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Heterotic Studies for Yield and its Related Traits in Pearl Millet (*Pennisetum glaucum* (L.) R. Br.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present study was conducted on six parents and eighteen hybrids developed at ICAR Indian institute of millets reaserch, rajendranagar, hyderabad, for sixteen characters. ANOVA revealed significant difference among genotypes for all characters studied. In the present investigation eighteen crosses generated by Line × Tester mating design were evaluated and heterosis

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estimated. Heterosis studies helps in finding out superior hybrids over mid parent (Average heterosis), better parent (heterobeltiosis) and standard check crosses studied four crosses *viz*., 291A X 23S216, 291A X 23S168, 291A X 23S156 and 291A X 23S224 were found as the best performing hybrids for grain yield and its component traits.

Keywords: Average heterosis; heterobeltiosis; economic heterosis.

1. INTRODUCTION

Pearl millet was domesticated in Africa (west of the Nile), nearly 3000 to 5000 years ago and subsequently spread to southern Asia [1]. It belongs to the family Poaceae (Gramineae), subfamily Panicoideae with chromosome number 2n=14. Other names of bajra are cat tail, spiked or bulrush millet, cumbu and locally known as bajra or bajari, in telugu it is called as 'sajjalu'. Nearly around 90 million people living in semi-arid and arid climates eat pearl millet as staple food. The utility of pearl millet varies, ranging from food and feed, through forage, fodder, building material, brewing and biofuel, making it an important crop species for food and livelihood security for millions of poor and nutritionally insecure people around the world. In view of climate change, depleting water resources, burgeoning population and widespread malnutrition, there is a need to accelerate the rate of genetic gains in pearl millet. Pearl millet being a highly cross pollinated crop, efficient exploitation of heterosis leads to higher genetic gains. Pearl millet breeding in India has historically evolved very comprehensively from open-pollinated varieties to hybrid breeding. Hybrid breeding in bajra started with the development of a commercially and economical viable male-sterile line, i.e., Tift 23A. It was developed in the early 1960s in Tifton, Georgia, USA. These provided a breakthrough in the development of hybrids worldwide. Tift 23A was extensively used at Punjab Agricultural University (PAU) Ludhiana India, led to development of the first single-cross pearl millet hybrid, named Hybrid Bajra 1 (HB 1) and other hybrids (HB series). In 1970 downey mildew epidemic resulted due to continuous use of Tift 23 A. It led to diversification of parental lines. The accomplishments of pearl millet breeding are often referred to as one of the greatest success stories in Indian agriculture. There is a considerable scope to further accelerate the genetic gains with hybrid breeding.

2. MATERIALS AND METHODS

Eighteen crosses along with nine parents 247B, 275B, 292B, 23S110, 23S156, 23S168 and 23S216 developed at ICAR- Indian Institute of Millets Research, Rajendranagar, Hyderabad, and two (2) checks HHB 67 Improved and Pratap were evaluated during *rab*i, 2023 in Randomized Block Design replicated over three replications at Wet land farm, S.V. Agricultural college, Tirupati. Each entry was sown in one row of 3m length at a spacing of 45 cm between the rows and 15 cm between the plants in a row. The recommended dose of N, P and K were applied @ 60:30:20 kg ha^{-1}. The entire P and K and half dose of nitrogen were applied as basal, while remaining nitrogen is applied at 30 days after sowing. Intercultural operations and irigation schedules were followed as and when necessary. Need based plant protection measures were adopted to raise healthy crop. The mean values were subjected to statistical analysis as suggested by Snedecor and Cochran [2] and mid parent, better parent and economic heterosis was estimated.

3. RESULTS

Replicated mean data for the 16 characters studied were subjected to analysis of variance presented in the Table 1, revealed that mean sum of squares of the genotypes were highly significant for the characters studied indicating the existence of sufficient variability among genotypes for all the characters.

Heterosis studies helps in finding out superior hybrids over mid parent (Average heterosis), better parent (heterobeltiosis) and standard check (economic heterosis). In the present investigation eighteen crosses generated by Line × Tester mating design were evaluated and heterosis estimated and presented in Table 2.

