

Towards a zero hunger world

through nutraceutical pearl millet

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Pearl millet (Pennisetum glaucum) is the staple food of majority of the poor and small land holders, as well as feed and fodder for livestock in rainfed regions of the country. Pearl millet has the inherent potential to contribute to food security as well as health status of the burgeoning population. Pearl millet excels all other cereals due to its unique features - C₄ plant with high photosynthetic efficiency, high dry matter production capacity and is grown under the most adverse agro-climatic conditions where other crops like sorghum and maize fail to produce economic yields. It requires less inputs, matures in short duration and is considered as nutritious food, feed and fodder.

Key words: Nutraceutical, Pearl millet, Zero hunger

FOOD security is the condition in which all people, at all times, have physical, social and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Global climate change, burgeoning global population, rising food prices and different environmental factors have significantly influenced parameters associated with food security in the past few decades. Nutritional security highlights need of appropriate nutritious diets with all essential nutrients and water, adequate sanitation, healthy environment and proper health services for all the household members. It emphasizes the health component and nutritional status of the individual or society.

In India, pearl millet is the fourth most widely cultivated food crop after rice, wheat and maize. It is grown on 7.5 million ha with an average production of 9.73 million tonne and productivity of 1,305 kg/ha during 2016-17 (Directorate of Millet Development, 2018). The major pearl millet growing states are Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana which



Fig. 1. Pearl millet is a nutri-cereal crop

account for more than 94.82% of pearl millet acreage in the country and contributed to 87.70% of total production. Pearl millet is commonly grown in rainy season (June/July–September/October). It is also cultivated during summer (February to May) in parts of Gujarat, Rajasthan and Uttar Pradesh; and during the post-rainy season (November to February) at a small scale in Maharashtra and Gujarat.

Pearl millet is the major millet occupying first position among all the millets in India followed by

sorghum and ragi. As millets are climate smart crops with high nutritional value they are rightly termed as Nutri-cereals. Millets are declared as Nutri-cereals through a gazette notification on 13 April, 2018. To bring millets into mainstream, exploit their nutritional rich properties and promoting their cultivation, Government of India has made efforts to include pearl millet under Public Distribution System and Millet mission. Efforts are also initiated to declare this year as the 'Year of Millets'. Pearl millet is rightly termed as 'nutricereal' as it is a good source of energy, carbohydrate, protein, fat, ash, dietary fibre, iron, zinc and more balanced amino acid profile. It is a rich source of energy (361 K cal/100g) comparable to sorghum (349 K cal/100g), wheat (346 Kcal/100g), rice (345K cal/100g), and maize (325 K cal/100g). The carbohydrate content of pearl millet is 67.5 g/100 g; with 56 to 65% starch comprising 20 to 22% amylase and 2.6 to 2.8% free sugars - mainly sucrose. It is high in fiber (1.2 g/100 g) and α -amylase activity. The protein content of pearl millet is (11.6/100g), comparable to wheat



Fig. 2. Research on pearl millet improvement in India is carried out through AICRP-PM.

but higher than rice. It is rich in methionine but poor in sulphur containing amino acids. With low prolamine fraction, pearl millet is gluten free grain and is the only grain that retains its alkaline properties after being cooked which is ideal for people with gluten allergy. Pearl millet is rich in fat content (5 mg/100 g) with better fat digestibility and rich in unsaturated fatty acids (75%) with higher content of nutritionally important n-3 fatty acids. It is a rich source of vitamins and minerals with overall mineral content of 2.3 mg/100 g constituting potassium (K), phosphorous (P), magnesium (Mg), iron (Fe), zinc (Zn), copper (Cu), and manganese (Mn). It is rich in B-vitamins (thiamine, riboflavin and niacin).

Recently, there has been global recognition of widespread deficiencies of iron (Fe) and zinc (Zn), leading to numerous adverse health consequences, especially in the

growing states such as Rajasthan, Gujarat and Maharashtra. In these areas, it contributes 19 to 63% of the total Fe intake and 16 to 56% of the total Zn intake from all food sources. The Fe and Zn densities in pearl millet are largely under additive genetic control, suggesting that population improvement and open pollinated varieties development for these two micronutrients is likely to be highly effective leading to the development of Dhanashakti. To breed hybrids with high Fe and Zn densities would require breeding both parental lines with high levels of these micronutrients and hybrids like AHB 1200, HHB 299 with high levels of iron and zinc were developed.

