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Performance of different characters of parents & hybrids, analysis of variance & heterosis studies in pearl millet (*Pennisetum glaucum* (L.)

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Abstract
The present investigation was undertaken for "Heterosis and Combining ability studies in Pearl Millet (*Pennisetum glaucum (*L.) R.Br.)". Experiment was conducted or taken at field of National Agricultural Research Project (NARP) Breeding section, Aurangabad (VNMKV, Parbhani, M.S.) during *Kharif* 2019.The objective of present study is to estimate the standard heterosis and combining ability effects among parents and crosses to find out promising cross combinations for grain yield and its components. The experimental material comprised of thirty two crosses along with twelve parents (four lines and eight testers) and standard checks AHB 1200 Fe and AHB 1269 Fe. The experiment was laid out in Randomized Block Design with two replications. The observations were recorded on ten characters *viz.*, days to 50 per cent flowering, days to maturity, plant height, total number of tillers, Number of effective tillers, earhead length, earhead head girth, 1000 grain weight, grain yield and fodder yield. The analysis of variance revealed that there were significant differences among the parents and crosses for all the characters studied. Considering the heterosis ICMA 93333 x AUBI 15022, ICMA 98222 x AUBI 15022, ICMA 98222 x AUBI 15051 and ICMA 99222 x AUBI 15004 appeared to be the more promising hybrids for breeding.

Keywords: Performance, characters, parents, hybrids, variance, heterosis & pearl millet

1. Introduction
Pearl millet or bajra (*Pennisetum glaucum* (L.) R. Br.) is the world's sixth and India's fourth most important cereal food crop after rice, wheat and maize. It is commonly known as pearl millet, cat tail, spiked or bulrush millet, cumbu and locally known as bajra or bajari in different parts of the world. It belongs to family poaceae (graminae), sub family *Panicoideae* having chromosome number 2n=14, genus *Pennisetum* and species *glaucum* and also others. Pearl millet or bajra is a highly cross-pollinated crop with protogynous (pistil mature before stamens) flowering and wind borne pollination mechanism, which fulfils one of the essential biological requirements for hybrid development programme.

Pearl millet is being grown, about 28 million ha in arid and semiarid regions of Asia and Africa (Yadav *et al*. 2012) [1], India and Pakistan with the rainfall ranging from 150-700 mm. India is a major pearl millet producing country with 43.3 per cent of the world area and 42 per cent of world production. Major bajra production or cultivated states in india are Rajasthan, Maharashtra, Haryana, UP, Gujarat (Directorate of Millets Development). India is the largest producer of pearl millet both in terms of area (7.47 million ha) and production (9.80 million ton), with an average productivity is 1305 kg/ha (Anonymous, 2017). Maharashtra is the fifth largest producer of pearl millet in India with 11.31% area and 8.60% production. In Maharashtra pearl millet is cultivated over an area of 5.04 lakh ha with production of 5.39 lakh tons and productivity was 623 kg/ha (Anonymous, 2018-19) and in Marathwada region pearl millet cultivated over an area of 3.15 lakh ha with production of 3.10 lakh tons and productivity was 987 kg/ha (Anonymous, 2018-19).

Pearl millet is an erect annual plant growing 5 to 6 feet tall with varying number of tillers. Evidence of its secondary polyploidy nature is also available (Swaminathan and Nath, 1956). Pearl millet is an allogamous crop belongs to the genus *Pennisetum*. Pearl millet is an erect, tillering annual. Stem is round to oval green divided into nodes and internodes. Leaves are long scabrous, medium broad, linear, lanceolate, wavy margin, green or light green and usually sparsely hairy. The inflorescence is 20-25 cm long cylindrical compound terminal spike consists of central rachis on which fascicles are closely packed.

Each fascicle consists of one or more spikelets and a whorl of bristles. Generally spikelets contain two florets, the lower being staminate and the other bisexual. These flowers are partly enclosed by short outer glume, while inner glume is longer than it and covers nearly half of the spikelets. The lower floret is staminate often represented by sterile lemma enclosing three stamens and there are neither paleas nor lodicules.