Heterosis studies revealed that, out of eighteen hybrids studied two hybrids (246A x 23S224) and (274A x 23S224) recorded highest significant negative heterosis over mid parent, better parent, and standard check pratap and non significant negative heterosis over HHB 67 Improoved for days to 50% flowering.

Four hybrids 291A X 23S216, 291A X 23S168, 291A X 23S156 and 291A X 23S224 out of eighteen hybrids registered significant positive heterosis over mid parent, better parent, and standard checks HHB67 Improved, and non significant positive heterosis over pratap for grain yield.

Table 1. Mean performance of hybrids of pearl millet for yield and yield contributing characters

Sl. No.	Crosses & Parents	DFF	DM	SCMR	SLA (cm^2.g-1)	LL (cm)	LW (cm)	PH (cm)	NPT (no)	PL (cm)	PG (cm)	FLL (cm)	FLW (cm)	FY (th^{-1})	TW (g)	HI (%)	GYPP (g)
1	246A x 23S110	38.33	76.00	53.43	97.07	39.00	2.70	106.46	3.13	17.87	2.44	28.10	2.93	7.70	16.50	30.98	12.67
2	274A X 23S110	39.33	77.66	63.37	95.23	40.00	2.77	111.80	2.47	16.59	2.29	27.33	2.70	7.30	14.27	30.78	11.87
3	291A X 23S110	42.33	80.67	57.53	99.90	46.00	3.07	126.47	1.73	21.33	2.59	33.93	3.30	9.21	13.37	31.41	16.80
4	246A x 23S156	39.00	77.33	50.33	102.90	46.33	2.90	132.33	1.53	20.47	2.72	31.17	3.33	8.54	17.60	34.46	17.60
5	274A X 23S156	38.33	78.33	55.03	100.00	45.67	3.17	130.87	2.33	21.10	2.63	29.47	3.20	8.77	18.17	40.87	22.27
6	291A X 23S156	40.33	79.33	60.90	92.23	51.33	3.40	143.60	1.20	24.73	2.88	36.47	3.47	9.17	15.00	37.22	25.07
7	246A x 23S168	41.33	80.67	59.27	106.90	45.00	2.67	129.36	1.53	20.13	2.43	28.73	2.83	6.28	14.77	35.11	16.80
8	274A X 23S168	40.00	79.33	70.53	108.27	47.00	2.80	135.33	1.40	23.70	2.52	33.93	2.97	9.09	18.73	45.09	22.40
9	291A X 23S168	43.67	84.00	66.83	96.37	53.33	3.03	154.73	2.20	26.13	2.68	35.47	3.10	14.03	16.97	32.25	24.93
10	246A x 23S216	36.33	78.00	61.70	104.13	41.67	2.73	124.40	1.73	19.57	2.64	31.13	2.83	7.28	17.53	35.79	18.53
11	274A X 23S216	38.00	77.33	62.47	104.60	42.00	2.77	130.20	1.60	20.87	2.50	29.80	3.00	8.48	19.60	31.69	16.93
12	291A X 23S216	40.00	78.00	69.36	93.93	48.66	2.83	149.26	1.26	25.33	3.02	35.23	3.40	12.62	17.36	36.03	27.33
13	246A x 23S222	42.33	81.33	70.46	119.26	43.33	3.00	129.93	1.60	20.70	2.54	33.07	3.17	7.45	17.50	40.59	20.53
14	274A X 23S222	42.00	80.67	58.23	91.73	46.33	2.97	124.66	1.73	20.56	2.63	28.93	3.20	4.86	16.56	48.80	20.40
15	291A X 23S222	41.67	80.67	59.37	102.47	45.00	3.13	141.46	1.73	24.16	2.61	29.87	3.47	8.40	17.70	32.63	20.26
16	246A x 23S224	34.67	76.00	53.93	114.50	38.33	2.27	112.80	2.20	20.16	2.39	26.80	2.73	7.28	17.53	39.22	14.53
17	274A X 23S224	34.67	76.00	62.93	142.27	39.67	2.67	119.13	1.80	19.80	2.24	25.23	2.83	6.11	18.73	40.37	13.47
18	291A X 23S224	39.00	76.67	55.20	104.60	48.33	3.33	136.67	1.46	25.03	2.89	27.50	3.20	12.31	19.03	40.46	24.67
mean		39.52	78.78	60.61	104.24	44.83	2.90	129.97	1.81	21.57	2.59	30.68	3.09	8.60	17.05	36.88	19.28

