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Current Breeding Approaches in Pearl Millet to Enhance the Nutritional Quality

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Review Article

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ABSTRACT

Pearl millet is an important millet crop, as it is a powerhouse of nutrition with capability to grow at harsh climatic conditions. It is able to overcome sudden climate changes and other natural disasters which can create food security problem by raising the price of foods there by reduce the availability of food materials. Pearl millet can be an alternative nutritious crop for the poor men which provide enough nutrition for active and healthy life. It is cheap source of nutrition when compared to other major cereal crops. While having its nutrition and health benefits, utilization of this crop is restricted due to lack of knowledge and poor keeping quality.
Different breeding strategies like biofortification breeding, making of synthetic and composites, hybridization techniques by using A,B,R lines, Genomics, Speed breeding are frequently utilized in worldwide. Different improved lines with enhanced zinc and iron content may be used under

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hybridization programme to overcome the problem of low zinc and iron varieties. Therefore, the aim of this review is to provide the information about nutritional profile, health benefits, biofortification process, current breeding approaches and future prospects.

Keywords: Pearl millet; nutrition; health benefits; biofortification; breeding approaches.

1. INTRODUCTION

"Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is also known as Bajra, is a highly nutritious warm season millet crop having a high photosynthetic efficiency and dry matter production capacity with a short life cycle. The genome size is (2352 Mbp)", [1]. "It belongs to family *Poaceae* and sub family *Panicoideae*. It is assumed to have originated in West Africa [2] from where it spread into India and other countries".

"Pearl millet is a diploid (2n = 2x = 14) in nature and most drought tolerant warm-season millet crop predominantly grown as a staple food grain, source of feed and fodder. It is nutritionally superior and staple food for millions of people living in harsh environments characterized by erratic rainfall and poor soil. It is the only suitable and efficient crop for arid and semiarid conditions because of its efficient utilization of soil moisture and higher level of heat tolerance than sorghum and maize. Farmers prefer the crop as low cost, low risk option not only by choice but also by necessity. It tolerates low soil pH better than sorghum" [3]. It also possesses unique genetic predisposition to withstand environmental stress and produce appreciable yield when grown on marginal soils. This is usually grown in the soil with depleted fertility, which receives annual rainfall of 150 mm-750 mm.

"In terms of area and production, pearl millet occupies the fourth rank in India after wheat, rice and maize. In India pearl millet is cultivated on about 7.52 million ha area and produced 10.28 million tones with the average productivity of 1368 kg per ha" [4]. The major pearl millet growing States are Rajasthan, Maharashtra, Uttar Pradesh, Gujarat and Haryana contributing 90 per cent of total national production. Most of pearl millet in India is grown in rainy (*kharif*) season (June/July – September/ October). It is also cultivated in summer season (February – May in parts of Gujarat, Rajasthan and Utter Pradesh; and during the post-rainy (*Rabi*) season (November – February) at a small scale in Maharashtra and Gujarat.

"Rajasthan has the highest area under pearl millet accompanied with highest production in the country. In Rajasthan, the area under this crop depends on the onset of monsoon whereas the production is governed by the amount and distribution of the rainfall. The state occupied 4.28 million ha area with the total production of 5.11 million tones and average productivity of 1192 kg per ha during 2019-20. The major pearl millet growing districts are Barmer, Jodhpur, Jaipur, Nagaur, Alwar, Sikar, Churu, and Jhunjhunu" [5].

Pearl millet is highly cross-pollinated crop due to protogynous nature and wind borne pollination mechanism, which fulfils the essential biological requirement for hybrid development. Exhibits cytoplasmic genetic male sterility (CGMS), making it possible for the development of single cross hybrid. Inflorescence is a cylindrical spike consisting of a central rachis on which the groups of spikelets are densely packed. Spikelet's bear two types of florets, one being bisexual and the other staminate. The unisexual staminate florets are sessile and born below the bisexual flowers. Having three anthers but lacking female organs. The bisexual floret consists of a single pistil with two feathery stigmas and three anthers enclosed between lemma and palea. The stigma remains receptive for one to two days. In hermaphrodite flowers anthesis starts from apex of the panicle toward the base where as the anthesis of the staminate flowers starts 2-3 days after the anthesis of hermaphrodite flowers. Anthesis occurs throughout the day and night but maximum occurs between 10 pm to mid night. Pollen grains remain viable for 5 (hrs).