The upper flower is a perfect with lemma, palea, three stamens and an ovary with two styles on the top. The three stamens are with filament and versatile linear anthers. The ovary is monocarpellate, one celled, containing a single ovule. Seeds are whitish yellow, gray or dual light blue, oval (Chalam and Venkateswarulu, 1965). For the development of effective heterosis breeding programme in pearl millet, one needs to have information about genetic architecture and estimated prepotency of parents in hybrid combinations. Selection made on phenotypic performance alone does not lead to expected success in hybrid breeding. Therefore, a study on combining ability of parents is essential in choosing parents. Many biometrical procedures have been developed to obtain information on combining ability.

A line x tester analysis is one among them which is widely used to study combining ability of the parents to be chosen for heterosis breeding. It also provides a guideline to determine the value of source populations and appropriate procedures to use in crop improvement programme. This knowledge in fact helps in exploiting heterosis for commercial purpose. The recombination of different desirable traits spread over in different diverse genotypes is important for the improvement of yield and its related traits in any crop. The improvement in pearl millet needs attention for the characters like early flowering, grain yield per plant, grain yield per ha, ear head length and girth, number of tillers/plant, effective tillers and fodder yield.

2. Materials and Methods

The present was conducted or taken at field of National Agricultural Research Project (NARP) Breeding section, Aurangabad during *Kharif* 2019. The details of materials and methods adopted in conducting the experiment and the statistical procedures followed during the course of research & investigation are given as below.

3. Experimental Materials

The parental materials consisting of four male sterile lines used as female, eight inbreds or tester used as male and two checks were used and obtained from National Agricultural Research Project (NARP), Aurangabad. The crosses were did in line x tester fashion during *Summer* 2019.

The following important parents are used in crossing programme and crosses produced for the studies in Pearl millet.

Parents

Female (A line):- 1) ICMA 92444 2) ICMA 93333 3) ICMA 98222 4) ICMA 99222

Male (R line):- 1) AUBI 15003 2) AUBI 15004 3) AUBI 15015 4) AUBI 15022 5) AUBI 15050 6) AUBI 15051 7) AUBI 15092 8) AUBI 15124

Checks

1) AHB 1200 Fe 2) AHB 1269 Fe

Table 1: Details of crosses produced in pearl millet

Sr. No.	Crosses	Sr. No.	Crosses
1.	ICMA 92444 X AUBI 15003	17.	ICMA 98222 X AUBI 15003
2.	ICMA 92444 X AUBI 15004	18.	ICMA 98222 X AUBI 15004
3.	ICMA 92444 X AUBI 15015	19.	ICMA 98222 X AUBI 15015
4.	ICMA 92444 X AUBI 15022	20.	ICMA 98222 X AUBI 15022
5.	ICMA 92444 X AUBI 15050	21.	ICMA 98222 X AUBI 15050
6.	ICMA 92444 X AUBI 15051	22.	ICMA 98222 X AUBI 15051
7.	ICMA 92444 X AUBI 15092	23.	ICMA 98222 X AUBI 15092
8.	ICMA 92444 X AUBI 15124	24.	ICMA 98222 X AUBI 15124
9.	ICMA 93333 X AUBI 15003	25.	ICMA 99222 X AUBI 15003
10.	ICMA 93333 X AUBI 15004	26.	ICMA 99222 X AUBI 15004
11.	ICMA 93333 X AUBI 15015	27.	ICMA 99222 X AUBI 15015
12.	ICMA 93333 X AUBI 15022	28.	ICMA 99222 X AUBI 15022
13.	ICMA 93333 X AUBI 15050	29.	ICMA 99222 X AUBI 15050
14.	ICMA 93333 X AUBI 15051	30.	ICMA 99222 X AUBI 15051
15.	ICMA 93333 X AUBI 15092	31.	ICMA 99222 X AUBI 15092
16.	ICMA 93333 X AUBI 15124	32.	ICMA 99222 X AUBI 15124

3.1 Experimental Methods

The experimental material comprised or consist of parents and hybrids along with two released hybrid checks were grown in randomized block design (RBD) with two replications at field of National Agricultural Research Project (NARP) Breeding section, Aurangabad.

