Minireview Article

Millet as a Superfood in climate change agriculture-A review

ABSTRACT

Global climate change and extreme weather variations have occurred as the most threatening challenge to agriculture and allied activities. The entire food production system has faced a serious challenges due to theimpact of climate change as increase in average temperature, intensity and frequency of drought and flood, aberration of rainfall patterns, and elevation in CO_2 concentration. In today's world climate change is a major concern. Millets are considered highly nutrition-rich and climate-resilient coarse grain cereals and it can enhance income, enhance food and nutrition security in the aspect of climate change in rainfed areas. Millets have climate-resilient features because of which they have adaptation to a wide range of ecological conditions, fewer water requirements, better growth and productivity in low nutrient input conditions, less dependent on chemical fertilizers, and minimum susceptibility to environmental stresses. In comparison to cereals, millets are rich in dietary fibres, resistant starches, vitamins, essential amino acids, storage proteins, and other bioactive compounds and are nutritionally superior. Millet escapes from stress as they require 12–14 weeks to complete their life cycle (seed to seed) whereas rice and wheat require a maximum of 20–24 weeks. They are nutritious, possess additional health benefits, require significantly fewer input costs for cultivation, and are naturally tolerant to most biotic and abiotic stresses. Millets are the choice for today's world alongwith increase population growth and climate change. Farmers in arid parts of Karnataka have adapted to climate change by switching from water-intensive rice, sugarcane, and maize cultivation to various types of drought-resistant millets. They are possibly the first cereal grain to be used for domestic purposes, the commonly grown millets are Sorghum, Pearl Millet, Finger Millet, Barnyard Millet, Foxtail Millet, Kodo Millet, Proso Millet, and Little Millet.

Key Words: *Millet, Climate change, Nutrition, Rainfed*

1.INTRODUCTION

Around 82% of the total agriculture land is covered under rainfed agriculture in the world. Moreover, rainfed areas continue to produce about 70% of the world's staple food and will continue to do so in the future. The value of rainfed agriculture can be measured in the fact that rainfed areas grow 55 percent of rice, 91 percent coarse grains, 90 percent pulses, 85 percent oilseeds, and 65 percent cotton[1]. Millets and other coarse grains can be grown anywhere with annual rainfall less than 350 mm, while other cereal crops cannot be able to grow under such moisture stress and climate variability. Millets are considered as highly nutrition rich and climate resilient coarse grain cereals which can enhance income, enhance food and nutrition security in the aspect of climate change in the rainfed areas. They are also rich in dietary fibres, resistant starches, vitamins, essential amino acids, storage proteins, and other bioactive compounds and are so nutritionally superior to other major cereals. In term of calcium content, finger millet has more than thirty times more calcium than rice while every other millet has at least twice the amount of calcium compared to rice. Millets possess several morpho-physiological, molecular and biochemical characteristics which confer better tolerance to environmental stresses than major cereals. Primarily, the short life-cycle of millets assists in escaping from stress as they require 12–14 weeks to complete their life-cycle (seed to seed) whereas rice and wheat requires a maximum of 20–24 weeks. The prevalence of stress conditions and their consequences in millets are avoided by several traits such as short stature, small leaf area, thickened cell walls, and the capability to form dense root system[2]. Major cereals *viz.,* rice, maize, wheat, etc., have dominated the agriculture sector with their capability of meeting rising food demands due to their high potential yields, but fail to sustain under changing climate [3]. India ranks second in the incidences of malnutrition among children and more than one third of the world's malnourished children live in India [4]. Nutricereal can minimize the malnourished problem in India to some extent.

The major cereals are deficient in many of the nutritional factors, hence cannot check the nutritional balance that are essential components of one's daily diet for being healthy [5]. Millets are known for their climate-resilient features including adaptation to a wide range of ecological conditions, less irrigational requirements, better growth and productivity in low nutrient input conditions, less reliance on synthetic fertilizers, and minimum vulnerability to environmental stresses[6]. Also, millets are nutritionally superior to other major cereals as they are rich in dietary fibers, resistant starches, vitamins, essential amino acids, storage proteins and other bioactive compounds[7].