"Pearl millet is very rich in calories, proteins (6-15%), fat (5-6%), carbohydrates (60-72%), fibre (1-1.8%) and minerals with less amount of HCN, which makes it highly nutritive and palatable crop in comparison with other crops" [6]. "Micronutrient deficiency has become a global threat and especially, people inhabiting in developing countries who predominantly feed on cereal diet (wheat and rice) are more prone to this micronutrient malnutrition. Millets are nutri-cereals which can combat with this malnutrition. Among all the millets, pearl millet is a rich source of essential amino acids and minerals like Fe and

Zn content" (Anuradha et al. 2018). "It is also the cheapest source of Fe and Zn as compared to other cereals and vegetables" [7]. "As a food crop, pearl millet grain possesses the highest number of calories per 100 grams [8], which is mainly supplied by carbohydrates, fats and proteins. Important quality aspects of pearl millet forage are high protein (11.6%), low lignin, high dry matter yield, easy to digestible and possesses less oxalic acid which is an anti-nutritional factor" [9].

Pearl millet is also a dual purpose drought resistant crop useful for fodder purpose, traditionally grown as a rainfed crop mostly under low fertility conditions. Green fodder of pearl millet is preferred over that of sorghum because of its low HCN content so it can be fed to cattle without harm at any stage of growth. The green fodder of bajra also rates high as it possesses high concentrations of albuminoids, carbohydrates and fat and also it has easy digestibility.

"The low production of pearl millet in India leads to the need of developing varieties with stable production irrespective of growing place and time under stress conditions. Information on genetic variability about a crop is prerequisite for crop improvement program" [10]. Availability of sufficient genetic diversity in the germplasm, which is the basis of all breeding programmes.

Therefore the main emphasis of this article is to explore nutritional security, health benefits, processing techniques, identifying new breeding techniques, problems and product of pearl millet grain so as to use it for further research in the area of post harvest processing and value addition of Pearl millet crop. Pearl millet is a staple food with superior nutritional value and also have health benefits. As consumers are more attentive towards their health so the pearl millet has one of the alternative options for nutritious food. Despite high nutrition value and health benefits, use of pearl millet is limited because high lipid content which reduce the shelf life and acceptability of pearl millet products. Biofortified breeding, hybridizing techniques, transgenic breeding, speed breeding and molecular techniques may utilize to improve the crop and released as nutritious varieties to overcome nutrition problem.

2. CURRENT NUTRITION AND HEALTH STATUS IN INDIA

According to the latest National Family Health Survey (NFHS-5) 2019-21 in India;

1. **Children's nutritional status:** 3 percent are overweight, 3 percent are underweight, 36 percent are stunted (short for their age), 19 percent are wasted (thin for their height), and 32 percent are wasted (underweight) (heavy for their height).
2. **Micronutrient intake:** In the six months before to the study, 37 percent of children aged 6-59 months received vitamin A supplements. The day or night before the interview, 47% of kids aged 6 to 23 months ate foods high in vitamin A, and 21% ate foods high in iron.
3. **Adult nutritional status:** Between the ages of 15 and 49, 19% of women and 16% of men are overweight. Overweight or obese people make up about the same percentage (24 percent of women and 23 percent of men).
4. **Anaemia in adults:** 57 percent of women and 25 percent of males between the ages of 15 and 49 have anemia.

"India still has one of the worst rates of child malnutrition in the world, despite decades of investment to address this problem. India is ranked at the bottom of the Global Hunger Index (2022), which is determined by factors such as child stunting, wasting, and death placing India in 107th rank of 121 Countries and to overcome this situation it has to be lead in the sector of biofortified crop and millets may be the good option further".

Biofertilization of millets is one of the ways for combating hunger by genetically enhancing major food crops to produce more nutrients. It is a multidisciplinary approach that aims to use the full capacity of agricultural development and nutrition science to address the ongoing micronutrient problem.