3.1.1 Crossing programme

The crossing programme for obtaining crossed or hybrid seed was undertaken during *Summer* 2019 at field of National Agricultural Research Project (NARP), Aurangabad. Four male sterile lines (female) and eight inbreds (male) were crossed in line x tester fashion (4 x 8 =32). These crossed seed obtained were utilized as F1 or hybrid seed in present research or investigation.

4. Result and Discussion

1. Mean performance of different characters of parents & hybrids in pearl millet

a) Plant height (cm)

Among the female parents ICMA 99922 was medium in height (165.73 cm). The remaining three females ICMA 92444, ICMA 93333 and ICMA 98222 had height measuring from 171.90 cm, 181.94 cm, and 187.64 cm respectively. Among male parents, AUBI 15050 was tallest in height (202.95 cm). The male parent AUBI 15003 (164.50 cm) was

medium. The height of remaining males measured from 175.25 to 201.04 cm.

Among thirty two hybrids, ICMA 99222 x AUBI 15022 (158.79 cm) was dwarf however, ICMA 98222 x AUBI 15092 (210.10 cm) and ICMA 98222 x AUBI 15124 (205.75 cm) were tall. Other hybrids had plant height measuring from 166.44 to 202.95 cm. However, six and twenty one hybrids dwarf than standard hybrid checks AHB 1200 Fe (171.90 cm) and AHB 1269 Fe (190.75 cm) respectively.

b) Total number of tillers per plant

Among the four female lines, ICMA 99222 (2.55) produced more total no. of tillers. Other three females ranged from 1.35 to 2.10. Among the males, AUBI 15015 had highest number of total number of tillers per plant (2.75) while, lowest number of total number of tillers per plant were recorded in the male AUBI 15003 (1.90). Remaining male parents had mean value ranging from 1.95 to 2.65.

Among the hybrids, ICMA 99222 x AUBI 15124 (3.25), ICMA 93333 x AUBI 15124 (3.10) and ICMA 99222 x AUBI 15092 (3.10) total no of tillers per plant. However, twenty three and twenty five hybrids had more total no of tillers per plant than standard hybrid checks AHB 1200 Fe (2.10) and AHB 1269 Fe (2.00) respectively.

c) Number of effective tillers per plant

Among the four female lines, ICMA 99222 (1.65) produced more productive tillers. Other three females ranged from 1.30 to 1.45. Among the males, AUBI 15022 had highest number of effective tillers per plant (2.05) while, lowest number of effective tillers were recorded in the male AUBI 15051 (1.15). Remaining male parents had mean value ranging from 1.55 to 1.90.

Among the hybrids, ICMA 99222 x AUBI 15124 and ICMA 93333 x AUBI 15050 produced 2.70 and 2.50 effective tillers per plant respectively. However, three and six hybrids had less effective tillers per plant than standard hybrid check AHB 1200 Fe (1.30) and AHB 1269 Fe (1.45) respectively.

d) Earhead length (cm)

Among the four female lines, ICMA 92444 produced longer earhead (23.75 cm). The earhead length of remaining females measured from 16.85 to 21.90 cm. As regards the male parents, AUBI 15022 produced longest earhead length (27.25 cm). For the remaining male parents, the range for this trait was 21.10 to 23.45 cm.

Out of thirty two hybrids studied, the hybrids *viz;* ICMA 98222 x AUBI 15004 (27.90), followed by ICMA 99222 x AUBI 15050 (27.65 cm) produced longer earheads and ICMA 92444 x AUBI 15022 (16.85 cm) produced shorter earhead. The rest of the hybrids had a range from 17.00 to 26.25 cm. The hybrids involving ICMA 98222 and ICMA 99222 as female and AUBI 15022 as male parents produced longer earheads. However, six and eight hybrids recorded higher earhead length than standard hybrid checks AHB 1200 Fe (23.75 cm) and AHB 1269 Fe (23.40 cm) respectively.

