Minireview Article

a. Millets as nutricereal and climate resilient smart crop-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. b.Review of different literature from different studies to know the 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, 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, Resilient*

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. C. Millets are multipurpose as they take up 70 percent less water than rice; grow in half the time of wheat; and require 40 percent less energy in processing. They are solution in issues of climate change, water scarcity, and drought conditions along with high nutritive value to provide sustainable food security[2].They are also rich in dietary fibres, resistant starches, vitamins, essential aminoacids, 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[3]. 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 [4]. India ranks second in the incidences of malnutrition among children and more than one third of the world's malnourished children live in India [5]. 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 [6]. 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[7]. 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[8].

3. 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

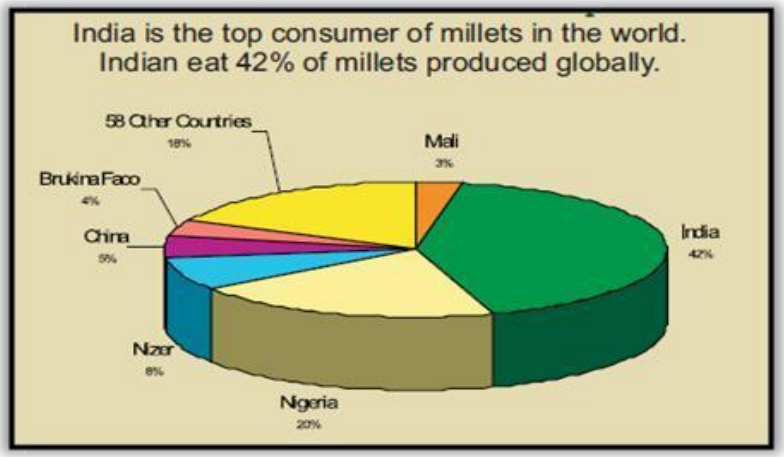

Fig.1 Global millet consumption pattern [9]

millet cultivation. In India, Rajasthan stands first in production of millet with a production of 6.57 m t from 5.91 m ha [9]. 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) d.[6].

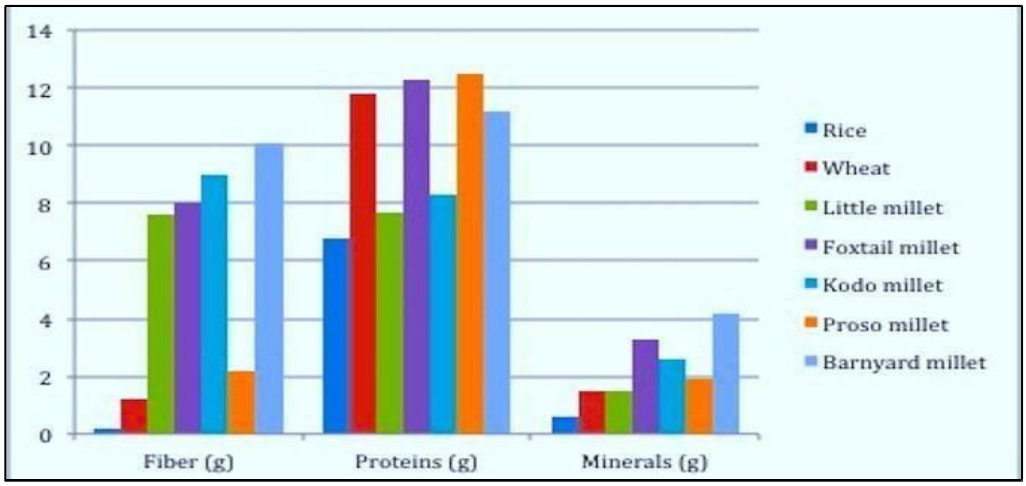

Fig.2 Nutrition content of different crops[6]

4.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[10].

