24.81 **
38	23 A x S-19/12	28.71 **	19.71 **	15.17 **	18.06 **	90.28 **	87.82 **	7.16	26.30 **
39	23 A x S-19/13	43.01 **	40.33 **	16.14 **	19.05 **	104.05**	85.98 **	6.11	25.06 **
40	23 A x S-19/14	14.60 **	12.53 **	-3.38	-0.95	89.30 **	89.30 **	8.00	27.30 **
	SE (d) (±)	0.474	0.548	0.548	0.548	2.581	2.980	2.980	2.980
	CD @ 95 %	0.959	1.108	1.108	1.108	5.221	6.029	6.029	6.029
	CD @ 99 %	1.285	1.483	1.483	1.483	6.990	8.071	8.071	8.071

		Fodder yield per plant (g)				**Harvest index (%)**			
Sr. No.	**Crosses**	**M.P.(%)**	**B.P. (%)**	**SC-1**	**SC-2**	**M.P.(%)**	**B.P. (%)**	**SC-1**	**SC-2**
1	760 A x S-19/03	22.83 *	-7.61	-5.56	48.60 **	15.05 **	-1.69	-0.85	-17.21 **
2	760 A x S-19/04	31.84 **	4.83	-8.44	44.06 **	16.83 **	-0.83	0.01	-16.48 **
3	760 A x S-19/05	12.37	-14.12	-16.22 *	31.82 *	23.73 **	11.98 *	12.94 **	-5.69
4	760 A x S-19/08	-19.47	-23.24	-56.33 **	-31.29 *	63.71 **	40.98 **	42.18 **	18.73 **
5	760 A x S-19/09	-21.35	-23.20	-58.44 **	-34.62 **	42.87 **	25.41 **	26.48 **	5.62
6	760 A x S-19/10	15.10	12.84	-39.44 **	-4.72	11.79 **	-0.39	28.46 **	7.27
7	760 A x S-19/11	31.42*	28.45	-33.78 **	4.20	22.49 **	20.19 **	25.94 **	5.17
8	760 A x S-19/12	6.84	0.19	-41.00 **	-7.17	28.01 **	24.92 **	25.99 **	5.21
9	760 A x S-19/13	6.33	4.13	-44.00 **	-11.89	30.27 **	23.86 **	24.92 **	4.31
10	760 A x S-19/14	-14.23	-16.67	-54.44 **	-28.32 *	47.52 **	45.75 **	50.60 **	25.76 **
11	769 A x S-19/03	27.37 **	-12.50	-10.56	40.73 **	10.15 *	-8.51	-1.07	-17.39 **
12	769 A x S-19/04	27.43 *	-8.40	-20.00 *	25.87 *	21.66 **	0.41	8.58	-9.33 *
13	769 A x S-19/05	21.11 *	-15.72 *	-17.78 *	29.37 *	17.11 **	2.80	11.16 *	-7.18
14	769 A x S-19/08	66.12 **	38.87 **	-21.00 **	24.30 *	33.43 **	11.66 *	20.74 **	0.82
15	769 A x S-19/09	21.54	3.70	-43.89 **	-11.71	37.55 **	17.24 **	26.77 **	5.86
16	769 A x S-19/10	45.10 **	24.22	-33.33 **	4.90	16.43 **	7.02	38.03 **	15.26 **
17	769 A x S-19/11	108.64**	85.33 **	-8.78	43.53 **	17.54 **	15.72 **	25.13 **	4.49
18	769 A x S-19/12	70.94 **	40.94 **	-17.00 *	30.59 *	22.12 **	15.27 **	24.64 **	4.08
19	769 A x S-19/13	57.00 **	34.30 *	-27.78 **	13.64	44.60 **	33.09 **	43.92 **	20.18 **
20	769 A x S-19/14	101.67**	71.34 **	-6.33	47.38 **	8.16 *	5.75	14.35 **	-4.51
21	704 A x S-19/03	23.46 **	-6.20	-4.11	50.87 **	6.47	-12.89 **	-2.13	-18.27 **
22	704 A x S-19/04	2.53	-17.56 *	-28.00 **	13.29	21.75 **	-1.00	11.23 *	-7.12
23	704 A x S-19/05	1.47	-21.64 **	-23.56 **	20.28	-5.61	-18.49 **	-8.42	-23.53 **
24	704 A x S-19/08	14.14	10.35	-37.22 **	-1.22	29.06 **	6.36	19.51**	-0.21
25	704 A x S-19/09	3.83	2.87	-44.33 **	-12.41	14.31 **	-4.08	7.77	-10.00 *
26	704 A x S-19/10	21.75	21.12	-35.00 **	2.27	8.80 *	1.80	31.28 **	9.63 *

