View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by ICRISAT Open Access Repository

Evaluation and identification of promising pearl millet germplasm for grain and fodder traits

IS Khairwal[1]*, SK Yadav[1], KN Rai[2], HD Upadhyaya[2], D Kachhawa[1], B Nirwan[1], R Bhattacharjee[2], BS Rajpurohit[1], CJ Dangaria[3] and **Srikant[4]**

1. All India Coordinated Pearl Millet Improvement Project (AICPMIP), Mandor, Jodhpur 342 304, Rajasthan, India
2. International Crops Research Institute for the Semi Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India
3. Millet Research Station, Junagadh Agricultural University, Jamnagar 361 006, Gujarat, India
4. Agricultural Research Station, Rajasthan Agricultural University, Durgapura, Jaipur 302 018, Rajasthan, India

*Correspondence address: pcunit@sify.com

Citation : Khairwal IS, Yadav SK, Rai KN, Upadhyaya HD, Kachhawa D, Nirwan B, Bhattacharjee R, Rajpurohit BS, Dangaria CJ and Srikant, (2007) Evaluation and identification of promising pearl millet germplasm for grain and fodder traits. Journal of SAT Agricultural Research 5(1).

Introduction

India is the largest producer of pearl millet (*Pennisetum glaucum*), both in terms of area (9.43 million ha) and production (8.01 million t), with an average productivity of 850 kg ha^{-1} (Khairwal 2007). This grain crop contributes significantly to food and nutritional security of the rural and urban poor people in drier areas where it is valued equally for both its grain and fodder. Although demand for pearl millet grain as human food in India is currently decreasing, it is emerging as forerunner in the form of alternative food, feed and industrial products. Being a C_4 species, it has tremendous potential for biomass production, most of which is accumulated in its vegetative parts (Appa Rao 1999). It is considered as a high quality forage crop in USA and Australia, and is being experimented as a new forage crop in South America and Korea. There is a new interest in USA in growing pearl millet as grain crop because of its drought tolerance and high quality grain (Andrews et al. 1993).

Because of its tolerance to high temperature and better ability to withstand drought and to grow even in low soil fertility conditions, pearl millet is best suited for arid and semi-arid regions of the country. The major thrust is to improve yield potential in fragile arid regions. This may be achieved either through direct selection of landraces/ germplasm lines or by developing populations/hybrids that are adapted to such environments and provide higher yield of both grain and fodder. It is a well-established fact that the progress in improvement of a crop depends on the degree of variability in the desired traits in the base material vis-à-vis germplasm (Sharma et al. 2003).

Any germplasm collection is of little value in crop improvement until it is evaluated and characterized. Germplasm lines and landraces are obviously rich sources of resistance to various biotic and abiotic stresses (Yadav and Weltzein 2000) as well as traits for improving grain and fodder quality (Kelley et al. 1996).

The objective of the present study was to evaluate and characterize available germplasm lines, landraces and core collection lines of pearl millet and to exploit genetic variability so as to identify promising germplasm lines for metric traits for utilization in different breeding programs and develop early and high-yielding potential hybrids/open-pollinated varieties (OPVs) for grain and fodder in drier areas of India.

Materials and methods

The materials in the present study consisted of 2375 germplasm accessions, 180 landraces and 504 core collection lines. These were evaluated for grain and fodder yield and their component traits in augmented block design (Federer 1956). The germplasm lines and landraces were evaluated during the 2006 rainy season at the experimental farm of the All India Coordinated Pearl Millet Improvement Project (AICPMIP), Mandor, Jodhpur, Rajasthan, India. Accessions were sown in 22 blocks. Each block consisted of 120 accessions and four checks (J 2405, J 2340, NMP 24 and PP 29). The pearl millet core collection was also evaluated during the 2006 rainy season at three locations, ie, AICPMIP, Mandor, Jodhpur; Agricultural Research Station, Rajasthan Agricultural