2. MILLETS STATISTICS

Millets are most likely to be originated from and around India where they are largely cultivated with a production of 10.91 mt and stand first among the top ten countries having largest area under

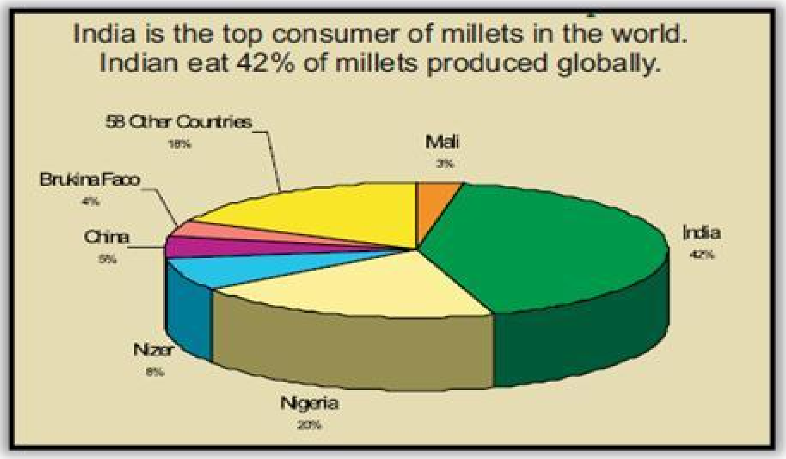

Fig.1 Global millet consumption pattern (Source: Indiastat,2018)

millet cultivation. In India, Rajasthan stands first in production of millet with a production of 6.57 m t from 5.91 m ha [8]. Recently Karnataka was awarded the GI tag for finger millet by the central government. Karnataka state is majorly known for the cultivation of minor millet in India with finger millet as a staple food in southern parts. Millets are indispensable constituents of Indian traditional foods because of their taste and nutritional aspects. Hence, India is the major consumer of millets (Fig. 1) for ages and is the main reason for a healthy life of those Indians consuming the nutritionally rich food made from millets (Fig. 2) [5].

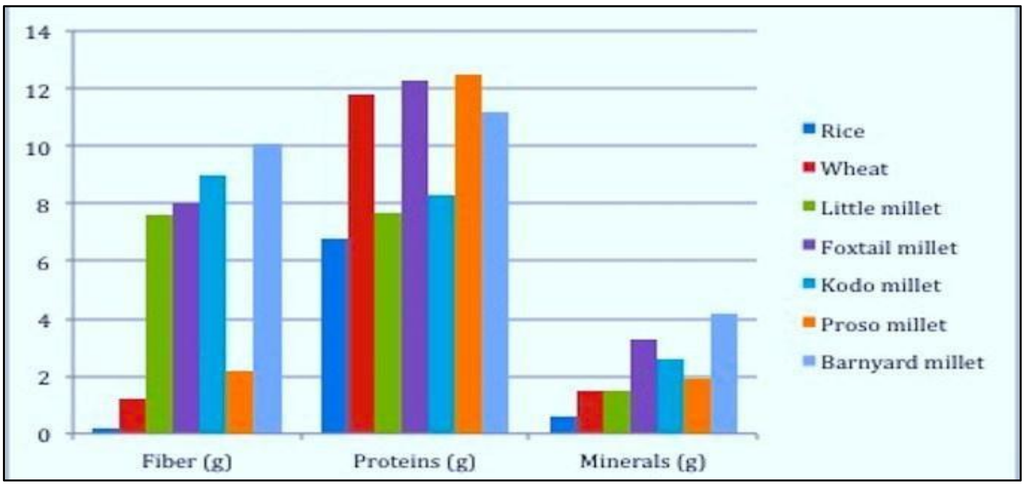

Fig.2 Nutrition content of different crops

3.IMPORTANCE OF MILLETS

Millets are small-seeded, round whole grain, widely grown around the world as cereal crops or grains for fodder and human consumption purpose. It has an excellent nutritional profile and is a non-glutinous food, which make them easy to digest and non-allergenic. They are rich source of nutrients especially phosphorus, potassium, calcium, magnesium and also provide more essential amino acid than other cereals. Although all millet varieties belong to the Poaceae family, they differ in colour, appearance, species and specific characteristics. Based on the popularity and extent of cultivation this crop has been divided into two categories- major and minor millets. Major millets are sorghum, pearl millet and finger millet whereas the minor millets are foxtail, barnyard, proso, kodo and little millet[9].

