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Millets as Nutricereal Climate Resilient Smart Crop: A Review

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Authors' contributions

This work was carried out in collaboration between both authors. Author RB prepared the first draft of the manuscript. Author AKS managed the literature searches. Both authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Worldwide climate change and extreme weather variations are the most threatening challenge to agriculture and allied activities. The entire food production system has faced serious challenges due to 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. Review of different literature from different reports and studies for different nutritional benefit of millets and how it can thrive in climate change conditions are important. Different literature have been searched from different sources and complied. Millets are considered highly nutrition-rich and climate-resilient coarse grain cereals and it can enhance income as well as improve food and nutrition security. Millets have climate-resilient features and that' s why they can thrive in adjust to a vast changing ecological conditions, less water requirements, low nutrient input conditions and also they have more resistance to environmental hassels. In comparison to cereals, millets have more dietary fibres, resistant starches and are nutritionally superior. Millet require less time to complete

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its life cycle than rice and wheat, so they have the capacity to escape the stresses. Millets also provide several health benefits as they have nutritious. The cost of cultivation is also less compare to other cereals. As population growth increases and climate is changing day by day so millets are the alternative choice for today's world. In Karnataka most of the farmers already have started to cultivate drought resistant millets than more water required crop like rice, sugarcane, and maize to due to climate change. They commonly grown millets from domestic purposes are sorghum, pearl millet, finger - millet, barnyard, foxtail, kodo, proso and Little millet.

Keywords: Millet; climate change; nutrition; resilient.

1. INTRODUCTION

"The rainfed is the most common feature in world of agriculture, but it produces about 70% of the world's staple food. In the world 55 % of r ice, 91 % of coarse grains, 90 % pulses, 85 % oilseeds and 65% cotton are grown as rainfed" [1]. Millets and other coarse grains can be grown with annual rainfall less than 350 mm, but other cereal crops can't grow under minimum water and climate variability. Millets are considered highly nutrition-rich and climate-resilient coarse grain cereals and it can enhance income as well as improve food and nutrition security. Millets require 70 % less water than rice and half of that required by wheat and also it requires almost 40 % less energy in processing. Millets are the best and they are figure out for situations like climate change, water scarcity, and drought conditions and also can provide sustainable food security with high nutritive value [2]. Finger millet has calcium content more than 30 times compare to rice while every other millets have at least twice the amount of calcium compared to rice. Millets are not susceptible to environmental stresses due to its various morpho-physiological, molecular and biochemical attributes than other major cereals. As millets posses short life-cycle so it can escape stress whereas rice and wheat requires long life cycle. They have the quality like short stature nature, small leaf area, thickened cell walls and dense root system which help to prevent the stress conditions and their outcomes [3]. Major cereals like rice, maize, wheat, etc. cannot give assured production under changing climate though they have very high potential for food production [4]. Malnutrition is a major problem where world's one third undernourished children live in India and it ranks second in the world [5]. This problem of malnutrition in India can be minimized to some extent by consumption of nutricereal.

For being a healthy, the diet should have all nutritional components which many of the major cereals lack [6]. Millets have climate-resilient features and that' s why they can thrive in adjust to a vast changing ecological conditions, less water requirements, low nutrient input conditions and also they have more resistance to environmental hassles [7]. Also, Millets have high dietary fibres, resistant starches, vitamins, amino acids that are essential for human body, storage proteins and other bioactive compounds and that's why they promote growth as well as provide energy compare to other major cereals [8].

2. MILLETS STATISTICS

India has the highest area under millets cultivation with a production of 10.91 mt, highest among top ten countries.

