Electronic Journal of Plant Breeding, 5(4): 844-850 (Sep 2014)
ISSN 0975-928X

Research Note

Characterization and variability for important biometrical traits of newly developed male sterile lines of pearl millet [*Pennisetum glaucum* (L.) R. Br.]

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(Received: 20 Oct 2014; Accepted:03 Dec 2014)

Abstract
The present study on genetic variability, heritability and genetic advance for yield and yield contributing traits was conducted in 20 newly developed male sterile lines of pearl millet, developed at the Central Arid Zone Research Institute, Jodhpur, during the rainy season of the year 2013. Significant genetic variability among genotypes was observed for all the traits studied *i.e.* days to flowering, plant height, ear head length, ear head girth, effective tillers per plant, ear head number, ear head weight, grain yield, 500 grain weight and panicle harvest index. Mean performance of all traits revealed that ms lines CZMS 0021A and CZMS 0008A had higher manifestation of most of the desired traits. High values of genotypic coefficients of variation and phenotypic coefficient of variation were observed for traits like grain yield per plot, ear head weight per plot and effective tillers per plant, indicating that these traits contributed significantly to the total variability. High heritability estimates were observed for grain yield per plot, ear head weight per plot, plant height and days to flowering. High genetic advance as percentage, was recorded for grain yield per plot and ear head weight per plot. Greater magnitude of heritability coupled with higher genetic advance for grain yield per plot and ear head weight/plot revealed additive genetic effects for inheritance of these traits, while, high heritability estimates with low genetic advance indicated the presence of non-additive gene action for days to flowering, plant height and ear head length.

Key words:
Pennisetum glaucum, pearl millet, male sterility, genetic variability

Pearl millet (*Pennisetum glaucum* (L.) R.Br.) is the world's hardiest warm season coarse cereal predominantly cultivated as a grain crop but is also valued for its stover and fodder. The crop residue forms an important source of fodder (particularly in low rainfall regions) accounting for 40-50% of the dry matter intake and is often the only source of feed in dry months. India is the largest producer of pearl millet, both in terms of area (9.3 m ha) and production (7.97 m t), with an average productivity of 856 kg ha ⁻1. It contributes 7.8% to the total food grain area of the country and 3.9% to the total food grain production. Rajasthan constitutes about 50% area and 42% of production of pearl millet in the country. Other principle pearl millet growing states are Maharashtra, Uttar pradesh, Gujarat, and Haryana. Pearl millet is a cross pollinated crop and expresses high degree of heterosis for grain yield. This has been exploited through the development and cultivation of hybrids, as a result, yield of pearl millet increased substantially in states having good environmental conditions like moderate temperatures and better rainfall during cropping season. While, in Rajasthan, increase in productivity was not satisfactory due to lack of desired adaptability and characteristics required for this region (Kelley *et al.,* 1996). For successful cultivation of pearl millet hybrids in the arid western Rajasthan, it is important that the hybrids are developed using parents (male and female) that are adapted to the harsh climatic conditions of this region. Such hybrids would lead to better adaptation and performance. CAZRI, Jodhpur has a strong restorer parent development program (Manga and Dubey 2004, Manga, 2004, 2008, 2009, and 2013), and used them in crossing with male sterile (ms) lines from other sources to develop hybrids. Majority of the ms lines from other sources are having lack of adaptability to the harsh climatic conditions of arid region. Hence, a strong need was felt to develop pearl millet male-sterile lines that are well adapted to the harsh climatic conditions of western Rajasthan. Hybrids developed from such ms lines would have better adaptation to the harsh climatic conditions of this region, leading to their successful cultivation with increased productivity in this area. Keeping this in mind, a targeted male sterile development programme was initiated at CAZRI, Jodhpur in 2002. From B composites and segregating populaltions of BxB crosses, promising 'B' progenies were carried forward by pedigree selection to develop maintainer inbred lines, which were crossed with other ms lines as source of A_1 and A_4 cytoplasm, followed by backcrossing to develop a set of new male sterile lines (Manga and Kumar 2013). Development of these male sterile lines will add to the genetic diversity of existing ms lines as well hybrids.

