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Evaluation of landraces and elite populations of pearl millet for their potential in genetic improvement for adaptation to drought-prone environments

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Abstract

Pearl millet growing regions in north-western India are characteristically drought-prone which emphasizes the importance of drought tolerance for pearl millet cultivars targeted for these regions. This study was conducted to evaluate the potential of five each of landraces and elite composites by evaluating their 25 crosses under drought conditions of arid zone for three years. Variation in landraces and elite composites accounted for more than 60% of variation in crosses for various traits. Both landraces and elite composites possessed contrasting GCA effects showing their differential ability to produce crosses adapted to drought environments. While the landrace 220 had significant and positive effects for biomass and stover yield, the landrace 184 had significant negative effects for biomass, grain and stover yields. The landraces 235 and 238 largely produced grain type materials. Elite composites, in general, had much lesser effects than landraces. The elite composite 923 had maximum positive effects for grain yield which was presumably due to its positive significant effects for harvest index and average effect for biomass. The composite HHVBC had highest desirable effects for stover yield and hence can be a potential source of improving stover yield in the genetic background of elite material. The results showed that there existed exploitable differences in landraces and elite composites which can be utilized in genetic improvement for adaptation to drought-prone environments.

Key words: Pearl millet, drought tolerance, landraces, genetic diversification, adaptation

Introduction

The arid regions of north-western India represent one-third area of pearl millet [*Pennisetum glaucum* (L.) R. Br.] in India. These regions receive very low annual rainfall (200-400 mm) and distribution of rains during the crop season is also erratic [1]. High evaporational losses and low water-holding capacity of soils further amplify the moisture stress which seriously affects pearl millet growth and yields. This situation emphasizes the importance of drought tolerance for pearl millet cultivars targeted for arid regions.

The landraces commonly grown in western Rajasthan are good sources of drought tolerance [2] but often fail to respond to better environments. On the other hand, elite genotypes have much higher yield potential expressed under optimum growing conditions but may not necessarily possess the required levels of drought adaptation [3-5]. As a result, a high cross-over genotype x environment interactions are often encountered in pearl millet with adapted landraces significantly outyielding elite materials in severe drought stress environments and elite material providing higher yields in optimum environments [6-8]. Hence genetic diversification of landraces using elite genetic materials has been suggested as an alternative approach [9] to amalgamate drought tolerance and high yield [10]. This study was, therefore, conducted to evaluate effects of selected landraces and elite composites in producing crosses that provide high grain and stover yields under drought conditions of arid regions.

Materials and methods

Five landraces and five elite composites were chosen for this study. The landraces 108, 184, 221, 225 and 238 were collected from western Rajasthan between 2001 and 2003 [11]. The elite composites included

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HHVBC, SRC II, MCSRC, MCNELC and 923 which were developed mainly from Togo African germplasm at ICRISAT and had no known contribution of Indian material in their parentage. Each of five landraces was manually crossed with five composites taking advantage of protogynous nature of flowering in pearl millet. A minimum of 100 plants from parental populations was used in each cross.

Twenty-five crosses and ten parental populations were evaluated during *Kharif* seaons for three years (2006-2008) at the Central Arid Zone Research Institute, Jodhpur using randomized block design with three replications. Each entry was grown in two rows of 4m length spaced at 60 cm. The plant-to-plant distance of 15 cm was maintained by thinning out extra plants within two weeks of sowing. Each year, the trials received a fertilizer dose of 40 kg N and 20 kg P_2O_5/ha. The weeds were controlled manually.

Data on flowering was recorded as number of days from sowing till emergence of stigma in the main panicle of 50% plants in a plot. Average length of main panicle of five randomly taken competitive plants in a plot recorded at maturity was taken as mean panicle length. At the time of harvesting, all panicles in a plot were harvested, counted, dried, weighed and threshed. Grain and dry stover yields were calculated on plot basis. The weights of dry panicles and stover were added to obtain biomass. Harvest index was calculated as ratio of grain yield and biomass expressed in percent.

The data were subjected to analysis of variance (ANOVA) for individual environment as well as across environments assuming fixed effect model of analysis.