DFF - Days to 50 % flowering, DM - Days to Maturity, NPT - No of Productive Tillers Per Plant, PL - Panicle Length, PG - Panicle Girth, FLL - Flag leaf Length, FLW - Flag Leaf Width, SCMR - SPAD Chlorophyll Meter Reading SLA - Specific Leaf Area, LL - Leaf Length LW- Leaf Width PH - Plant Height, FY - Fodder Yield, TW - Test Weight, HI - Harvest index, GYPP - Grain Yield Per Plant

Table 2. Mid parent, Better parent and Standard heterosis of the hybrids for all the characters studied

		Days to 50 % Flowering				Days to Maturity			
		Mid	**Better**	**HHB 67**	**Pratap**	**Mid**	**Better**	**HHB 67**	**Pratap**
1	246A*23S110	-10.85 **	-10.85 **	8.49 *	-8.00 *	-5.98 **	-8.43 **	1.79	-8.80 **
2	274A*23S110	-7.81 *	-8.53 *	11.32 **	-5.6	-4.51 *	-6.43 **	4.02	-6.80 **
3	291A*23S110	-9.93 **	-16.99 **	19.81 **	1.6	-13.42 **	-21.94 **	8.04 **	-3.2
4	246A*23S156	-8.95 **	-9.30 **	10.38 *	-6.4	-2.11	-2.52	3.57	-7.20 **
5	274A*23S156	-9.80 **	-10.16 **	8.49 *	-8.00 *	-1.47	-1.67	4.91	-6.00 **
6	291A*23S156	-13.88 **	-20.92 **	14.15 **	-3.2	-13.14 **	-23.23 **	6.25 *	-4.80 *
7	246A*23S168	-7.12 *	-10.14 **	16.98 **	-0.8	-0.41	-3.2	8.04 **	-3.2
8	274A*23S168	-9.43 **	-13.04 **	13.21 **	-4	-2.66	-4.80 *	6.25 *	-4.80 *
9	291A*23S168	-9.97 **	-14.38 **	23.58 **	4.8	-10.00 **	-18.71 **	12.50 **	0.8
10	246A*23S216	-15.18 **	-15.50 **	2.83	-12.80 **	-2.09	-3.31	4.46	-6.40 **
11	274A*23S216	-10.59 **	-10.94 **	7.55	-8.80 *	-3.53	-4.13	3.57	-7.20 **
12	291A*23S216	-14.59 **	-21.57 **	13.21 **	-4	-15.22 **	-24.52 **	4.46	-6.40 **
13	246A*23S222	-3.42	-5.22	19.81 **	1.6	1.04	-1.21	8.93 **	-2.4