Table 2: Mean performance of different characters of parents & hybrids in pearl millet

Sr. No.	Parents	Days to 50% flowering	Days to maturity	Plant height (cm)	Total No. of tillers/plant	No. of effective tillers/ Plant	Ear head length (cm)	Ear head girth (cm)	1000 grain weight (g)	Grain yield /Plant (g)	Fodder yield /plant (g)
1	2	3	4	5	6	7	8	9	10	11	12
	LINES										
1	ICMA 92444	48.50	89.50	171.90	2.10	1.30	23.75	3.64	17.15	42.45	55.52
2	ICMA 93333	49.50	84.00	181.94	1.35	1.35	21.20	3.25	16.45	36.49	51.56
3	ICMA 98222	48.00	84.00	187.64	1.95	1.45	21.90	2.86	15.79	34.54	46.20
4	ICMA 99222	48.00	85.00	165.73	2.55	1.65	16.85	3.63	15.50	33.53	44.01
TESTER											
5	AUBI 15003	51.00	89.00	164.50	1.90	1.90	22.00	3.63	16.26	36.16	55.20
6	AUBI 15004	47.00	84.00	171.50	2.65	1.70	21.10	3.81	16.71	30.98	53.55
7	AUBI 15015	53.00	90.50	181.80	2.75	1.90	23.10	3.30	16.23	35.00	53.53
8	AUBI 15022	50.00	92.00	201.04	2.15	2.05	27.25	3.00	16.33	22.94	53.18
9	AUBI 15050	50.00	81.00	202.95	2.35	1.30	18.70	3.24	18.93	30.80	34.99
10	AUBI 15051	50.00	85.00	200.20	2.45	1.15	19.85	3.53	14.60	29.55	52.25
11	AUBI 15092	51.50	82.00	175.25	1.95	1.55	23.35	3.07	11.59	25.30	55.00
12	AUBI 15124	49.00	83.00	192.60	1.95	1.65	23.45	4.00	14.15	47.55	43.51
	Crosses										
13	ICMA 92444 X AUBI 15003	48.50	89.50	171.90	2.10	1.30	23.75	3.64	17.15	42.45	55.52
14	ICMA 92444 X AUBI 15004	49.50	84.00	181.94	1.35	1.35	21.20	3.25	16.45	36.49	51.56
15	ICMA 92444 X AUBI 15015	48.00	84.00	187.64	1.95	1.45	21.90	2.86	15.79	34.54	46.20
16	ICMA 92444 X AUBI 15022	48.00	85.00	165.73	2.55	1.65	16.85	3.63	15.50	33.53	44.01
17	ICMA 92444 X AUBI 15050	51.00	89.00	164.50	1.90	1.90	22.00	3.63	16.26	36.16	55.20
18	ICMA 92444 X AUBI 15051	47.00	84.00	171.50	2.65	1.70	21.10	3.81	16.71	30.98	53.55
19	ICMA 92444 X AUBI 15092	53.00	90.50	181.80	2.75	1.90	23.10	3.30	16.23	35.00	53.53
20	ICMA 92444 X AUBI 15124	50.00	92.00	201.04	2.15	2.05	27.25	3.00	16.33	22.94	53.18
21	ICMA 93333 X AUBI 15003	50.00	81.00	202.95	2.35	1.30	18.70	3.24	18.93	30.80	34.99
22	ICMA 93333 X AUBI 15004	50.00	85.00	200.20	2.45	1.15	19.85	3.53	14.60	29.55	52.25
23	ICMA 93333 X AUBI 15015	51.50	82.00	175.25	1.95	1.55	23.35	3.07	11.59	25.30	55.00
24	ICMA 93333 X AUBI 15022	49.00	83.00	192.60	1.95	1.65	23.45	4.00	14.15	47.55	43.51
25	ICMA 93333 X AUBI 15050	49.00	87.00	201.24	2.15	2.50	22.95	3.28	16.66	30.43	37.00
26	ICMA 93333 X AUBI 15051	46.00	89.50	199.20	2.95	1.90	17.00	4.53	17.66	44.46	43.50
27	ICMA 93333 X AUBI 15092	45.00	86.00	180.88	2.30	2.45	21.20	3.07	15.91	35.12	54.65
28	ICMA 93333 X AUBI 15124	47.00	80.00	192.50	3.10	2.05	23.17	3.38	17.73	33.79	51.91
29	ICMA 98222 X AUBI 15003	48.00	88.00	166.44	2.85	2.05	21.85	3.68	16.87	34.46	42.67

