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International Year of Millets 2023: Opportunity for Enhancing the Use of Indian Millets Germplasm

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The global as well as Indian agriculture has witnessed tremendous growth in food production in the recent decades to meet the growing population, however it is also facing challenges such as climate change and malnutrition. Millets provide a great opportunity due to their climate resilient hardy nature and can be chosen to replace the conventional crops in the dry and marginal areas. In addition, millets are also rich in several vital micronutrients and vitamins necessary for reducing malnutrition and provide multiple health benefits. The National Genebank at ICAR-NBPGR, New Delhi and Millets Genebank at ICAR-IIMR, Hyderabad conserves approximately one lakh accessions of millets germplasm which can be of great use in identification and development of improved millets cultivars. This article enlists the different aspects of importance of millets in reducing the risk of climate change and malnutrition, SWOT analysis for utilization of millets germplasm resources, future prospects and action points for greater and efficient use of millet germplasm in India.

Introduction

The global as well as Indian agriculture has witnessed tremendous growth in food production in the recent decades, however it is also facing challenges such as climate change and malnutrition (Sharma *et al.*, 2015; Kumar *et al.*, 2018). The nation has witnessed over exploitation of irrigated agriculture lands in the past however there is a need to change the focus towards dry and marginal lands to address the adverse effects of ongoing and future climate change scenario. Generally, the lower fertility of dry and marginal lands makes it difficult to achieve higher production from conventional crops such as rice and wheat. Millets provide a great opportunity due to their climate resilient hardy nature and can be chosen to replace the conventional crops in the dry and marginal areas. In addition to their climate resilience, millets are also rich in several vital micronutrients and vitamins necessary for reducing malnutrition (Hariprasanna *et al.*, 2014; Elangovan *et al.*, 2022). Millets also known as nutri-cereals are reported to be the treasure house of vitamins, minerals, essential fatty acids, phyto-chemicals and antioxidants that can help to eradicate the hidden hunger. Due to the richness of millets in polyphenols and other biological active compounds, they are also considered to impart role in lowering rate of fat absorption, slow release of sugars (low glycemic index) and thus reducing risk of heart disease, diabetes and high blood pressure (Kumar *et al.*, 2018).

The major millets are Pearl millet (*Pennisetum glaucum*, with synonyms of *P. americanum*, *P. typhoides*, and *P. typhoideum*), Foxtail millet (*Setaria italica*), Proso millet or white millet (*Panicum miliaceum*), and Finger millet (*Eleusine coracana*). Minor millets include Barnyard millet (*Echinochloa spp*.), Kodo millet (*Paspalum scrobiculatum*), Little millet (*Panicum sumatrense*) and Browntop millet (*Urochloa ramose/ Brachiaria ramose/Panicum ramosum*) (Upadhyaya *et al.*, 2006).

Millets are Climate Resilient Crops

- Pearl millet and finger millet can grow up to a soil salinity of 11–12 dS/m
- The rainfall requirement of pearl millet and proso millet is as low as 20 cm, which is several folds lower than the rice
- Most of the millets mature in 60–90 days after sowing which makes them a water saving crop
- Millets fall under the group of C4 cereals, have better photosynthetic efficiency, water use efficiency compared to C3 crops

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Nutritional Profile of Millets

Millets being rich in gluten-free proteins, high fibre content, low glycemic index and bioactive compounds have made them a suitable health food