14	274A*23S222	-3.45	-5.97	18.87 **	0.8	-0.41	-2.02	8.04 **	-3.2
15	291A*23S222	-12.89 **	-18.30 **	17.92 **	0	-13.11 **	-21.94 **	8.04 **	-3.2
16	246A*23S224	-16.80 **	-19.38 **	-1.89	-16.80 **	-4.80 *	-6.17 **	1.79	-8.80 **
17	274A*23S224	-16.13 **	-18.11 **	-1.89	-16.80 **	-5.39 **	-6.17 **	1.79	-8.80 **
18	291A*23S224	-14.60 **	-23.53 **	10.38 *	-6.4	-16.82 **	-25.81 **	2.68	-8.00 **
SE		1.26	1.45	1.45	1.45	1.57	1.82	1.82	1.82
		SCMR -SPAD Chlorophyll meter reading				**SLA-Specific leaf area ($cm^2 g$-1)**			
		Mid	**Better**	**HHB 67**	**Pratap**	**Mid**	**Better**	**HHB 67**	**Pratap**
1	246A*23S110	-15.99 **	-16.38 *	-4.64	-9.02	-18.27 *	-24.32 **	-7.56	5.78
2	274A*23S110	1.82	0.11	13.09	7.89	-7.39	-12.84	-9.3	3.78
3	291A*23S110	-3.09	-9.11	2.68	-2.04	-2.76	-8.57	-4.86	8.86
4	246A*23S156	-16.16 *	-21.23 **	-10.17	-14.3	-13.36	-19.78 *	-2	12.13
5	274A*23S156	-6.19	-10.03	-1.78	-6.3	-2.76	-8.48	-4.76	8.97
6	291A*23S156	9.14	8.43	8.69	3.69	-10.22	-15.59	-12.16	0.51
7	246A*23S168	-2.71	-7.25	5.77	0.91	-12.7	-16.66 *	1.81	16.49
8	274A*23S168	18.44 **	15.31 *	25.88 **	20.09 **	1.64	-7.17	3.11	17.98
9	291A*23S168	17.91 **	15.36 *	19.27 *	13.79	-9.44	-17.38	-8.22	5.01
10	246A*23S216	5.41	-3.44	10.11	5.05	-5.92	-18.81 *	-0.83	13.48
11	274A*23S216	9.27	2.13	11.48	6.36	10.4	8.51	-0.38	13.98
12	291A*23S216	27.75 **	25.14 **	23.80 **	18.10 *	-0.76	-2.36	-10.54	2.36
13	246A*23S222	12.45 *	10.28	25.76 **	19.98 **	5.65	-7.02	13.59	29.97 *
14	274A*23S222	-5	-5.21	3.93	-0.85	-5.38	-5.91	-12.63	-0.04
15	291A*23S222	1.6	-3.36	5.95	1.08	5.8	5.09	-2.41	11.66
16	246A*23S224	-3.26	-15.60 *	-3.75	-8.17	-1.46	-10.73	9.05	24.77 *
17	274A*23S224	15.72 *	2.89	12.31	7.15	41.89 **	36.62 **	35.49 **	55.03 **
18	291A*23S224	7.15	-0.42	-1.49	-6.02	4.43	0.45	-0.38	13.98
SE		3.72	4.29	4.29	4.29	8.80	10.16	10.16	10.16
		Leaf length (cm)				**Leaf width (cm)**			
		Mid	**Better**	**HHB 67**	**Pratap**	**Mid**	**Better**	**HHB 67**	**Pratap**
1	246A*23S110	-3.7	-6.40 *	3.54	-20.95 **	-0.61	-1.22	8	-19.80 **
2	274A*23S110	3.45	1.69	6.19	-18.92 **	-3.49	-7.78	10.67 *	-17.82 **
3	291A*23S110	2.99	-8.00 **	22.12 **	-6.76 *	0	-9.80 *	22.67 **	-8.91 *
4	246A*23S156	2.58	-4.79	23.01 **	-6.08 *	-3.33	-12.12 **	16.00 **	-13.86 **
5	274A*23S156	5.38 *	-6.16 *	21.24 **	-7.43 **	0.53	-4.04	26.67 **	-5.94
6	291A*23S156	4.05	2.67	36.28 **	4.05	1.49	0	36.00 **	0.99
7	246A*23S168	0	-6.90 *	19.47 **	-8.78 **	-3.61	-5.88	6.67	-20.79 **
8	274A*23S168	8.88 **	-2.76	24.78 **	-4.73	-4	-6.67	12.00 *	-16.83 **
9	291A*23S168	8.47 **	6.67 *	41.59 **	8.11 **	-2.67	-10.78 **	21.33 **	-9.90 *
10	246A*23S216	-2.72	-5.3	10.62 **	-15.54 **	-7.87 *	-15.46 **	9.33	-18.81 **
11	274A*23S216	2.44	-4.55	11.50 **	-14.86 **	-11.23 **	-14.43 **	10.67 *	-17.82 **
12	291A*23S216	3.55	-2.67	29.20 **	-1.35	-14.57 **	-16.67 **	13.33 *	-15.84 **
13	246A*23S222	1.56	-0.76	15.04 **	-12.16 **	2.27	-5.26	20.00 **	-10.89 **
14	274A*23S222	13.47 **	6.11 *	23.01 **	-6.08 *	-3.78	-6.32	18.67 **	-11.88 **
15	291A*23S222	-3.91	-10.00 **	19.47 **	-8.78 **	-4.57	-7.84 *	25.33 **	-6.93