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and Mahatma Phule Krishi Vidyapeeth collaborated on Dhanashakti, a high-iron pearl millet variety that was released in Maharashtra in 2012 and later in India in 2013, making it the first mineral biofortified product of any crop cultivar released in India, spearheaded by the CGIAR's Harvest Plus Program. Dhanashakti has a total iron content of 71 mg and a zinc content of 40 mg per kilogram. ICRISAT has also created a high-iron pearl millet hybrid (ICMH 1201), which is being marketed by Shakti Vardhak Seed Company under the brand name Shakti 1201, using

Truthfully Labelled Seed (self-certification).This hybrid has 75 mg/kg iron and 40 mg/kg zinc (similar to Dhanashakti).

3. IMPORTANCE OF PEARL MILLET AS FOOD

1. **Bajra consumption protect from type 2 diabetes.** Diabetes is a chronic disease that affects millions of people all over the world. Sudden spikes in blood sugar are concerning, and dietary choices play an important role in blood glucose regulation. Bajra being an amazing combination of good carbs along with ample amounts of dietary fibre makes an ideal diet for those suffering from diabetes.
2. **Bajra assist in losing weight.** Being overweight comes with various health problems and if we are looking forward to shedding those extra fat, Pearl Millet should top our food choices. Rich in protein, Bajra aids in muscle development, strength, and tissue repair. It's an excellent choice for vegans who want to reduce their carbohydrate intake.
3. **Protect from polycystic ovarian syndrome:** It is a widespread condition that affects women of all ages, from adolescence to menopausal people. This hormonal imbalance can disrupt not just health but also emotions, cause severe exhaustion, and result in undesirable hair growth. Aside from medication, decreasing weight and maintaining a strict eating regimen might help overcome this disease, and Bajra is one such food source. Pearl Millet, which is high in iron and fiber, helps to reduce visceral fat (fat around the abdomen.
4. **Good for Heart: Heart** is a vital organ and a regulated diet helps it to function at the optimum level. Bajra is a powerhouse of magnesium and potassium which plays a crucial role in dilating blood vessels facilitating better blood circulation. As this miracle millet is a high source of Omega-3 fatty acids, plant lignans, and other nutrients, regular consumption of Pearl Millet helps to lower bad or LDL cholesterol, preventing artery blockages.
5. **It aids in digestion and helps to prevent constipation**, which is an indicator of general health. It's a gluten-free cereal that's perfect for celiac disease sufferers. If anyone have constipation, eat bajra on a daily basis because the insoluble fiber in it bulks up stool and controls bowel motions. Pearl millets are one of the few foods which reduce the acidity of the stomach thereby limiting ulcer formation and discomfort due to frequent bouts of acidity. It makes the stomach pH alkaline, and thus reduces the risk of colon cancers.
6. **Serve as antioxidant**: Pearl millet has a variety of beneficial components and antioxidants, such as phenols, tannins, and phytic acid, which can help prevent stroke, cardiovascular disease, and cancer. In addition to encouraging attractive skin, the catechins and quercetin in Bajra cleanse the liver, kidneys, and purify the body from within.
7. **Dietary bajra improves lung capacity.** It is an excellent winter diet, especially for individuals who suffer from asthma or COPD. Pearl Millet's anti-inflammatory qualities, as well as the inclusion of Omega-3 oils, help to reduce swelling, clear mucus, and improve breathing.
8. **Bajra diet is a great way to lessen acidity.** Since it is an alkaline food it is an excellent choice for reducing acidity. Gas accumulation can result in a range of health issues, including severe chest pain and a burning sensation in the stomach and esophagus.
9. **Bajra is a traditional pregnant meal.** If females are pregnant, Pearl Millet is must-have in diet, thanks to its rich presence of Vitamin B9 also known as folic acid. Folate is a crucial for forming DNA and RNA and is key for producing red blood cells, a major factor that can define the growth rate of the foetus in the pregnancy.
10. **Bajra helps in bone fortification.** If peoples over 30 and already suffering from joint aches, add Bajra to the diet. This phosphorus-rich millet, when combined with calcium, strengthens bones, reduces joint discomfort, and reduces the incidence of chronic diseases like osteoporosis**.**
11. **Bajra aids in the improvement of vision.** Night blindness is a long-term disorder that can be passed on in some families. Poor eyesight in children and adults can lead to major consequences, and Bajra, which is high in vitamin A and zinc, helps to prevent night blindness, improve eyesight, and lessen other vision-related issues such as macular degeneration and presbyopia.
12. **It alleviates weariness.** Sudden tiredness is often a sign of a sluggish metabolism, and the body need immediate fuel in the form of