Research on pearl millet improvement in India is carried through the All India Coordinated Research Project on Pearl Millet (AICRP-PM) administered by Indian Council of Agricultural Research

developing countries which are 41 heavily dependent on the cereal-based diets. India loses about 4 million disability-adjusted life years (DALYs) annually due to Fe deficiency and another 2.8 million disability-adjusted life years due to Zn deficiency. Pearl millet accounts for 20 to 63% of the total cereal consumption in parts of the major pearl millet

(Fig. 1). The AICRP-PM has a network of 13 AICRP centers in Rajasthan, Gujarat, Maharashtra, Uttar Pradesh, Karnataka, Andhra Pradesh, Madhya Pradesh, Punjab, Haryana and Tamil Nadu. The AICRP-PM centers located in 12 state agricultural universities and University of Mysore pursue mandated activities and strategic research on pearl millet in the area of germplasm utilization, improvement, production, protection and value addition etc. As the growing conditions for pearl millet vary from near-optimum with high external inputs to highly drought-prone environments, prioritization of research in cognizance of production constraints and differential requirement of various crop growing regions led to formation of three zones viz. A₁, A and B. Zone A₁ is comprised of parts of Rajasthan, Gujarat and Haryana receiving less than 400 mm annual rainfall (Fig. 2).

Pearl millet is a highly cross-pollinated crop with outcrossing rate more than 85 % and showed high degree of heterosis for grain and stover yields. Attempts were made to exploit heterosis in the 1950s utilizing the protogynous nature of flowering of this crop. The usual practice for hybrid seed production at that time was growing the parental lines in mixture and allowing them to cross-pollinate i.e. the development of 'chance hybrids'. The resultant seed contained approximately 40% hybrid seed when the two parental lines had synchronous flowering. These chance hybrids thus produced out yielded local varieties by 10 to 15%. But again, they could not become popular due to their limited yield advantage over open pollinated varieties narrow range of adaptation and lack of seed production

Table 1. Five-year means for grain yield and per cent improvement in yield over average yield of 1986-90 of principal food crops in India between 1985 and 2015.

Years	Grain yield (kg/ha)					% improvement in yield over average yields of 1986-90				
	Rice	Wheat	Sorghum	Maize	Pearl millet	Rice	Wheat	Sorghum	Maize	Pearl millet
1986-90	1,622	2,113	744	1,371	539	-	-	-	-	-
1991-95	1,818	2,429	827	1,564	620	12	15	11	14	15
1996-00	1,918	2,648	825	1,768	733	18	25	10	29	36
2001-05	1,997	2,661	784	1,913	856	23	26	5	40	59
2006-10	2,161	2,812	962	2,124	932	33	33	29	55	73
2011-15	2,416	3,092	913	2,569	1,206	49	46	23	87	124

programmes. The above-mentioned limitations in the exploitation of heterosis were overcome with the discovery of cytoplasmic-nuclear male sterility and release of male-sterile lines Tift 23A and Tift 18A in early 1960s at Tifton, Georgia, USA. The male-sterile line Tift 23A was extensively utilized, both at Punjab Agricultural University, Ludhiana, and Indian Agricultural Research Institute, New Delhi, because of its short stature, profuse tillering, uniform flowering and good combining ability. This laid the foundation of pearl millet hybrid breeding in India. High-yielding hybrids and open-pollinated varieties were widely adopted by Indian farmers. These limitations in the exploitation of heterosis were overcome with the discovery of cytoplasmic-nuclear male sterility and release of male-sterile lines Tift 23A and Tift 18A in early 1960s at Tifton, Georgia, USA. The male-sterile line Tift 23A was extensively utilized, both at Punjab Agricultural University, Ludhiana, and Indian Agricultural Research Institute, New Delhi, because of its short stature, profuse tillering, uniform flowering and good combining ability. This laid the foundation of pearl millet hybrid breeding in India. With the adoption of high-yielding and disease-resistant cultivars, pearl millet productivity has gone up from 5.39 q/ha from 1986-90 to 12.70 q/ha during 2010-16 registering a 124% improvement, which is highest among all food crops (Fig. 3 and Table 1). Till date a total of 165 hybrids and 63 varieties were identified and released for cultivation in different agro-ecological zones of the country.

