

# Morphological characterization of world's proso millet germplasm collection

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## Introduction

Proso millet (*Panicum miliaceum*) is one of the cultivated cereals. It has been known for thousands of years in China, India and the CIS countries (former USSR) and is still under cultivation in these countries. It is also cultivated in Iran, Iraq, Syria, Turkey, Afghanistan and Romania (Martin et al. 1976). It is well adapted to many soil and climatic conditions, and requires very little water, possibly the lowest water requirement of any cereal and converts water most efficiently to dry matter/grain (Theisen et al. 1978, Hulse et al. 1980). This high water use efficiency is not because of its drought-tolerance but because of its short growing period (Arnon 1972). It has good nutritive values with higher protein content (>14%) than wheat (*Triticum aestivum*) (11.8%) and rice (*Oryza sativa*) (6.8%). Proso millet is also rich in minerals and trace elements like iron, zinc, copper and manganese. There is wide genetic diversity available in proso millet germplasm, and hence characterizing these resources is a prerequisite for their efficient use in crop improvement. In this article, we report the characterization of proso millet germplasm conserved at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India.

## Materials and methods

The genebank at ICRISAT, Patancheru conserves 842 proso millet germplasm accessions originating from 27 countries (Table 1). They were characterized from 1977 onwards at ICRISAT, Patancheru located at 18° N and 78° E, at an altitude of 545 m asl. The average annual rainfall at this location is about 750 mm, which normally occurs during June to September. The accessions were grown in Alfisols, in a single row of 4 m length, with interrow spacing of 75 cm, and plant spacing of 10 cm. Diammonium phosphate was applied at the rate of 100 kg ha<sup>-1</sup> as a basal dose to supply nitrogen and phosphorus. In addition, 100 kg ha<sup>-1</sup> of urea was applied as top dressing. Sowing was done in the last week of July. All cultural practices and data recordings were the same for all the years of evaluation. Data were recorded on various morpho-agronomic traits such as time to 50% flowering,

plant height, growth habit, culm branching, sheath pubescence, ligule pubescence, leaf pubescence, and inflorescence traits like exertion and inflorescence length, as per descriptors for *P. miliaceum* and *P. sumatrense* (IBPGR 1985).

## Results and discussion

**Plant and growth traits.** The number of accessions from different countries ranged from 1 (9 countries) to 128 (former USSR) and 358 with unknown origin (Table 1). For describing range and other measures of diversity, countries with 6 or more accessions were considered. Time to 50% flowering varied for accessions both within country and amongst different countries. To calculate mean, all the countries where the number of accessions is more than one was considered. The mean time to 50% flowering ranged from 31 days (former USSR, Germany and Hungary) to 39 days (India). However, the range within countries varied from 26–43 days in the accessions from Syria to 31–49 days in accessions from India (Table 1), indicating that early flowering accessions were from Syria and late flowering accessions were found in India. Similarly, the mean plant height ranged from 33 (Mexico) to 92 cm (Nepal). The range within countries was from 20–55 cm in the accessions from Mexico to 95–100 cm in the accessions from Sri Lanka (Table 1), indicating that dwarf plant height accessions occurred in Mexico and tall plant height accessions are from Sri Lanka. Depending on the growth habit of proso millet, the accessions were classified into decumbent, erect, and erect-geniculate. The decumbent types were dominant (74.5%) followed by erect (17.7%), and erect-geniculate (7.8%) (Table 2). Culm branching was predominantly high (45.0%) followed by medium (35.3%) and low (19.7%) (Table 2). Sheath pubescence, ligule pubescence and leaf pubescence were recorded as dense, medium and sparse (Table 2). Medium sheath pubescence was dominant (40.5%) followed by sparse (29.8%) and dense (29.7%). However, in case of ligule pubescence and leaf pubescence, sparse type was dominant (45.4% ligule pubescence, 51% leaf pubescence) followed by medium (39.8% ligule pubescence, 35.3 leaf pubescence) and dense (14.8% ligule pubescence, 13.7% leaf pubescence).