University, Durgapura, Jaipur, Rajasthan; and Millet Research Station, Junagadh Agricultural University, Jamnagar, Gujarat. The core collection accessions were accommodated in 19 blocks. Each block consisted of 27 test accessions and three checks, namely IP 17862 (ICTP 8203), IP 22281 (Raj 171) (grain type) and IP 3616 (fodder type). After every nine test accessions, one of the three checks was sown. Each accession (germplasm, landraces and core collection) was sown in a single-row plot of 5 m length. Interrow and intra-row distance was kept at 50 cm and 15 cm, respectively. All accessions were evaluated under good management conditions to realize their full potential. Observations were recorded on morphological/metric traits, viz, vigor, time to 50% flowering (days), time to maturity (days), plant height (cm), productive tillers per plant, total tillers per plant, nodes per plant, sheath length (cm), blade length (cm), blade width (cm), panicle exsertion (cm), bristle length (score), panicle length (cm), panicle thickness (mm), panicle density (score), 1000-grain weight (g), grain yield (g), grain yield potential, green fodder yield (g), green fodder yield potential and overall plant aspect. Observations on vigor, time to 50% flowering, time to maturity, bristle length, panicle density, grain yield potential, fodder yield potential and overall plant aspect were recorded on whole plot basis on a 1–9 scale while observations on the rest of the traits were recorded on five randomly selected plants. Mean and range were computed as per design of the experiment.

Results and discussion

An evaluation of 2375 germplasm lines, 180 landraces and 504 accessions of core collection of pearl millet for grain and fodder yield and their related traits in an augmented design revealed wide range for almost all the traits studied (Table 1). The materials may serve as valuable sources of variation for specific breeding objectives.

Germplasm. Pearl millet germplasm has been widely used in developing composites, which include a wide range of germplasm and improved breeding lines. For example, the *Iniadi* germplasm from the Togo-Ghana-Burkina Faso-Benin region of western Africa is most commonly used in pearl millet breeding programs world-wide (Andrews and Anand Kumar 1996).

Evaluation of germplasm accessions revealed considerable variation among accessions for all the traits studied (Table 1) and the most promising accessions were identified for traits studied (Table 2). Accessions IP 1024, IP 3467 and IP 3986 were identified as promising for vigor; OPY 197, IP 4006, IP 550 and IP 3549 as extra-early flowering types; OPY 197, IP 3549 and SNV 26 for early maturity; IP 1497, IP 947, IP 3541 and IP 3749 for plant height; and RMFB 35 and RMFB 34 for high productive tillers. Accessions IP 1763 and IP 1745 were promising for long panicle; NSS 7776, NSS 7799 and IP 4394 for thick panicle; and IP 399 for bold grains. Accessions IP 128, IP 3416, IP 33 and NSS 7911 were promising for high grain yield per plant while accessions IP 3416, IP 17880 and IP 104 were promising for high fodder yield per plant. Similar pattern of variability and promising germplasm lines for fodder yield and related traits were earlier reported by Sharma et al. (2003). Several OPVs in the past (eg, WC-C75, ICTP 8203 and Raj 171) have been developed through utilization of germplasm lines and have been released and are widely grown in India. In developing these varieties, traits of visual appeal such as flowering, plant height, panicle size and shape, and grain size, shape and color are kept sufficiently uniform for varietal identification purposes, even if large numbers of progenies (>50) are used in breeding productive OPVs of pearl millet (eg, ICMV 155, ICMV 221 and ICMV 88908) (Rai et al. 1999). The variety ITMV 8304, released in Niger, is an example of using germplasm from within its region (INRAN 1985). The component lines of World Composite were used to breed WC-C 75 (a high-yielding and downy mildew resistant variety) and HC 4, which were released for general cultivation in India in 1982 and 1984, respectively.

