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PEARL AND FINGER MILLETS: THE HOPE OF FOOD SECURITY

[1]Anubha Shukla, [2]Adarsh Lalit, [1]Vinay Sharma, [1]Sharad Vats and [1*]Afroz Alam

[1]Department of Bioscience and Biotechnology, Banasthali University, Banasthali (Rajasthan).
[2]An Xcellventure Institute of Fundamental Research Pvt. Ltd., Bhopal.

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ABSTRACT

Millets are grown expansively in different areas of India as a staple crop to feed a huge section of the inhabitants. In India, its production holds the sixth position after wheat, rice, maize, sorghum and bajra. The most important cultivated species of millets in India are foxtail millet (Setaria italic), finger millet (Eleusine coracana), pearl or cattail millet (Pennisetum glaucum), proso millet (Panicum miliaceum), Japanese / barnyard millet (Echinochola crusgalli), brown top millet (Panicum ramosum) and kodo or ditch millet (Paspalum scrobiculatum). Among these, finger millet (Eleusine coracana L.) and pearl or cattail millet (Pennisetum glaucum) offers high nutritional, anti-diabetic and antioxidant properties. India is a socioeconomic meager country needs a large amount food grain to fulfill the requirement of its ever increasing population with good nutrients value. To facilitate an improved and healthy food supply, these easy growing vigorous crops would be a good option for the farmers in semiarid regions of India. The planned cultivation of these millets will provide a very nutritious and economical food for a large proportion of poor people.

1. INTRODUCTION

In 1986, World Bank's report regarding "Poverty and Hunger" defined the food security as "access of all people at all times to enough food for an active and healthy life". In 2001, FAO (Food and Agriculture Organization) for a second time defined that the food security as a circumstance that exists when all people, at all times, have physical, social and economic right to use for sufficient, secure and healthful food that congregates their dietary needs and food preferences for an active and healthy life [1].Millets, the staple food grains in tropic and semi-arid regions of the world, particularly in the desert can be a good choice to manage sustainable food supply. Millets provide a good yield in these areas because of their great adaptive nature in harsh environment, especially drought conditions [2]. Taylor *et al* [3] extensively studied and explained its drought tolerance and considered millets as one of the most drought-tolerant cereal grain crops. The growth requirements are very limited as millets not only withstand several abiotic factors like, unpredictable climate; limited and inconsistent precipitation and nutrient-depleted soils, but also they are somewhat less suffered from many biological agricultural constraints [4, 5]. Sharma *et al.* [6] emphasized the urgent requirement to improve those crops which are relevant to the small scale farmers and economically poor consumers especially in the developing countries. This important objective can be achieved by sincere efforts in the development of these somewhat neglected crops. However, there is an ease in their cultivation in those areas which are not conducive for other cereals, hence there would be no competition for resources. International Crops Research Institute for the Semiarid Tropics (ICRISAT) along with the Food and Agriculture

Corresponding author:* **Afroz Alam, Email: afrozalamsafvi@gmail.com
Department of Bioscience and Biotechnology, Banasthali University, Banasthali (Rajasthan).

Organization (FAO) had an agreement in 1996 [7] regarding the potential of these crops towards the food security in many of the world's most food-insecure agro-ecological zones. In these agro-ecological regions the this objective can be attained by escalating the production and productivity of these tolerant crops. Taylor [8] also supported this view and emphasized the potential of millets in the improvement of domestic food security in harsh environmental conditions because of their remarkable adaptability against such environments. In a country like India, millets can augment domestic food security of sidelined pastoral farmers in semi-arid areas. For instance, Medak District of Andhra Pradesh (India), the most neglected rural people not only managed to achieve food security, but also affirm food independence by cultivation of sorghum and millet as the keystone of their stratagem [9]. These communities are neglected in the sense that they are women and they practice their survival farming on the Deccan Plateau, the driest and depleted soil zone of India. Nevertheless, they achieve domestic food safety by cultivating sorghum and millet, which are ecologically well-suited to the semi-arid areas. Consequently, they attained domestic food safety and autonomy from government offerings [10]. In case of eastern Kenya, a study was conducted in semi-arid regions and interestingly, it was established that domestic food safety was more steady for those households that cultivated more flexible crops such as sorghum and millet. On the other hand, because of unpredictable precipitation, food uncertainty was elevated for those farmers that grew less adaptable crops to the ambient environment for instance, beans and maize. These examples are good enough to explain the importance of these adjustable crops towards food safety in water deficit regions of the world [11]. In the context of Africa, Taylor [8] stated that millets, because of their high levels of adaptation to African conditions are equally vital cereals for the safeguarding of food safety. The same belief is maintained by FAO [12] that these grains are the counter to continual food scarcity to pastoral populations who exist in semi-arid regions in particular, the sub Saharan region. Millets correspond to about 50% of the whole cereal production in Africa and serve as a major supply of protein for the African inhabitants. The same observation was made by Alumira and Rusike [11]; they revealed that novel varieties of millet and sorghum can diminish the likelihood of nil yields. Therefore, these crops can make a noteworthy role in domestic food safety during drought [11]. Taylor [8] declared that millets still need more research compared to other common cereals crops. He concluded that due to their great adaptive capabilities, the role of millets is very important for healthier long-term food safety than maize. Similar considerations were mentioned by Rohrbach [13], he stated that millet and sorghum present impending staple food for many developing semi-arid countries.

