Millets Research

Genetic Resources

Pearl Millet Germplasm Adapted to Saline Conditions

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Introduction

Soil salinity is a major crop production constraint affecting approximately 77 million ha worldwide (5–7% of arable land). This problem has been observed to be getting further aggravated (Munns et al. 2002). Development and adoption of salinity-tolerant crop varieties is a cost-effective and sustainable approach to managing salt-affected lands (Epstein et al. 1980). Among the warm-season cereal crops, pearl millet [*Pennisetum glaucum* (L.) R. Br.] is comparatively more tolerant to salinity (Hajor et al. 1996). Wide genetic variability for salinity tolerance has been reported in pearl millet (Dua and Bhattacharya 1988; Ashraf and McNeilly 1992; Chopra and Chopra 1997). The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India, in collaboration with ICBA, has initiated a project to improve salinity tolerance in pearl millet. Highly significant positive correlation ($r > 0.65$; $P > 0.01$) has been observed between biomass yield under saline pot conditions and salinity tolerance index, indicating that biomass yield itself can be used as an effective selection criterion to select for salinity tolerance and biomass productivity under saline conditions (ICBA 2004). Among a large number and diverse range of materials, 45 germplasm accessions of diverse origin, selected on the basis of their high forage and grain yield potential, were screened for yield performance under saline conditions in pot culture at ICBA. This paper reports on the origin of accessions identified from these pot studies for adaptation to saline conditions and their yield potential under saline field situations in India and West Asia.

Materials and Methods

The 45 germplasm accessions [23 landraces, 18 dual-purpose (grain and fodder yield) lines and 4 accessions of *P. purpureum*], which included 40 accessions from five countries of Western and Central Africa (WCA), 3 from three countries of Eastern and Southern Africa (ESA) and 2 from India, were selected for high biomass production and grain and stover yield based on ICRISAT genebank data. They were evaluated for agronomic performance in pot culture at three salinity levels (5, 10 and 15 dS m^{-1}) at ICBA during 2002 and 2003. Fifteen promising germplasm accessions were identified on the basis of high biomass yield at harvest across two years' screening. An additional 8 accessions each in 2002 and 2003 were selected for their good performance under saline conditions. At the Agricultural Research Station, Gangavathi (Karnataka, India), 15 germplasm accessions (chosen on the basis of two seasons' pot screening at ICBA), and at Rumais (Sultanate of Oman) and Dubai (UAE), 16 accessions (12 based on the two seasons, three based on the 2002 screening and one based on the 2003 screening) were evaluated in randomized complete block designs with three replications (Gangavathi) or 4 replications (Rumais and Dubai). At Gangavathi, the trial was conducted for two years (rainy seasons of 2004 and 2005) in Vertisols with an initial salinity level of 10 dS m^{-1}, while it was conducted in the summer of 2005 in sandy soils with initial salinity levels ranging from 4.8 dS m^{-1} to 15.6 dS m^{-1} at Rumais and Dubai. Sowing was done in 2 rows of 3 m length with 60 cm row-to-row and 15 cm plant-to-plant spacing at Gangavathi, and 4 rows of 4 m drip rows with spacing of 50 cm between rows and 15 cm between plants at Rumais and Dubai. The trials at Dubai and Rumais were drip-irrigated with saline water (7.5–8.25 dS m^{-1}), but the trials at Gangavathi were rainfed. Fertilizer doses of 100 N (50% basal and remaining in two equal split doses): 50P:50K at Rumais and Dubai and 50N:25P at Gangavathi were applied manually. At the time of maturity, data on grain yield and dry fodder yield were recorded on a per plot basis at Gangavathi. At Rumais and Dubai the dry fodder yield was recorded per square meter and converted into tons per hectare (t ha^{-1}). The data were subjected to statistical analysis using the GenStat statistical software package.

Results and Discussion

Of the 45 *Pennisetum* germplasm accessions initially evaluated for adaptation to pot culture saline conditions at Dubai, about 65% were from Niger. Of the 15 accessions identified as adapted to saline conditions based on the two-year pot screening at ICBA, 87% (13) were from Niger (Fig. 1), and 10 of these were oasis millets (landraces from the drier parts of West Africa) and 3 were dual-purpose types. The remaining two were dual-purpose accessions from India. None of the four *P. purpureum* accessions evaluated was adapted to saline conditions. The screening experiments suggested that the accessions from Agadez province (16.98–19.07°N latitude and 7.95–8.93°E longitude) of Niger in general, and Aouderas and Tabelot in particular (8 of the 15 selected accessions were from these locations) were adapted to salinity. More collections from these areas could be screened to identify additional germplasm sources with even higher levels of productivity under saline conditions.