Landraces. Landraces are primitive varieties, which have been evolved without systematic and sustained plant breeding efforts. They are storehouses of genetic variability and valuable genes. They are adapted to the local soil type, climatic conditions, etc. Inbred lines are also developed from selected landrace accessions to widen the genetic base for potential pearl millet hybrids/population development for arid regions of Rajasthan where drought is very common. The most useful germplasm to supply desirable variability to breeding programs for earliness has come from *Iniadi*, a prominent, productive, bold-seeded, and early-maturing landrace that is found in Benin, Burkina Faso, Ghana and Togo. This material was used in the formation of composites of the Serere series and the male-sterile line Serere 10LA.

Evaluation of 180 landraces of pearl millet collected from Rajasthan revealed a high degree of variation (Table 1) and most promising landraces were identified for the traits studied (Table 2). The landrace accessions identified for earliness were SR 15, SR 17 and SR 54. The Chadi landrace from Rajasthan and Bhilodi of Gujarat represent desert types, and the Pittaganti type,

Table 1. Mean and range for grain and fodder traits in pearl millet evaluated at different locations in India in 2006 rainy season.

	Germplasm			Landraces			Core collection		
		Range			Range			Range	
Character	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Vigor (score)	2.6	1	5	–	–	–	–	–	–
Time to 50% flowering (days)	63.1	37	86	50	42	60	65.9	45.0	89.3
Time to maturity (days)	87.4	68	117	–	–	–	–	–	–
Plant height (cm)	239.4	90.0	358.0	196.6	97.3	284.0	207.4	45.2	314.6
Productive tillers per plant	3.9	1.0	17.0	2.5	1.0	15.0	2.1	1.0	4.7
Total tillers per plant	–	–	–	–	-	–	3.7	1.2	8.3
Nodes per plant	–	–	–	9.5	6.0	14.0	–	–	–
Sheath length (cm)	–	–	–	12.6	6.4	21.0	–	–	–
Blade length (cm)	–	–	–	64.4	46.8	89.0	–	–	–
Blade width (cm)	–	–	–	2.9	1.2	4.7	–	–	–
Panicle exsertion (cm)	–	–	–	–	–	–	4.8	1.3	18.3
Bristle length (score)	–	–	–	–	–	–	3.0	1.3	8.6
Panicle length (cm)	23.8	8.3	48.6	25.4	14.7	51.1	24.9	8.4	62.9
Panicle thickness (mm)	2.0	0.8	3.7	1.7	1.0	2.5	22.5	11.6	38.9
Panicle density (score)	–	–	–	–	–	–	4.3	1.67	9.0
1000-grain weight (g)	5.8	2.0	9.9	6.2	2.0	9.5	6.9	3.5	14.3
Grain yield per plant (g)	15.1	1.1	136.5	–	–	–	–	–	–
Grain yield potential (score)	–	–	–	–	–	–	4.0	1.0	7.3
Green fodder yield per plant (g)	84.7	3.5	666.6	–	–	–	–	–	–
Green fodder yield potential (score)	–	–	–	–	–	–	5.0	1.0	9.0
Overall plant aspect (score)	–	–	–	–	–	–	3.6	1.0	7.6

Table 2. Promising pearl millet accessions identified from germplasm, landraces and core collection (over locations) for grain and fodder traits.