There are enough evidences from literature which recommend that the these small grain crops can do better than maize in terms of yield and drought tolerance particularly, in semi-arid areas. In the incident of drought, maize is prone to be shattered, but these drought tolerant small grain cereals such as millet are able to provide some food for survival [14]. Hence, small grains (millet) are the possible candidates to do better than maize under a well-organized, supportive agenda in marginal areas of the world [14].
However, Van Oosterhout [15] signified some rewards for the growers of small grains over maize:

- A lesser quantity of flour is required to bake the main meal compared to maize;
- Small grains assured starvation for a longer period and gives added energy;
- The storage procedure of small grains is much better than maize that cannot be stored further than eight months. Local cost effective storage knowledge is also available for these millets while maize wants noxious organophosphate protectants, often too expensive by farmers.
- There is no need for the purchase of these seeds because seeds of several varieties of these grains are accessible for planting. These seeds can be exchanged with relatives and neighbours, hence omitting the need of procurement.
- In years of short precipitation, in a multi-cropped system, less quantity of grains will give some yield especially when grown in a multi cropped system, whereas maize will be a absolute disappointment.

Production of wheat, paddy and maize continues to dictate the terms in semi-arid regions of India compared to small grains as millet because they recommended high yields. Sukume *et al* [16] noted that the squat yields of millets are one of the major obstructions and a challenge for common farmers. Macgarry [17] pointed out some of the common challenges that farmers had faced in millet production. The drawback related to poorer yield is the prime reason for their negligence by the farmers of environmentally challenged [18]. The depredations of the quelea birds on sorghum and millet than did wheat, paddy and maize is another major challenge in front of the farmers. The going up the cost of manpower in the production of millets have exaggerated most growers, tedious land preparation, removal of unwanted weeds, protection from birds, cost of harvesting and subsequent processing of harvested grains are other factors that are responsible for limited production [7]. All these factors are cost effective in case of wheat, paddy and maize. This is one of the main causes why wheat became extensively customary in India during the green revolution [11]. Sukume *et al.*

[16] have also explained the lack of processing technologies is yet another factor that has hindered the development of alternative formal markets for millet. By using traditional processing technologies, millet takes longer to process than maize, especially during harvesting [16]. These factors have reduced its demand by even the poorest of the poor communal households. Alumira and Rusike [11] expand more on the challenges that even under semi-arid conditions, it might be very difficult for small grains to compete with maize. This is because millet does not yield much crop residue, which plays a very important role of communal farmers in terms of animal feed and crop manure. Mapfumo [19] refers that livestock depends upon crop residues for survival during winter, mainly from maize stoves. Changing food preferences is an additional significant factor, which has been acting as a limitation in millet production, FAO [7] made clear that as earnings of consumers get higher, it has a propensity to pay for wheat, paddy and maize, rather than usual common grains. As a result, common farmers are likely to view millet production as inferior returns than other economically striking crops. With the inception of the trade liberalization program, costs for millets along with edible legumes went down noticeably compared to the cash crops. This also has a detrimental role for shunning in millet production by the rural farmers. In this review attempt has been made to highlight the utility of millet production with all possible relevant details.