**Table 1. Geographic diversity for time to flower, plant height, panicle exertion and inflorescence length in proso millet germplasm accessions conserved at ICRISAT, Patancheru, India.**

Country	No. of accessions	Time to flower (days)		Plant height (cm)		Panicle exertion (mm)		Inflorescence length (mm)	
		Range	Mean±SE	Range	Mean±SE	Range	Mean±SE	Range	Mean±SE
Afghanistan	17	33-38	35.35±0.31	36-65	54.88±2.3	0-120	65.29±8.19	130-260	188.24±9.24
Argentina	1	33	33±0.00	58	58±0.00	70	70±0.00	230	230±0.00
Australia	2	32	32±0.00	70-80	75±5.00	110-200	155±45.00	260-320	290±30.00
Bangladesh	2	33-34	33.5±0.50	52-53	52.5±0.5	80-90	85±5.00	200	200±0.00
Canada	1	30	30±0.00	60	60±0.00	110	110±0.00	250	250±0.00
China	2	32	32±0.00	68-75	71.5±3.5	110-200	155±45.00	150-250	200±50.00
Germany	12	30-33	31.58±0.26	42-95	68.08±5.04	40-270	171.67±21.1	150-260	204.17±10.48
Hungary	10	30-35	31.9±0.46	40-78	52.9±3.62	50-260	153.5±21.1	120-280	181±16.09
India	69	31-49	39.18±0.48	44-100	72.31±1.49	0-200	53.82±3.96	160-310	249.56±3.96
Iran	9	32-37	34.33±0.58	36-60	48.89±2.77	10-120	67.78±13.00	120-220	177.78±10.9
Iraq	2	38	38±0.00	55-68	61.5±6.5	60-90	75±15.00	160	160±0.00
Japan	1	32	32±0.00	45	45±0.00	120	120±0.00	140	140±0.00
Kenya	1	50	50±0.00	68	68±0.00	10	10±0.00	300	300±0.00
Korea	73	30-43	38.47±0.34	35-70	51.1±1	10-210	111.1±5.54	110-230	169.86±3.57
Lebanon	1	37	37±0.00	70	70±0.00	80	80±0.00	200	200±0.00
Malawi	1	37	37±0.00	105	105±0.00	150	150±0.00	300	300±0.00
Mexico	13	30-43	36.31±1.07	20-55	33.85±3.11	0-300	96.92±21.3	110-230	167.69±12.36
Nepal	6	32-44	37.33±2.23	65-120	92.83±9.18	50-140	98.33±3.5	240-400	306.67±27.16
Pakistan	41	32-40	35.05±0.29	30-90	65.8±2.15	0-180	90.12±6.82	130-300	238.29±7.1
Romania	1	35	35±0.00	50	50±0.00	70	70±0.00	200	200±0.00
Russia & CISs	128	28-37	31.44±0.13	35-80	54.49±0.94	40-280	151.02±5.16	80-280	168.36±4.02
Spain	1	33	33±0.00	45	45±0.00	100	100±0.00	180	180±0.00
Sri Lanka	2	42-44	43±1.00	95-100	97.5±2.5	40-100	70±30.00	260-300	280±20.00
Syria	34	26-43	35.38±0.54	38-82	60.59±2.61	30-160	70.59±6.15	100-280	204.41±8.48
Turkey	48	30-36	33.27±0.2	25-105	50.96±2.4	10-230	88.96±6.07	90-300	172.77±7.5
United Kingdom	4	30-43	35.75±2.68	42-85	60.5±9.00	60-140	107.5±18	170-250	215±18.48
Yugoslavia	1	33	33±0.00	60	60±0.00	140	140±0.00	180	180±0.00
Unknown	358	28-44	33.85±0.13	23-133	60.85±0.05	0-320	91.61±3.09	22-370	190.09±3.33

**Table 2. Geographic diversity for growth habit, culm branching, sheath pubescence, ligule pubescence and leaf pubescence in proso millet germplasm accessions conserved at ICRISAT, Patancheru, India.**