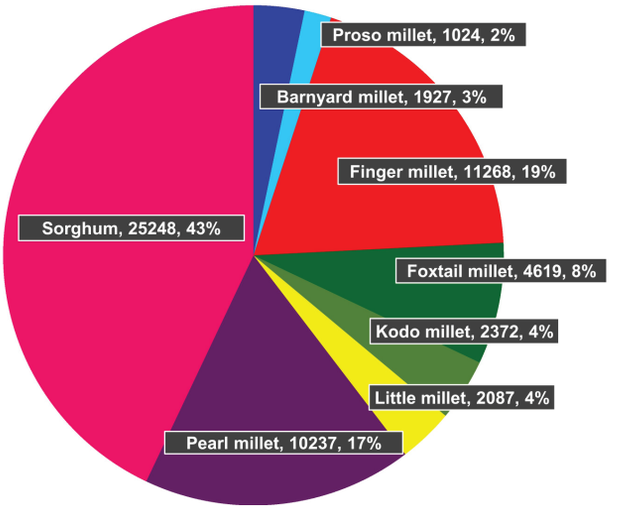
- **Carbohydrates**: The average carbohydrates content of millets varies from 56.88 to 72.97 g/100 g
- **Protein**: The protein content of all the millets is comparable to each other with an average protein content of 10 to 11%, except finger millet, which contain protein in the range of 4.76 to 11.70 g/100 g (Kumar *et al.*, 2018). Finger millet protein is rich in essential amino acids like methionine, valine and lysine, and of the total amino acids present, 44.7% are essential amino acids. Proso millet has the highest protein content among millets and the amount of essential amino acids are higher compared to conventional cereals
- **Fibres**: Millets are richest source of fibres, i.e. crude fibre as well as dietary fibre. Barnyard millet is the richest source of crude fibre with an average content of 12.8 g/100 g. The highest dietary fibre content, i.e. 38% and 37%, has been reported to be in little millet and kodo millet respectively
- **Calcium**: Calcium content of finger millet is about eight times higher than wheat and being the richest source of calcium (348 mg/100 g) it has the ability to prevent osteoporosis
- **Iron**: Barnyard millet and pearl millet are the rich source of iron, and their consumption can meet the iron requirement of pregnant women suffering from anaemia. The iron content of barnyard millet is 17.47 mg/100 g which is only 10 mg lower than the required daily value.
- **Zinc:** Foxtail millet contains highest content of zinc (4.1 mg/100 g) among all millets and is also a good source of iron (2.7 mg/100 g)
- **Thiamine**: The highest thiamine content in millets, i.e. 0.60 mg/100 g, is found in foxtail millet
- **Riboflavin**: Barnyard millet (4.20 mg/100 g) has the highest content of riboflavin followed by foxtail millet (1.65 mg/100 g) and pearl millet (1.48 mg/100g)

Status of Millets Germplasm holdings at Global, National and Institutional Genebanks

Vast collections of millets germplasm from 92 countries are conserved at ICAR-Indian Institute of Millets Research (IIMR), Hyderabad; ICAR-National Bureau of Plant Genetic Resources (NBPGR), New Delhi and International Crops for Semi-Arid Tropics (ICRISAT), Patancheru genebanks. The status of millets genetic resources in the genebanks are given in Table 1.

Table 1. Status of millets genetic resources in the Genebank

Crop name	ICRISAT	NGB-ICAR-NBPGR	MGB-ICAR IIMR
Sorghum (IS)	42,788	20,376	27,140
Pearl millet (IP)	24,390	7,841	4,128
Finger millet (IE)	7,519	11,587	7,806
Foxtail millet (ISe)	1,542	4,244	4,653
Kodo millet (IPs)	665	2362	344
Little millet (IPmr)	473	1885	694
Proso millet (IPm)	849	1005	2128
Barnyard millet (IEc)	749	1888	1705
Total	78,975	51,188	48,598



Status of millets germplasm in National Genebank

Contribution of Indian accessions to the global minicore collections

The Indian millet germplasm accessions contributed significantly to the global germplasm diversity which can indirectly be measured by assessing the proportion of Indian accessions in the global millet minicore collections (Upadhyaya *et al.*, 2011, 2019; Babu *et al.*, 2013). The contribution of Indian millet germplasm accessions to the global minicore collections varies from 6.6 % (7 acc.) in proso millet to 100 % (total 75 acc.) in kodo millet (Table 2).

Table 2. Contribution of Indian accessions to the global minicore collections

Crop	No. of acc. in Minicore	Indian accessions	% contribution by Indian origin acc.
Sorghum	242	30	12.4
Barnyard millet	89	49	55.1
Finger millet	80	17	21.3
Foxtail millet	35	12	34.3
Kodo millet	75	75	100.0
Little millet	57	55	96.5
Pearl millet	238	60	25.2
Proso millet	106	7	6.6

Millet Species Diversity and Variability

Millets species diversity is high in many Indian states *viz*., Uttar Pradesh (21), Odisha (16), Rajasthan (15), Bihar (14), Telangana and Himachal Pradesh (12), Chhattisgarh and Jammu & Kashmir (11). Jharkhand (10), Arunachal Pradesh (9), Punjab and Haryana (8), Kerala (6), West Bengal and Nagaland (5) etc. Tremendous genetic variability in the indigenous millets germplasm accessions has been recorded through characterization efforts carried out at ICAR-IIMR, ICAR-NBPGR, ICRISAT and AICRP centres under Sorghum, Pearl millet and Small millets programme.

Sorghum [*Sorghum bicolor* (L.) Moench]: Sorghum is being grown in two important seasons viz., *kharif* (rainy) and *rabi* (post-rainy) and season-specific Indian landraces are collected and conserved. Overall, the variability in Indian sorghum germplasm for days to 50 % flowering ranged between 41 and 141 days with a mean value of 75 days. Flowering is an important phonological trait helping the breeders in selecting varieties suited to different agro-ecological zones and climatic conditions. The plant height ranged between 30 and 480 cm with a mean of 213 cm. The variability in plant height provides opportunity for selection of germplasm suiting to different end uses like, grain, fodder, high biomass, dual purpose (grain and fodder) etc. The grain yield (g plant^{-1}) varied from 10.0 to 144.5 g with a mean of 30.2 g whereas, 100-seed weight is varying from 0.5 g to 6.2 g with an average value of 2.74 g.