2. PEARL MILLET OR BAJRA: *Pennisetum glaucum* (L.) R. Br.

Synonyms: *Pennisetum typhoides* (Burm.f.) Stapf and Hubbard; *P. americanum* (L.) Leeke, *P. spicatum* Roem and Schult.

Pennisetum glaucum has several vernacular names all over the world, in India it is known as bajra/bajri/cumbu/sajje. In english, it is known as pearl millet, bulrush millet, cattail millet and candle millet.

Pearl millet the Bajra [*Pennisetum glaucum* (L.) R. Br.] is conventionally an arid land crop, it grows habitually in the harsh environments of the semi-arid and arid regions, typified by low precipitation, less fertile sandy soils, where other coarse cereals such as sorghum and maize fail to give certain yields. This crop is a diploid (2n = 14) cultivar, chiefly grown for its grains, however, the residue/stover of this crop forms an imperative source of fodder, particularly in the areas of low precipitation. It has been estimated that about 40-50% of the dry matter eating feed for cattle is provided by this particular crop during the arid time span. The twofold rationale character of pearl millet puts forward both food and fodder safety in the semi-arid and arid tropical zones of the world. Pearl millet grains have higher protein content (10.6%), most balanced amino acid profile, and also contribute about one third of iron and zinc requirements. These nutritional factors play important role in the nutritional security. A small proportion of grain is also used for poultry feed. Grains of this millet are also gaining importance as an economical source of starch for making fine quality breweries [20, 21]. India is the largest producer of this crop, both in terms of land (9.3 m ha) and yield (7.97 metric ton), with a middling output of 856 kg ha^{-1}. This crop shared 7.8% of the total food grain area of the India and 3.9% of the total food grain production. Drought hit Rajasthan state of India, comprises approx. 50% land and 42% of yield of pearl millet. Maharashtra (16% area, 13% production), Uttar Pradesh (9.5% area and 16% production), Gujarat (8% area and 7% production) and Haryana (6.6% area and 13% production) are the other principle producers of pearl millet in India [22].

2.1. Nutritional Value

Table 1. Nutritional Value

Moisture (g)	10	Cystine (mg)	1.8
Food Energy (Kc)	353	Isoleucine (mg)	3.9
Protein (g)	11.8	Leucine (mg)	9.5
Carbohydrate (g)	70	Lysine (mg)	3.2
Fat (g)	4.8	Methionine (mg)	1.8
Fiber (g)	1.9	Phenylalanine (mg)	4.1
Ash (g)	2.3	Threonine (mg)	3.3
Vitamin A (RE)	22	Tryptophan (mg)	1.4
Thiamin (mg)	0.31	Tyrosine (mg)	3.0
Riboflavin (mg)	0.19	Valine (mg)	4.9
Niacin (mg)	2.6	Mg (mg)	114
Ca (mg)	37	Mn (mg)	0.8
Cl (mg)	43	Mo (μg)	190
Cu (mg)	0.5	P (mg)	339
Fe (mg)	9.8	K (mg)	418
Zn(mg)	2.0	Na (mg)	15

2.2. Problems associated with its production

Downy mildew (DM) or 'green ear' disease is the most prevalent and damaging cause of pearl millet cultivation. It has been rated as a national problem in Indian context [23]. In the mid-sixties, high yielding F1 hybrid (single cross) cultivars based on A1 cytoplasmic-nuclear male sterility (CMS) with good tillering ability and a large number of compact, well filled ear heads were introduced, but the presumed yield impending could not be attained due to the infection caused by *Sclerospora graminicola*, the downy mildew pathogen [24]. In a few states of India, yield losses caused by a re-occurrence of *Sclerospora graminicola* in farmers' fields in the last 40 years led to the withdrawal of even promising cultivars that succumbed to the disease [25]. Hence, intensive skill and management is needed for optimum production of this crop.