In the field trials under saline conditions, large and significant differences were observed among the germplasm accessions for grain yield at Gangavathi during 2004 and for dry fodder yield at all the three locations. Mean grain yields of accessions varied from 0.83 t ha^{-1} to 1.98 t ha^{-1} in 2004 with a mean of 1.32 t ha^{-1}, and from 0.49 t ha^{-1} to 1.21 t ha^{-1} in 2005 with a mean of 0.84 t ha^{-1} at Gangavathi (Table 1). Similarly, mean dry fodder yields ranged from 2.65 t ha^{-1} to 8.33 t ha^{-1} in 2004 with a mean of 4.60 t ha^{-1}, and from 0.50 t ha^{-1} to 3.67 t ha^{-1} in 2005 with mean of 2.06 t ha^{-1}. These results showed 36% reduction in mean grain yield and 51% reduction in mean fodder yield during 2005 compared to respective yields in 2004, which could be attributed to higher salinity levels at flowering and dough stages of the crop in 2005. The initial salinity level was 10 dS m^{-1} in both seasons but good and well-distributed rainfall reduced the mean salinity level of the field to 8 dS m^{-1} at the dough stage of the crop in 2004, and a dry spell of 30 days after sowing caused the salinity level to increase to 12 dS m^{-1} in 2005. This coupled with continuous rainfall affecting initial crop growth reduced the yield levels in 2005. Based on the data of two seasons, two germplasm accessions, IP 22269 and IP 6098, were identified as promising dual-purpose types, producing about 1.40 t ha^{-1} grain yield, which was comparable to the 1.49 t ha^{-1} grain yield of the control variety Raj 171. Their fodder yield was 40–60% higher than Raj 171 (3.51 t ha^{-1}). Another two accessions, IP 3616 and IP 6105, were also identified as promising for fodder yield as they gave 20–55% higher dry fodder yield than Raj 171.

The mean dry fodder yield was 65% higher at Dubai (8.1–17 t ha^{-1}) than that of Rumais (2.7–12.8 t ha^{-1}). At Dubai five accessions had 29–75% higher dry fodder yield than the control ICBA Synthetic (9.7 t ha^{-1}), among them IP 3616 showed significant superiority (17.0 t ha^{-1}). At Rumais, five accessions produced 21–121% higher dry fodder yield than ICBA Synthetic (5.8 t ha^{-1}), among them IP 6112 showed significant superiority. Based on the mean performance across Rumais and Dubai, dry fodder yield of the accessions varied from 6.2 t ha^{-1} to 12.7 t ha^{-1} with a mean of 8.7 t ha^{-1}. Seven germplasm accessions had numerically higher (19–65%) dry fodder yield than ICBA Synthetic (7.7 t ha^{-1}), but only IP 3616 was significantly higher yielding. The mean dry fodder yield of IP 3616 (12.7 t ha^{-1}) was highest across the two locations, followed by IP 6112 and IP 6104 (both 10.9 t ha^{-1}) and IP 22269 (9.6 t ha^{-1}). Germplasm accessions IP 22269 and IP 3616, which occupied the 1st and 2nd ranks for high dry fodder yield at Gangavathi, had 4th and 1st ranks respectively for mean dry fodder yield across Rumais and Dubai. IP 22269 is a High-Tillering Gene Pool developed at ICRISAT from 1093 diverse germplasm accessions that produce 5–35 effective tillers (Appa Rao et al. 1998) and IP 3616 is a dual-purpose collection from Thulayatham (Tamil Nadu). Other high dry fodder yielding accessions (IP 6098, IP 6104, IP 6105 and IP 6112) across Rumais and Dubai were all oasis millets from Agadez province of Niger.

The germplasm accessions tested were initially identified as promising for saline conditions on the basis of biomass yield in pot screenings at ICBA and not grain yield; hence, the germplasm accessions showed no advantage for grain yield in field trials. However, substantial numerical superiority for dry fodder yield was noticed in some of the germplasm accessions over the high-yielding controls, indicating their high dry fodder yielding potential under saline conditions. Pearl millet, having high forage yield potential, can be a useful alternative forage crop in the salinity-affected areas of West Asia and India as well as other parts of the world.

Acknowledgment. The authors acknowledge the partial funding support from the Organization of the Petroleum Exporting Countries (OPEC) Fund.

Figure 1. Origin of pearl millet germplasm accessions from West Africa evaluated for adaptation to salinity in pot screening (2002–03) at ICBA, Dubai.