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})[11] . 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 [12]. 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 [12,13]. 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[14]. Pearl millet is the sixth most significant crop farmed globally[15]. 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 [16]. 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[17]. 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[18]. Foxtail millet is ideal for use as a catch crop because of its quick ripening mechanism and strong photosynthetic efficiency [19]. Additionally, it is nutrient-dense and has strong resilience to pests and illnesses[20]. Two varieties of barnyard millet that are grown commercially are *Echniochloa utilis* and *Echniochloa. frumentacea* [21]. *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[22]. In India, barnyard millet comes in second to finger millet in terms of annual production (87,000 tonnes) and productivity (0.86tons ha^{-1})[23].It is a crop that tolerates drought, matures quickly, and has excellent nutritional properties [24]. In India, Kodo millet first appeared. This millet is thought to have been domesticated some 3000 years ago[25,26]. The tropical and subtropical climates are ideal for kodo millet [27,26]. 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.

5.DIFFERENT TYPES OF MILLETS

About 20 different species of millet have been cultivated throughout the world at different points in time[28] .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[10]. 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[29]. 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[30]. 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.[10]. 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 [31]. 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 [10].

6.MILLETS AS FOOD

The four pillars of millets food security are availability of food, access to food, utilization of food and food security[32]. 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[20]. 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[13]. 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[33].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” [8]. 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}) [34]. 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 [5]. 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 [6].

7.CLIMATE CHANGE’S AND MILLETS

By 2050, the expected human population will have grown from 7.4 billion to 9.1 billion [35]. 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 [36,37,38,39]. **e.**The agriculture in near future will face many environmental changes like enhanced temperature, uncertainties in rainfall, elevated CO_2 and Green House Gas emission levels, and more frequency in natural calamities. Under these conditions, there should be adoption of climate resilient agriculture where cultivation of climate smart crops will play a pivotal role. There is no doubt that millets are the climate smart crops which can simultaneously mitigate the ill effects of climate change and adapt to the changed and wider agro-climatic conditions [40]. As millets have some efficient morphological, physiological, molecular and biochemical traits which can withstand abiotic stresses. Due to short-duration nature of millet crops, thus completing a cycle within a short time span, they can escape the possibility of environmental stress conditions under early or late sowing conditions. Since, millets possess less leaf area a thickened cell wall and a dense

fibrous root system hence they facilitate their capability to tolerate abiotic stress" [41]. Millets are C4 plants, so 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" [42].Wheat and rice have a global warming potential of around 4 tons CO_2 eq ha^{-1} and 3.4 tons CO_2 eq ha^{-1}, respectively. Wheat, rice and maize also have high carbon equivalent emissions of 1000, 956 and 935 kg C $ha^{-1}$for wheat, rice and maize, respectively. But the carbon footprint of millets are comparatively less than major cereals and therefore cultivation of millets can reduce the carbon footprint [43]. 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% [44]. 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 [45]. 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 [46]. 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 [47]. Drought and heat are the two most significant production constraints existing among the different environmental stresses. **f.**Among all major abiotic stresses, increased drought and heat due to climate change adversely affect current crop production and alone can cause more annual losses. The climate change models predict that drought stress would continue as a major abiotic limitation for food production [48]. Compared to maize, pearl millet can modulate their membrane dynamics better for water permeability to attain better water status during osmotic stress [40]. An increase in leaf tensile strength and root length was reported in teff and little millet under drought [49]. "Several biochemical events, e.g., reactive oxygen species (ROS) regulation, enhances ROS scavenging enzymes (catalase and superoxide), and other stress-related proteins. The accumulation of antioxidants and osmolytes has been reported in response to abiotic stresses in millets" [50].C4 grasses dominate natural and agricultural settings, attributable to their resilience to environmental extremes. Much of this natural stress 21 tolerance 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 favored tolerance and stability over yield[51].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 [52]. 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 [53]. 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 [54]. Millets are grains for the future in a context of climate change and global warming because they are drought, temperature, and pest tolerant [55]. 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 [56].

8.CONCLUSION

Millets can be considered as the nutritious future crop. In the present climate change situation they will have a wide adaptability in stress situation. They 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 **g.** they will be the best nutritious and climate smart crop in present as well as future climate change scenario.