2.3. Development of high yielding varieties and their spread

Extensive efforts related to the heterosis first started in India duing 1950s [26, 27] utilizing the protogynous flowering habit of the crop. The breakthrough in the form of cytoplasmic male sterility by Burton [28, 29] fulfilled the need for a viable and economic method of producing pure hybrid seed on a commercial scale. The first pearl millet hybrid HB-1was released in India in 1965 [30, 31]. In the 1970, not more than two hybrids of 75 days maturity were available for countrywide cultivation in India. By the year 1996, more than 50 hybrids [32] and by 2006 more than 80 hybrids were cultivated in India. This colossal cultivar range since 1990 has added not only to augmented output, but has also arrested the repetition of any downy mildew epidemics earlier observed as frequent in regards to pearl millet hybrids. The extent of adoption of high yielding varieties in the country was 55% by 1992 [33]. It rose to 74.86% by 2005 [34] with many states having 100% area under high yielding varieties. The situation in Rajasthan with respect to adoption of high yielding varieties is worst among the pearl millet growing states. It has only 1.75 million hectares (2007-08) under high yielding varieties, which accounts for only 39% of the area under pearl millet. Farmers in western In case of Rajasthan farmers are still choosing local cultivars inspite of hybrids due to the larger risk of crop collapse during harsh and arid years. Lack of availability of sufficient quantity of seed of high yielding varieties (Hybrids as well as OPVs) is another factor. Those farmers who somehow manage to plant hybrid seed first time, do a second sowing with local seed after first sowing fails due to unfavorable climate or soil crusting. The state government has planned to achieve seed replacement rate (SRR) of 100% by the year 2011-12, while presently the SRR of pearl millet in the state is 42%. It has been estimated that to attain 100% pearl millet region under better yield varieties, magnitude r of seed required would be 180000 Quintals [35]. A quantity of pearl millet hybrids and some varieties (open pollinated) have been released for crop growing in arid regions; genetic differences in maturity and drought tolerance make some cultivars more suitable for dry regions. Early maturing cultivars escape terminal drought, making these more suitable for regions having extreme arid conditions, like western Rajasthan, parts of Gujarat and Haryana. The type of cultivar adoption by farmers of the arid regions however depends upon the timely and sufficient availability of seed of the cultivar (hybrid or OPV) in the market, and time and amount of rainfall received (timely and good rainfall of 30 mm received in the late June to the mid of July) would promote cultivation of high yield verities, while late arrival of effective rainfall would discourage use of high yielding variety seed and sowing of local cultivar. Number of times planting is required due to failure of crop sown earlier either due to the crust formation or early season drought. This would generally lead to second or third planting with local cultivars. These are a big shot of problem of farmers in cultivation of pearl millet in such areas.

3. FINGURE MILLET THE RAGI: *Eleusine coracana* (L.) Gaertner

Eleusine coracana has several vernacular names all over the world, in India it is known as ragi. In english, it is known as finger millet.

Eleusine coracana has a tuft type of life form. The plant is an annual growing, with the length of 45-125 cm. For complete maturation it takes about 2.5 to 6 months. The leaves of this plant are typically narrow, grass like in appearance. The plant has many tillers and twigs. The head looks like a cluster of digitately orderly spikes. Its chromosome number is x = 9. A subspecies of this genus, *E. coracana* subs. *coracana* is tetraploid in nature that has originated from the uncultivated diploid subspecies *africana* [36].

Eleusine coracana (Finger millet) is barely vanished. Undeniably, it is one of the few unusual species that presently holds the world's food supplies. In India, it is staple crop that provides the food for millions of people. In terms of production, Africa is the largest having about 2 million tons of the total 4.5 million tons/ year worldwide production.

In India the overall cultivated region under Ragi was projected as 1587.15 thousand hectares. Out of this, virtually 13.30% was grown as irrigated. In states like Tamil Nadu and Gujarat it has been grown mainly as irrigated crop. The total outcome of Ragi grains was estimated at 2282.84 thousand tonnes, out of which the input of irrigated Ragi is 20.58 %. While, in the case of high yielding varities the total production was estimated as 1614.53 thousand tonnes, i.e. 70.73 %. This estimated account further indicates the requirement for the encouragement of HYV to meet the aggressive global marketing setting [37].

The plants are fruitful and flourish in a range of environmental surroundings. In India, finger millet like other cereals is planted in rows with appropriate management practices. But in the case of African countries, it is more often than not treated in a different way. In India, the final harvesting is usually done by hand. Heads of individual plant are cut off with a knife, having a few centimeters of stalk with these heads. Then they are heaped in mounts for a few days, where fermentation is induced, the warmth produced and hydrolysis makes the grains easier for threshing. The seeds of finger millet are very minute that weevils cannot pinch inside. In actual fact, its un-threshed heads oppose storage vermin so efficiently that they can be stored for more than 10 years without any threat caused by pests [38].

