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Exotic elite populations as sources for diversification of landraces of pearl millet [*Pennisetum glaucum* (L.) R. Br.]

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Abstract

The major requirement of pearl millet [*Pennisetum glaucum* (L.) R. Br.] breeding programmes targeting environmentally fragile arid regions is to breed genetically diverse materials that are both adapted to environmental stresses and also have an improved yield potential to allow them to respond to favourable conditions in good rainfall seasons. Genetic diversification of indigenous landraces using selected exotic, elite sources could be an effective mean to achieve this objective. This study evaluated 13 diverse, exotic populations for their phenotypic characteristics, their productivity under arid zone conditions, and their potential usefulness as sources of diversification for local landraces. The biomass productivity, which was the major determinant of both grain and stover productivity, varied between 747 g m^{-2} and 942 g m^{-2}. A higher panicle number and early flowering favored greater grain yield, while later flowering and greater height favored higher stover yield. Although biomass and HI were negatively correlated, grain yield was similarly and positively correlated to both, suggesting that both biomass accumulation and its partitioning to grain are important in determining grain yield performance in arid environments. The best populations for grain yield were ICMV 98792, MCNELC and ICMP 96132, which outyielded two improved checks (Raj 171 and CZP 923) by 16-24%. The magnitude of superiority of best populations over two checks for stover yield was 55-83%. There existed a good opportunity to select exotic sources with different combinations of panicle length and tillering. In addition, the downy mildew reaction of elite exotic sources is not likely to be a deterrent factor in utilizing the selected elite populations as sources of diversification of landraces.

Key words: Pearl millet, adaptation, genetic diversification, exotic germplasm, landraces

Introduction

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is the most adapted cereal crop to the arid and drier semi-arid areas of India and is valued equally for both its grain and stover. Presently, traditional landraces that possess good adaptation to the environmental stresses of drought and high temperature conditions are widely grown in western Rajasthan, though they have a much lower yield potential than modem elite cultivars [1, 2] and appear to lack adequate disease resistance [3]. As a result millet productivity in Rajasthan, and especially in western regions, continues to be the lowest from among pearl millet growing states [4].

The major requirement of millet breeding programmes that aim to improve food security in fragile arid regions by developing suitable cultivars is to breed populations that are adapted to environmental stresses and also have the ability to provide higher yield during exceptional favourable seasons [5]. There can be two approaches to achieve this objective. In the first, the adapted landraces are taken as base material and then improved for productivity, by direct selection. This approach ensures adaptation but puts a ceiling on degree of improvement in productivity that might be obtained [6] as landraces generally have limited variation for grain yield per se [2,7] though there have been a few exceptions [8]. Moreover, the new product is not very different from the source material which is sometimes an important factor influencing adoption of new cultivars. In the second approach, adapted landraces could be hybridized with new (exotic) germplasm with character combinations lacking in landraces [9] and then using this hybridized material for improving the productivity. The obvious advantage of this approach is that novel gene combinations will be created, leading to new character combinations like bold seed, disease resistance and high productivity potential that are not found frequently in landraces [10, 11].

The most critical step for adopting second approach is to have appropriate exotic sources which possess the traits complimentary to those in landraces like higher productivity potential, under arid zone conditions. The present study was, therefore, planned to evaluate very diverse elite populations of exotic origin so as to identify potential sources with which diversify the genetic base of indigenous landraces. The association of grain yield with other traits was also studied to identify morphological traits influencing grain and stover yields in the elite populations.

Materials and methods

Genetic material: The genetic material consisted of 13 exotic elite pearl millet populations obtained from ICRISAT that had their genetic origins mainly from drier areas of sub-Saharan Africa, that is from environments which are characterized by similar limitations as those of the arid zone of NW India: frequent drought, high temperatures and poor soils. The brief history of each population is provided in Table 1. Two checks, improved open-pollinated varieties CZP 923 and Raj 171, which were bred in the arid zone, were included for comparisons.

Evaluations: The material was evaluated at two locations in western Rajasthan. The evaluations were undertaken under rainfed conditions at the Central Arid Zone Research Institute, Jodhpur in 2001 and at the Regional Research Station of Rajasthan Agricultural University at Nagaur in 2003. Each entry was grown in four rows of 4m length spaced at 60 cm apart in either four (Jodhpur) or two (Nagaur) replications. The plots were oversown with a planter but were thinned within two weeks of sowing at a plant-to-plant distance of 20 cm. Both trials were well fertilized and managed; moisture was generally adequate in both years.