REFERENCES

1.Sharma K D. Rain-fed agriculture could meet the challenges of food security in India. Curr. Sci. 2011; 100 (11) :1615-1616.

h. 2.Li P, Brutnell TP. Setaria viridis and Setaria italica, model genetic systems for the panicoid grasses. J. Exp. Bot. 2011; 62 :3031–3037.

3.Davis KF, Chhatre A, Rao ND, Singh D, DeFries R. Sensitivity of grain yields to historical climate variability in India. Environ Res Lett. 2019;14(6):064013.

4.Cheng A, Mayes S, Dalle G, Demissew S. Massawe F.Diversifying crops for food and nutrition security- A case of teff. Biol. Rev. 2017;92(1): 188-198.

5.Nainwal K, Verma O, Reena. Conservation of millets for sustaining agricultural biodiversity and nutritional security. J. Pharmacognosy Phytochem. 2018; 3:1576-1580.

6.Ashoka P, Gangaiah B, Sunitha NH Millets-Foods of Twenty First Century, .Int. J. Curr. .Microb. Applied Sci.2020; 9 (12): 2404-2410 *ISSN: 2319-7706*, *https://doi.org/10.20546/ijcmas.2020.912.285.*

7.Kole C, Muthamilarasan M, Henry R, Edwards D, Sharma R, Abberton M. Application of genomics-assisted breeding for generation of climate resilient crops: progress and prospects. Front. Plant Sci. 2015; 6:563. doi: 10.3389/fpls.2015.00563.

8.Amadou I, Gounga ME, Le GW. Millets: nutritional composition, some health benefits and processing - a review. Emirant J. Food Agric.2023. 25; 501–508. doi: 10.9755/ejfa.v25i7.12045.

9.Indiastat 2018-19.

10.Bera A. Importance of Millets Cultivation in the Context of Climate Change. Just Agriculture, Multi-disciplinary e newsletter.2021; 1(9): 1-5(e-ISSN: 2582-8223).

11. Jain N, Arora P, Tomer R, Mishra SV, Bhatia A, Pathak H. Greenhouse gases emission from soils under major crops in Northwest India. Sci. Total Environ. 2016; 542:551-561.

12. Prasad PV, Staggenborg SA. Growth and production of sorghum and millets. In Soils, Plant Growth and Crop Production; EOLSS Publishers Co., Ltd.: Oxford, UK, 2009; 2.

13. Awika JM. Major cereal grains production and use around the world. In Advances in cereal science:implications to food processing and health promotion. American Chemical Society. Chapter 1pp 1 13.2011.DOI : 10.1021/bk-2011-1089.ch001.

14. Guigaz M. Memento Del' agronome; CIRAD GRET and Minister edges Affaires Étrangers: Montpellier, France; c2002.

15. Food and Agriculture Organization of the United Nations. The State of Food and Agriculture Innovation in family farming. FAO: Rome, Italy, 2014.

16. Devi PB, Vijayabharathi R, Sathyabama S, Malleshi NG, Priyadarisini VP . Health benefits of finger millet (Eleusine coracana L.) polyphenols and dietary fiber: a review. J.Food Sci. Tech. 2014; 51:1021-1040.

17. Upadhyaya HD, Reddy VG, Sastry DVSSR. Regeneration Guidelines Finger Millet; CGIAR System.Wide Genetic Resource Programme: Rome, Italy; c2008.

18. Zarnkow M, Kebler M, Back W, Arendt EK, Gastl M.. Optimisation of the mashing procedure for 100% malted proso millet (Panicum miliaceum L.) as a raw material ~ 1049 ~ J. Pharm. Innov. https://www.thepharmajournal.com for gluten-free beverages and beers. Journal of the Institute of Brewing. 2010;116(2):141-150.

19. Léder I. Sorghum and millets. Cultivated plants, primarily as food sources.2004;1:66-84.

20. Vetriventhan M, Upadhyaya HD, Anandakumar CR, Senthilvel S, Parzies HK, Bharathi A. Assessing genetic diversity, allelic richness and genetic relationship among races in ICRISAT foxtail millet core collection. Plant Gen. Resour. 2012; 10(3):214-223.

