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MILLET, THE FIRST, AND THE FUTURE CROP- A REVIEW ARTICLE

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Abstract: Millets are the most farmer-friendly crops, which can be sown with the least amount of equipment, grow on very low fertility soils, practically never require inputs, and only require one weeding. They also don't need to be deeply ploughed. Millets have decreased because of many reasons including changing dietary choices, and a lack of research, while being formerly important in the diets of Asians and Africans. The study highlights millets' potential to address concerns related to food security and malnutrition brought on by climate change and global population expansion by highlighting their minimal input requirements, flexibility, and nutritional richness. It discusses recent global recognition, notably in India, with government initiatives to promote millet cultivation and consumption. Rich in minerals, vitamins, and antioxidants, several kinds of millet have health benefits that make them effective treatments for conditions like anemia, heart disease, migraines, obesity, gastrointestinal disorders, malignancies, neurological disorders, dermatitis, blood-related problems, and diabetes. The declaration of the International Year of Millets and the initiatives taken by the Indian government highlight the benefits of millets in reducing hunger and improving food security worldwide. The historical significance, decrease, advantages of millet production, and health benefits are examined in this paper.

Index Terms – Millets, Millet Production, Health Benefits of Millets, Sorghum millet, Pearl millet, Finger millet, Foxtail millet, Kodo millet, Little millet

I. INTRODUCTION-

Millets are small-seeded grasses commonly cultivated as cereal crops or grains for human consumption and animal fodder worldwide. In human history, millets have played a significant role as a staple food, especially in Asia and Africa. In East Asia, they have been cultivated for the past 10,000 years. Throughout India, eight millet species: Kodo millet, Proso millet, Barnyard millet, Finger millet, Pearl millet, Foxtail millet, Little millet, and Kodo millet are frequently grown in rain-fed environments. However, diminishing institutional support compared to the promotion of rice and wheat has led to a gradual reduction in the cultivation of diverse millet species, limiting their growth and adaptation despite their rich diversity and climate resilience (*Dayakar et al.*, 2017). The strong economic expansion of India has resulted in significant progress in improving the livelihoods of the most vulnerable. However, the country's relatively high economic growth rates have still not decreased hunger and undernutrition, and India continues to prioritize food security when it comes to development (Chakrabarty, 2016).

This economic growth has been greatly affected by undernutrition, maternal & mortality rates, overweight, and obesity which addressed the burden of non-communicable diseases. Malnutrition, poverty, and chronic diseases are all interrelated in such a way that each affects the other's occurrence and persistence, having a long-term effect (Adebisi *et al.*,2009). The government of India is strongly committed to achieving the 2030 Sustainable Development Goals (SDGs). By 2030, Sustainable Development Goal 2 seeks to eradicate hunger worldwide. However, between 720 million and 811 million people globally experienced hunger in 2020, an increase of about 161 million from the previous year. Additionally, in 2020, an enormous 2.4 billion individuals, or more than 30% of the world's population, had moderate to severe food insecurity and lacked regular access to a sufficient diet. In just one year, the number had risen by around 320 million (CNNS Report 2016). India fell short of cutting the number of people who experience hunger in half, which was a Millennium Development Goal (Chakrabarty, 2016).

Many families lack the resources to buy or obtain enough nutrient-dense foods including fresh fruits and vegetables, legumes, nuts, meat, and milk. Additionally, parents may lack awareness of appropriate care, health-seeking behaviors, and information on foods and feeding techniques for children of a certain age, which further leads to malnutrition. Malnutrition is characterized by deficiencies, excesses, or imbalances in a person's energy and/or nutrient consumption. Undernutrition, as well as being overweight and obese, are all included in the condition. (CNNS Report 2016).

A study conducted by Mittal in 2006 states that due to increasing populations, shifting consumer tastes and habits, and the demand for high-value commodities, such as cereals and pulses, is rising. In India, low productivity in the agricultural sector is one of the main problems (Chakrabarty 2016). Due to its numerous effects on food production, climate change adds additional stress to India's long-term food security problems (Mittal 2006). Due to their high potential yields and ability to fulfill expanding food demand, major cereals like rice, maize, wheat, etc. have dominated the agriculture industry. However, these crops struggle to survive in a changing climate (Ashoka *et al*.,2020).

