Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; Sp 9(5): 480-483
Received: 17-08-2020
Accepted: 05-10-2020

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Analysis of variance for combining ability, gene action and heritability, Proportional contribution of lines, testers and lines x testers of different characters in pearl millet (*Pennisetum glaucum* (L.)

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Abstract
The present investigation 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. However, the other crosses which showed promise were ICMA 98222 x AUBI 15003 for No. of effective tillers per plant, ICMA 98222 x AUBI 15004 for earhead length, ICMA 93333 x AUBI 15051 for earhead girth, ICMA 92444 x AUBI 15124 for 1000 grain weight and ICMA 93333 x AUBI 15015 for fodder yield per plant. Thus, it desirable that these parent have to be utilized in future bajra or pearl millet improvement programme.

Keywords: Analysis, variance, combining ability, gene action, heritability, characters, line, tester, pearl millet

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) [3], 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. 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.

Materials & 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.

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

S. No.	Crosses	S. 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

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.

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.

Review of literature

Jethva *et al.*, (2011) [1] studied combining ability gca and sca for grain yield and its component in pearl millet. They indicated and given the preponderance of additive type of gene action in the expression of ear head length and ear head girth, while non-additive gene action was more importance for no. of effective tillers per plant, ear head weight, 1000

seed weight, harvest index, threshing index, fodder yield per plant and protein content.

Thakare D. S. (2011) observed that the *gca* variance was higher than the sca for the characters *viz.*, days to 50 per cent flowering, plant height, number of effective tillers per plant and earhead girth and number of grains per cm2 which shows presence of additive gene action in above important characters. the characters days to maturity, earhead length, grain yield per plant, grain yield per ha, fodder yield per plant, 1000 grain weight and protein content, the sca variance are higher than the gca variance which indicates the preponderance of non-additive gene action.

Yadav *et al*., (2012) [3] observed and concluded that the magnitude of SCA was more important for traits viz., number of productive tillers per plant, plant height, panicle length, panicle weight, 1000 grain weight and grain yield, indicating that non-additive genetic variance (dominance variance) was mainly responsible or due to in the inheritance of these traits. They further stated that the predominance of non- additive interaction is also sometimes caused by the presence of epistasis and /or a correlated gene distribution.

Mangra *et al*., (2015) [2] observed and noted the ratio of GCA and SCA variance indicated the predominance of non-additive gene action for the characters days to 50% flowering, number of nodes per plant, plant height, number of productive tillers per plant, ear head weight per plant, days to maturity, 1000-grain weight, dry fodder yield per plant, grain yield per plant, harvest index and threshing index and additive gene action for ear head girth and ear head length.

Result & Discussion

Analysis of variance for Combining ability and specific combining ability

Analysis of the variance of combining ability for the different characters under the investigation or study is presented in Table 2. This analysis was carried out with a view to test combining ability gca ans sca of parents and hybrids.

It was revealed or noted from the Table 7 that, the mean sum of squares for replication were non-significant for all the characters. The magnitudes of mean sum of squares due to crosses were found to be significant for all the characters. While due to males were significant for all the characters except plant height and earhead girth.

Table 2: Analysis of variance for combining ability

Source of variation	d.f.	Days to 50%flowe-ring	Days to maturity	Plant height	Total No. of tillers/plant	No. of effective tillers/ Plant	Ear head length	Ear head girth	1000 grain weight	Grain yield /Plant	Fodder yield /plant
Replication(MSS)	1	2.22	3.28	28.94	0.06	0.007	5.13	0.06	0.20	1.43	0.20
Treatment(MSS)	43	11.46**	25.32**	374.94**	0.46**	0.32**	15.15**	0.30**	8.34**	101.80**	118.88**
Parent(MSS)	11	20.30**	21.49**	328.64**	0.67**	0.18**	17.47**	0.09**	9.48**	120.76**	80.92**
Lines(MSS)	3	25.83**	38.12**	497.54**	0.32**	0.21**	11.90**	0.079	20.87**	216.29**	88.80**
Tester (MSS)	7	19.39**	13.14**	140.37	0.20**	0.12**	12.46**	0.074	5.92**	96.90**	66.78**
Line vs tester (MSS)	1	10.08*	30.08**	539.81*	5.00**	0.42**	69.21**	0.29**	0.31	1.15	156.02**
Parent vs crosses (MSS)	1	1.48	27.72**	149.97	0.003	1.18**	5.56	1.09**	21.99**	345.40**	273.33**
Crosses(MSS)	31	8.64**	26.61**	398.63**	0.40**	0.35**	14.63**	0.35**	7.50**	87.22**	127.37**
Error(MSS)	43	1.87	1.81	88.73	0.020	0.01	1.52	0.03	1.09	5.43	10.41

*, ** denote significant at 5% and 1% levels, respectively

Gene action and heritability

The value of estimates of gca and sca variances, their ratios and gene action is presented in table 10. It was observed that the magnitude of specific combining ability variances was larger than general combining ability variance for the all characters except days to 50% flowering, days to maturity and plant height (cm).