16	246A*23S224	-5.74 *	-8.00 *	1.77	-22.30 **	-15.00 **	-16.05 **	-9.33	-32.67 **
17	274A*23S224	2.15	0	5.31	-19.59 **	-5.33	-11.11 *	6.67	-20.79 **
18	291A*23S224	7.81 **	-3.33	28.32 **	-2.03	10.50 **	-1.96	33.33 **	-0.99
SE		1.07	1.24	1.24	1.24	0.11	0.13	0.13	0.13
		Plant height(cm)				**NPT - No of productive tillers**			
		Mid	**Better**	**HHB 67**	**Pratap**	**Mid**	**Better**	**HHB 67**	**Pratap**
1	246A*23S110	28.14 **	21.54 **	2.63	-4.71	56.67 **	20.51 **	46.88 **	80.77 **
2	274A*23S110	30.51 **	27.63 **	7.78	0.06	8.82	-5.13	15.63 *	42.31 **
3	291A*23S110	40.62 **	37.07 **	21.92 **	13.19 *	-22.39 **	-33.33 **	-18.75 **	0
4	246A*23S156	31.83 **	8.29	27.57 **	18.44 **	-13.21	-28.13 **	-28.13 **	-11.54
5	274A*23S156	27.10 **	7.09	26.16 **	17.12 **	14.75 *	9.38	9.38	34.62 **
6	291A*23S156	33.91 **	17.51 **	38.43 **	28.52 **	-40.00 **	-43.75 **	-43.75 **	-30.77 **
7	246A*23S168	28.23 **	5	24.70 **	15.78 **	-6.12	-17.86 *	-28.13 **	-11.54
8	274A*23S168	30.80 **	9.85	30.46 **	21.12 **	-26.32 **	-27.59 **	-34.38 **	-19.23 *
9	291A*23S168	43.63 **	25.60 **	49.16 **	38.48 **	17.86 **	17.86 *	3.13	26.92 **
10	246A*23S216	26.02 **	4.66	19.92 **	11.34 *	-5.45	-23.53 **	-18.75 **	0
11	274A*23S216	28.53 **	9.53	25.51 **	16.53 **	-23.81 **	-29.41 **	-25.00 **	-7.69
12	291A*23S216	41.40 **	25.57 **	43.89 **	33.59 **	-38.71 **	-44.12 **	-40.63 **	-26.92 **
13	246A*23S222	33.52 **	11.95 *	25.26 **	16.29 **	29.73 **	14.29	-25.00 **	-7.69
14	274A*23S222	24.79 **	7.41	20.18 **	11.58 *	15.56	-10.34	-18.75 **	0
15	291A*23S222	35.81 **	21.88 **	36.38 **	26.61 **	18.18 *	-7.14	-18.75 **	0
16	246A*23S224	30.58 **	19.75 **	8.74	0.95	50.00 **	43.48 **	3.13	26.92 **
17	274A*23S224	33.91 **	26.47 **	14.85 *	6.62	3.85	-6.9	-15.63 *	3.85
18	291A*23S224	46.59 **	45.08 **	31.75 **	22.32 **	-13.73	-21.43 **	-31.25 **	-15.38
SE		5.20	5.99	5.99	5.99	0.12	0.14	0.14	0.14
		Panicle length(cm)				**Panicle girth (cm)**			
		Mid	**Better**	**HHB 67**	**Pratap**	**Mid**	**Better**	**HHB 67**	**Pratap**
1	246A*23S110	16.65 **	15.27 **	12.84 *	-8.84 *	7.65	2.81	23.23 **	-15.28 **
2	274A*23S110	-0.14	-8.32	4.8	-15.34 **	16.67 **	6.17	15.82 **	-20.37 **
3	291A*23S110	16.36 **	-0.93	34.74 **	8.84 *	7.76 *	-2.26	30.98 **	-9.95 **
4	246A*23S156	8.87 *	-7.39	29.26 **	4.42	5.56	-2.16	37.37 **	-5.56
5	274A*23S156	4.98	-4.52	33.26 **	7.65	15.42 **	-5.52	32.66 **	-8.80 *
6	291A*23S156	13.37 **	11.92 **	56.21 **	26.19 **	6.01	3.6	45.45 **	0
7	246A*23S168	0.83	-17.60 **	27.16 **	2.72	2.39	2.25	22.56 **	-15.74 **
8	274A*23S168	11.44 **	-3	49.68 **	20.92 **	21.80 **	6.48	27.27 **	-12.50 **
9	291A*23S168	13.71 **	6.96 *	65.05 **	33.33 **	6.77	1.01	35.35 **	-6.94
10	246A*23S216	11.70 **	0.17	23.58 **	-0.17	10.31 **	9.39 *	33.33 **	-8.33 *
11	274A*23S216	10.89 **	6.83	31.79 **	6.46	19.48 **	3.59	26.26 **	-13.19 **
12	291A*23S216	23.38 **	17.65 **	60.00 **	29.25 **	19.21 **	13.82 **	52.53 **	4.86
13	246A*23S222	27.65 **	22.24 **	30.74 **	5.61	5.82	4.37	28.62 **	-11.57 **
14	274A*23S222	17.41 **	13.63 **	29.89 **	4.93	25.06 **	7.92	33.00 **	-8.56 *
15	291A*23S222	25.65 **	12.23 **	52.63 **	23.30 **	2.62	-1.51	31.99 **	-9.26 *
16	246A*23S224	17.82 **	7.65	27.37 **	2.89	0.99	0.56	20.54 **	-17.13 **
17	274A*23S224	7.51	5.69	25.05 **	1.02	8.61	-4.82	13.13 *	-22.22 **