21. Yabuno T. Japanese barnyard millet (Echinochloa utilis, Poaceae) in Japan. Econ.Bot. 1987;41(4):484- 493.

22. Gomashe SS. Barnyard millet: present status and future thrust areas. Millets and sorghum: biology and genetic improvement. 184-198. Guigaz M.2002. Memento Del' agronome; CIRAD GRET and Minister edges Affaires Étrangers: Montpellier, France.2017.

23. Padulosi S, Mal B, Ravi SB, Gowda J, Gowda KTK, Shanthakumar G. Food security and climate change: role of plant genetic resources of minor millets. Indian J. Plant Genet. Resour. 2009; 22(1):1-16.

24. Wallace JG, Upadhyaya HD, Vetriventhan M, Buckler ES, Tom Hash C, Ramu CP. The genetic makeup of a global barnyard millet germplasm collection. Plant Genome. 2015 ;8.

25. LR, Osmanzai M, Gomez MI, Monyo ES, Gupta SC. Agronomic Principles. In Sorghum and Millets: Chemistry and Technology; American Association for Cereal Chemist: St. Paul, MN, USA; c1995. p. 27-67.

26. Arendt E, Dal Bello F, (Eds.) Gluten-free cereal products and beverages. Elsevier.2023.

27. Hulse JH, Laing EM, Pearson OE. Sorghum and the millets: their composition and nutritive value. Academic press.1980.

28. Fuller, D. Q. (2006). A Millet Atlas: Some Identification Guidance. London: University College London.

29.Satyavathi CT, Ambawat S, Khandelwal V, Srivastava RK. Pearl Millet: A Climate-Resilient Nutricereal for Mitigating Hidden Hunger and Provide Nutritional Security. Front. Plant Sci. 2021; 12:659938. doi: 10.3389/fpls.2021.659938

30.Zhang, L., Liu, R., and Niu, W. (2014). Phytochemical and antiproliferative activity of proso millet. PLoS ONE 9:e104058. doi: 10.1371/journal.pone. 0104058.

31.Habiyaremye C, Matanguihan JB, Guedes JD, Ganjyal G.M, Whiteman MR, KidwellK.K., Murphy KM. Proso Millet (Panicum miliaceum L.) and Its Potential for Cultivation in the Pacific Northwest, U.S.: A Review. Front. Plant Sci. 2017; 7:1961. doi: 10.3389/fpls.2016.01961.

32.Tiwari H, Naresh RK, Bhatt R, AdityaY, Kumar M. Underutilized Nutrient Rich Millets: Challenges and Solutions for India's Food and Nutritional Security: A Review. Int. J.Plant Soil Sci. 2023; 35(2):45- 56.

33.Nayak B K, Dash CR. A study on millet-based production system and its agroecological practices in Koraput district of Odisha. Research & Reviews: J. Agric. Allied Sci. 2021;l10(2): 6-12.

34.Veena B, Chimmad BV, Naik RK, Shantakumar G. Physico-chemical and nutritional studies in barnyard millet. Karnataka J. Agric. Sci.2005*;* 18(1): 101-105.

35.Godfray HCJ, Beddington, JR, Crute, IR, HaddadL., Lawrence L, Muir JF. Food security: the challenge of feeding 9 billion people. Sci. 2010; 327(5967):812-818.

36.Busari MA, Kukal SS, Kaur A, Bhatt R, Dulazi AA. Conservation tillage impacts on soil, crop and the environment. Int. Soil Water Conserv. Res. 2015; 3(2):119-129. http://dx.doi.org/10.1016/j.iswcr.

37.Bhatt R, Hossain A, Hasanuzzaman M .Adaptation Strategies to Mitigate the Evapotranspiration for Sustainable Crop Production: A Perspective of Rice Wheat Cropping System. Agron. Crops Manag. practices. p. 559-582.2020. https://doi.org/10.1007/978-981-32-9783-8 .