Twenty new male sterile lines (ms) were developed at CAZRI Jodhpur, by crossing maintainers developed by selection from a B composite developed jointly by CAZRI and ICRISAT under CAZRI-ICRISAT collaborative project, and from F_2 populations of eighteen selected crosses from a diallel crosses among B lines of twenty ms lines coming from CAZRI, ICRISAT and HAU. Promising S_6 progenies from the composite and F_6 progenies from segregating populations were crossed with male sterile lines, *viz.*, ICMA 95111 and ICMA 94555 having A_1 cytoplasm and ICMA 97555 having A_4 cytoplasm and then backcrossed with their respective B lines to generate new ms lines. Pedigree of the ms lines is given in table 1. These male sterile lines were planted during the rainy season (July to September) of 2013, in a randomized complete block design with three replications at the Central Arid Zone Research Institute, Jodhpur (26º 18´ N, 73º 01´ E). The experiment was planted in the month of July and harvested in October. During the cropping period, crop received total precipitation of 389.9 mm. Out of this 244.8 mm rainfall was received in the months of July and August, remaining 145.1 mm rainfall was received in the last week of September, when the crop was almost matured. Each entry was planted in two rows of four meter length with row spacing of 60 cm and plant to plant spacing of 15 cm. The experiment was conducted in the loamy sand with applied fertilizer of 40 kg nitrogen ha^{-1} (50% basal and rest as top dressing) and 20 kg phosphorous ha^{-1} (basal dose). The standard cultural and agronomic practices were followed that included thinning and weeding at 15 days after sowing. Data were recorded on five plants for plant height, days to 50 per cent flowering, effective tillers per plant, ear head length (cm), ear head girth (cm), ear head weight (g) per plot, grain yield (g) per plot, and 500 grain weight (g). The above data were used to compute panicle harvest index as ratio of the grain yield to panicle weight. The data were subjected to analysis of variance according to Steel and Torrie (1980). The phenotypic and genotypic coefficients of variations were computed as suggested by Burton and Davane (1952). The heritability estimates were computed as ratio between estimates of genetic variance and phenotypic variance following formula and procedures as outlined by Singh and Chaudhary (1985). Expected genetic advance was estimated as described by Johnson *et al.* (1955). Correlation coefficients among traits were worked out according to Robinson *et al*. (1951).

Significant F values for all the traits (Table 2) revealed presence of genetic variability among the genotypes for all the traits studied *i.e.* days to flowering, plant height, ear head length, ear head girth, effective tillers per plant, ear head number/plot, ear head weight/plot, grain yield/plot, 500 grain weight and panicle harvest index. Mean values and range for different characteristics of each ms line is given in table 3. It was observed that the range was wider for days to flowering

(40-53 days), plant height (81-179 cm), effective tillers/plant (2 to 6), ear head numbers/plot (51-138), ear head weight/plot (522-2481 g), grain yield/plot (197-1855 g) and panicle harvest index (0.39-0.75), suggesting the possibility of selecting desirable material to utilize in the breeding programme. Detailed characteristics of each male sterile line are given in table 4. It was observed that CZMS 0009A was earliest in flowering (40 days) followed by CZMS 0021A (44 days), CZMS 0015A (45 days) and CZMS 0008A (46 days). These early materials assume great importance under arid environments of western Rajasthan, where, this pearl millet crop frequently faces terminal drought. With regard to plant height, CZMS 0021A was the tallest (179 cm) followed by CZMS 0008A (174 cm) and CZMS 0022A (164 cm). Male sterile lines, CZMS 0017A had shortest height (81 cm) followed by CZMS 0002A and CZMS 0018A (83 cm each). The trait, effective tillers per plant showed highest number of tillers per plant in CZMS 0009A (6 tillers per plant), followed by CZMS 0003A, CZMS 0008A, 0013A, 0014A, 0021A and 0022A (each 3 tillers per plant). The line, CZMS 0021A recorded the highest grain yield per plot (1855 g) followed by CZMS 0014A (1222 g) and CZMS 008A (967 g). CZMS 009A recorded the highest 500 grain weight (4.3 g) followed by CZMS 0007A (4.1 g) and CZMS 0021A (4.0 g). Panicle harvest index, which is an indicator of a variety's ability to set seed under terminal drought situations, was highest in case of CZMS 0021A (0.75) and was followed by CZMS 0011A (0.69) and CZMS 0009A (0.68). Based on overall mean performance, the ms lines CZMS 0021A and CZMS 0008A showed high positive values for most of the traits and these lines could be further utilized in the breeding programme.

