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Genetic variation and trait relationship in the pearl millet landraces from Rajasthan

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Abstract

Landraces of pearl millet (*Pennisetum glaucum*) are potential sources of adaptation to stress conditions. Genetic variation among landraces is of vital importance to breeding programmes that aim to produce improved landrace-based cultivars for marginal growing environments. Twenty-eight landraces of pearl millet from Rajasthan were evaluated in two contrasting environments to estimate genetic variation for nine traits including grain yield. Trait association was also studied with correlation analysis. Significant genetic variation was observed for six traits including time to flower, dry stover and total biomass yields. There were no genetic differences for panicles/plant and threshing percentage while differences for grain yield per se were significant at only 10% level of probability. Heritability estimates were low to moderate and ranged from 11 to 52%. Expected genetic advance with 5% selection intensity, expressed as per cent of mean, varied from 2-10%. Correlation analysis showed that grain yield was most strongly associated with biomass yield and stover yield. Plant height, panicle length and threshing percentage were also significantly associated with grain yield. However, individual trait could explain only 22-34% of variation in grain yield. Comparison between landraces and improved cultivars revealed that, in general, the landraces performed better in stress conditions while high yielding modern cultivars were clearly superior in more productive environment. In view of the limited variation for grain yield per se, the genetic diversification of landraces is suggested.

Key words : *Pennisetum glaucum*, pearl millet, landrace, adaptation, genetic variation and selection

Introduction

A landrace is a mixture of genotypes which evolved, largely as a result of natural selection over numerous generations, under the environmental conditions in which landraces are presently grown [1]. Natural selection was further assisted by farmers' selections for higher productivity. Thus natural selection coupled with human selection had led to the establishment of ecological well adapted local materials. Such landraces obviously have high adaptation to prevalent abiotic stresses [2-4].

During the past five decades significant progress has been made in developing the new improved cultivars in several crops. The development and rapid dissemination of high yielding varieties replaced the traditional landrace varieties and accelerated their extinction. This is particularly applicable to pearl millet (*Pennisetum glaucum* (L.) R. Br.) where considerable progress has occurred in the development of single cross hybrids during the past three decades [5-6]. Hybrids have virtually replaced the traditional landraces of pearl millet particularly in the areas having favourable growing conditions or made favourable by applying irrigation and fertilizer inputs [7- 8]. This has created a situation of genetic homogeneity and simultaneously increased the vulnerability to stress conditions. For this reason, there is renewed interest in landraces and local cultivars as a source of genetic variation.

Several studies have evaluated pearl millet landraces for various traits. Wilson *et al.* [9-10] evaluated the genetic diversity in landraces collected in central and south Burkino Faso and found considerable variation for plant height, panicle length and shape, maturity time, disease resistance and also for several seed characteristics. Oundeba *et al.* [11] characterised the landrace populations from Niger, Senegal and Sudan and observed that Nigar landraces were less variable in comparison to other African landrace populations. Pearl millet landraces collected from several parts of India have also been evaluated and characterised [12-13] for several morphological traits. However, the amount of genetic variation in pearl millet landraces has not been quantified. Such an information is of vital importance to breeding programmes that have the long-term goal of developing improved landrace cultivars for marginal crop environments such as found in the

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rainfed areas of north-western India. In the present study, we used landraces collected from north-western India to quantify the genetic variation that exists for grain yield and several productivity-related traits in landraces, and to explore the possibility of improving them through breeding programmes. In addition, association between grain yield and other plant traits was also studied.

Materials and methods

A total of 28 landraces from different parts of Rajasthan and two early maturing improved cultivars, hybrid HHB 67 and an open-pollinated variety RCB-IC 911, were included in this study. Among the landraces used, 26 were collected during kharif 1992 from various parts of Barmer district of Rajasthan. Other two landraces were from Bikaner and Jodhpur districts. Trials were conducted as rainfed at the Central Arid Zone Research Institute, Jodhpur, Rajasthan and the International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh. Total seasonal rainfall was 280 mm and 481 mm at Jodhpur and Patancheru, respectively. The crop experienced severe moisture stress at Jodhpur during early development stage. However, the crop recovered well following sufficient rains from flowering stage onwards, though the yields were still lower. Higher rainfall at Patancheru resulted into overall good growth of crop and higher yield levels.