18	291A*23S224	24.34 **	16.25 **	58.11 **	27.72 **	15.58 **	9.05 *	46.13 **	0.46
SE		0.72	0.84	0.84	0.84	0.09	0.10	0.10	0.10
		Flag leaf length(cm)				**Flag leaf width(cm)**			
		Mid	**Better**	**HHB 67**	**Pratap**	**Mid**	**Better**	**HHB 67**	**Pratap**
1	246A*23S110	-7.16	-15.19	5.9	-17.35 *	4.14	-4.35	15.79 *	-16.19 **
2	274A*23S110	0.61	-0.24	3.02	-19.61 *	-4.71	-12.90 *	6.58	-22.86 **
3	291A*23S110	5.82	-7.62	27.89 **	-0.2	8.2	-6.6	30.26 **	-5.71
4	246A*23S156	-6.08	-6.22	17.46	-8.33	2.04	-3.85	31.58 **	-4.76
5	274A*23S156	-2.05	-11.33	11.06	-13.33	-2.54	-7.69	26.32 **	-8.57
6	291A*23S156	4.24	-0.73	37.44 **	7.25	-0.95	-1.89	36.84 **	-0.95
7	246A*23S168	-16.63 *	-19.74 **	8.29	-15.49 *	-5.03	-7.61	11.84	-19.05 **
8	274A*23S168	8.18	-5.21	27.89 **	-0.2	-1.11	-4.3	17.11 *	-15.24 **
9	291A*23S168	-2.21	-3.45	33.67 **	4.31	-3.63	-12.26 *	22.37 **	-11.43 *
10	246A*23S216	-1.99	-6.04	17.34	-8.43	-10.05	-12.37 *	11.84	-19.05 **
11	274A*23S216	3.95	-1.97	12.31	-12.35	-5.26	-7.22	18.42 *	-14.29 *
12	291A*23S216	4.97	-4.08	32.79 **	3.63	0.49	-3.77	34.21 **	-2.86
13	246A*23S222	1.12	-0.2	24.62 *	-2.75	6.74	3.26	25.00 **	-9.52
14	274A*23S222	-2.25	-10.33	9.05	-14.90 *	7.26	3.23	26.32 **	-8.57
15	291A*23S222	-13.43 *	-18.69 **	12.56	-12.16	8.33	-1.89	36.84 **	-0.95
16	246A*23S224	-7.21	-19.11 *	1.01	-21.18 **	-1.2	-10.87	7.89	-21.90 **
17	274A*23S224	-2.13	-6.31	-4.9	-25.78 **	1.8	-8.6	11.84	-19.05 **
18	291A*23S224	-10.37	-25.14 **	3.64	-19.12 *	6.67	-9.43	26.32 **	-8.57
SE		2.15	2.48	2.48	2.48	0.16	0.18	0.18	0.18
		Fodder yield(th^{-1})				**1000 - grain weight (g)**			
		Mid	**Better**	**HHB 67**	**Pratap**	**Mid**	**Better**	**HHB 67**	**Pratap**
1	246A*23S110	80.89 **	77.46 **	10.91	-14.12	6.11	-6.78	-18.32 **	-12.23 *
2	274A*23S110	52.27 **	38.97 **	5.23	-18.52 *	-7.86	-18.79 **	-29.37 **	-24.11 **
3	291A*23S110	55.64 **	22.85 *	32.67 **	2.73	-7.18	-13.20 *	-33.83 **	-28.90 **
4	246A*23S156	74.90 **	52.75 **	23.00 *	-4.76	10.34	-0.56	-12.87 *	-6.38
5	274A*23S156	61.54 **	56.72 **	26.19 **	-2.29	14.38 *	3.42	-10.07 *	-3.37
6	291A*23S156	40.09 **	22.27 *	32.04 **	2.24	1.35	-2.6	-25.74 **	-20.21 **
7	246A*23S168	25.22 *	7.26	-9.57	-29.98 **	-8.09	-16.57 **	-26.90 **	-21.45 **
8	274A*23S168	63.48 **	55.15 **	30.80 **	1.28	17.08 **	6.64	-7.26	-0.35
9	291A*23S168	110.06 **	87.02 **	101.97 **	56.38 **	13.74 *	10.17	-16.01 **	-9.75
10	246A*23S216	37.97 **	14.2	4.76	-18.88 *	11.32 *	-0.94	-13.20 *	-6.74
11	274A*23S216	45.84 **	33.11 **	22.10 *	-5.45	24.97 **	11.57 *	-2.97	4.26
12	291A*23S216	81.90 **	68.21 **	81.65 **	40.65 **	18.95 **	12.77	-14.03 **	-7.62
13	246A*23S222	34.00 **	7.27	7.31	-16.91 *	-6.83	-11.91 *	-13.37 **	-6.91
14	274A*23S222	-20.31 *	-29.99 **	-29.97 **	-45.78 **	-11.49 *	-16.61 **	-17.99 **	-11.88 *
15	291A*23S222	16.31 *	12.02	20.97 *	-6.33	0.38	-10.91 *	-12.38 *	-5.85
16	246A*23S224	125.91 **	74.39 **	4.86	-18.81 *	6.91	-0.94	-13.20 *	-6.74
17	274A*23S224	62.24 **	16.16	-12.05	-31.90 **	14.69 **	6.64	-7.26	-0.35
18	291A*23S224	151.91 **	64.10 **	77.21 **	37.21 **	24.81 **	23.59 **	-5.78	1.24
SE		0.57	0.65	0.65	0.65	0.85	0.98	0.98	0.98