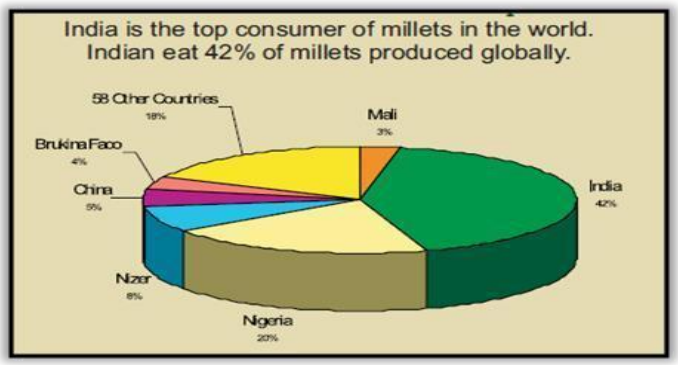

Fig. 1. Global millet consumption pattern [9]

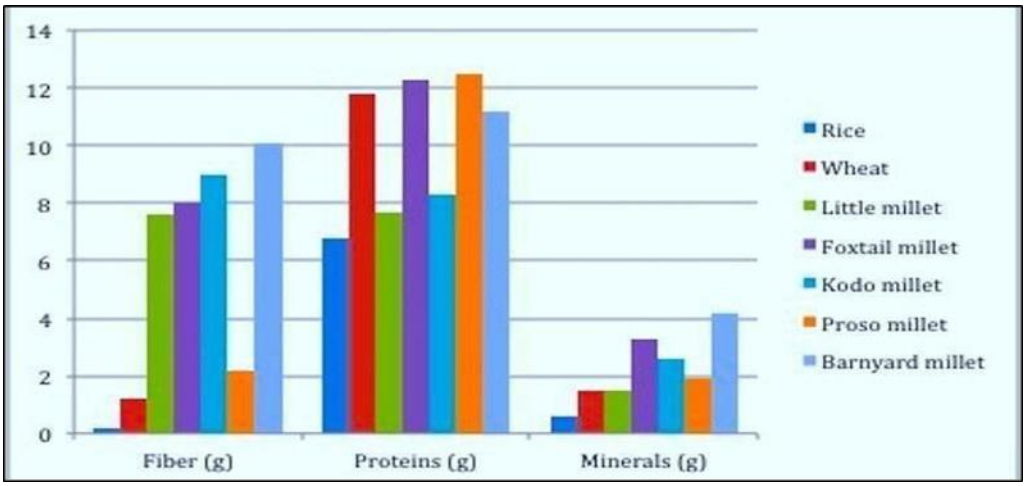

Fig. 2. Nutrition content of different Crops [6]

In India, Rajasthan stands first with 6.57 mt of millet production from 5.91 m ha [9]. "Recently Karnataka was awarded the GI tag for finger millet by the central government. It is majorly known for the cultivation of minor millet in India with finger millet as a staple food in southern parts. Because their taste and other nutritional factors, millets are commonly included in Indian traditional foods. Hence, India is the major consumer of millets with 42% compared to other countries (Fig. 1). As per Fig. 2, proso has the highest protein content whereas barnyard has the highest content of fibre and minerals compared to other cereals" [6].

3. IMPORTANCE OF MILLETS

Millets are not like other cereals as their seeds are small and grow around the world. The grains are used to grow as fodder as well as for human use. Millets have high nutritional values, also they are non glutinous, easily digestible and also non-allergic. Nutrients like phosphorus, potassium, calcium, magnesium and essential amino acid which are found in millets compared to other cereals. All the millets belong to the Poaceae family, though their colour and appearance differ from species to species. This crop has been divided into two groups ie 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 [10].