Contribution of each character towards total variability is reflected in figure 1. It was revealed that grain yield per plot, ear head weight per plot, effective tillers per plant, plant height and ear head numbers/plot were the major contributors to the variability. A comparison of the phenotypic coefficients of variation (PCV) and genotypic coefficients of variation (GCV) revealed that, phenotypic coefficients of variation were higher than the genotypic coefficients of variation for ear head girth, effective tillers/plant and 500 grain weight, indicating the influence of environment. The remaining traits showed meagre difference between PCV and GCV. High GCV and PCV were observed for traits *viz*., grain yield per plot, ear head weight per plot and effective tillers per plant, indicating that variation for these traits contributed significantly to the total variability. Similar results have earlier been reported by Manga (2013), and Borkhataria *et al.*, (2005).

Though the total variability present in a character is indicated by the coefficient of variation, the extent of variability, which could be transferred from parent to offspring, would determine the response to selection and this is provided by the estimates of heritability. The heritability estimates for various traits ranged from 0.22 to 0.94. High heritability estimates were observed for grain yield per plot (0.94), ear head weight per plot (0.93), plant height (0.87) and days to flowering (0.84). This indicated the prospects of improvement in these traits through selection. This observation is in agreement with the results of Govindaraj *et al*. (2010) and Dubey and Manga (2005). The traits, ear head length, ear head girth, effective tillers/plant, ear head numbers/plot and panicle harvest index showed moderate values of heritability, while, low heritability was observed for 500 grain weight. Further, heritability in combination with genetic advance has been found to be a more effective and reliable by means of predicting response to selection. Genetic advance expressed as percent of mean showed wider range of variations for different traits. The high estimates of genetic advance as percent was recorded for grain yield per plot and ear head weight per plot. Greater magnitude of heritability coupled with higher genetic advance for grain yield per plot and ear head weight per plot is the evidence that these plant traits were under the control of additive genetic effects for inheritance of these traits, and hence selection should lead to fast genetic improvement of these traits.

However, high heritability estimates with low genetic advance were observed for days to flowering, plant height and ear head length. This indicates the presence of non-additive gene action, thus simple selection will not be effective for screening of these characters for potential breeding programme.

Overall the study revealed that the existence of sufficient genetic variability among the newly developed ms lines for various traits. Based upon mean performance for grain yield/plot CZMS 0021A, CZMS 0014A and CZMS 008A were found to be promising and could be utilized in different hybridization programme with different restorer lines to develop new hybrid combinations.

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Table 1. Pedigree of male sterile lines of pearl millet developed at CAZRI, Jodhpur