30	ICMA 98222 X AUBI 15004	52.00	85.00	177.50	2.95	1.65	27.90	3.02	15.91	30.72	42.97
31	ICMA 98222 X AUBI 15015	51.00	90.00	179.00	2.25	2.15	19.72	2.61	17.90	26.24	42.85
32	ICMA 98222 X AUBI 15022	50.00	90.50	175.10	3.10	1.45	22.90	3.02	19.23	45.56	39.67
33	ICMA 98222 X AUBI 15050	53.00	93.00	176.92	2.30	1.55	22.50	2.82	17.69	31.03	33.55
34	ICMA 98222 X AUBI 15051	48.00	94.00	202.95	1.95	1.05	21.50	3.52	17.60	47.14	40.85
35	ICMA 98222 X AUBI 15092	47.50	92.00	210.10	1.95	1.25	24.10	2.79	16.82	29.89	36.50
36	ICMA 98222 X AUBI 15124	49.00	87.50	205.75	2.30	1.55	24.00	3.50	1052	27.05	49.01
37	ICMA 99222 X AUBI 15003	51.00	83.00	180.70	2.35	1.65	26.50	3.40	18.92	35.14	34.27
38	ICMA 99222 X AUBI 15004	47.50	86.00	181.00	2.10	1.95	23.30	3.37	16.97	45.95	36.31
39	ICMA 99222 X AUBI 15015	49.00	85.00	169.00	2.60	2.15	23.20	3.13	16.70	34.35	34.51
40	ICMA 99222 X AUBI 15022	47.00	85.00	158.79	2.90	1.90	22.91	3.93	19.45	36.40	46.75
41	ICMA 99222 X AUBI 15050	48.50	86.00	177.28	2.65	1.95	27.65	4.00	17.48	27.99	44.62
42	ICMA 99222 X AUBI 15051	45.00	86.50	172.00	2.50	2.15	22.60	2.96	17.48	34.51	53.73
43	ICMA 99222 X AUBI 15092	49.00	90.00	177.50	3.10	2.55	18.13	3.17	14.11	24.80	36.69
44	ICMA 99222 X AUBI 15124	46.00	92.00	202.39	3.25	2.70	20.30	2.95	15.57	32.54	63.13
	Checks										
45	AHB 1200 Fe	48.50	89.50	171.90	2.10	1.30	23.75	3.65	17.15	42.45	55.52
46	AHB 1269 Fe	54	91	190.75	2.00	1.45	23.40	3.63	17.24	41.10	52.74
	S.E.	1.37	1.34	9.42	0.14	0.10	1.23	0.18	1.04	2.33	3.22
	C.D. at 5%	2.79	2.75	19.21	0.29	0.21	2.52	0.38	2.12	4.75	6.58
	C.D. at 1%	3.76	3.70	25.84	0.39	0.29	3.39	0.51	2.86	6.39	8.85
	CV (%)	2.81	1.54	5.03	5.91	6.09	5.36	5.64	6.33	6.47	7.19

e) Earhead girth (cm)

The girth of earhead among female was highest in ICMA 92444 (3.64 cm) and ICMA 99222 (3.63 cm). Other two females ICMA 93333 and ICMA 98222 had earhead girth of (3.25 cm) and (2.86 cm), respectively. The male parents, AUBI 15124 (4.00 cm) had highest while AUBI 15022 (3.00 cm) had lowest earhead girth. Remaining male parents ranged from 3.07 to 3.81 cm.

Out of thirty two cross combination studied, ICMA 93333 x AUBI 15051 (4.53 cm) and ICMA 98222 x AUBI 15015 (2.61 cm), had highest and lowest girth of earhead, respectively. Other hybrids produced earhead having girth ranging from 2.82 to 4.00 cm. However, five and seven hybrids recorded higher earhead girth than standard hybrid checks AHB 1200 Fe (3.65 cm) and AHB 1269 Fe (3.63 cm) respectively.

f) 1000 grain weight (g)

The grain weight of ICMA 92444 was highest (17.15 g) among the female parents. Remaining females produced grain weight ranging from 15.50 and 16.45 g. The male parent AUBI 15050 recorded highest grain weight (18.93 g) followed by AUBI 15004 (16.71 g). The remaining male parents exhibited grain weight ranging from 11.59 to 16.66 g grain weight.