The ratio of (δ2gca/δ2sca) was more than unity for characters *viz.*, days to 50% flowering (1.06), days to maturity (1.31), plant height (1.40) indicating additive gene action. Similarly the ratio of GCA/ SCA was less than 1 for total No. of tillers/plant (0.04), number of effective tillers/ plant (0.25), earhead length (-0.05), ear head girth (0.18), 1000 grain weight (-0.03), grain yield /plant (-0.02), fodder yield /plant (0.23) which indicate that presence of non-additive gene action.

The heritability in narrow sense was observed higher for days to maturity (52.69%) followed by number of effective tillers/ plant (44.11%), plant height (42.96%) and Fodder yield/plant (41.92%). The heritability was observed moderate for earhead girth (37.62%), days to 50% flowering (33.86%) and total No. of tillers/plant (28.56%). However, low estimate of heritability for grain yield /plant (23.39%), 1000 grain weight (18.29%) and earhead length (16.76%).

Table 3: The estimate of gca, sca, additive and dominance variances, gene action and heritability for different characters in pearl millet

S. No	Character	Variance GCA (□2 A)	Variance SCA (□2 D)	Ratio Var. gca/var. Sca (□2 A : □2 D)	Gene action	h2 (n.s.)%
1	Days to 50% flowering	0.96**	0.90**	1.06	Additive	33.86
2	Days to maturity	3.50**	2.67**	1.31	Additive	52.69
3	Plant Height	36.69**	26.17**	1.40	Additive	42.96
4	Total No. of tillers/plant	0.008	0.18**	0.04	Non-additive	28.56
5	No. of effective tillers/ Plant	0.03**	0.12**	0.25	Non-additive	44.11
6	Ear head length	-0.41	7.43**	-0.05	Non-additive	16.76
7	Ear head girth	0.02**	0.11**	0.18	Non-additive	37.62
8	1000 grain weight	-0.11	3.28**	-0.03	Non-additive	18.29
9	Grain yield /Plant	-0.09	36.21**	-0.02	Non-additive	23.39
10	Fodder yield /plant	10.54**	44.59**	0.23	Non-additive	41.92

*, ** denote significant at 5% and 1% levels, respectively.

Table 4: Proportional contribution of lines, testers and lines x testers for ten characters in Pearl millet

S. No.	Characters	Percent contribution of		
		Lines	Testers	Lines x Testers
1	Days to 50% flowering	13.85%	32.46%	53.68%
2	Days to maturity	33.10%	23.20%	43.69%
3	Plant Height	21.69%	30.87%	47.42%
4	Total No. of tillers/plant	15.53%	16.92%	66.53%
5	No. effective tillers/plant	24.97%	23.89%	51.13%
6	Ear head length	8.34%	15.79%	75.86%
7	Ear head girth	11.57%	38.10%	50.31%
8	1000 grains weight	5.06%	25.73%	69.19%
9	Grain yield / plant	0.17%	39.34%	60.47%
10	Fodder yield/plant	24.84%	22.18%	52.97%

The percent contribution of lines to total variance in hybrid or F1 were higher in magnitude or frequency as compared to testers for the characters days to maturity (33.10%), number of effective tillers per plant (24.97%) and fodder yield per plant (24.84%).

Percent contribution of testers to total variance were higher in frequency for the characters days to 50% flowering (32.46%), Plant Height (30.87%), Total number of tillers/plant (16.92%), Ear head length (15.79%), Ear head girth (38.10%) 1000 grains weight (25.73%) Grain yield / plant (39.34%) and Fodder yield/plant (22.18%).

The highest contribution in the hybrid or F1 sum of square was recorded by Ear head length (75.86%), 1000 grains weight (69.19%), Total number of tillers/plant (66.53%) and Grain yield / plant (60.47%).

Conclusion

The values of heritability narrow sense for most of these characters was also found to be moderate to high suggesting that there would be good response for selection to improve these characters or traits. Non-additive gene action was found to be important for total no. of tillers per plant, No. of effective tillers per plant, earhead length, earhead girth, 1000 grain weight, grain yield per plant, fodder yield per plant. Therefore, it would be possible to improve these characters by delayed selection. From the studies on combining ability it was observed that none of the parents showed good general combiner uniformly for all the characters or traits.

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