"Among the cereal crops, wheat contribute to global warming with an estimated 4 ton CO_2 eq ha^{-1} followed by rice and maize with an estimated 3.4 tons CO_2 eq ha^{-1}. They also have a large source of macro nutrients including carbohydrates, lipids, and proteins" [11]. "Still these cereals are cultivated widely as a major source of food around the world. But as comparison to these cereals, minor cereal crops like millets and sorghum have low carbon emission. Because of this characteristics, millets could be one of the crops that lessen the global carbon footprint" [12]. "In present climate change scenario, sorghum and millets have the capacity to grow with limited water supplies. They have the capacity to grow in semi-arid and arid areas because of their resilience to biotic and abiotic stresses, low quality soils with less external inputs" [12,13]. "High temperature is suitable for millet. Pearl millet is suited to marginal sandy and poor soil with less rainfall in contrast to sorghum or maize. It can grow with annual rainfall of 200-500 mm" [14]. "Pearl millet is ranked globally the sixth most significant crop [15]. Finger millet can grow at higher temperatures between 11 and 27°C and on soil with pH ranging from 5 to 8 with moderate rainfall" [16]. "Proso is grown mainly in China, India, and Russia and it is a short duration crop (60-75 days) and needs an average rainfall of less than 600mm with 17°C daily ideal temperature" [17]. "Foxtail millet is a suitable catch crop as it ripened fast and has strong photosynthetic efficiency" [18]. "Due to high nutrient content it has strong resilience to pests and illnesses" [19]. " Barnyard millet is produced extensively in India, China, Japan, Pakistan, Africa, and Nepal and it is known as minor cereal" [20]. "In India, barnyard millet comes in second to finger millet in terms of annual production and productivity" [21].Barnyard millet can tolerates drought, short duration and has

very high nutritional qualities [22]. Kodo millet was the first millet appeared in India and was domesticated around 3000 years ago [23,24]. The favourable climate is tropical and subtropical climates for kodo millet [25,24]. It has 80 to 135 days duration of crop period. Kodo millet also has the characteristic of the strongest drought resistance with good production ability.

4. DIFFERENT TYPES OF MILLETS

There are about 20 different species of millets which are grown around the world at different times [26]. Sorghum *(Sorghum bicolo*r L.) tolerates moisture stress condition because of it's morpho-physiological structures of root system, leaves which are waxy, stem with morter cells. Sorghum can be cultivated in dry land condition with higher temperature and it can tolerate temperature at all the growth stages [10]. Pearl millet (*Pennisetum glaucum*) grow well under poor sandy soils and is well suited to moisture stress situation as compared to sorghum or maize. In moisture stress situation pearl millet reduce its life cycle by early flowering. This is the mechanism for get away from drought. In arid regions, farmer's income and food security can be enhanced by cultivation of pearl millet as it is a climate resilient crop and has the capacity to minimize the adverse effects of climate change [27]. Pearl millet can survive in varieties of ecological situations under drought due to its deep root system It has also high photosynthetic efficiency with an excellent productivity and growth in poor low nutrient soil without addition of inorganic fertilizers. Finger millet (*Eleusine coracana*) was considered early as minor millet but recently because of its vast adaptability it becomes popular among the other cereal. It is suitable to cultivate in saline soils [9]. Foxtail millet (*Setaria italica* L.) is suited good as catch crop because of its fast ripening process and a high photosynthetic efficiency. For yielding a good yield it only needs a pre sowing rainfall.This crop is more water efficient compared to maize and sorghum [28]. Proso (*Panicum miliaceum* L.) is a short life cycle and irrigated crop with low moisture requirements. It has also the characteristics of low demanding crop with no known diseases. Proso is well suited for various soil types and climatic conditions. Proso is a warm season grass with a growing season of 60–100 days. It is a highly nutritious cereal grain hence very good for human consumption, as feed for bird, and/or ethanol production [29]. Barnyard millet (*Echinochloa frumentacea*) is widely grown in India, China, Japan,Pakistan, Africa and Nepal and it is considered as minor cereal apart from millet. It is also has the quality of fast maturation with high nutritional property,drought-tolerant and can be grown in marginal lands [10]. Kodo millet (*Paspalum scorbiculatum*) possess highest drought tolerant capacity and is considered as the coarsest cereal of the world.It has the life cycle of 80-135 days with good yielding potential. It is best suited in both shallow and deep soil.Little millet *(Panicum sumatrense*) has short growing period and can tolerate both drought and water logging. The grain size is smaller than rice.It has high fibre content and so healthier food than rice. Little millet has high B-vitamins,minerals like calcium, iron, zinc and potassium [10].