One of the best crops for sustainable agriculture and long-term food security is Millet due to its short growing season and extensive adaptability to many environmental conditions. Underutilized grains like millet are among the best ways to supply the food demand and eliminate malnutrition (Verma *et al*., 2020). Millets can provide noticeably greater yields on marginal soils with low fertility and minimal input agricultural systems than many other crops. With the ability to prevent food shortages and starvation, millet can save the world's constantly expanding population (Das *et al.*, 2019). As per the data provided by FAO Stat 2021, India is the leading producer of millet, with China and Niger following immediately afterward (figure 1).

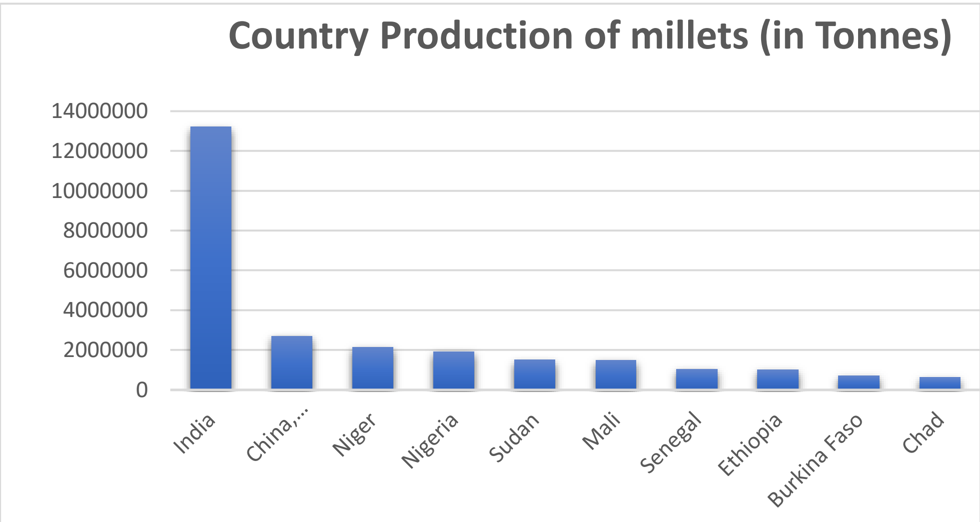

Figure 1. Production of Millet in Different Countries

Source: FAO Stat 2021

II. FACTORS RESPONSIBLE FOR THE DECLINE IN MILLET PRODUCTION

With 20 agro-climatic regions and 157.35 million hectares of land under cultivation, India has the second-largest agricultural land area in the world (Nelson *et al.*, 2019). In the past, millets were cultivated and consumed in large quantities in the nation, covering almost as much land as both rice and wheat, and are grown in about 35–37 million hectares of land in India (Vision2050, 2015). Millets are also considered Nutri cereal since it is extremely nutritious and significantly improve the consumer's food and nutritional security (Rao *et al.*, 2018). Although it has a variety of uses and advantages, Nutri-cereal cultivation drastically decreased in the post-green revolution era, falling by 41.65% between 1950–51 and 2018–19 (Sreekala *et al.*, 2022). After the Green Revolution, millets were no longer produced in large quantities but used as fodder. Meanwhile, the government's reliance on monoculture and the manufacture of subsidized high-yielding hybrid crops contributed to the loss of species in India (Nelson *et al.*, 2019; Status Paper on Coarse Cereals, 2014). Other than these reasons, there are several causes of the decline in the production of millet.

The "major" grains (rice, wheat, and barley) have gotten significantly more research than millets, which were also frequently undervalued and understudied throughout the colonial era, which set a regrettable precedent for present governmental and nongovernmental agriculture. The fact that some of them have a particularly strong flavor is probably the cause of these criticisms. People appear to choose bland and mild-tasting grains like wheat and rice when given the option groups (Bhat *et al.*,2018). This was further aided by the availability of fertilizers with subsidies, the expansion of irrigation due to dam construction, and other factors. Eventually, government initiatives to distribute rice and wheat at significantly reduced rates made sure that millet was quickly eliminated from all kitchens. When rice and wheat were more widely available and more reasonably priced in the late 1960s, millet was gradually phased out of the Indian diet (Status Paper on Coarse Cereals, 2014). Additionally, problems like inadequate domestic storage, inefficient marketing infrastructure, inadequate processing methods, and decreased availability of grains all contributed to the decline in consumption (Chandel *et al.*, 2014; Sreekala *et al.*, 2022).