The phenomenal increase (86 to 161%) was recorded in Haryana, Rajasthan, Madhya Pradesh, Maharashtra and Uttar Pradesh. Increase in average yields was also around 60% in Andhra Pradesh, Tamil Nadu and Karnataka. The assessment of annual rate of improvement in pearl millet productivity, for two periods of 25-year duration each, in the two phases due to adoption of high-yielding cultivars and improved crop production technologies depicted

that the crop productivity increased @ 6.3 kg / ha / year during first 25 years (1960-85) of hybrid development and this increase went up to over 20 kg/ha/year in next 25 years (1986-2010) 24 kg / ha / year (1987-2012) and 27 kg/ha/year (1991-2015).

Till 1990, there were no specific molecular markers developed for pearl millet, no marker-based genetic linkage map generated, and traits could not be linked to marker locus positions on a non-existent map. By 2001, hundreds of pearl millet molecular markers was created. Detailed marker-based genetic linkage maps produced, and using those maps, genomic positions of quantitative trait loci for pearl millet downy mildew resistance were flagged. Initial map development was followed by identification of quantitative trait loci using several different mapping populations. The target traits for pearl millet quantitative trait loci mapping were downy mildew resistance; grain and stover yield under drought and favourable conditions and stover quality. Pearl millet hybrid HHB 67 Improved, a downy mildew resistant version of HHB 67, was released in 2005 which was developed using parental lines bred through marker-assisted selection. HHB 67 Improved was the first marker assisted selection

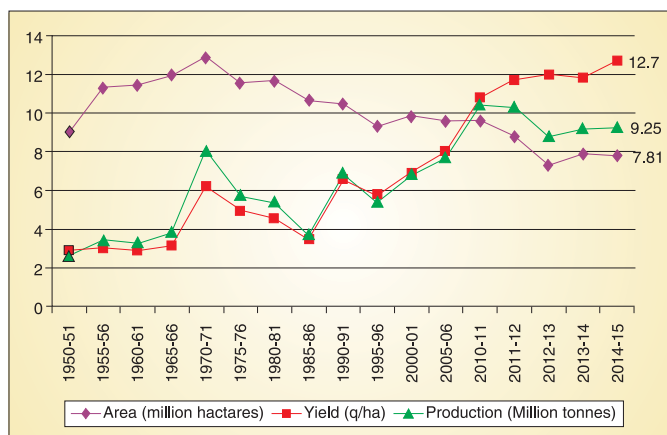


Fig. 3. Pearl millet productivity has gone up with the adoption of high-yielding and disease resistant varieties

product that was released in India and was widely adopted by farmers. In 2017, the pearl millet genome sequence was made public with concerted efforts of ICRISAT and other consortium members.

Many crop rotations of crops involving pearl millet are feasible involving crops like wheat, barley, chickpea, potato, *toria* after the harvest of pearl millet in areas where irrigation is available.

Pearl millet – Uses

Both whole grains and dehulled grains of pearl millet are used for preparing various types of food products. Grains are milled using different mills in different areas and the flour is used in making *roti/rab* etc. The major problem hindering pearl millet as a staple food in non-traditional areas is the poor keeping quality of the flour. The flour turns rancid, colour changes with foul smell due to oxidation of the free fatty acids available. Techniques are available where flour can be stored for 2 to 3 months under certain treatments while milling. Other ways of using the grain are through malting, blanching, acid treatment, dry heat treatment, parboiling etc.

The simplest and the most common traditional food made from pearl millet are thin porridge, thick porridge (fermented and unfermented), flat and unfermented bread like *roti*. Various types of traditional foods and snacks are also made from pearl millet in India like *laddoo*, *namkeen sev*, *bhakri*, *khichri*, *dalia*, popped grain etc.

Extruded products from pearl

Some important cropping systems available are:
 Pearl millet- Barley
 Pearl millet- Wheat
 Pearl millet- Chickpea
 Pearl millet- Field pea
 Pearl millet- Potato
 Pearl millet- Potato- wheat
 Pearl millet- Wheat- Mung bean
 Pearl millet- Wheat- Jowar (Fodder)
 Pearl millet- Wheat- Pearl millet (Fodder)

millet are increasingly used to make ready-to-eat products. Noodles, *macaroni* and *pasta* like extruded products are also available from pearl millet flour. Popped pearl millet is a good source of energy, fibre and carbohydrates. The nutritional advantage of popped pearl millet is utilized in developing formulations for supplementary foods or weaning foods for children and mothers. Since pearl millet is rich in iron (Fe), zinc (Zn) and balanced nutritional profile it scores better than rice and wheat products in the weaning food category as it satisfies the nutritional requirement of the infants during the crucial transitional phase of life from breast milk to other type of food, that too at reasonable cost.