		Harvest index(%)				Grain yield per plant (g)			
		Mid	**Better**	**HHB 67**	**Pratap**	**Mid**	**Better**	**HHB 67**	**Pratap**
1	246A*23S110	-5.11	-13.46 **	11.48 *	-9.95 *	32.87 **	26.67 *	33.80 **	-45.09 **
2	274A*23S110	14.83 **	4.35	10.76 *	-10.53 *	40.16 **	18.67	25.35 *	-48.55 **
3	291A*23S110	5.68	4.9	13.01 *	-8.71 *	44.83 **	27.27 **	77.46 **	-27.17 **
4	246A*23S156	-18.61 **	-29.50 **	24.00 **	0.16	30.05 **	-2.22	85.92 **	-23.70 **
5	274A*23S156	11.98 **	-16.39 **	47.05 **	18.79 **	78.61 **	23.70 **	135.21 **	-3.47
6	291A*23S156	-5.56	-23.85 **	33.93 **	8.19 *	60.68 **	39.26 **	164.79 **	8.67
7	246A*23S168	-7.52 *	-12.50 **	26.34 **	2.05	8.15	-23.64 **	77.46 **	-27.17 **
8	274A*23S168	40.39 **	12.38 **	62.26 **	31.07 **	54.84 **	1.82	136.62 **	-2.89
9	291A*23S168	-7.94 *	-19.63 **	16.05 **	-6.26	41.67 **	13.33 **	163.38 **	8.09
10	246A*23S216	0.72	-0.05	28.76 **	4.01	40.40 **	6.92	95.77 **	-19.65 **
11	274A*23S216	6.75	-10.12 *	14.02 **	-7.90 *	39.56 **	-2.31	78.87 **	-26.59 **
12	291A*23S216	10.53 **	2.2	29.65 **	4.73	79.04 **	57.69 **	188.73 **	18.50 **
13	246A*23S222	3.71	-4.43	46.04 **	17.97 **	43.93 **	5.48	116.90 **	-10.98 *
14	274A*23S222	46.59 **	14.90 **	75.59 **	41.84 **	54.55 **	4.79	115.49 **	-11.56 *
15	291A*23S222	-9.93 **	-23.21 **	17.34 **	-5.21	24.08 **	4.11	114.08 **	-12.14 *
16	246A*23S224	-8.09 **	-20.84 **	41.12 **	14.00 **	30.54 **	10.1	53.52 **	-36.99 **
17	274A*23S224	9.62 **	-18.51 **	45.26 **	17.34 **	33.77 **	2.02	42.25 **	-41.62 **
18	291A*23S224	1.79	-18.35 **	45.56 **	17.58 **	86.87 **	86.87 **	160.56 **	6.94
SE		1.15	1.33	1.33	1.33	0.89	1.03	1.03	1.03