Table 1. Mean days to flower, biomass, grain and stover yields, yield components and rainfall during three years of evaluations at Jodhpur

Trait	Unit	2006	2007	2008
Time to flower	days	46.6	60.5	48.6
Biomass yield	g m^{-2}	414.9	532.2	766.4
Harvest index	%	19.4	18.8	24.2
Stover yield	g m^{-2}	287.1	334.9	507.0
Grain yield	g m^{-2}	80.5	100.1	185.5
Panicles m^{-2}	no.	8.9	10.1	11.1
Panicle length	cm	27.7	31.4	28.1
Rainfall	mm	208.0	229.0	197.0
Pre-flowering	mm	197.0	166.0	183.0
Post-flowering	mm	11.0	62.0	13+25*

*In form of life-saving irrigation

The variation in crosses was partitioned into variation due to landraces, composites and landrace x composite interactions. The general combining ability (GCA) effects of individual landrace and elite composite were determined following the line x tester analysis [12]. The GCA for each parental population was estimated as the mean of all crosses involving that parent minus the overall mean. Significance of the parental GCA was determined by t-test with error d.f.

Results and discussion

Growing conditions

During three years of evaluation, the rainfall during the crop period varied from 197 to 229 mm (Table 1) which was 35-45% lower than the long-term average rainfall (360 mm) of Jodhpur. The years also varied considerably in distribution of rainfall which primarily determined the trial productivity. The total rainfall in 2006 was 208 mm, most of which fell before mean flowering time. The crop was severely affected by drought stress during post-flowering period resulting in low biomass (415 g/m^2) and harvest index (19%). In 2007, trials faced a drought spell of 3 weeks immediately after sowing which resulted in delayed flowering (Table 1). The 62 mm of post-flowering rains could do only a partial crop recovery and yields were still low with mean biomass of 532 g/m^2. The year 2008 received only 197 mm of seasonal rains, almost all of which was received during early vegetative growth stage period. The crop experienced very severe moisture stress from flowering stage onwards and was on the verge of extermination and hence was provided a life-saving irrigation of approximately 25 mm after 55 days of sowing. The mean biomass yield was 776 g/m^2 with a harvest index of 24%. Thus the environmental conditions encountered during evaluations provided excellent opportunities to assess the performance of test genetic materials under average drought conditions implying that the results are applicable for drier environments normally encountered in the arid zone.

Effects of landraces and elite composites

Highly significant mean squares due to crosses suggested that the crosses differed significantly for all measured traits (Table 2) and variation among them could be partitioned further into that due to landraces, elite composites and landrace x composite interactions.

Landraces contributed significantly in determining the performance of crosses for all traits (Table 2). The

Table 2. Mean squares from analysis of variance for biomass, grain and stover yields and other phenotypic traits in pearl millet evaluated at Jodhpur for three years

Source	df	Mean squares						
		Days to flower	Panicle length	Pan/m^2	Biomass	Harvest index	Grain yield	Stover yield
Environments (E)	2	6106.5**	495.5**	86.7**	3338313**	909.6**	294788**	1444161**
Crosses	24	16.5**	25.8**	13.5**	17553**	54.7**	3131**	7985**
Landrace effect (L)	4	63.2**	10.9*	52.6**	50426**	169.9**	9777**	18858**
Elite composite effect (C)	4	7.5**	93.1**	10.9**	1767*	25.6*	869*	3343**
L x C effect	16	7.0**	12.7**	4.4**	13281**	33.2**	2035**	6427**
E x Crosses	48	5.5**	8.6**	5.1**	21343**	24.2**	1697**	11427**
E x L effect	8	16.1**	14.3**	10.6**	23749**	82.1**	3115**	15020**
E x C effect	8	2.4	14.6**	3.2	17209**	14.9*	1051**	11474**
E x L x T effect	32	3.6**	5.7*	4.2**	21775**	12.1*	1504**	10517**
Error	204	1.648	3.3	1.7	691	7.3	302	550

*,**Significant at P<0.05 and 0.01, respectively

mean magnitude of variation accounted for by landraces, calculated as per cent sums of squares (SS) due to landraces out of SS due to crosses, was over 50% for all traits except panicle length, for which only 7% of cross variation was explained by landraces but it was still significant (Table 2). Effects of landraces were significantly modified by environments as revealed by significant mean squares due to landrace x environment interactions suggesting multi-environment evaluation to obtain precise estimates of their effects.