Healthy food pearl millet has a relatively higher proportion of insoluble dietary fibre causing slow release of sugar thus making it suitable for those suffering from diabetes. The beauty of pearl millet is free from gluten and good for celiac patients; it has low glycemic index, slowly digestible and is considered good for diabetics.

Pearl millet is rich in oil and linoleic acid accounts for 4% of the total fatty acids in this oil, giving it a higher percentage of n-3 fatty acids compared to maize where linoleic acid accounts only for 0.9% of the total fatty acids. The n-3 fatty acids play an important role in physiological functions like platelet aggregation, cholesterol accumulation and the immune system. Hence pearl millet in the poultry feed can have a significant effect on the fatty acid composition of the eggs and consequently on human health. Eggs produced from layers fed with pearl millet-based diets had lower n-6 fatty acid and higher n-3 fatty acids leading to lower n-6:n-3 fatty acid ratios. These eggs are of special health value for those prone to high levels of LDL in the cholesterol.

Drinks: Pearl millet is used in making different types of drinks. A fermented drink known as *rab/rabari* is consumed widely in summer in Rajasthan. Similarly in Tamil Nadu a traditional drink called *cumbu cool* is prepared and consumed in summer. NDRI, Karnal has launched pearl

millet *lassi* made of pearl millet flour.

Future prospects and opportunities for commercialization

- Pearl millet being the most water use efficient major cereal under water-limiting environments is also the most heat-tolerant cereal. It is also the most salinity-tolerant cereal next only to barley. These attributes of pearl millet put it in a unique advantageous position to address the multiple environmental challenges, which are likely to be of increasingly serious proportion in the future.
- Recent growth and future projections of aggregate food demand patterns suggest that there will be substantial increase in the demand for animal products (meat, milk and eggs) in India by 2050. Pearl millet, being a C 4 species with high photosynthetic potential and biomass production ability, has a greater role to play in arid and drier semi-arid regions to bridge the gap between demand and supply of dry fodder which is the main maintenance ration in dry periods.
- Pearl millet grains can also be right choice against wheat and rice for the elite who will benefit from its nutraceutical properties.
- Policy support from the government plays an important role in product and process commercialization, at least in the initial stages when the food products from grains of new crop species must compete with those from the established crop species. With the governments decision to support millets through Millet Mission as sub-mission under NFSM, inclusion in Public Distribution System and increased Minimum Support Price would definitely boost the production and use of pearl millet.
- Development of pearl millet hybrids/ varieties with seedling stress tolerance that can withstand the prolonged dry spells faced between June and August in the major pearl millet growing areas can certainly increase production by 20 to 25%.
- Also shifting the focus of breeding

from productivity enhancement to specific end use traits – shelf-life enhancement, high quality protein pearl millet.

- Further, message of pearl millet as a *nutricereal* and health food as it is a rich source of micro-nutrients and antioxidants, needs to be promoted not only in areas where it is traditionally produced and consumed, but also in other areas within India and elsewhere.
- *Public-private-partnerships policy recommendations to upscale the pearl millet promotion:* Continuous entrepreneurship development programmes need to formulate for the farmers and other stakeholders utilizing modern and innovative techniques. These should be mainly focused on the micro-entrepreneurs to motivate them for value addition, product development and marketing.
- The aspects like health and our social benefits related to pearl millet should be considered by policy makers. Inclusion of pearl millet in mid-day meal programmes in schools, promoting industry for processing, assured support price are some of the urgently needed solutions for sustaining pearl millet production ecologies.

SUMMARY

Pearl millet is primarily grown for food and dry fodder. Its grains are highly nutritious with high levels of metabolizable energy and protein. It has high iron (Fe) and zinc (Zn), and more balanced amino acid profile compared to rice, wheat, maize or sorghum. Grains are mainly used for human consumption as leavened and unleavened flat breads and porridges. Dry stover of pearl millet is a major component of livestock ration during the dry period of year. Pearl millet is also an excellent forage crop. Its green fodder is rich in protein, calcium (Ca), phosphorous (P) and other minerals with oxalic acid within limits.

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