Entries were evaluated in lattice design with three replicates in each of two environments. Each plot consisted of 4 m long four rows spaced 60 cm apart. Interplant distance within row was 30 cm at Jodhpur and 15 cm at Patancheru. Weeds were controlled by intercultivation and one to two hand weddings.

Data were recorded for time to flower as number of days from sowing to stigma emergence on the main panicle of 50% plants in a plot. Plant height (cm) and main panicle length (cm) were recorded on five competitive plants from central two rows of a plot, the mean values of which were used in analysis. Number of panicles/plant was obtained by dividing the total number of panicles by number of plants in a plot at the time of maturity. Panicles were sun-dried for two weeks and weighed before threshing them using an electricity-operated thresher. Both grain yield (g/m^2) and stover yield (g/m^2) were estimated on plot basis. Stover was cut at ground level and fresh weight recorded. One Kg sample of fresh stover was then chopped and sun-dried for two weeks. Dry stover yield of plot was determined as [dry weight of stover sample/fresh weight of stover sample] × fresh weight of stover. Grain, stover and panicle weights were added to get biomass yield per plot. Harvest index was calculated as the ratio of grain yield to biological yield and multiplied by 100; and threshing percentage as the ratio of grain weight and panicle weight expressed in percentage.

Data for both locations were analysed separately and error variances compared using Bartlett's test, which indicated homogeneity of error variances, and hence the results based on pooled analysis are presented. Pooled analysis of variance (ANOVA) was used to quantify the genetic differences among the landraces. The components of genetic variance were estimated by equating the expected mean squares with the observed mean squares and solving for individual variance components.

Results and discussion

Variation exhibited by various characters is shown in Table 1. Genetic differences were from significant ($P < 0.05$) to highly significant ($P < 0.01$) in six of nine traits including time to flower, dry stover yield and total biomass yield. The differences in grain yield per se were significant only at 10% level of probability, while there were no significant genetic differences for panicles/plant and threshing percentage among the landraces. Significant genetic variation exhibited by landraces for several yield-attributes like panicle length, time to flower and plant height used in this study indicated that selection for these characters might be effective. However, the variation for grain yield per se was indicated to be only limited. This might be due to the fact that most of the landraces included in this study came from Barmer district of Rajasthan and thus might not included the entire spectrum of variability at least for the grain yield per se. An earlier study [14] that included landraces from other parts of Rajasthan as well, also indicated that variation for grain yield per se though exists among landraces but variation within landraces was again limited. In fact, yield performance has been under strong human selection in landraces

Table 1. Phenotypic variation in 9 characters in 28 pearl millet landraces

Character	Unit	Range	Mean ± SE	Significance of F value for genotypes
Time to flower	days	47.5-57.5	51.1 ± 1.3	**
Plant height	cm	160.8-200.3	176.2 ± 5.9	**
Panicle length	cm	19.0-26.8	22.7 ± 1.1	**
Panicles/plant	no.	3.1-5.1	4.2 ± 0.4	ns
Grain yield	g/m^2	154.9-220.7	180.0 ± 13.9	+
Dry stover yield	g/m^2	228.9-341.8	282.8 ± 21.3	**
Biomass yield	g/m^2	453.1-626.7	534.4 ± 50.0	**
Harvest index	%	29.2-35.2	31.7 ± 1.6	*
Threshing percentage	%	64.2-73.3	68.2 ± 2.0	ns

+, * and ** significant at 10%, 5% and 1% level of probability, ns = non-significant over long time. Thus reduced variability for grain yield was not unexpected.

Table 2. Phenotypic (PCV) and genetic (GCV) coefficients of variation, components of variance, heritability (h^2) and genetic advance (GA) for 9 characters of pearl millet landraces

Character	Unit	PCV (%)	GCV (%)	h^2 (%)	GA as % of mean
Time to flower	days	3.14	2.29	53	4.71
Plant height	cm	3.71	2.56	48	5.29
Panicle length	cm	6.35	3.84	37	7.94
Panicles/plant	no.	9.98	4.71	22	9.65
Grain yield	g/m^2	6.34	4.01	40	8.26
Dry stover yield	g/m^2	8.81	4.90	31	10.10
Biomass yield	g/m^2	6.08	4.05	44	8.31
Harvest index	%	4.77	2.11	20	4.41
Threshing percentage	%	3.04	1.03	11	2.08

PCV was 2 to 3 times larger than GCV for panicles/plant and threshing percentage, while for other traits it was on an average 1.5 times as large as GCV. The heritability estimated ranged from a low value of 11% for threshing percentage to moderately high of 53% for time to flower. The moderate estimate of heritability was also shown by plant height, biomass yield and grain yield. Low values of heritability were given for harvest index and panicles/plant too.