Source country	No. of accessions	Growth habit				Culm branching			Sheath pubescence			Ligule pubescence			Leaf pubescence		
		Decum- bent	Erect	Erect- geniculate	High	Low	Medium	Dense	Medium	Sparse	Dense	Medium	Sparse	Dense	Medium	Sparse	
Afghanistan	17	14	3		14	1	2	10	7		10	7		10	7		
Argentina	1	1			1				1						1		
Australia	2	2			2					2					2		
Bangladesh	2	2			2			2							2		
Canada	1	1			1										1		
China	2	1	1		1	1			1						1	1	
Germany	12	7	5		4		8	1	1	10	1	1	10	1	1	10	
Hungary	10	2	7		3	2	5		2	8		1	9		1	9	
India	69	33	36		57	6	6	27	38	4	25	36	8	18	33	18	
Iran	9	8	1		8	1	1	1	5	3	1	5	3	1	5	3	
Iraq	2	1	1		2			2			2			2			
Japan	1	1				1			1						1		
Kenya	1	1			1			1							1		
Korea	73		27	46	16	36	21	54	19		18	18	55	2	71		
Lebanon	1	1			1				1						1		
Malawi	1	1					1		1						1		
Mexico	13			13		10	3	9	2	2	1	4	8	1	12		
Nepal	6	2	4			3	3	1	5		1	5		1	5		
Pakistan	41	31	10		18	9	14	20	19	2	15	20	6	14	24	3	
Romania	1			1		1		1				1			1		
Russia & CISs	128	102	26		45	28	55	10	22	96	9	21	98	8	21	99	
Spain	1	1			1					1			1		1		
Sri Lanka	2		2		2			1	1		1	1		1	1		
Syria	34	16	17	1	19	4	11	8	21	5	3	24	7	4	20	10	
Turkey	48	42	6		27	3	18	5	18	25	5	18	25	5	18	25	
United Kingdom	4		1	3		3	1	3		1		2	2		4		
Yugoslavia	1	1					1			1			1		1		
Unknown	358				156	56	146	93	176	89	48	165	145	47	153	158	

**Inflorescence characters.** Mean panicle exertion ranged from 53 mm (India) to 171 mm (Germany). The range varied from 0 (Afghanistan, Pakistan, India, Mexico and unknown origin) to 110 mm (Australia and China). This indicates that accessions with poor exertion were from Afghanistan, Pakistan, India, Mexico, and unknown origin, and good exertion accessions were found in Australia and China. Similarly the mean of inflorescence length ranged from 167 (Mexico) to 306 mm (Nepal). However, the range varied from 80–280 mm in the accessions from former USSR to 240–400 mm in the accessions from Nepal (Table 1), indicating that accessions with shorter panicles occurred in former USSR, while the longest were found in Nepal.

**Grain color.** A wide range of grain colors such as black, brown, dark brown, dark green, dark olive green, dark red, light brown, light red, olive green, straw and white were observed in ICRISAT germplasm collection. Most of the accessions were light brown (42.1%), followed by straw (21.4%), white (16.9%), light red (6.5%), dark olive green (5.1%), dark red (2.8%), olive green (2.3%), dark brown (1.4%), dark green (0.6%), brown (0.5%) and black (0.4%). About 80% of the accessions were light brown, straw and white, while the rest of colors constituted 20%.

## Classification

Cultivated landraces of *P. miliaceum* are commonly subdivided into five subspecies or races (Lyssov 1975). Race *miliaceum* resembles wild *P. miliaceum* in inflorescence morphology. It is characterized by large, open inflorescences with sub-erect branches that are sparingly subdivided. Race *patentissimum* with its slender and diffused panicle branches is often difficult to distinguish from race *miliaceum*. These two races occur across the range of proso millet cultivation from eastern Europe to Japan. Highly evolved cultivars of proso millet have more or less compact inflorescences. These are classified into races *contractum*, *compactum* and *ovatum*. Cultivars included in race *contractum* have compact, drooping inflorescences. Those belonging to race *compactum* have cylindrical inflorescences that are essentially erect. Cultivars with compact and slightly curved inflorescences that are ovate in shape are included in race *ovatum* (de Wet 1986). In the ICRISAT proso millet germplasm collection all the five races were represented. The race *miliaceum* was dominant (64.1%), followed by *compactum* (11.7%), *contractum* (11.0%), *patentissimum* (7.5%) and *ovatum* (5.7%).

## Germplasm sharing

In total, 5334 proso millet germplasm samples were distributed to scientists in 36 countries during 1978 to 2006. Of these, 488 samples were supplied to scientists in 12 countries of Africa, 3733 samples to scientists in 11 countries of Asia, 268 samples to scientists in 4 countries of Americas, 825 samples to scientists in 8 countries of Europe, and 20 samples to scientists in Australia (Oceania). Of 842 proso millet germplasm accessions available in ICRISAT genebank, 776 accessions (92.1%) were distributed to 36 countries.

## Conclusion

The characterization data of proso millet reveals that early flowering accessions were from Syria and late flowering accessions were from India; dwarf plant height accessions were from Mexico and tall plant height accessions were from Sri Lanka. Good exertion accessions were from Australia and China, and shorter panicle accessions occurred in former USSR, while the longest was found in Nepal.

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