The landraces possessed contrasting GCA effects showing their differential ability to produce crosses adapted to drought environments (Table 3). The landraces 184 and 221 represented two extremes for their ability to produce dual-purpose materials. The landrace 221 had significant and positive effects for biomass and stover yield and average positive effects for grain yield. On the other hand, landrace 184 had significant negative effects for biomass, grain and stover yields. This might be ascribed to their opposite GCA for flowering time. The landrace 221 inherited significantly greater earliness in their crosses which might have been contributed to their better performance for both grain and stover yields under terminal drought stress environments of this study. There is a significant advantage of earliness in late season moisture stress in pearl millet [13-16].

The landraces 235 and 238 largely produced grain type material as revealed by their significant positive GCA effects for grain yield. This was presumably due to their significant positive effects for harvest index coupled with either significant positive (landrace 235) or average positive (landrace 238) effects for biomass. These results are supported by an earlier study [17] which indicated that positive GCA effects for harvest index would result into significant positive GCA for grain yield but at the same time would also lead to negative effects for stover yield provided improvement in biomass is only modest. Such an indication was also obtained in this study as both these landraces possessed negative estimates (though non-significant) for stover yield. Both landraces 235 and 238 contributed earliness in their crosses.

Composites were also a significant source of variation for all traits (Table 2). However, their contribution was maximum for panicle length (>60%); for flowering, tillering, harvest index and grain and stover yields the contribution varied from 5 to 15%. Like landraces, their effects had significant interaction with environments for all traits. Elite composites, in general, had much lesser effects than landraces except for panicle length which was expected from their relative contribution in determining cross performance. Though both landraces and elite composites came from specific geographical regions, landraces represented relatively greater range in plant type in terms of tillering capacity, panicle size, biomass accumulation and its partitioning which might be influencing the magnitude of their effects [10].

The elite composite 923 had maximum positive

Table 3. General combining ability (GCA) estimates of five landraces and five elite populations for biomass, grain and stover yields and other phenotypic traits in pearl millet evaluated at Jodhpur for three years

Parents	Days to flower	Panicle length	Pan/m^2	Biomass	Harvest index	Grain yield	Stover yield
Landrace							
108	-0.76**	0.74*	0.19	11.63**	-0.03	0.29	6.39
184	2.10**	-0.07	-1.88**	-56.88**	-2.99**	-24.63**	-27.17**
221	-0.36*	-0.35	0.82**	31.74**	-0.39	1.81	29.30**
235	-0.54*	0.19	0.24	9.32*	1.44**	9.69**	-3.11
238	-0.43*	-0.52	0.62**	4.19	1.98**	12.85**	-5.42
Elite composite							
HHVBC	0.10	-0.31	-0.54*	7.68	-0.57	-1.28	14.50**
923	-0.68*	-1.77**	0.65*	2.20	1.30*	7.70*	-7.27*
SRC II	0.24	-0.59*	0.23	1.89	-0.05	-0.94	-2.18
MCSRC II	0.37*	2.08**	0.10	-9.09	-0.45	-3.23	-5.42
MCNELC	-0.03	0.60*	-0.44*	-2.68	-0.24	-2.26	0.38

*,**GCA effect significantly different from zero at P<0.05 and 0.01, respectively

effects for grain yield and negative effects for stover yield which was presumably due to its positive significant effects for harvest index and average effects for biomass. It was the only elite composite that had desirable significant effects for earliness. This composite made a contrast with other composite MCNELC in determining plant type of their crosses. While composite 923 significantly improved tillering and reduced panicle length of its crosses, composite MCNELC enhanced panicle length and reduced tillering. Thus these two composites would be an obvious choice to amalgamate tillering and panicle length in elite material. The composite HHVBC had highest desirable effects for stover yield and hence can be a potential source of improving stover yield in the genetic background of elite material. This assumes a particular importance for arid zone as pearl millet stover is as important as grain especially in drought years [18, 19] since its stover is used as the maintenance ration for livestock during long dry periods [20].

Though majority of variation (>60%) of crosses was accounted for by landraces and elite composites, the presence of significant landrace x elite composite interaction for all traits (Table 2) indicated that these interaction effects can best be exploited through hybridization of landraces with various elite composites.

The results of this study demonstrated that there existed exploitable differences in landraces and elite composite which can be easily uitlized in breeding for drought tolerance. Significant landrace x elite composite interaction also warrants positively for hybridization between these two groups of materials.

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