The expected genetic advance, expressed as percentage of mean, varied from 2% for threshing percentage to 10% for dry stover yield. The magnitude of expected genetic advance ranged between 8% and 10% for panicle length, panicles/plant and grain and biomass yields, while time to flower, plant height and harvest index had relatively low value for genetic advance.

Effectiveness of selection is influenced by the magnitude of heritability and genetic advance. Moderate estimates of heritability and genetic advance observed for grain yield in this study corraborates well with the results of many other studies [15]. Moderate heritability estimate for grain yield suggests that the environmental effects constitute a considerable portion of total phenotypic variation. Thus, the selection for superior genotypes on the basis of yield per se may not be highly effective. Hence, for a more efficient improvement of grain yield selection should be made on components of grain yield. The relationship of plant characters with grain yield thus assumes a special importance as the basis for selecting high-yielding genotypes.

All traits except harvest index and threshing percentage were in general significantly correlated with each other (Table 3). Grain yield was most strongly associated with biomass and stover yields. High correlation coefficients of grain yield with stover yield indicated the possibility of improving grain and stover yields simultaneously. This result is encouraging since the stover yield is an extremely important criterion for farmer of arid zones [18] as it is the basis of dry season livestock maintenance ration. Association of grain yield with other traits viz., plant height, panicle length and threshing percentage was also positive and significant. However, the correlation coefficients between grain yield and these traits were not high enough to suggest them as alternated selection criteria as these traits could individually account for only 22-34% of variation in grain yield.

It appeared that late landraces tended to yield more as indicated by significant and positive correlation between grain yield and time to flower. In fact, the relationship between genotypes duration and grain yield depends upon the timing of water stress [19-20]. The late season rains at Jodhpur and good rains during crop season at Patancheru might have favoured the late genotypes resulting into a positive association between lateness and grain yield. Otherwise, in pearl millet early maturity is preferred as it is considered as a good drought escape mechanism in production areas where terminal drought is encountered because of early withdrawal of rains [21-22].

Table 3. Phenotypic correlations among 9 characters in pearl millet landraces

Character	Plant height	Panicle length	Panicles/ plant	Grain yield	Dry stover yield	Biomass yield	Harvest index	Threshing percentage
Time to flower	0.72**	0.48**	–0.71**	0.51**	0.64**	0.62**	–0.21	0.29
Plant height		0.64**	–0.64**	0.57**	0.77**	0.74**	–0.27	0.24
Panicle length			–0.68**	0.47*	0.65**	0.65**	–0.24	0.10
Panicles/plant				–0.28	–0.55**	–0.45*	0.33	–0.30
Grain yield					0.70**	0.86**	0.35	0.56**
Dry stover yield						0.96**	–0.38*	0.26
Biomass yield							–0.16	0.30
Harvest index								0.56**

*, ** significant at 10% and 5% level of probability

Table 4. Mean values of three traits in 28 pearl millet landraces and two improved cultivars at Jodhpur and Patancheru in 1993