** significant at p = 0.05 level, ** significant at p = 0.01 level SE - Standard error*

Hybrid 291A X 23S216 recorded significant positive heterosis over mid parent, better parent and standard checks HHB67 Improved and Pratap for grain yield. Along with grain yield 291A X 23S216 also recorded significant positive heterosis for SCMR, plant height, panicle length, panicle girth and fodder yield.

Another hybrid 291A X 23S168, recorded significant positive heterosis over mid parent, better parent and standard check HHB 67 Improoved and positive hetrosis over pratap for grain yield. Along with grain yield 291A X 23S168 also recorded positive significant heterosis for plant height, leaf length, panicle length and fodder yield. The results are in agreement with Vetriventhan et al. [3], Bachkar et al*.* [4], Jog et al*.* [5], Bhuri Singh et al*.* [6], Salagarkar and Wali [7], Acharya et al*.* [8], Sumathi and Revathi [9], Gupta et al*.* [10], Athoni et al [11] and Choudary et al [12].

Among all the crosses studied four crosses *viz*., 291A X 23S216, 291A X 23S168, 291A X 23S156 and 291A X 23S224 were found as the best performing hybrids for grain yield and its component traits. These hybrids can be tested in multi location trials for their performance and may be released if found suitable.

4. DISCUSSION AND CONCLUSION

The general expectation of hybrid breeding is to develop hybrids that are superior than the available standard hybrids which are grown widely. So, there is a need to evaluate the newly developed hybrids with standard hybrids. Hence, hybrids in the current study were evaluated with HHB67 Improved and Pratap. Hybrid 291A X 23S216 recorded significant positive standard heterosis for majority of characters studied *i.e.,* SCMR, plant height, panicle length, panicle girth and fodder yield and grain yield and other hybrid 291A X 23S168 recorded significant positive standard heterosis for plant height, leaf length, panicle length and fodder yield. From all the hybrids studied 291A X 23S216 identified as best cross for grain yield and its component traits.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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