5. MILLETS AS FOOD

"Millets have the four pillars of quality like food availability, easy access to food, good utilization of food and food security" [30]. " The perfect crop are those which has the capability to meet the people's dietary requirement as presently shifted towards millet from other cereals, adaptation to changing climate by short crop duration, more photosynthetic efficiency, rich in nutrition and tolerant to pest and diseases" [19]. " They have high levels of proteins, fibre, niacin, mecithin, methionine and low amount of vitamin E. Apart from these they are very good source of various minerals including iron, magnesium, calcium, and potassium. As the nutritional properties of millets they help to prevent carcinogenic diseases, heart diseases, prevent the tumors formation, lower blood pressure, fat absorption rate minimize, lowering gastritis and increase gastrointestinal bulk. But during milling process millets loss vital elements, such as dietary fibre, phenolics, vitamins, and minerals" [13]. They have good amount of phytochemicals which are good for health such as polyphenols, lignans and phytosterols. They also help in immune system regulators, detoxifying agents, antioxidant. They have the ability to prevent age related degenerative illness like cancer, diabetes and heart related diseases. Some vitamins, minerals, and essential fatty acids present in them also help in prevention of degenerative diseases occurred due to nutritional deficiencies. As they are non glutinous, so they are safe for those with celiac disease and gluten allergies. They help to minimize gastritis as they don't produce acids and help in easy digestion as well as allergy free. Millets 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	10.6	1.3	2.3	16.9	38
Finger	7.3	3.6	2.7	3.9	344
Foxtail	12.3	8	3.3	2.8	31
Proso	12.5	2.2	1.9	0.8	14
Kodo	8.3	9	2.6	0.5	27
Little	7.7	7.6	1.5	9.3	17
Barnyard	11.2	10.1	4.4	15.2	11
Browntop	11.5	12.5	4.2	0.65	0.01
Rice	6.8	0.2	0.6	0.7	10
Wheat	11.8	1.2	1.5	5.3	41

Source: IIMR, 2020

Millets lower the risk of heart disease, minimize diabetes, help the digestive system, lower the risk of cancer, detoxify the body, immunity to the respiratory system increase, energy level also increase along with improve the mascular and neural systems Millets have essential elements such as resistant starch, oligosaccharides, lipids, antioxidants such phenolic acids, phytosterols etc which are responsible for maximum health advantages. Traditionally tribal people consume millets and have believe that they heal headache, body pain and other various problems related to intestine and also strengthen the immunity system. Their body strength increase after drinking one glass of millet porridge for which they can work longer time under sun [31]. Millets are known a super food because of 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 [8]. They are the perfect food for all different ages of people. As calcium and iron are essential for children with growing age and pregnant and lactating women as they are easily prone to anaemic condition. As reported among all food crops, fingermillet has a more calcium (344 mg g^{-1}) than that of foxtail millet (12.9 mg 100 g^{-1}) followed by little millet (10.0 mg 100 g^{-1}) [32]. They are the best diabetic food as they provide energy for a long time due to slow digestion. Wheat protein which is responsible for celiac disease that cause damage of intestine is absent in millets as they are 'free of gluten' [5]. The standardized processing techniques are still lacking to compete with fine cereals and because of that consumption of these millets are being declined. Recently health foods are available in market which are marketed to increase the utilization of millets. Several small millets based products have been value added with standardization such as traditional recipes, bakery product, pasta product, flaked and popped products and instant food mixes [6].

6. CLIMATE CHANGE'S AND MILLETS

As reported the expected population will grow from 7.4 billion to 9.1 billion by 2050 [33]. "Hence requirement of food, feed and fibre will grow more and there must be increased in production of food, feed and fibre to meet the growing population's desire for nutrient rich foods. Dietary requirement and food habits of the human has been changed with increasing population, climate change day by day, water crisis all become a global problem" [34,35,36,37]. "In coming days agriculture will face various environmental changes like high temperature, uncertainties in rainfall, elevated CO_2 and Green House Gas emission levels, and more frequency uncertain and unpredictable natural calamities. Under these conditions, there should be adoption of climate resilient agriculture where cultivation of climate smart crops will play a pivotal role. Millets are the alternative crop for the climate change condition. They are the climate smart crops as they can fight the ill effects of climate change and adapt to the changed and wider agro-climatic conditions" [38]. "As millets have some efficient morphological, physiological, molecular and biochemical traits which can withstand abiotic stresses. Millets crop have less duration crop so they can escape the possible environmental stress under early and late sown condition. Millets possess small leaf area with thickened cell wall and a high density fibrous root system and thereby they facilitate their capability to tolerate abiotic stress" [39]. "Millets are C4 plants, hence they can utilize more atmospheric CO_2 and by the process of photosynthesis can produce more assimilates, even under elevated CO_2 levels into the