Genotype	Grain yield (g/m^2)		Days to flower		Dry stover yield (g/m^2)	
.	Jodhpur	Patancheru	Jodhpur	Patancheru	Jodhpur	Patancheru
Nokha Local	86.2	242.5	60.7	41.3	188.9	307.9
BNO 73	91.9	236.6	61.0	42.7	204.6	307.0
BNO 12	95.3	251.5	57.7	40.0	212.8	283.5
BNO 13	100.7	300.5	59.0	42.0	208.5	332.5
BNO 24	93.1	302.3	54.3	42.3	199.4	343.5
BNO 30	99.2	308.5	62.7	44.7	231.3	357.4
BNO 40	85.3	224.5	55.7	41.0	190.8	300.4
BNO 44	93.5	272.6	55.0	42.7	199.1	353.3
BNO 45	79.4	243.8	62.7	45.0	192.0	393.7
BNO 46	100.6	294.6	64.0	45.7	264.0	419.6
BNO 48	91.2	222.4	60.3	43.0	219.8	307.4
BNO 49	74.7	268.4	61.7	41.7	187.5	330.2
BNO 51	82.8	262.2	61.7	41.7	192.9	345.8
BNO 52	119.9	319.2	61.0	44.0	263.8	403.7
BNO 53	106.4	273.6	59.7	43.0	246.8	330.7
BNO 55	82.3	284.1	55.0	42.7	164.3	354.9
BNO 58	87.0	261.9	55.0	43.7	206.6	420.2
BNO 59	103.8	290.0	63.0	47.0	270.8	407.1
BNO 60	95.3	220.8	56.3	41.7	198.3	259.5
BNO 61	91.0	267.9	61.0	42.7	219.7	396.5
BNO 66	107.8	278.2	64.3	43.3	258.2	406.9
BNO 72	77.6	235.1	57.7	40.7	200.5	318.1
BNO 74	88.9	233.2	55.0	40.0	205.8	308.5
BNO 75	86.6	242.4	61.3	41.3	173.9	336.5
BNO 77	101.4	259.1	59.7	41.7	213.4	333.8
BNO 78	95.0	284.2	55.0	41.7	214.1	382.0
BNO 79	93.8	245.8	57.7	41.0	249.9	357.5
LRE 179	95.0	346.4	65.0	50.0	208.0	450.4
HHB 67 (Check)	70.7	386.6	49.4	38.0	123.9	224.8
RCB-IC 911 (Check)	75.9	449.0	51.8	46.1	169.1	408.3
LSD (P = 0.05)	35.3	72.8	5.8	1.8	78.9	115.0

Later genotypes tended to grow taller with high stover and biomass yields but had lower panicles/plant. Similarly taller plants produced longer panicles and resulted into higher stover and biomass yields. As expected, stover and biomass yields were highly correlated. Similarly harvest index and threshing percentage showed positive correlations. These results are in agreement with earlier observations [15-17].

Mean values of grain and stover yields and time to flower for individual landraces along with two control cultivars in two environments are shown in Table 4. In both experiments RCB-IC 911 produced higher grain as well as stover yields than the other control, HHB 67. All but one landraces produced higher grain yields than both controls under low yielding environment of Jodhpur. As many as 13 landraces produced 25% or more grain yield than higher yielding control cultivar, RCB-IC 911 but only one landrace BNO 52 could significantly outyield it. The best landrace produced 58% higher grain yield than RCB-IC 911. However, in productive environment of Patancheru both controls were clearly superior to all the landraces. Superiority of landraces over modern cultivars under stress conditions and vice-versa confirmed the view that landraces have lower yield potential but yield substantially more, though not always significantly, than high yielding cultivars. None of the landraces could match the earliness of early maturing hybrid HHB 67 at either location.

Given that early maturing and dual purpose cultivars producing good grain as well as stover yield are the requirement of farmers, the potential landraces meeting these criteria were identified as BNO 13, BNO 24, BNO 44, BNO 52, BNO 53, BNO 55 and BNO 78. Thus these landraces can be potential source of earliness and high grain and stover yields. The cultivars derived from such landraces are expected to acceptable to farmers because of their good adaptation to the target environment and possessing the various trait combinations preferred by farmers.

One genetically broad population (BarPop) has been synthesised by utilising five landraces used in this study (BNO 46, BNO 52, BNO 53, BNO 59 and BNO 66) that were selected by farmers on the basis of their being true to typical landrace plant type [23]. This population has established its superiority over modern cultivars in extremely stress conditions [4] and thus could serve as suitable base material for deriving the cultivars suited to stress-prone environments.

Limited genetic variation exhibited by local landraces, as observed in this study, underlines the need for the genetic diversification of Rajasthan landraces using other suitable sources of variation. Given that local landrace types of Rajasthan, are characteristically high tillering, small seeded [13-14], west African landrace 'Iniadi' seems a potential source for introgression of variation. Because Iniadi has distinct features like lustrous and bold grain, compact, conical head with excellent exertion [24] that appeal to plant breeders and farmers. Apart from being early maturing and relatively photo-insensitive, its rapid grain filling [24] is another advantage in environments characterised by frequent terminal drought coinciding with grain filling periods.

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