III. ADVANTAGES OF MILLET PRODUCTION

In the previous three years, the production of cereals worldwide increased by an average of 56 million tons annually (FAO 2022). Strategic scientific advancements in agriculture, such as the creation and selection of high-yielding varieties, the use of synthetic fertilizers and pesticides, mechanization, and irrigation systems, have led to a sufficient supply of food (Kumar *et al.*,2018). Agriculture soils must maintain sufficient levels of quantity and quality to produce food, fiber, and energy to withstand the pressure of use brought on by the expanding human population without harming their nutritional balance, health, or functionality (Krasilnikov *et al.*,2022). Farmers have been using nitrogen fertilizers more frequently to enhance crop output due to rising demand and a lack of available land. However, long-term use of chemical fertilizers may result in major soil acidification, nutritional imbalance, and worsening of the rhizosphere micro-ecological environment, which in turn may increase the activity of heavy metal ions in the soil (Lin *et al.*, 2019). This may damage soil health and the environment by releasing greenhouse gases and disturbing climatic conditions. Climate change adversely affects both human welfare and agricultural output (Ashoka *et al*., 2020).

Millets are one of the most farmer-friendly crops because they essentially never require inputs, can grow on extremely low fertility soils, don't require deep ploughing, can be sown with the least amount of equipment, and only need one weeding. With high micronutrients and low glycemic indices, millet crops survive in harsh environments and have exceptional nutritional qualities. These millets are crops that are resilient to climate change in addition to being a powerhouse of nutrients (Rao *et al.*,2018). Millets are small-grained graminaceous plants recognized for their exceptional nutrient content, water-use efficiency, adaptability to various ecological circumstances, and capacity to grow in nutrient-deficient soil (Kole *et al.*, 2015; Bunkar *et al.*, 2021). These crops are known as eco-friendly crops since they require less water, chemicals, and managerial interventions to grow. Additionally, some millets can survive in adverse climates and poor soils where no other grain can. While fine cereals take between 100 and 140 days to mature, some millets take between 60 and 75 days to mature (Bhat *et al.*, 2018; Bunkar *et al.*, 2021). To increase production and productivity, cultivate high-yielding cultivars, provide irrigation at least at the crop's essential stage, and use good cropping techniques (Sreekala *et al.*, 2022). Millets are referred to as "famine reserves" since they can be kept in storage for longer than two years. Since these millets are grown using conventional techniques, no pests are drawn to them. They are referred to as pest-free crops. The bulk of them are also not impacted by storage bugs (Ashoka *et al*., 2020). 2023 has been designated as the International Year of Millets by the United Nations (Rao *et al*., 2021).

The Government of India has, however, recently implemented several measures to increase millets' production and consumption, the most recent of which was Ms. Nirmala Sitharaman, the Union Finance Minister, who declared 2022–2023 the International Year of Millets during her address presenting the budget on January 2, 2022. (Sreekala *et al.,* 2022). The goal of IYM 2023, according to Prime Minister Narendra Modi, is to establish India as the "Global Hub for Millets." This will result in the production of millets and hence the utilization and growth of new millet entrepreneurs and innovative interventions

IV. HEALTH BENEFITS OF MILLETS

Food and nutritional security have recently attracted a lot of attention due to recent changes in eating habits related to multigrain. Small millets serve as a strategic food source for the poor and, more recently, as a nutritious diet for people living in cities, highlighting the need to focus more research and development on these crops (Vetriventhan *et al.,* 2020). Small millets are being taken into consideration due to their crucial role in nutritional characteristics that other staple crops do not offer. All millets are high in potassium, magnesium, zinc, folic acid, iron, calcium, and other nutrients (Bunkar *et al.,* 2021). The Nutri-cereal millets have the potential to be a game-changer in the fight against hunger and malnutrition. The important macro-nutrients and micronutrients, carbs, protein, dietary fiber, fats, and phytochemicals are all rich in nutri cereals (Gowda *et al.,* 2022).

Small millets have been used as a specific remedy for anemic diseases because of their high folic acid content (Pramitha *et al.* 2023). Milled grains of rice, wheat, and maize have overtaken the traditional, nutrient-dense crops in developing nations. These refined meals are high in carbohydrates but low in minerals, particularly micronutrients like zinc (Zn) and iron (Fe). The systematic review and meta-analysis results demonstrated that millets have a low-cost potential for lowering iron deficiency anemia and are an effective source of iron. An effective approach to fight Iron Deficiency Anemia (IDA) may include selecting millet varieties that are high in iron and creating millet that is biofortified with iron to supply more bioavailable iron. (Anitha *et al.,* 2021). Sorghum and bajra are the two major millets, whereas finger millet, foxtail millet, little millet, proso millet, kodo millet, and barnyard millet are the six minor millets (Ashoka *et al*., 2020). Millet and other whole grains are good sources of magnesium, and eating them may lower your chance of developing type-2 diabetes mellitus. Numerous enzymatic pathways that control the release of insulin and glucose need magnesium as a co-factor (Habiyaremye *et al.,* 2017).Table 1: nutritive value of millets per 100 gm (macronutrients)