Data on days to flower were recorded as number of days from sowing till stigma emerged in the main panicles of 50% plants in a plot. Grain yield and stover yield were recorded on plot basis and converted to g m^{-2}. Dry panicle and stover weights per plot were added to obtain total biomass yield that was also converted to g m^{-2}. Only two central rows were harvested at Nagaur. Harvest index was determined as ratio of grain yield to total biomass and was expressed in percentage. Plant height and panicle length were recorded on 5 randomly taken competitive plants from central two rows of each of the plots at the time of maturity. Panicles per plot were counted after harvesting and were expressed as panicles m^{-2}. The number of downy mildew-infected plants was counted at 30 days after planting and at dough stage at Jodhpur location. Downy mildew incidence was calculated as percentage of plants infected with downy mildew. The data were analyzed for individual as well as across locations using ANOVA. The simple correlation analysis was run using mean data of two locations to study the relationship among traits.

Table 1. Brief breeding history of thirteen exotic pearl millet source populations used in the study. All populations (except as noted) were bred at ICRISAT, Patancheru

ICMP 87200	Initial cycle random mated bulk of Ergot Resistant Composite (ERC) developed by random mating 52 selected ergot resistant lines
ICMP 89410	Tenth cycle random mated bulk of Medium Composite (MC) developed from 197 geographically diverse lines from India and Africa that flowered in 45-55 days
ICMP 96132	Second cycle random mated half sib bulk of Large Grain Population (LaGraP) developed by random mating lines from Large Seeded Gene Pool, ICGP, ICTP and BSEC lines.
ICMP 96201	First cycle random mated half sib bulk of Large and Bold Headed Composite (LBHC) developed by random mating SRC II C2, ESRC II C2, IVC-C8, ICMV 88909 and ICMV 31293
ICMV 98552	Bred by random mating 15 S1 progenies of the New Elite Composite II (NELC II CO) developed by random mating population F_1s of ICMV 155, SenPop, ICMV 91059, SRC II, Lubasi and ERC.
ICMV 98792	Bred by random mating 20 S1 progenies of the Smut Resistant Composite III (SRC III CO) which was developed by random mating in population of IVC, ESRCII, Lubasi, ERC, SRCII and SenPop.
IAC-ISC TCP3	Bred at ICRISAT, Sadore by random mating 7042(DMR) and 9 ISC open-pollinated varieties/populations.
GICKV 93191	Bred from Early Composite 91 (EC 91) which was developed by random mating EC II and ESRC II.
Sudan Pop I	Developed by random mating F_1s involving 3 parents (ICMV 91059, SenPop, Sudan yellow) selected from the late population diallel
Sudan Pop II	Developed by random mating F_1s involving 8 parents (ICMV 91059, SenPop, ICMP 91751, AfPop 90, ICMP 92591, ICMP 87307, ICMV 155 and Sudan yellow) selected from the late population diallel
Sudan Pop III	Developed by random mating F_1s involving 5 parents (ICMV 91059, SenPop, ICMV 155, ICMP 91751 and Sudan yellow) selected from the late population diallel.
MCNELC	Bred by random mating 23 selected F_1s of the cross of the Medium Composite 94 (MC 94) × NELC II
MCSRC	Bred by random mating 20 selected F_1s of MC 94 × SRC III

Results and discussion

The biomass productivity obtained at the two test environments was between 747 g m^{-2} and 942 g m^{-2} (Table 2). Mean biomass productivity of the two trials was 845 g m^{-2} reflecting the generally favorable nature of the test environments, which allowed the expression of productivity potential of the exotic populations under arid zone environments [12]. Thus this data set should be useful for identifying those elite populations that are able to produce high levels of biomass and grain yield under arid conditions. Test locations were a significant source of variation for all variables except harvest index (data not shown). Biomass yield was 26% higher at Jodhpur (942 g m^{-2}) than Nagaur (747 g m^{-2}), but harvest index was similar (25.2%) at both locations (Table 2). Thus the difference in biomass production was translated into grain yield differences of almost the same magnitude (25%) at two test environments. This observation suggests that biomass accumulation is the major determinant of grain productivity under arid environments, which corroborates with results of earlier studies conducted under similar environmental conditions [12, 17].