In addition to being a large source of macronutrients including carbohydrates, lipids, and proteins, cereal crops also have a sizable potential to contribute to global warming. Wheat has the biggest global warming potential of all the major cereal crops, with an estimated 4 tons CO_2 eq ha^{-1}, followed by rice and maize (an estimated 3.4 tons CO_2 eq ha^{-1})[10] . Though they have greater emission rates but they are widely cultivated and the main sources of nutrition for the entire world's population. Other minor cereal crops, including millets and sorghum, have significantly lower carbon footprints. This is one of the main rationality, millets could be one of the crops that lessen the global carbon footprint [11]. Sorghum and millets are cultivated in regions with limited water supplies. It can also be grown in semi-arid and arid areas because of their resilience to biotic and abiotic stresses and their high yield on low quality soils with little additional input [11,12]. Millets typically thrive at quite high temperatures and are xerophilic (love moisture). In contrast to sorghum or maize, pearl millet is better at using moisture, allowing it to grow on sandy, poor soils and thrive in dry conditions. Therefore, pearl millets are typically farmed in regions with marginal soil and little annual precipitation, ranging from 200 to 500 mm[13]. Pearl millet is the sixth most significant crop farmed globally[14]. Finger millet, is cultivated in some regions of Africa and India. When production figures are taken into account, it ranks sixth among the country's principal cereal grains in India, behind wheat, rice, maize, sorghum, and bajra [15]. Compared to other cereal crops, it can grow at higher temperatures and on more salinized soils. Temperatures between 11 and 27 °C, soil pH ranging from 5 to 8, and moderate rainfall are ideal for cultivating finger millet[16]. China, India, and Russia are the three countries that grow proso millet. Proso millet is a short-season crop that is typically grown for 60–75 days. It needs an average annual rainfall of less than 600 mm, and an ideal daily temperature is 17^0C[17]. Foxtail millet is ideal for use as a catch crop because of its quick ripening mechanism and strong photosynthetic efficiency [18]. Additionally, it is nutrient-dense and has strong resilience to pests and illnesses[19]. Two varieties of barnyard millet that are grown commercially are *Echniochloa utilis* and *Echniochloa. frumentacea* [20]. *Echniochloa utilis* is often referred to as Japanese barnyard millet, but *Echniochloa frumentacea* is also called Indian barnyard millet, sawa millet, and billion dollar grass. This variety of millet, which is produced extensively in India, China, Japan, Pakistan, Africa, and Nepal, is regarded as a minor cereal[21]. In India, barnyard millet comes in second to finger millet in terms of annual production (87,000 tonnes) and productivity (0.86tons ha^{-1})[22].It is a crop that tolerates drought, matures quickly, and has excellent nutritional properties [23]. In India, Kodo millet first appeared. This millet is thought to have been domesticated some 3000 years ago[24,25]. The tropical and subtropical climates are ideal for kodo millet [26,25]. When grown for 80 to 135 days, Kodo millet is considered to have the strongest drought resistance of any minor millet and to produce a respectable yield.