Grains	**Energy (kcal)**	**Protein (g)**	**Carbohydrate (g)**	**Fat (g)**
Sorghum	349	10.4	72.6	1.9
Pearl millet	361	11.6	67.5	5
Finger millet	328	7.3	72.0	1.3
Proso millet	341	12.5	70.4	1.1
Foxtail millet	331	12.3	60.9	4.3
Kodo millet	309	8.3	65.9	1.4
Little millet	341	7.7	67.0	4.7
Barnyard millet	307	11.9	65.5	2.2

(Source: nutritive value of Indian foods, NIN, 2018)

Table 2: Nutritive value of Millets per 100 gm (micronutrients)

Grains	Caro - tene (µg.)	Thia-mine (mg.)	Ribo - flavin (mg.)	Niacin (mg.)	Folic acid (µg.)	Calcium (mg.)	Iron (mg.)	Magnesium (mg.)	Sodium (mg.)	Potassium(mg.)	Copper (mg.)	Zinc (mg.)
Sorghum	47	0.37	0.13	3.1	20	25	4.1	171	7.3	131	0.46	1.6
Pearl millet	132	0.33	0.25	2.3	45.5	42	8	137	10.9	307	1.06	3.1
Finger millet	42	0.42	0.19	1.1	18.3	344	3.9	137	11.0	408	0.47	2.3
Proso millet	-	0.20	0.18	2.3	-	14	0.8	153	8.2	113	1.6	1.4
Foxtail millet	32	0.59	0.11	3.2	15	31	2.8	81	4.6	250	1.4	2.4
Kodo millet	-	0.33	0.09	2	23.1	27	0.5	147	4.6	144	1.6	0.7
Little millet	-	0.30	0.09	3.2	9	17	9.3	133	8.1	129	1	3.7
Barnyard millet	-	0.33	0.09	2	23.1	20	5	82	-	-	0.6	3

(Source: nutritive value of Indian foods, NIN, 2018)

Table 3: Essential amino acids in Millets

Grains	Approx total N (g/100 gms)	Arginine	Histidine	Lysine	Tryptophan	Phenylalanine	Tyrosine	Methionine	Cystine	Threonine	Leucine	Isoleucine	Valine
		mg per gm N											
Sorghum millet	1.66	240	160	150	70	300	180	100	90	210	880	270	340
Pearl millet	1.86	300	140	190	110	290	200	150	110	240	750	260	330
Finger millet	1.17	300	130	220	100	310	220	210	140	240	690	400	480
Proso millet	2.00	290	110	190	50	310	-	160	-	150	760	410	410
Foxtail millet	1.97	220	130	140	60	420	-	180	100	190	1040	480	430
Kodo millet	1.33	270	120	150	50	430	-	180	110	200	650	360	410
Little millet	1.23	250	120	110	60	330	-	180	90	190	760	370	350

(Source: nutritive value of Indian foods, NIN, 2018)

- **Kodo millet:** Kodo millet leaves contain lecithin and are used to cure joint pain, gastrointestinal issues, and snake bites. Kodo millet is chosen for treating colon cancer, migraines, insomnia, depression, and anxiety. Also, it is particularly simple to digest, making it advantageous for the formulation of products for infants and older people. (Pramitha *et al.* 2023; Gowda *et al.* 2022). Kodo grains constitute 8.35% protein, 1.45% fat, 65.65% carbohydrate, and 2.95% ash (Bunkar *et al.*, 2021; NIN, 2018). Lecithin, which is beneficial for the health of the neurological system and is found in greater quantities in Kodo millet, makes it very simple to digest. Kodo millet has a high concentration of phenolics and antioxidants, including phytates, phenols, and tannins, which may have substantial antioxidant effects on aging, metabolic syndrome, and general health, also because of its high antioxidant content it prevents oxidative stress and keeps glucose concentrations stable in type 2 diabetes. The presence of antinutritional factors such as phytates, tannins, and phenolic acids reduces the risk of breast and colon cancer (Bunkar *et al.*, 2021). It is particularly helpful for postmenopausal women exhibiting symptoms of cardiovascular diseases, such as high blood pressure and high cholesterol levels (Patel *et al.*, 2018).