Table 2. Mean time to flowering, biomass, grain and stover yields and harvest index of 15 pearl millet genotypes evaluated at two locations in Rajasthan

Trait	Unit	Jodhpur 2001	Nagaur 2003	Mean
Days to flower	no.	48.5	55.4	51.9
Biomass yield	g m^{-2}	942.4	747.2	844.8
Harvest index	%	25.3	25.1	25.2
Stover yield	g m^{-2}	579.5	471.2	525.3
Grain yield	g m^{-2}	234.0	191.7	212.8

The differences among test entries were significant for all traits evaluated and the performance of entries was significantly modified by test environment (data not shown). The range in flowering time among genotypes was 12 days, from 46 days (GICKV 93191) to 58 days (ICMP 87200) (Table 3). Grain yield range was 108 g m^{-2}, from 151.2 g m^{-2} (ICMP 87200) to 258.7 g m^{-2} (ICMV 98792). The range in stover yield was also very wide (362 g m^{-2}). The differences among exotic populations for panicle length were two-fold with ICMP 96132 producing the smallest panicle (22 cm) and MCSRC the longest panicles (32 cm). Similarly, tillering of test genotypes varied immensely (9.6 to 15.8 panicles m^{-2}). This magnitude of the ranges in different traits should provide a good choice for selecting diverse sources with different combinations of traits for improving specific aspects of the adapted landraces.

A significant and positive association (r = 0.61**) existed between grain yield and biomass (Table 4), reinforcing our earlier claim that biomass accumulation mainly decides the grain productivity. A high panicle number and early flowering were also associated with greater grain yield. These two traits have previously been reported to be associated with millet performance in arid zone stress environments [11] as well as in more favourable environments [13-16]. A significant and positive association of these two traits for arid environments in exotic sources indicated that selection of sources with these traits would not sacrifice yield potential in favourable years. There was also no significant association between grain and stover yields (Table 4) which indicated that grain and stover yields in millet are not mutually exclusive traits and can be improved simultaneously, provided that overall biomass is improved [17]. Other characters too contributed significantly to higher stover yield. The later flowering genotypes produced higher stover (r = 0.77**). Similarly, taller plants produced more stover (r = 0.63**). As expected, stover yield and biomass were positively correlated and harvest index was significantly and

Table 3. Time to flower, tillering, panicle length, grain and stover yields and downy mildew incidence of 13 exotic elite pearl millet populations *vis-a-vis* two check cultivars at two locations in Rajasthan

Exotic population/ checks	Days to flowering (no.)			Panicles m^{-2} (no.)			Panicle length (cm)			Grain yield (g m^{-2})			Stover yield (g m^{-2})			Downy mildew (%)
	Jodhpur	Nagaur	Mean	Jodhpur	Nagaur	Mean	Jodhpur	Nagaur	Mean	Jodhpur	Nagaur	Mean	Jodhpur	Nagaur	Mean	Jodhpur
ICMP 87200	54	62	58	10.2	15.4	12.8	29.6	25.8	27.7	163.9	138.5	151.2	677.1	516.6	596.8	3.7
ICMP 89410	47	54	50	12.0	14.0	13.0	26.7	24.8	25.8	300.8	170.1	235.5	541.7	373.3	457.5	5.7
ICMP 96132	45	53	49	10.3	14.2	12.2	24.0	19.5	21.8	281.6	199.3	240.5	463.5	349.0	406.3	7.0
ICMP 96201	48	52	50	9.2	15.8	12.5	26.8	20.8	23.8	219.9	247.2	233.6	432.2	386.7	409.5	5.3
ICMP 98552	48	56	52	8.2	18.1	13.1	26.6	23.7	25.1	195.6	229.7	212.7	531.2	563.2	547.2	18.3
ICMV 98792	50	55	52	7.8	20.7	14.3	32.1	24.3	28.2	213.8	303.6	258.7	588.2	620.6	604.5	14.9
IAC-ISC TCP3	45	50	47	9.5	16.7	13.1	25.6	21.8	23.7	223.5	199.0	211.3	494.8	371.1	433.0	4.6
GICKV 93191	44	49	46	13.1	14.9	14.0	27.9	21.0	24.4	285.6	178.1	231.8	572.9	323.9	448.4	7.4
Sudan Pop I	51	62	56	8.4	10.8	9.6	27.6	22.7	25.2	188.3	121.8	155.0	817.7	522.6	670.2	1.5
Sudan Pop II	51	61	56	8.9	18.9	13.9	30.0	25.2	27.6	203.5	170.8	187.1	692.7	659.6	676.1	1.9
Sudan Pop III	54	55	54	8.8	21.8	15.3	28.1	22.5	25.3	194.0	258.1	226.0	692.7	844.7	768.7	9.8
MCNELC	47	57	52	10.7	21.0	15.8	28.4	21.3	24.9	311.0	176.1	243.6	557.3	436.0	496.6	8.9
MCSRC	49	58	53	8.4	11.5	9.9	35.2	28.8	32.0	204.0	144.3	174.1	531.3	368.9	450.1	13.4
CZP 923	46	52	49	11.2	16.1	13.6	25.1	21.0	23.1	252.5	193.6	223.1	489.6	346.9	418.3	7.1
Raj 171	48	55	51	12.7	15.8	14.3	26.5	20.7	23.6	271.7	144.3	208.0	609.4	380.8	495.1	7.5
LSD	2.87	4.79	2.64	2.67	12.59	4.26	2.6	4.6	2.4	37.4	146.7	33.2	195.5	268.4	170.7	7.59