4.DIFFERENT TYPES OF MILLETS

About 20 different species of millet have been cultivated throughout the world at different points in time[27] .Sorghum (*Sorghum bicolor* L.), also known as Jowar can tolerate drought condition because of it's deep root system, waxy leaves, the presence of mortar cells in stem. It is more suitable than any other cereal crops in dryland condition as it can withstand higher temperature at any stage of it's growth[9]. Pearl millet (*Pennisetum glaucum* L.), also known as Bajra can grow on poor sandy soils and is well suited for dry climates due to its ability to use moisture efficiently compared to sorghum or maize. However, unlike sorghum it can't resist drought or water stress condition but, in such condition, it can shorten it's life cycle and comes to flowering earlier. This is known as drought escaping mechanism. Pearl millets are thus generally grown in areas having marginal soil with low annual rainfall in the range of 200–500 mm. that Pearl millet being a climate-resilient crop is important to minimize the adverse effects of climate change and has the potential to increase income and food security of farming communities in arid regions[28]. Pearl millet has a deep root system and can survive in a wide range of ecological conditions under water scarcity. It has high photosynthetic efficiency with an excellent productivity and growth in low nutrient soil conditions and is less reliant on chemical fertilizers. These attributes have made it a crop of choice for cultivation in arid and semi-arid regions of the world. Finger millet (*Eleusine corocana* L.), also known as Ragi was earlier considered as minor millets but presently it's wider adaptability makes it much more popular among other cereals. It has the best ability to tolerate salinity among cereals[9]. Foxtail millet (*Setaria italica* L.) has a fast ripening mechanism and a high photosynthetic efficiency; hence, it is perfectly suited to be used as a catch crop. It can provide a good yield with only single pre-sowing precipitation. This crop is more water efficient compared to maize and sorghum[29]. Proso millet (*Panicum miliaceum* L.) is a relatively short-duration emergency or quick-season irrigated crop with low moisture requirements. It is a relatively low demanding crop with no known diseases. Proso millet is well suited for many soil types and climate conditions. Barnyard millet (*Echinochloa frumentacea* L.) is a type of millet is considered a minor cereal and is grown widely in India, China, Japan, Pakistan, Africa, and Nepal. It is a drought-tolerant crop can be grown in marginal lands with a rapid maturation rate and possesses high nutritional qualities.[9]. Proso millet (*Panicum miliaceum* L.) is a warm season grass with a growing season of 60–100 days. It is a highly nutritious cereal grain used for human consumption, bird seed, and/or ethanol production [30]. Kodo millet (*Paspalum scorbiculatum* L.) is considered as the coarsest cereal of the world. It is said to possess the highest drought resistance among all minor millets and believed to give good yield with a growing period lasting 80–135 days, can thrive well in both shallow and deep soil. Little millet (*Panicum sumatrense* L.) matures quickly and withstands both drought and water logging. The grains are similar to that of rice. Its high fiber content makes it a healthy replacement for rice. Packed with the goodness of B-vitamins, minerals like calcium, iron, zinc and potassium [9].

5.MILLETS AS FOOD

The four pillars of millets food security are availability of food, access to food, utilization of food and food security[31]. Millets are a perfect crop for adapting to people's shifting dietary preferences and climatic conditions because of their short lifespan, high photosynthetic efficiency, nutritional richness, and mediocre resistance to pests and diseases[19]. High levels of proteins, niacin, fibre, thiamine, riboflavin, methionine, lecithin, and a negligible amount of vitamin E can all be found in millets. They are rich source of minerals including iron, magnesium, calcium, and potassium. Due to the nutritional benefits of millet it helps to prevent cancer, lower the risk of heart disease, limit the formation of tumors, lower blood pressure, slow down the rate at which fat is absorbed, postpone gastric emptying, and increase gastrointestinal bulk. The millets are deprived of vital elements, such as dietary fibre, phenolics, vitamins, and minerals, during the milling process[12]. They are also a great source of phytochemicals that are good for your health, such as polyphenols, lignans, phytosterols, phytoestrogens, and phytocyanin's. They serve as immune system regulators, detoxifying agents, antioxidants, and other roles, preventing age-related degenerative illnesses like cancer, diabetes, and cardiovascular diseases (CVD). In addition to their well-known roles in avoiding diseases caused by nutritional deficiencies, some vitamins, minerals, and essential fatty acids also offer advantages in the prevention of degenerative diseases. They are safe for those with celiac disease and gluten allergies because they are non-glutinous. They don't produce acids, are simple to digest, and are allergy-free. Millets may offer defence against age-related degenerative illnesses. They are protective against several degenerative diseases, including metabolic syndrome and Parkinson's disease.

Table.1. Nutrient content of millets (100 g^{-1})

Crop/nutrient	Protein (g)	Fiber (g)	Minerals (g)	Iron (mg)	Calcium (mg)
Sorghum	10	4	1.6	2.6	54
Pearl millet	10.6	1.3	2.3	16.9	38
Finger millet	7.3	3.6	2.7	3.9	344
Foxtail millet	12.3	8	3.3	2.8	31
Proso millet	12.5	2.2	1.9	0.8	14
Kodo millet	8.3	9	2.6	0.5	27
Little millet	7.7	7.6	1.5	9.3	17

Barnyard millet	11.2	10.1	4.4	15.2	11
Browntop millet	11.5	12.5	4.2	0.65	0.01
Quinoa	14.1	7	-	4.6	47
Teff	13	8	0.85	7.6	180
Fonio	11	11.3	5.31	84.8	18
Rice	6.8	0.2	0.6	0.7	10
Wheat	11.8	1.2	1.5	5.3	41