Character	Germplasm accession	Landraces	Core collection accession
Vigor (score)	IP 1024, IP 3467, IP 3986, IP 4021, IP 13523	–	–
Time to 50% flowering (days)	OPY 197, IP 4006, IP 550, IP 3549	SR 15, SR 17, SR 54	IP 4066, IP 9496, IP 9426
Time to maturity (days)	OPY 197, IP 3549, SNV 26	–	–
Plant height (cm)	IP 1497, IP 947, IP 3541, IP 3749	SR 40, SR 121, SR 33	IP 3616, IP 19190, IP 19405, IP 13150, IP 5452
Productive tillers per plant	RMFB-35, RMFB-34	SR 75, SR 74, Desi Chothina	IP 13645, IP 15273, IP 17493
Total tillers per plant	–	–	IP 6148, IP 15257
Nodes per plant	–	–	–
Sheath length (cm)	–	Dhodsar (Sunda Ram), Jhakrana (ex-situ), Sulkania (ex-situ), SR 54, Chadi (bristle)/ex-situ	–
Blade length (cm)	–	SR 13, SR 16	–
Blade width (cm)	–	Dhodsar local (original), SR 46, Ardi (Karansar)	–
Panicle exsertion (cm)	–	–	IP 12331, IP 7838, IP 8344, IP 10085, IP 18062
Bristle length (score)	–	–	IP 19215, IP 10471, IP 17364, IP 11211, IP 18389
Panicle length (cm)	IP 1763, IP 1745	Sulkania (ex-situ), Jhakrana (ex-situ)	IP 5447, IP 10273, IP 12848, IP 10456
Panicle thickness (mm)	NSS 7776, NSS 7799, IP 4394, IP 7042	–	IP 7935, IP 5396, IP 18797, IP 15917
Panicle density (score)	–	–	IP 14100, IP 8350, IP 14160, IP 12925, IP 9595
1000-grain weight (g)	IP 399	–	IP 14160, IP 11893, IP 19160, IP 10705
Grain yield per plant (g)	IP 128, IP 3416, IP 33, NSS 7911, IC-296718 HMS 1B	–	–
Grain yield potential (score)	–	–	IP 17350, IP 3150, IP 17945, IP 7095
Green fodder yield per plant (g)	IP 3416, IP 17880, IP 104	–	–
Green fodder yield potential (score)	–	–	IP 15304, IP 3616, IP 6125, IP 13885, IP 6146, IP 6897
Overall plant aspect (score)	–	–	IP 16131, IP 22281, IP 15817, IP 17945, IP 7095

grown by the hill tribes of the Eastern Ghats, represents a unique early type in India (Anand Kumar and Appa Rao 1987). Landraces SR 40, SR 121 and SR 33 were the best for tallness; SR 75, SR 74 and Desi Chothina for high productive tillering; and Sulkania (ex-situ) and Jhakrana (ex-situ) for long panicles. Landraces Dhodsar (Sunda Ram), Jhakrana (ex-situ), Sulkania (ex-situ) and SR 54 were identified for long sheath length, the blade length and width contributing directly to the production as well as quality of the fodder. Landraces SR 13 and SR 16 were promising for very long blade length and Dhodsar local, SR 46 and Ardi (Karansar) were superior for blade width.

Core collection. A core collection consists of a limited set of accessions derived from an existing collection, chosen to represent the genetic spectrum in the collection (Brown 1989). The core should include as much of the genetic diversity as possible. It provides the user a set of genetically and ecologically distinct accessions.

The core collection accessions evaluated at all the three locations indicated a wider range for all the traits studied (Table 1). Accessions IP 4066, IP 9496 and IP 9426 were promising for earliness at Jaipur. Very high variability was observed for plant height and accessions IP 3616, IP 19190, IP 19405, IP 13150 and IP 5452 were identified as very tall. These accessions may be used as parents to develop potential pearl millet forage hybrids/ population. Accessions IP 13645, IP 15273 and IP 17493 had high productive tillering when evaluated at Mandor. The number of total tillers per plant is also an important trait that contributes to high biomass. Accessions found to have high total tillering were IP 6148 and IP 15257 at Mandor. Accessions IP 12331, IP 7838 and IP 8344 at Jaipur, IP 10085 at Jamnagar and IP 18062 at Mandor were promising for panicle exsertion. For bristle length, based on a 1 (very small) to 9 (longest) scale, accessions IP 19215 and IP 10471 at Mandor and IP 17364, IP 11211and IP 18389 at Jaipur were promising for long bristles. Accessions IP 5447, IP 10273 and IP 12848 at Mandor and IP 10456 at Jaipur were promising for panicle length; IP 7935 and IP 5396 at Mandor and IP 18797 and IP 15917 at Jaipur were promising for panicle thickness. Anand Kumar and Appa Rao (1987) reported that panicle length varied from 4 cm in oasis millets to 200 cm in Zongo of Niger. Panicle density was recorded on a 1–9 scale and varied from 1 (very loose) to 9 (very compact); accessions IP 14100 and IP 8350 at Mandor, and IP 14160 at Jaipur were identified as very compact. The grain size of accessions varied considerably and accessions IP 11893, IP 19160, IP 10705 and IP 14160 were found promising at Jaipur. Anand Kumar and Appa Rao (1987) reported grain size up to 19 g 1000^{-1} grain in accessions from Ghana and Togo. Accessions IP 15304, IP 3616 and IP 6125 at Mandor, IP 13885 and IP 6146 at Jaipur, and IP 6897 at Jamnagar were identified as promising for green fodder potential and IP 17350 and IP 3150 at Mandor and IP 17945 and IP 7095 at Jaipur were identified as promising for grain yield potential. Accessions IP 16131, IP 22281 and IP 15817 at Mandor and IP 17945 and IP 7095 at Jaipur were identified as promising for overall plant aspect.