Male sterile line	Pedigree	Cytoplasm
CZMS 0001A	95111A source of A_1 cytoplasm backcrossed to CZMS 0001B = ICMB 95111 x [843B x EEBC-S1-407]12-2-B-B)7-2-B-B-B-B-1-1-1-1	A_1
CZMS 0002A	95111A source of A_1 cytoplasm backcrossed to CZMS 0002B = IC CZBC C0-96-5-B-1-2-1-1	A_1
CZMS 0003A	95111A source of A_1 cytoplasm backcrossed to CZMS 0003B = ICMB 95111 x [843B x EEBC-S1-407]12-2-B-B)7-2-B-B-B-B-2-1-1-1	A_1
CZMS 0004A	94555A source of A_1 cytoplasm backcrossed to CZMS 0004B = IC CZBC C0-60-3-B-2-1-1-1-1	A_1
CZMS 0005A	94555A source of A_1 cytoplasm backcrossed to CZMS 0005B = IC CZBC C0-60-3-B-2-1-2-1-1	A_1
CZMS 0006A	94555A source of A_1 cytoplasm backcrossed to CZMS 0006B = IC CZBC C0-96-5-B-1-2-2-1	A_1
CZMS 0007A	94555A source of A_1 cytoplasm backcrossed to CZMS 0007B = IC CZBC-C0-19-5-B-1-1-1-1-1	A_1
CZMS 0008A	97555A source of A_4 cytoplasm backcrossed to CZMS 0007B = [ICMB 94555 x ICMB 96333] -4-B-1-1-1-1	A_4
CZMS 0009A	97555A source of A_4 cytoplasm backcrossed to CZMS 0009B = [ICMB 94555 x ICMB 96333] -4-B-2-1-1-1	A_4
CZMS 0011A	97555A source of A_4 cytoplasm backcrossed to CZMS 0011B = IC CZBC C0-60-3-B-2-1-2-2-1	A_4
CZMS 0012A	97555A source of A_4 cytoplasm backcrossed to CZMS 0012B = IC CZBC C0-96-5-B-1-3-1-1	A_4
CZMS 0013A	94555A source of A_1 cytoplasm backcrossed to CZMS 0013B = ICMB 95111 x [843B x EEBC-S1-407]12-2-B-B)7-2-B-B-B-B-2-1-1-2	A_1
CZMS 0014A	94555A source of A_1 cytoplasm backcrossed to CZMS 0014B = ICMB 95111 x [843B x EEBC-S1-407]12-2-B-B)7-2-B-B-B-B-3-1-1-1	A_1
CZMS 0015A	97555A source of A_4 cytoplasm backcrossed to CZMS 0015B = IC CZBC C0-60-3-B-2-1-2-2-2	A_4
CZMS 0017A	97555A source of A_4 cytoplasm backcrossed to CZMS 0017B = IC CZBC C0-60-3-B-2-1-3-1-1	A_4
CZMS 0018A	97555A source of A_4 cytoplasm backcrossed to CZMS 0018B = IC CZBC C0-60-3-B-4-1-1-1-1	A_4
CZMS 0019A	97555A source of A_4 cytoplasm backcrossed to CZMS 0019B = IC CZBC C0-60-3-B-2-1-5-1-1	A_4
CZMS 0020A	97555A source of A_4 cytoplasm backcrossed to CZMS 0020B= IC CZBC C0-60-3-B-2-6-1-1-1	A_4
CZMS 0021A	97555A source of A_4 cytoplasm backcrossed to CZMS 0021B = IC CZBC C0-60-3-B-2-5-1-1-1	A_4
CZMS 0022A	97555A source of A_4 cytoplasm backcrossed to CZMS 0022B = (DTBLT-T-15-P2-P4) IC CZBC C0-60-3-B-2-4-2-1-1	A_4

Table 2. Analysis of variance for various traits of pearl millet male sterile lines

Source	df	Mean sum of squares									
		DF	PHT	EL	EG	ET	EHN	EHW	GY	500GW	PHI
Replication	2	0.32	152.9	0.91	0.01	0.969	314.8	86933*	42739*	0.503	0.002
Genotype	19	30.57**	2897.2**	20.47**	0.127**	2.421**	1401.4**	712825**	430449**	0.394*	0.024**
Error	38	1.81	132.4	1.76	0.029	0.502	242.7	18628	9226	0.211	0.004

DF-Days to flower; PHT-Plant height; EL-Ear head length; EG-Ear head girth; ET-Effective tiller/plant; EHN – ear head number/plot; EHW-ear head weight g/plot, GY-Grain yield g/plot; PHI-Panicle harvest index; 500 GW- 500 grain weight

Table 3. Mean, range, and other variability parameters for different characters in pearl millet

Character	Mean	Range	PCV	GCV	h^2(bs)	GA	GAM
Days to flowering	48.38	40-53	6.98	6.40	0.84	5.85	12.10
Plant height (cm)	120	81-179	26.95	25.20	0.87	58.48	48.54
Ear head length (cm)	14.31	11-20	19.76	17.45	0.78	4.54	31.74
Ear head girth (cm)	1.60	1.17-1.97	15.57	11.26	0.52	0.27	16.77
Effective tiller/plant	2.63	1.73-5.72	40.63	30.41	0.56	1.23	46.89
Ear head numbers/plot	79.68	51-138	31.47	24.66	0.61	31.73	39.82
Ear head weight/plot (g)	996	522-2481	50.19	48.28	0.93	953.31	95.68
Grain yield/plot (g)	605	197-1855	63.94	61.94	0.94	747.73	123.60
500 grain wt (g)	3.69	3.03-4.27	14.14	6.67	0.22	0.24	6.49
Panicle harvest Index	0.58	0.39-0.75	17.86	14.39	0.65	0.14	23.89

PCV-Phenotypic coefficient of variation; GCV- genotypic coefficient of variation:
h^2(bs)- Heritability in broad sense; GA- Genetic advance; GAM- Genetic advance as percent of mean