meals. Because Bajra is high in Vitamin B1, it aids in greater nutritional absorption by converting it to Adenosine Triphosphate, or ATP.

13. **Good for skin:** Pearl millet is a nutrient-dense superfood that can help you achieve beautiful skin and strong hair development. **Dietary consistency of this wonderful food strengthens hair follicles and makes the skin glow from within** because to the inclusion of protein, fibre, iron, zinc, folate, and niacin.
14. **Bajra lowers the chance of dying from inflammatory illness:** Inflammatory disorders include rheumatoid arthritis, gout, asthma, ulcerative colitis, Crohn's disease, and neurological diseases including Alzheimer's and Parkinson's disease. According to the Iowa Women's Health Study, women who ate two or more servings of whole grains per day had a 30% lower risk of dying from an inflammation-related disease.

Pearl millet is a type of millet that is a staple food in the Indian subcontinent. It is also used as animal feed in India as well as for making flour for breads or other products like rotis or chapatis. Bajra millet is high in protein, fiber, and iron. Bajra Millet is one of the most important food crops in India and it has many health benefits. It has been found to have anti-diabetes properties, lower cholesterol levels, and help with digestive issues. So it could be the useful in diet for overall development of human being in Indian condition.

4. CURRENT BREEDING APPROACHES FOR DEVELOPING BIOFORTIFIED VARIETIES OF PEARL MILLET

1. **Biofortification breeding approach:** The pearl millet biofortification breeding program at ICRISAT has taken a three-pronged breeding phase-I, II and III. The first phase is a short-term strategy that focuses on trait genetics, germplasm screening, and genetic variability creation. The second phase is a medium-term strategy that involves confirming high-iron and zinc breeding lines and hybrid parents from the standard breeding programme in order to generate biofortified varieties/hybrids quickly. Long-term goal creation of high-Fe/Zn breeding lines and hybrid parents, as well as genetic diversification through steady mainstreaming micronutrient characteristics at ICRISAT and NARS breeding programmes, comprised the third phase, additive genes govern these micronutrients, and therefore biofortification breeding procedures are the same as for any other quantitative characteristic.

Previous research has also suggested that additive gene activity is more important for grain Fe and Zn in pearl millet. Well defined the pedigree breeding approach, which is the most frequent method in pearl millet breeding and deals exclusively with progenies resulting from bi-parental crossings.

The pearl millet biofortification process is currently moving from fast-track breeding to genetic diversification and mainstreaming the development of biofortified fast-track hybrids/varieties at ICRISAT. ICRISAT has proved the use of traditional breeding methods to combine micronutrients and grain yield. Despite high Fe levels, breeding parental lines (seed- and restorer-parents) with high Fe density as a target attribute will help achieve the long-term goal of hybridization. In this direction, 174 high-Fe early-generation progenies (BB progenies and RR progenies) have been produced, with > 90 mg kg1 Fe density and 36 to 72 mg kg1 Zn density in trials conducted at Patancheru. According to preliminary research, the identified common and overlapping Quantitative Trait Loci (QTL) for Fe and Zn densities are in LG3 (chromosome 3) .As a result, there is a lot of Fe and Zn variation in elite breeding populations, and additional research is needed in the future to develop diagnostic methods for screening segregating materials.