38.Bhatt R, Arora S, . Soil matric potential based irrigation using tensiometers for conserving irrigation water. Curr. Sci..2021;121(2):197-200.

39. Bhatt RD, Majumder, Tiwari, AK, Singh SR, Prasad S, Palanisamy G . Climate-Smart Technologies for Improving Sugarcane Sustainability in India–A Review. Sugar Tech. 2023;25(1):1-14. ~ 1047~J. Pharm. Innov.. https://www.thepharmajournal.com *https://doi.org/10.1007/s12355-022-01198-0.*

i 40.Bandyopadhyay T, Muthamilarasan M, Prasad M. Millets for next generation climate-smart agriculture. Front Plant Sci. 2017;8:1266.

j.41.Li P, Brutnell TP. Setaria viridis and Setaria italica model genetic systems for the panicoid grasses. J Exp Bot. 2011;62(9):3031-7

k.42.Aubry S, Brown NJ, Hibberd JM. The role of proteins in C3 plants prior to their recruitment into the C4 pathway. J Exp Bot. 2011;62(9):3049-59.

l.43.Saxena R, Vanga SK, Wang J, Orsat V, Raghavan V. Millets for food security in the context of climate change: a review. Sustainability. 2018;10(7):2228.

44..Lesk C, Rowhani P, Ramankutty N. Influence of extreme weather disasters on global crop production. Nature. 2016; 529(7584):84-87.

45.Lipper L, Thornton P, Campbell BM, Baedeker T, Braimoh A, Bwalya M. Climate-smart agriculture for food security. Nat. Clim. change. 2014; 4(12):1068-1072.

46.Bray EA, Bailey-E, Weretilnyk J. "Responses to abiotic stresses." in Biochemistry and Molecular Biology of Plants, eds W. Gruissem, B. Buchannan, R. Jones (Rockville, MD: American Society of Plant Physiologists). 2000;1158–1249.

47.Dita M.A, Rispail N, Prats E, Singh DKB. Biotechnology approaches to overcome biotic and abiotic stress constraints in legumes. Euphytica. 2006; 147, 1–24. doi: 10.1007/s10681-

006-6156-9.
m.48.Simmons T, Styer AB, Pierroz G, Gonçalves AP, Pasricha R, Hazra AB, et al. Drought drives spatial variation in the millet root microbiome. Front Plant Sci. 2020;11:599.
n.49.Balsamo RA, VanderWilligen CV, Bauer AM, Farrant J. Drought tolerance of selected Eragrostis species correlates with leaf tensile properties. Ann Bot. 2006;97(6):985-91.
o.50.Ajithkumar IP, Panneerselvam R. ROS scavenging system, osmotic maintenance, pigment and growth status of panicum sumatrense roth. Under Drought Stress. Cell Biochem Biophys. 2014;68(3): 587-95.
p.51.Wilson ML, VanBuren, R. Leveraging millets for developing climate resilient agriculture. Curr.Opin. Biotechnol.2022; 75*:* 102683.
p.52. Chaturvedi P,Govindaraj M, Govindan V, Weckwerth W.Editorial: Sorghum and Pearl Millet as Climate Resilient Crops for Food and Nutrition Security.Front Plant Sci. 2022; 13: 851970

53.Tiwari H, Naresh RK, Kumar L, Kataria SK, Tewari S, Saini A. Millets for Food and Nutritional Security for Small and Marginal Farmers of North West India in the Context of Climate Change: A Review. Int. J. Plant Soil Sci. 2022; 34(23):1694-1705.

54.Saxena R, Vanga SK, Wang J, Orsat Raghavan V. Millets for food security in the context of climate change: A review. Sustain. 2018*;*10(7):2228. doi:10.3390/su10072228.

55.NAAS. Role of Millets in Nutritional Security of India. Policy Paper No. 66, National Academy of Agricultural Sciences. New Delhi. 2013;p. 16.

56.Bose HK. Farmers turn to millets as a climate-smart crop is a journalist based in Thane, Maharashtra published in September,17.2018.

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.