Table 1. Grain and dry fodder yield of promising germplasm accessions of pearl millet (identified for salinity adaptation based on two-year pot screenings at ICBA, Dubai) in saline field conditions.

	Grain yield (t ha^{-1})			Dry fodder yield (t ha^{-1})					
	Gangavathi			Gangavathi			Dubai	Rumais	
Germplasm	2004	2005	Mean	2004	2005	Mean	(UAE)	(Oman)	Mean
IP 3616	0.83	0.83	0.83	7.22	3.67	5.44	17.0	8.5	12.7
IP 6112	1.29	0.92	1.11	3.95	1.75	2.85	9.1	12.8	10.9
IP 6104	1.44	0.75	1.10	3.70	2.17	2.94	13.0	8.7	10.9
IP 22269	1.61	1.21	1.41	8.33	3.00	5.67	13.0	6.2	9.6
IP 19586	1.01	0.96	0.99	3.95	1.33	2.64	9.7	8.7	9.2
IP 6105	1.55	0.76	1.16	5.31	3.08	4.20	12.5	5.5	9.0
IP 6106	1.62	0.65	1.14	5.12	1.17	3.15	11.2	6.1	8.6
IP 6101	1.39	0.94	1.17	4.26	3.17	3.71	10.9	6.2	8.6
IP 6107	1.06	0.72	0.89	5.00	1.50	3.25	10.6	5.7	8.1
IP 19612	1.15	0.60	0.87	3.33	0.58	1.96	10.5	5.7	8.1
IP 6110	1.12	0.63	0.88	4.51	2.08	3.29	8.7	6.3	7.5
IP 6109	1.23	0.99	1.11	4.07	1.67	2.87	8.4	5.3	6.8
IP 19613	–[1]	–	–	–	–	–	8.1	5.0	6.5
IP 5253	–	–	–	–	–	–	9.8	2.7	6.2
IP 13151	–	–	–	–	–	–	13.4	5.2	9.3
IP 13150	–	–	–	–	–	–	11.5	7.0	9.2
IP 6094	1.00	0.85	0.92	3.40	1.33	2.36	–	–	–
IP 6101	1.54	0.49	1.02	2.84	0.50	1.67	–	–	–
IP 6098	1.61	1.17	1.39	6.11	3.50	4.81	–	–	–
Control									
ICBA Synthetic	–	–	–	–	–	–	9.7	5.8	7.7
CZP 9802/ ICTP 8203	0.93	0.80	0.86	2.65	0.92	1.79	–	–	–
Raj 171	1.98	1.01	1.49	4.44	2.58	3.51	–	–	–
Trial mean	1.32	0.84	1.08	4.60	2.00	3.30	11.0	6.55	8.76
LSD ($P = 0.05$)	0.55	0.81	0.75	1.61	1.66	1.68	5.1	4.2	4.9
CV (%)	27.5	52.5	38.3	25.6	46.5	46.1	46.8	48.4	48.1

1. Not evaluated.

References

Appa Rao S, Mengesha MH and **Reddy KN.** 1998. Development and characterization of trait-specific genepools in pearl millet. Plant Genetic Resources Newsletter 113:27–30.

Ashraf M and **McNeilly T.** 1992. Exploitation of useful variation for salt tolerance in pearl millet (*Pennisetum americanum* (L.) Leeke). Plant Breeding 108:234–240.

Chopra NK and **Chopra N.** 1997. Performance of pearl millet genotypes at different salinity levels in western Rajasthan. Annals of Arid Zone 27(3&4):183–189.

Dua RP and **Bhattacharya RK.** 1988. Relative salinity tolerance of pearl millet hybrids and populations. Annals of Arid Zone 36(4):391–393.

Epstein E, Norlyn JD, Rush DW, Kingsbury R, Kelly DB and **Wrana AF.** 1980. Saline culture of crops: a genetic approach. Science 210:399–404.

Hajor AS, Al-Hatalani LS and **Khafagi OA.** 1996. A comparative study on salt tolerance of millet (*Pennisetum glaucum* L.) and sorghum (*Sorghum bicolor* L.). Alexandria Journal of Agriculture Research 41(3):23–39.

ICBA (International Center for Biosaline Agriculture). 2004. Development of salinity-tolerant sorghum and pearl millet cultivars for enhanced productivity on saline lands. Progress Report 2003-2004. Dubai, United Arab Emirates: ICBA.

Munns R, Husain S, Rivelli AR, James RA, Condon AG, Lindsay MP, Lagudah ES, Schachtman DP and **Hare RA.** 2002. Avenues for increasing salt tolerance of crops, and the role of physiologically based selection traits. Plant and Soil 247:93–105.