negatively associated with both stover and biomass yield (Table 4). Panicle length had no association with any of the traits measured except flowering time with which it had a positive and significant correlation, suggesting that later flowering plants produced longer panicles and vice-versa. These results are in agreement with earlier observations [18-19].

Table 4. Correlation coefficient among eight characters recorded on 15 genotypes of pearl millet evaluated at two locations in Rajasthan

	Days to flower	Plant height	Panicle length	Panicle/ m^{-2}	Grain yield	Stover yield	Biomass yield	Harvest index
Days to flower	1							
Plant Height	–0.77**	1						
Panicle length	0.54*	0.51	1					
Panicle m^{-2}	–0.19	–0.37	–0.29	1				
Grain yield	–0.65**	–0.65**	–0.42	0.61*	1			
Stover yield	0.77**	0.63**	0.32	0.15	–0.33	1		
Biomass yield	0.57*	0.42	0.19	0.37	0.61*	0.93**	1	
Harvest index	–0.90**	–0.81**	–0.52	0.15	0.75**	–0.85**	–0.61*	1

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

The best populations for grain yield were ICMV 98792, MCNELC and ICMP 96132 which had produced significantly higher grain yield than check variety Raj 171, though only ICMV 98792 significantly outyielded the better check CZP 923 (Table 3). The degree of superiority of these three populations was 16% to 24% over Raj 171 and 8% to 16% over CZP 923. It was quite interesting to observe that this degree of superiority was with the same flowering range as of checks (Table 3). This is very important as the scope of improvement in grain yield through extension of crop duration is very limited because longer crop duration increases the risk of losses due to drought towards the end of the growing season due to early withdrawal of rains in the season.

The choice of elite populations for improving stover yield was greater than that for grain yield. As many as five populations produced significantly higher stover than CZP 923 and three populations yielded significantly higher stover than Raj 171; with magnitude of improvement in the best population Sudan Population III being between 55% to 83% over two checks. These are very encouraging results as the stover is as important as grain in arid zone environments. The importance of stover might become even greater than grain especially during drought years because stover provides an essential livestock maintenance ration during dry periods. The population ICMV 98792 appeared the most promising as a dual-purpose source though its downy mildew incidence (15%) was a bit higher than that of the other sources (Table 3). Hence, crosses utilizing this population as donor source of improving grain and/or stover yield would require a stringent selection for downy mildew resistance. For other exotic populations the downy mildew incidence was lesser than 10%, except for ICMP 98552 and MCSRC, showing that downy mildew is not likely to be a deterrent factor in utilizing the selected elite populations as sources of diversification of landraces.

The landraces especially from arid tract of western Rajasthan (Chadi and desert type) characteristically produce a large number of small panicles [10-11] which underlines the need of integrating traits like longer panicles into new breeding populations, even with reduced tillering from exotic sources. From among sources evaluated in this study, a few appeared to have a plant type complementing to that of desert landraces.

MCSRC produced significantly longer panicles than two checks and other sources. However, it had one of the lowest tillering potentials (Table 3). The other populations that produced significantly longer panicles than checks were ICMP 87200, ICMV 98792 and Sudan Pop II: but in these cases their tillering was almost at par with that of the checks. Obviously, these populations should prove a good source of panicle length to diversify the base of landraces.

The results of the present study have demonstrated that wide difference existed in productivity potential and plant type of selected exotic sources. Wide range for grain and stover productivity and traits determining the plant type facilitated the identification of a few sources that would be worthwhile to use in hybridization with landraces to generate diverse, but adapted genetic material.

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