Pearl millet [*Pennisetum glaucum* (L.) R. Br.]: Pearl millet in India is being grown in *kharif* and summer season in parts of Gujarat, Rajasthan and Uttar Pradesh and during the *rabi* season at a small scale in Maharashtra and Gujarat (Yadav and Rai, 2013). In general, the variability in the Indian pearl millet germplasm for days to 50 % flowering varied from 33 to 159 days with a mean value of 72.7 days. The number of productive tillers attained by each plant ranged between 1 and 19 tillers with an average of 2.07 tillers per plant. The yield attributing traits like panicle length and width also recorded huge diversity. The panicle length recorded a minimum value of 5 cm and a maximum of 134 cm with a mean of 28.8 cm whereas the panicle width had a minimum of 8 cm to 58 cm with a mean of 23.9 cm. The plant height showed a minimum height of 30 cm and a maximum height of 490 cm with an average of 248 cm. Another yield attributing trait, 100-seed weight also has recorded huge variability between lowest of 0.15g and highest of 2.11 g per with an average value of 0.85 g.

Finger millet [*Eleusine coracana* (L.) Gaertn]: The finger millet is a major staple crop among tribal farmers and it can adapt to adverse climatic conditions, require minimal inputs and possess superior nutritional properties (Pradhan *et al.*, 2019). In general, the Indian finger millet variability for days to 50 % flowering ranged from 33 to 143 days with a mean of 87.7 days. The productive tillers varied from 1 to a maximum of 32 tillers per plant with an average of 9.2 tillers. The finger number on the main head ranged between 2.3 and 16.3 fingers with a mean value of 7.3 fingers per ear head. The individual finger length and width also showed tremendous diversity, the length of finger ranged between 2.5 and 19.5 cm with a mean of 7.17 cm while the width of the finger varied between 0.3 cm and 8.7 cm with a mean of 1.26 cm. The potential grain yield in Indian finger millet germplasm ranged between 1 g and 177.3 g per plant. The 100-seed weight also depicted a vast variability with a minimum value of 0.1 g and a maximum value of 1.35 g and a mean value of 0.25 g.

Foxtail millet [*Setaria italica* (L.) P. Beaurv]: Foxtail millet is an important grain crop cultivated for food in some parts of China, India and Japan. The foxtail millet grains are a rich source of protein, minerals (calcium, iron, potassium, magnesium, and zinc) and vitamins (Upadhyaya *et al.*, 2011). The variability in the conserved germplasm accessions of Indian origin for days to 50 % flowering ranged between 34 and 99 days with a mean flowering days of 50.7 days. The number of basal tillers recorded the range of 1.3 to 27 tillers with a mean value of 6.4 tillers. The stem diameter ranged between 0.2 cm and 1.2 cm with an average of 0.4 cm. The yield attributing traits such as panicle length and panicle width showed tremendous variation. The panicle length ranged

between 3.4 cm and 37.8 cm with a mean of 17.9 cm and panicle width varied from 0.3 cm to 4.3 cm with a mean of 1.5 cm. The grain yield harvested from a single plant varied from a minimum of 1g to a maximum of 154.5 g with a mean of 25.2 g. The 100-seed weight of the foxtail millet grains showed variability between 0.03 g to 0.85 g with a mean of 0.26 g.

Proso millet (*Panicum miliaceum* L.): Proso millet is widely cultivated in India, China, Nepal, Africa, Russia, Ukraine, Belarus, Middle East, Turkey and Romania. The shallow root system (90–120 cm) and very short growing season (60–90 days) make it an ideal dryland crop and can fit into cropping system approach (Das *et al.*, 2019). In general, the variability of the Indian proso millet accessions for the number of basal tillers varied from 2.5 to 24 tillers per plant with a mean of 7.5 tillers. The days to 50 % flowering showed from very early flowering days of 38 days to very late flowering with 60 days and the mean of all the accessions was 48.2 days. The panicle length of the proso millet accessions varied between 12.4 cm and 46.7 cm with a mean of 25.9 cm while the panicle width ranged between 1.3 cm and 6.8 cm with an average value of 3 cm. The days to maturity of the proso millet accessions showed a diversity varying between 59 days and 89 days with a mean of 76 days. The grain yield harvested from each plant varied between 1 g to 18.4 g with an average harvest of 4.6 g from each plant. The 100 seed weight varied between 0.06 g and 0.8 g with a mean value of 0.4 g.