Besides, many advantages, the reduced size of the grains is also a severe disadvantage. Due to small size, the crop is very difficult to handle during the complete life cycle of the plants. This necessitates the great skill and serious efforts to change grains of finger millet into flour with the help of conventional methods. Even modern hammer mills have to face few difficulties in doing that. In mills, they have to be fixed with very fine screens to run at high speed. With the advancement in engineering, an exceptional mill for millet has been invented to ease out the flour production. However, the problems are still there that is related to the seed broadcasting practice. It is prone to bird attack which reduces the final yield to a great extent. On the whole, the plants are naturally resistant to diseases and many insects, but a violent fungal disease known as "blast" can demolish entire fields is still a challenge to work against [39-41].

Finger millet is dilapidated in most of the countries, however, almost 30 years ago, it was considered as one of the major crops. Certainly, if instantaneous attention is given, the obstructions causing the rejection will be most likely to be abolished. Actually, efforts are being made in this direction for the sustainable food security.

3.1. Nutritional Value

Table 2 Nutritional Value

Edible portion (g)	96	Cystine	1.6
Moisture (g)	11	Isoleucine	4.1
Foodenergy (Kc)	333	Leucine	7.7
Protein (g)	7.4	Lysine	2.6
Carbohydrates (g)	75	Methionine	5.1
Fats (g)	1.2	Phenylalanine	4.0
Fiber (g)	3.1	Threonine	3.0
Ash (g)	2.5	Tryptophan	1.27
Vitamin A(RE)	6.1	Tyrosine	4.2
Thiamin (mg)	0.25	Valine	6.35
Riboflavin (mg)	0.12	Magnesium(mg)	141
Niacin (mg)	1.1	Manganese (mg)	1.8
VitaminC (mg)	1.2	Mo (µg)	2.1
Ca (mg)	357	P (mg)	250
Cl (mg)	83	K (mg)	314
Cu (mg)	0.6	Na (mg)	49
I (µg)	10	Zn (mg)	1.5
Fe (mg)	9.9		

In some regions of the world, handsome revenues are coming by the sale of finger millet, it means that this crop is benefiting from something of a revival and now considered as a highly profitable one. This is an adaptable grain that can possibly be used in various types of foods, including modern as well as traditional [41].

1.3.1. Development of high yielding varieties and their spread

Finger millet is somewhat self-pollinating and it is very difficult to perform crosses between different strains. In the past, genetic enhancement was restricted to pedigree-based selection only, but now, heritable somaclonal variations that are induced by *in-vitro* cell culture can be used as an addition to plant breeding programmes related the improvement of this crop [42]. These practices were already in use in case of rice [43], wheat [44] and rye [45]. Now, millets such as pearl millet and figure millet are in focus for their great economic importance and ability to grow in the arid and semi-arid regions of the [46-48].

4. ANTIMICROBIAL AND PHYTOCHEMICAL PROPERTIES OF PEARL AND FINGER MILLET

Beside nutritional and food values, these crops have great medicinal properties. The plant phenolics have been found effective in reducing the power of some diseases and also to hamper the *in vitro* growth of several fungi. The phenolics present in finger millet along with tannins check the fungal invasion in plant tissue by constructing the physical barriers. Due to high polyphenol contents the seed coat also exhibits high antibacterial and antifungal activity [49]. Microbial membranes and cell components oxidation by the ROS formed, a irretrievable association with nucleophilic amino acids leading to the inactivation of enzymes, which are beneficial for the anti-fungal activity [50].

5. CONCLUSION

In view of all above mentioned qualities, it is possibly tough to realize why millet is being rejected? Compared to the ample researches related to wheat, rice, and maize, there were very few attempts have been made in the past related to these useful but neglected crops. Throughout the world, these important crops are still unknown to the common populations of developing countries and even many countries that grow it have left these crops as a "poor person's crop"; a "famine food"; or, even worse, just designated as a "bird seed." [12]. But the reason is simple, people are neglecting it because of their attention towards maize and sorghum. The cultivation is relatively tedious, which is another reason for lesser production of these crops. However, the reality is that millets have a great potential to fulfill the ever increasing demand of nutritious food for mankind. Hence, dedication and proper strategies are needed to popularize these crops for better investment and cultivation.

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