27	704 A x S-19/11	83.93 **	77.20 **	-5.89	48.08 **	5.91	2.34	14.99 **	-3.98
28	704 A x S-19/12	84.52 **	75.47 **	3.33	62.59 **	19.55 **	10.84 *	24.54 **	4.00
29	704 A x S-19/13	55.93 **	54.96 **	-16.67 *	31.12 *	28.02 **	15.81 **	30.13**	8.66 *
30	704 A x S-19/14	36.91 **	34.96 *	-26.22 **	16.08	11.93 **	7.43	20.71 **	0.80
31	23 A x S-19/03	26.36 **	-5.43	-3.33	52.10 **	23.00 **	2.28	10.29 *	-7.90
32	23 A x S-19/04	51.25 **	19.59 *	4.44	64.34 **	23.95 **	2.42	10.43 *	-7.78
33	23 A x S-19/05	48.76 **	13.10	10.33	73.60 **	5.31	-7.45	-0.20	-16.66 **
34	23 A x S-19/08	41.80 **	34.18 *	-23.67 **	20.10	30.32 **	9.18*	17.73 **	-1.69
35	23 A x S-19/09	13.56	10.06	-40.44 **	-6.29	39.03 **	18.64 **	27.93 **	6.83
36	23 A x S-19/10	33.19 *	29.61 *	-30.44 **	9.44	10.65 **	1.58	31.01 **	9.40 *
37	23 A x S-19/11	56.00 **	53.61 **	-22.00 **	22.73	13.62 **	12.02 **	20.79 **	0.87
38	23 A x S-19/12	62.11 **	50.94 **	-11.11	39.86 **	10.38 *	4.32	12.49 *	-6.07
39	23 A x S-19/13	36.66 **	32.85 *	-28.56**	12.41	28.16**	18.12 **	27.36 **	6.36
40	23 A x S-19/14	64.17 **	58.33 **	-13.44	36.19 **	8.81*	6.54	14.87 **	-4.07
	SE (d) (±)	5.875	6.784	6.784	6.784	1.407	1.625	1.625	1.625
	CD @ 95 %	11.884	13.723	13.723	13.723	2.847	3.287	3.287	3.287
	CD @ 99 %	15.911	18.372	18.372	18.372	3.812	4.401	4.401	4.401

* and ** Significant at 5 and 1 per cent level, respectively.
Where, SC-1 = Aadishakti SC-2 = AHB-1200 (Fe)

The cross S-16/769 A x S-19/10 recorded highest significant positive value over mid parent) 20.98%), the cross S-16/704 A x S-19/09) 17.56%) followed by S-16/769 A x S-19/10) 17.54%) and S-16/769 A x S-19/09) 13.66%) manifested highest significant positive heterosis over better parent, while highest significant and positive heterosis over both checks; Aadishakti) 22.35%) and AHB-1200) Fe)) 23.52%) exhibited by cross S-16/769 A x S-19/13 followed by S-16/769 A x S-19/12) 22.12% and 23.28%) respectively for the character earhead length. In case of earhead girth, the cross S-16/769 A x S-19/11) 19.66%) and S-16/769 A x S-19/08) 16.52%) registered highest significant positive average heterosis and heterobeltosis respectively. While, cross S-16/704 A x S-19/12 exhibited highest significantly positive heterosis over both standard checks; Aadishakti) 17.36%) and AHB-1200) Fe)) 7.04%) followed by S-16/704 A x S-19/14) 15.11% and 4.99%) respectively. The results are in the agreement with Athoni *et al*.,) 2016) and Acharya *et al*.,) 2017).

With regards to the character 1000 seed weight, the cross S-16/760 A x S-19/14 exhibited highest significant positive heterosis over mid parent) 47.68%) and better parent) 44.42%). Whereas, the cross S-16/769 A x S-19/11 manifested positively significant heterosis over both standard checks; Adishakti) 28.28%) and AHB-1200) Fe)) 31.50%) followed by S-16/704 A x S-19/11) 26.17% and 29.34%) and S-16/760 A x S-19/14) 24.00% and 27.11%)) respectively. Significant positive heterosis for earhead girth in pearl millet has been reported by several workers *viz*., Bachkar *et al*.) 2014) and Krishnan *et al*.) 2017). For major economic character) grain yield per plant), The highest heterosis over mid parent) 200.47%) and over better parent) 188.34%) was depicted by the cross S-16/769 A x S-19/13. While, the cross, S-16/704 A x S-19/12 depicted highest positively significant heterosis over both standard checks; Aadishakti) 48.00%) and AHB-1200) Fe)) 74.44%) followed by S-16/769 A x S-19/13) 35.37% and 59.55%) and S-16/769 A x S-19/11) 31.16% and 54.59%) respectively. The similar findings were also in accordance with previous workers Karvar *et al*.,) 2017), Gawali *et al*.,) 2017) and Ladumor *et al*.,) 2018).

In case of fodder yield per plant, The cross, S-16/769 A x S-19/11 registered highest

significant positive heterosis over mid parent) 108.64%) and better parent) 85.33%). While the cross, DHLB-23 A x S-19/05 exhibited significantly positive heterosis over standard check Aadishakti) 10.33%) and AHB-1200) Fe)) 73.60%) followed by DHLB-23 A x S-19/04) 4.44% and 64.34%) and S-16/704 A x S-19/12) 3.33% and 62.59%), respectively. For the character harvest index, The cross, S-16/760 A x S-19/08) 63.71%) and S-16/760 A x S-19/14) 45.75%) had exhibited positively significant heterosis over mid parent and better parent respectively. While, The cross, S-16/760 A x S-19/14 registered significantly positive heterosis over standard check Adishakti) 50.60%) and AHB-1200) Fe)) 25.76%) followed by S-16/769 A x S-19/13) 43.92% and 20.18%) respectively. Similar results has been reported by Karvar *et al*., (2017) and Krishnan *et al*., (2017).

In conclusion the highest values of average heterosis) 200.47 per cent), heterobeltosis) 188.34 per cent) and standard heterosis over standard checks; Aadishakti and AHB-1200) Fe) were 48 per cent and 74.44 per cent, respectively for grain yield per plant. Five crosses *viz*., S-16/704 A x S-19/12, S-16/769 A x S-19/13, S-16/769 A x S-19/11, S-16/704 A x S-19/13 and DHLB-23 A x S-19/04 manifested significant and positive heterosis over standard checks; Aadishakti and AHB-1200) Fe). The above mentioned highly heterotic crosses also occupied top ranks in *per se* performance for grain yield per plant. Above mentioned top crosses could be checked for their stable performance for multi location trials over environment.

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