atmosphere" [40]. "Wheat, rice and maize also have high carbon equivalent emissions of 1000, 956 and 935 kg C ha^{-1} respectively. But the carbon foot print of millets are less compared to other major cereals and therefore cultivation of millets can possibly reduce the carbon footprint" [41]. "The productivity of grain crops are reduced by 9-10% due to the poor meteorological conditions such as sharp raise in temperature, unexpected drought and sudden outburst of precipitation and such other factors" [42]. "To meet the increasing population's demand for food, the agricultural productivity should be enhanced by 60% by the year 2050.Therefore, the emphasis should be on increasing agricultural production which will lead to rise in income" [43]. "The abiotic stresses in present climate change scenario lead a huge risk for growth of plant and development leading to an over 50% decrease in the yield among the popular cereal crops" [44]. Out of total agricultural land only 10% of the agricultural land is free from these abiotic stresses and rest 90% cultivable area is affected by different abiotic stresses globally [45]. Among the different environmental stresses drought and heat are the most significant production constraint existing among the various environmental stresses. More annual losses may occur because of all the major abiotic stresses like increased drought and heat due to the climate change and thus it effects the crop production. The different models on climate change have been made and they predict that drought stress would be a major abiotic constraint for food production [46]. Pearl millet can modulate their membrane dynamics better for water permeability to attain better water status during the period of osmotic stress than maize [38]. Under drought situation there is a report which depict an increase in leaf tensile strength and root length in teff and little millet [47]. "Several biochemical events, e.g., reactive oxygen species (ROS) regulation, enhances ROS scavenging enzymes (Catalase and superoxide) and other stress related proteins. It has been reported the accumulation of antioxidants and osmolytes in millets due to abiotic stresses. [48]. C4 grasses dominate natural and agricultural settings, attributable to their resilience to environmental extremes. Under this natural condition, 21 tolerance traits has been lost in major cereals as a byproduct of domestication and intensive selection. 22 millets are an exception and they were domesticated in semi-arid regions of Sub-Saharan Africa and Asia where selection favoured tolerance and stability over yield [49].Sorghum and pearl millet are also regarded as climate-smart crops because of their extreme tolerance to heat (up to 42°C air temperature), drought, and salinity. Finger millet and foxtail millet also have the climate smart resilient and smart properties [50]. 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 chemical fertilizers and minimal susceptibility to environmental stresses [51]. Historically, millets served as poor farmer's protection from the unusual Indian monsoon. Millets may provide climate change insurance for future. They can withstand extreme weather like drought and high temperature. They may thrive in dries, toughest environments. When compared to other cereals like rice and wheat, millets require less water for growth [52]. Millets are grains for the future in a context of climate change and global warming because they are drought, temperature, and pest tolerant [53]. Millets may be grown under challenging conditions, protecting farmers and the agri-food sector from losses. The drier soils are suitable for growing it. As a result, tillage techniques can be avoided, shortening the time spent cultivating. In arid parts of Karnataka, many farmers have adapted to climate change by switching from water -intensive rice, sugarcane and maize cultivation to various types of drought-resistant millets [54].

7. CONCLUSION

Millets are the nutritious, climate resilient smart crop as it has so many nutrients, minerals etc and can well thrive in aberrant climate situation. Millets have a wide adaptability in stress situation. Millets will provide food security as well as livelihoods and would be a choice for the increasing population.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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