Out of thirty two hybrids studied, ICMA 99222 x AUBI 15022 (19.45 g) followed by ICMA 98222 x AUBI 15022 (19.23 g) produced more grain weight. The hybrid ICMA 98222 x AUBI 15124 was recorded as a poor yielder (10.52 g) for grain weight. The 1000 grain weight of standard hybrid checks AHB 1200 Fe (17.15 g) and AHB 1269 Fe (17.10 g).

g) Grain yield per plant (g)

Among the four female lines, the grain yield of ICMA 92444 was highest (42.45 g) followed by of ICMA 93333 (36.49 g). Other two females ICMA 98222 and ICMA 99222 produced grain yield of 34.54 g and 33.53 g per plant, respectively. The male parent AUBI 15124 recorded highest grain yield per plant (47.55 g) followed by AUBI 15003 (36.16) and AUBI 15015 (35.00 g). The remaining male parents exhibited grain yield ranging from 22.94 to 30.98 g per plant.

Among the hybrids, ICMA 93333 x AUBI 15022 was observed to be the highest yielding combination (47.55 g per plant) followed by ICMA 98222 x AUBI 15051 (47.14 g) and ICMA 99222 x AUBI 15004 (45.95 g). Other hybrids produced the grain yield ranging from 27.05 to 44.46 g per plant. However, five and six hybrids were observed to be better over the standard hybrid checks AHB 1200 Fe (42.45 g) and AHB 1269 Fe (41.10 g) in respect of grain yield per plant respectively.

h) Fodder yield per plant (g)

The parent ICMA 92444 (55.52 g) had the higher fodder yield per plant among the females. For remaining three females the range was from 44.01 to 51.56 g. The male parents AUBI 15003 (55.20 g), followed by AUBI 15051 (55.00 g) had the highest and AUBI 15050 (34.99 g) had the lowest mean performance for fodder yield per plant. The remaining males produced fodder yield ranging between 43.51 to 53.53 g per plant.

The fodder yield of the hybrids ICMA 99222 x AUBI 15124 (63.13 g) was more, while the hybrid ICMA 98222 x AUBI 15050 (33.55 g) showed lower fodder yield. The remaining hybrids produced fodder yield ranging from 34.27 to 55.52 g per plant. One and nine hybrids were better in fodder yield per plant as compared to the standard hybrid checks AHB 1200 Fe (55.52 g) and AHB 1269 Fe (52.75 g) in respect of grain yield per plant respectively.

5. Discussion

On the basis of mean performance of female parents, ICMA 92444 and ICMA 93333 and male parents, AUBI 15124 and AUBI 15003 were found to be most promising or emerging for grain yield. The hybrids: ICMA 93333 x AUBI 15022, ICMA 98222 x AUBI 15051 and ICMA 99222 x AUBI 15004 were identified and suggest to further study as these hybrids shown better combinations as these hybrids out yielded the standard hybrid check AHB 1200 Fe and AHB 1269 Fe and also population mean for grain yield per plant. These identified parents and hybrids also displayed higher intensity of expression for one or more other characters simultaneously under study. An appreciable or majorable amount of heterosis was found for all the characters or traits and higher magnitude was observed for fodder yield per plant and other characters. The crosses showing heterosis for grain yield were observed to be influenced by heterosis for one or

more important components of the grain yield or yield. To cite an example, the combination ICMA 93333 x AUBI 15022 showing very high % of heterosis for grain yield also shown or exhibited significant heterosis in desirable direction for other three characters.

6. Conclusion

It was observed that most of the hybrids exhibiting higher grain yield than the standard hybrid check AHB 1200 Fe and AHB 1269 Fe were based on two females *viz.*, ICMA 93333 and ICMA 98222, and involved based on males *viz.*, AUBI 15022, AUBI 15051 and AUBI 15004. Therefore, these parents seems to be most potential and deserve due consideration in further hybrid development programme in pearl millet or Bajra. The additive gene action was found to be an important for days to 50% per cent flowering, days to maturity and plant height.

7. References

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