Source: IIMR, 2020

They also lower the risk of heart disease, protect against diabetes, improve the digestive system, lower the risk of cancer, detoxify the body, increase immunity in the respiratory system, increase energy levels, improve the muscular and neural systems. Resistant starch, oligosaccharides, lipids, antioxidants such phenolic acids, avenanthramides, flavonoids, lignans, and phytosterols, which are thought to be responsible for a number of health advantages, are among the essential elements found in millets. Tribal communities do believe that consumption of millets heals headache, body pain, and various intestine problems and strengthen their immunity system. In sun, they can work for long time after consuming one glass of millet porridge[32].Each of the millets is three to five times nutritionally superior to the widely promoted rice and wheat in terms of proteins, minerals (calcium and iron) and vitamins and fibre hence, are known as “super foods” [7]. Millets are the ideal food group for all the people irrespective of age. Calcium and iron are essentially required for growing children, pregnant and lactating women who are more sensible for anaemic condition. Among all food crops, finger millet has a higher calcium (344 mg 100 g^{-1}) and than that of foxtail millet (12.9 mg 100 g^{-1}) followed by little millet (10.0 mg 100 g^{-1}) [33]. They are the best diabetic food as they provide energy for a long time due to slow digestion. The millets are “free of gluten”- wheat protein that is responsible for celiac disease (damage of the small intestine), is being seen predominately in western countries due to consumption of wheat [4]. They have diversified high food value but the consumption of these millets is being declined due to lack of standardized processing techniques to compete with fine cereals. Recently these millet products are marketed as 'health foods‟**-** to increase the utilization of small millets in popular foods. Small millet- based value-added products including traditional recipes, bakery products, pasta products, flaked and popped products instant food mixes were developed and standardized [5].

6.CLIMATE CHANGE’S AND MILLETS

By 2050, the expected human population will have grown from 7.4 billion to 9.1 billion [34]. Therefore, a dramatic increase in food, feed, and fibre production rates is required to meet the growing population's desire for nutrient-dense foods. Due to an increase in human population, a change in diet and feeding practices, and a climate change under a global warming scenario, water scarcity has become a global problem [35,36,37,38]. The recent poor meteorological conditions such as a sharp rise in temperature, drought, and other factors have reduced the productivity of grain crops by 9–10% [39]. To meet the growing population's demand for food, it is advised that agricultural productivity be boosted by 60% by 2050. Therefore, the emphasis should be on raising agricultural output, which will ultimately result in a rise in income for emerging nations [40]. In the present-changing climatic scenario, abiotic stresses entail a huge risk for plant growth and development leading to an over 50% decrease in the yield among the popular cereal crops [41]. Almost 90% of the cultivable land is affected by various abiotic stresses globally, while only 10% of the agricultural land is free from these abiotic stresses [42]. Drought and heat are the two most significant production constraints existing among the different environmental stresses. Millets have the characteristics that make them climate-resilient, such as adaptability to a wide range of ecological conditions, reduced irrigation needs, improved growth and productivity under low-nutrient input conditions, reduced reliance on synthetic fertilizers, and minimal susceptibility to environmental stresses [43]. Historically, millets served as poor farmers' protection from the unusual Indian monsoon. Millets may provide climate change insurance in the future. They can withstand extreme weather, such as drought and high temperatures. They may thrive in the driest, toughest environments. When compared to other cereal crops like rice and wheat, millet require less water for growth [44]. Millets are grains for the future in a context of climate change and global warming because they are drought, temperature, and pest tolerant [45]. Millets may be grown under challenging conditions, protecting farmers and the agri-food sector from losses. The drier soil is suitable for growing it. As a result, tillage techniques can be avoided, shortening the time spent cultivating.Several villages in arid parts of Karnataka have adapted to climate change by switching from water-intensive rice, sugarcane, and maize cultivation to various types of drought-resistant millets [46].

7.CONCLUSION

Millets can be considered as the nutritious future crop. In the present climate change situation it will have a wide adaptability in stress situation. It will provide food security as well as livelihoods. Millets will be a choice for the world population.The current population finds it challenging to incorporate millets into their diets, but if appropriate steps are taken by governments through workable regulations taking into account how critical the problem is then it will be the superfood in climate change scenario.

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