Table 4. Mean performance for different traits in CAZRI bred twenty new ms lines of pearl millet MS line

	DF	PHT	EL	EG	ET	EHN	EHW	GY	500GW	PHI
CZMS 0001A	48	110	14	2.0	2	62	743	374	3.6	0.50
CZMS 0002A	51	83	14	1.7	2	65	649	412	3.0	0.64
CZMS 0003A	48	85	15	1.4	3	95	868	523	4.1	0.60
CZMS 0004A	53	119	12	1.6	2	73	616	265	3.7	0.42
CZMS 0005A	51	151	17	1.7	2	61	1002	592	3.4	0.59
CZMS 0006A	51	99	11	1.8	2	65	654	376	3.3	0.57
CZMS 0007A	47	129	19	1.5	3	89	1042	597	4.1	0.57
CZMS 0008A	46	174	17	1.7	3	104	1666	967	3.4	0.58
CZMS 0009A	40	124	16	1.2	6	138	1078	734	4.3	0.68
CZMS 0011A	46	116	13	1.6	2	58	805	562	3.7	0.69
CZMS 0012A	48	120	15	1.5	2	51	522	197	3.3	0.39
CZMS 0013A	53	138	14	1.5	3	81	1093	717	3.5	0.66
CZMS 0014A	49	148	16	1.9	3	101	1871	1222	3.8	0.65
CZMS 0015A	45	126	17	1.5	3	66	557	365	3.7	0.65
CZMS 0017A	48	81	13	1.5	2	79	900	463	4.0	0.51
CZMS 0018A	49	83	20	1.5	2	62	651	315	3.9	0.48
CZMS 0019A	49	88	12	1.5	2	88	915	479	4.1	0.53
CZMS 0020A	48	92	12	1.4	2	73	837	494	3.9	0.60
CZMS 0021A	44	179	18	1.9	3	112	2481	1855	4.0	0.75
CZMS 0022A	53	164	16	1.8	3	73	977	591	3.1	0.61
CD 5%	2	18	2	0.3	1	25	218	153	0.7	0.09

DF-Days to flower; PHT-Plant height; EL-Ear head length; EG-Ear head girth; ET-Effective tiller/plant; EHN-ear head number/plot; EHW-ear head weight g/plot, GY-grain yield g/plot; PHI-Panicle harvest index; 500 GW-500 grain weight (g).

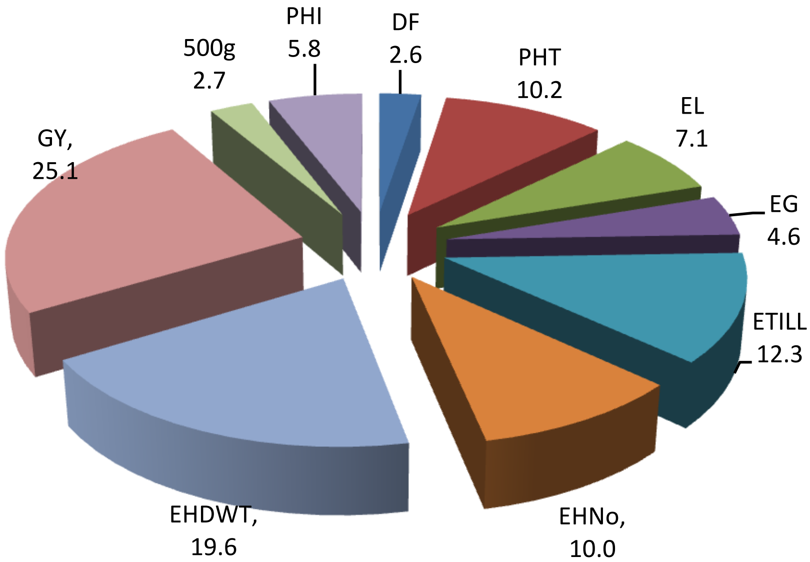

Fig. 1. Contribution of plant traits towards total genetic variability in the material

DF-Days to flower; PHT-Plant height; ETILL-Effective tillers per plant; EL-Ear head length; EG-Ear head girth; EHN-Ear head numbers/plot; EHW-Ear head wt g/plot, 500 GWT-500 grain wt (g).; GY-Grain yield g/plot; PHI-Panicle harvest index