2. **Use of Composites and CMS lines:** Composites are also used as a base population in this strategy, which has the potential to expedite genetic advances in hybrid yield and broaden the genetic basis of hybrid-parents and cultivars. Composites, on the other hand, will only be used for hybrid parent pedigree breeding if they have all of the requisite characteristics.
   Different cytoplasmic sterility systems (CMS) exist in pearl millet, however A1, A4, and A5 are the most extensively utilized. The typical three-line approach (A, B, and R) to make a hybrid seed includes the adoption of cytoplasmic genetic male sterility. A1 and A4 are currently utilized in commercial breeding projects in India. The A1 CMS is used in all pearl millet hybrids developed in India so far, while the biofortification effort uses.
3. **Micronutrient phenotyping, using a high throughput method:** The precise phenotyping efficiency of high throughput instruments is critical to the success of a

breeding program. This is a critical necessity in biofortification research, since it allows for rapid identification of high-Fe/Zn lines from a wide pool of germplasm and gene pools. The destructive techniques of Atomic Absorption Spectrophotometry (AAS) and Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) are widely employed by researchers, and their results for grain Fe and Zn densities are repeatable.

However, breeding for micronutrient dense cultivars necessitates the screening of a large amount of genetic material, such as germplasm collections, elite lines, segregating populations, hybrids, and so on; and phenotyping for micronutrients using destructive techniques requires a significant amount of analytical time and breeding resources. An innovative approach was used in a recent study.

4. **Genetic variability for micronutrients:** To begin any trait-specific breeding, breeders must have a lot of genetic variability. Thousands of pearl millet samples were examined for grain Fe and Zn density using the high throughput screening facilities. This is largely due to ICRISAT's efforts to scale the genetic variability available for these two micronutrients in working germplasm and breeding materials. ICRISAT researchers discovered a wide range of variability in grain Fe and Zn densities in a variety of breeding materials, including in IARI germplasm accessions (51–121 mg/kg Fe; 46–87 mg/kg Zn), population progenies (18.0–135.0 mg/ kg Fe; 22.0–92.0 mg/kg Zn), inbred parents (30.3–102.0 mg/kg Fe; 27.4 mg to 84.0 mg/kg Zn).

Table 1. Comparison of nutritional content in crops

Contents	Crop			
	Pearl millet	Sorghum	Rice	Wheat
Carbohydrates (g)	61.8	67.7	78.2	64.7
Protein (g)	10.9	09.9	07.9	10.6
Fat (g)	5.43	1.73	0.52	1.47
Energy (Kcal)	347.0	334.0	356.0	321.0
Dietary fiber (g)	11.5	10.2	02.8	11.2
Calcium (mg)	27.4	27.6	07.5	39.4
Phosphorus (mg)	289.0	274.0	96.0	315.0
Magnesium (mg)	124.0	133.0	19.0	125.0
Zinc (mg)	2.7	1.9	1.20	2.8
Fe (mg)	6.4	3.9	0.60	3.9
Thiamine (mg)	0.25	0.35	0.05	0.46
Riboflavin (mg)	0.20	0.14	0.05	0.15
Niacin (mg)	0.90	2.1	1.70	2.7
Folic acid (µg)	36.1	39.4	9.32	30.1

(Source: NIN, Hyderabad)

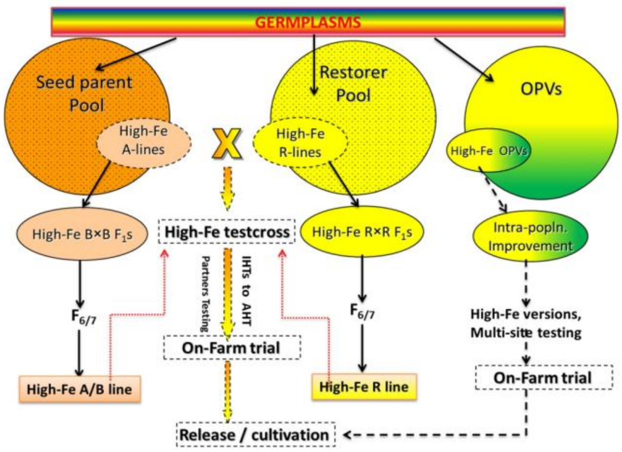

Fig. 1. Biofortification breeding approach

Fast-Track breeding approach followed at ICRISAT for biofortified hybrid development in India and OPV development in West Africa. (Source: Govindaraj et al. [11])