Barnyard millet (*Echinochloa frumentacea* Link): Barnyard millet is mainly grown in India, China, Japan, and Korea for human consumption as well as fodder (Upadhyaya *et al.*, 2016). The grains have superior nutritional properties including high micronutrients, dietary fiber content, and low glycemic index (GI) with potential health prospective (Upadhyaya *et al.*, 2016). In general, the variability in number of basal tillers ranged between 1 and 16.5 tillers per plant with a mean of 4.4 tillers. The days to 50 % flowering showed a minimum flowering day of 46 days as compared to the accession which showed delayed flowering in 86 days and the mean of all the accessions was 58 days. The panicle length of the barnyard millet accessions varied between 10.4 cm and 31.1 cm with a mean of 19.3 cm while the panicle width ranged between 1.5 cm and 6.8 cm with an average value of 3.7 cm. The plant height of the barnyard millet accessions showed a diversity varying between 60 cm and 291 cm with a mean of 122 cm. The grain yield harvested from each plant varied between 1.2 g and 37 g with an average harvest of 12 g from each plant. The 100-seed weight of the Indian barnyard millet accessions varied between 0.16 g and 0.47 g with a mean value of 0.27 g.

Little millet (*Panicum sumentranse* Roth): Little millet is largely cultivated throughout India by tribal people in small areas for food and fodder. It is a rich source of several micronutrients and vitamins. The variability present in the Indian little millet germplasm can be of great use for plant breeders. In general, the number of basal tillers among the accessions ranged between 3 and 46 tillers per plant with a mean tiller number of 14.6. The thickness of the culm varied from 2 mm to 18 mm with an average diameter of 6.6 mm. The minimum number of days required for the 50 % flowering was 39 days whereas the maximum days required for flowering were 138 days with a mean of 57.9 days. The panicle length was ranged between 27 mm and 500 mm with a mean of 282 mm. The width of the panicle was varying from 10 mm to 480 mm with an average width of 147.6 mm. The grain yield harvested from each plant varied between 2.95 g and 14.26 g with an average harvest of 7.37 g from each plant (Vetriventhan *et al.*, 2021). The 100-seed weight of the Indian little millet accessions varied between 0.14 g and 0.32 g with a mean value of 0.22 g.

SWOT Analysis of Utilization of Indian Millets Germplasm

Strength: The vast diversity of millets germplasm characterized and conserved in the National Genebank, Millets Genebank and AICRP Centres.

Weakness: Lack of data on multi-location evaluation of potential millets germplasm, nutritional characterization of nutri rich millets germplasm and difficult crop for breeding.

Opportunities: Awareness under International Year of Millets 2023 (IYoM) created a demand for value addition in millets and need to develop conventional breeding approaches

Threats: Millets cultivation area is decreasing due to occupation of commercial crops. Non-availability of processing machineries and minimum support price for the millets produce are the biggest concerns of the millet growing famers.

Kodo millet (*Paspalum scrobiculatum* L): Kodo millet is cultivated by tribal people across India for food and fodder. The Indian Kodo millet germplasm accessions depict a vast diversity for key traits of importance. In general, the accessions recorded a minimum of 2 basal tillers and maximum of 48 basal tillers per plant with a mean of 15.1. The days to 50 % flowering ranged between 51 days and 112 days with a mean value of 77.3 days. The number of leaves ranged between 3 and 15 with a mean value of 5.7 leaves per plant. The plant height varied from 30 cm to 97 cm with an average height of 54.7 cm. The raceme number varied from 1 to 8 racemes per plant with a mean of 3 racemes. The grain yield harvested from each plant varied between 5.37 g and 31.37 g with an average harvest of 15.19 g from each plant (Nirubana *et al.*, 2017). The 100-seed weight of the Indian Kodo millet accessions varied between 0.24 g and 0.49 g with a mean value of 0.36 g.

Future Prospective and Action Points

- India being the primary origin for Little millet, Kodo millet and Barnyard millet; secondary origin for Sorghum. Finger millet being the major crop in the semi-arid regions, the adaptation and diversity of these millets germplasm are exclusive to India for some extent
- Re-introduction of millets local landraces in the region of collections to rejuvenate its natural habitat capability
- More emphasis on the characterization of millets for nutritional parameters to know the nutritional status of all available millets germplasm
- Evaluation of millets germplasm in all adverse agro-climatic conditions in the country to identify the best germplasm and supportive evidence for millets as climate resilient crop
- The CVRC should encourage breeders to release nutritional-specific millet varieties wherein nutrition is the primary trait followed by grain and fodder yield
- Millets demand is created through awareness campaign on the benefits of millets and diverse products by the start-ups in the markets. However, afford to buy millets by the poorer comes only through Public Distribution System. Need to diversify the plate of the PDS of the country with nutri-cereals.

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