Pearl millet is a highly cross-pollinated crop and possesses enormous natural variability for quantitative, qualitative and quality traits. The available variability needs to be exploited in the form of development of high-yielding hybrids and OPVs. It requires evaluation, characterization and identification of trait specific germplasm lines. We evaluated a large number of germplasm lines, landraces and core collection accessions and identified specific accessions to develop trait specific genepools. The trait specific genepools will serve as a storehouse in future in pearl millet breeding programs.

References

Anand Kumar K and **Appa Rao S.** 1987. Diversity and utilization of pearl millet germplasm. Pages 69–82 *in* Proceedings of the International Pearl Millet Workshop, 7–11 April 1986, ICRISAT, Patancheru, India (Witcombe JR and Beckerman SR, eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Andrews DJ and **Anand Kumar K.** 1996. Use of the West African pearl millet landrace *Iniadi* in cultivar development. Plant Genetic Resources Newsletter 105:15–22.

Andrews DJ, Rajewski JF and **Anand Kumar K.** 1993. Pearl millet – a new feed grain crop. Pages 198–208 *in* New crops (Janick J and Simon JE, eds.). New York, USA: John Wiley & Sons.

Appa Rao S. 1999. Genetic resources. Pages 49–81 *in* Pearl millet breeding (Khairwal IS, Rai KN, Andrews DJ and Harinarayana G, eds.). New Delhi, India: Oxford & IBH Publishing Co. Pvt. Ltd.

Brown AHD. 1989. The case for core collections. Pages 136–156 *in* The use of plant genetic resource. Cambridge, UK: Cambridge University Press.

Federer WT. 1956. Augmented design. Hawain Planters Record 40:191–207.

INRAN. 1985. Catalogue des Variétés recommandées de mil, sorgho, niébé et autres cultures du Niger. (In Fr.) Niamey, Niger: Institut National de Recherches Agronomiques du Niger. 66 pp.

Kelley JD, Parthasarathy Rao P, Weltzein RE and **Purohit ML.** 1996. Adoption of improved cultivars of pearl millet in an arid environment: Straw yield and quality considerations in Western Rajasthan. Environmental Agriculture 32:161–172.

Khairwal IS. 2007. Coordinator's review. Pages 1–11 *in* Annual report 2006–2007. All India Coordinated Pearl Millet Improvement Project (Indian Council of Agricultural Research), Mandor, Jodhpur 342 304, Rajasthan, India.

Rai KN, Murty DS, Andrews DJ and **Bramel-Cox PJ.** 1999. Genetic enhancement of pearl millet and sorghum for the semi-arid tropics of Asia and Africa. Genome 42:617–628.

Sharma KC, Sharma RK, Singhania DL and **Singh D.** 2003. Variation and character association in fodder yield and related traits in pearl millet [*Pennisetum glaucum* (L.) R. Br.]. Indian Journal of Genetics and Plant Breeding 63:115–118.

Yadav OP and **Weltzein RE.** 2000. Differential response of pearl millet landrace based population and high yielding varieties in contrasting environments. Annals of Arid Zone 39:39–45.