Table 2. Biofortified pearl millet hybrids or varieties

Sl. No.	Name of the hybrid/variety	Year	Salient features	Yield (kg/ha)	Fe (ppm)	Zn (ppm)
1	DHANSHAKTI	2013	Early maturing variety, bold, globular, shining slate grey colour seed, cylindrical lanceolate earhead, resistant to downy mildew.	2199	81	43
2	HHB 229 (MH 2076)	2018	Medium maturing, purple anther colour, lanceolate shaped compact panicle, greyish hexagonal shape grain, resistant to major diseases and insect pests.	3274	73	41
3	AHB 1200 Fe (MH 2072) (AHB 1200)	2018	Medium maturing, long cylindrical panicle, resistant to downy mildew, stem borer, responsive to fertilizer.	3170	77	39
4	AHB 1269 Fe (MH 2185)	2019	Medium maturing, high Fe content.	3168	91	43
5	RHB 234 (MH 2174)	2019	Medium maturing, brown anther colour, complete exertion, greyish seed, resistant to major diseases and pests.	3169	84	41
6	RHB 233 (MH 2173)	2019	Medium maturing, yellow anther colour, complete exertion, greyish seed, resistant to major diseases and pests.	3157	83	46
7	HHB 311	2020	Medium maturing, compact panicle, grey coloured hexagonal shaped grains, highly resistant to downy mildew and other diseases.	3173	83	39

(Source: Devendra kumar yadav et al, ICAR, [12])

5. Breeding for genetic improvement:

a. Improving the nutritional characteristics of grain

"Because pearl millet is a highly nutritious cereal with higher levels of proteins and numerous minerals than other main cereals, the focus of core breeding has been to maximize production potential. According to previous study, germplasm can include up to 24.3 percent protein [13] and elite breeding lines can contain up to 19.8 per cent protein" [13]. However, because of the unfavorable associations between protein content and grain output, no substantial efforts were undertaken to improve it. "In light of global identification of severe inadequacies of iron (Fe) and zinc, improving grain nutritional characteristics is a recent addition to breeding objectives (Zn). The scope of genetic variation for grain Fe and Zn contents, the identification of diverse seed-mineral dense germplasm, the nature of genotype-environment interaction, relationships between grain minerals and agronomic traits, and genetic control of micronutrients are among the major topics covered" [11].

b. Continuous replacement of hybrids

In order to achieve continual genetic improvements, it is necessary to replace existing hybrids with new ones that have higher potential productivity.

Due to the widespread use of high-yielding and disease-resistant cultivars combined with improved production techniques, pearl millet productivity grew by more than 300 percent from 303 kg/ha in 1950–1954 to 1,239 kg/ha in 2015–2019.

c. Genomics-Assisted Breeding

"One of the most exciting developments that have implications on taking the genetic gains to the next levels in pearl millet is genomics and genomics-assisted breeding that can help improve the precision and efficiency of the breeding program. The ~1,000 genomes sequencing project has been a major milestone in pearl millet improvement" [14]. This work has created a good framework for finding, mapping, and deploying QTLs/alleles/candidate genes connected to economically important traits.

d. Precision Phenotyping

"While genotyping has become significantly cheaper and more precise in recent years, precision phenotyping has remained a significant problem, particularly in the case of drought. Only when rapid, reliable, and cost-effective phenotypic data, including root systems, is accessible for genetic dissection of drought tolerance and selection of drought-resilient genotypes, can genomic resources be fully utilized" [15].

e. Heterotic Grouping of Hybrid Parental Lines

"Heterotic grouping of hybrid parental lines is an important strategy to increase the magnitude of heterosis on a long-term basis" [16]. "Depending on their individual phenotypic features, a varied range of breeding material has historically been utilized to generate either seed parents (B lines) or restorers parents (R lines)" [17].

f. Taking on both host resistance and pathogen variability at the same time

"The experience, so far, in resistance breeding for DM has indicated that most of the hybrids become susceptible in about 5–6 years of cultivation in the same area because of selection pressure in the pathogen, although there are some clear exceptions where hybrids have shown durable resistance. It would be useful to investigate resistance mechanisms operative in the parents of such hybrids to identify and deploy genes for durable Downey Mildew resistance in high-yielding hybrids for the enhanced genetic gain" [18].

g. Hybrid Breeding for arid climates needs to be improved

"One of the key issues, often debated in past, has been the comparative advantage of hybrids or Open-pollinated varieties (OPVs) under severe drought conditions, given the reports that genetically heterogeneous to provide steady performance in unexpected drought settings, OPVs may use population buffering mechanisms" [19,20].

h. Bringing biofortification into the mainstream

To ensure nutritional security in SA and SSA, Fe and Zn should be mainstreamed in pearl millet breeding. Breeding for micronutrients and vitamins has been initiated by Harvest Plus, a CGIAR Challenge Program. In collaborations with national partners, ICRISAT has generated now enough data base for Fe and Zn. As part of the ICRISAT product profile, Fe levels more than 60 ppm and Zn levels greater than 40 ppm were sought for breeding. This is a significant step forward in top breeding lines' mainstreaming.

i. **Enhancing nutrient use efficiency**
Although pearl millet is mostly grown on sandy and sandy-loam soils with low nitrogen (N) and phosphorus (P) content, its adaptation to low nutrients is rarely addressed, with the assumption that this problem can be readily solved by applying fertilizers.

j. **Collaboration of breeding and agronomics**
To achieve greater genetic gains, a sustained increase in pearl millet productivity requires the integration of appropriate cultural practices in its diverse production environments for disease resistant and improved cultivars.

k. **Speed Breeding and Big-Data Analytics**
Genetic gains of any breeding program significantly depend upon the number of crop breeding cycles a program can undertake in a year. This changes depending on the local weather conditions in different breeding operations. In north India, for example, only one crop of pearl millet can be harvested per year, but western, central, and peninsular India can harvest two crops per year. In the current climate, breeding a new crop cultivar takes a decade or more, with 6 or 7 years spent on seasonal generational developments to arrive at elite materials ready for testing and distribution. Now, new environmentally controlled facilities, known as “Rapid Gen,” have been developed, which will shorten the 6–7-year window significantly. When used with the full suite of breeding acceleration techniques, Rapid Gen can make it possible to take four crop cycles in a year

In this way a comprehensive approach and different breeding techniques may be utilized as and when required according to climatic situation and necessity and suitable climate resilient varieties may develop which can enhance the yield potential as well as nutritional security.

5. FUTURE PROSPECTUS

In the semiarid and arid ecologies of South Asia (SA) and Sub-Saharan Africa (SSA), pearl millet (*Pennisetum glaucum* R. Br.) is an important crop (SSA), which are characterized by low and unpredictable rainfall, high mean temperature, and low organic carbon and water-holding capacity soils [21-25]. Beside from its unrivalled drought tolerance, pearl millet has a built-in adaptation to low-fertility soils. Because of its remarkable ability to respond to favorable environments due to its short developmental stages, high photosynthetic efficiency, and abundant capacity for high growth rate, pearl millet is emerging as an important alternative crop for feed, food, fodder, and relay crop in Brazil, Canada, Mexico, the United States, West Asia, and North Africa and India also [18]. During the previous six decades, India has made enormous progress in increasing productivity by introducing high-yielding cultivars and improving agronomic management. The accomplishments of pearl millet breeding are often referred to as one of the greatest success stories in Indian agriculture (Yadav et al. 2019). However, the biological potential of pearl millet has not been fully realized, as seen by the current national output in India. So different new breeding approaches along with combination of different agronomic practices, plant protection measures can be utilized to increase the yield as well as nutrition quality of Pearl millet [26-33].

6. CONCLUSION

Pearl millet is a staple food with superior nutritional value and also have health benefits. As consumers are more attentive towards their health so the pearl millet has one of the alternative options for nutritious food. This review successfully provided the information about nutritional profile, health benefits, biofortification process, current breeding approaches and future prospects.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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