- **Barnyard millet:** Barnyard millet is used to treat allergies, atopic dermatitis, cardiovascular conditions, constipation, and blood-related problems (Pramitha *et al.* 2023). The levels of crude fiber and total dietary fiber assure a slower rate of blood sugar release (Renganathan *et al.*, 2020; Pramitha *et al.*, 2023; Vision 2050, 2015), tryptophan, total carotenoids, α-tocopherol polyphenols, ortho-dihydroxy phenol, acid phosphatase, and α-galactosidase were all higher in barnyard millet. The antinutrient components found in finger millet and barnyard millet, such as phytate, tannins, and trypsin and amylase inhibitors, are also well known (Panwar *et al.*, 2016). Barnyard millet is high in minerals like iron (Fe) and zinc (Zn) calcium (Ca), protein, magnesium (mg), fat, vitamins, and some essential amino acids (Renganathan *et al.*, 2020; Chandel *et al.*, 2014; Vetriventhan *et al.*, 2020) and low in phytic acid. Niacin (B3) and magnesium, which are both present, can help lower cholesterol and the effects of migraine headaches, respectively. Barnyard millet contains phosphorus, which aids in the metabolism of fat, the repair of bodily tissues, and the conversion of food into energy (Singh *et al.*, 2010).

- **Foxtail millet:** Foxtail millet is used to treat stomach issues, fever, cholera, chicken pox, and heart attacks (Pramitha *et al.* 2023). Due to its abundant dietary fiber content, protein-rich, resistant starch, vitamins, minerals, and high amount of stearic and linoleic acids, which help in maintaining a good lipid profile, as well as essential amino acids, except lysine and methionine, foxtail millet has a greater nutritional value than major cereals like wheat and rice (Gowda *et al.*, 2022). Similar to other types of millet, foxtail millet is a rich source of crude fiber, aids in digestion, and encourages bowel movements, generating a laxative effect that is useful for a healthy digestive system. In addition to its nutritious qualities, foxtail millet has also been proven to have several health advantages, such as the ability to lower blood sugar and cholesterol levels and prevent cancer (Sharma *et al.*, 2017). Additionally, cattle are offered foxtail millet leaves to promote lactation (Pramitha *et al.* 2023). The most popular millet varieties grown in the United States are proso and foxtail millet, mostly used as cow and bird feed (Vetriventhan *et al.*, 2020; Ashoka *et al.*, 2020 *et al.*,2020; Bhatt *et al.*,2021).

- **Proso millet:** High levels of lecithin in proso millet help the neurological health system. B-complex vitamins, minerals like calcium, phosphorus, potassium, sodium, magnesium, manganese, iron, magnesium, and zinc, vitamins, and important amino acids (methionine, phenylalanine, tryptophan, and valine) that are abundant in them (Pramitha *et al.* 2023). Compared to rice, wheat, and barley, Proso Millet has a lower glycemic index (GI), making it a better choice of diet for those with type-2 diabetes (Ashoka *et al.*, 2020) and cardiovascular disease (CVD) (Das *et al.*, 2019). Also, it benefits those with atherosclerosis, diabetes, and heart disease, reducing the frequency of heart attacks and migraine headaches (Habiyaremye *et al.*, 2017). To enhance levels of high-density lipoprotein (HDL) cholesterol, namely the HDL2 subfraction, without increasing levels of low-density lipoprotein (LDL) cholesterol, proso millet's dietary protein is essential (Shimanuki *et al.* 2006).
- **Sorghum millets:** For people with celiac disease, sorghum starch is a viable substitute for wheat flour because it is gluten-free. Sorghum is almost sodium-free and regarded as a good source of potassium (Bhat *et al.*, 2018). Chronic inflammation brought on by oxidative stress over an extended period can result in several chronic illnesses. Sorghum has a high concentration of polyphenolic compounds like procyanidins (condensed tannins), 3-deoxyantocyanidins, and phenolic acids which have strong antioxidant properties to prevent diseases brought on by oxidative stress, antiproliferative properties to prevent several cancers, antimicrobial properties, and improve glucose metabolism, which is a process linked to diabetes, lower

blood cholesterol, prevent obesity, helps in improving bone health (Mohamed *et al*., 2022; Prasad *et al.*, 2010; Simnadis *et al.*, 2016).

- **Pearl millet**: Pearl millet grain phenolic extracts showed a variety of anti-carcinogenic properties. The synergistic action of several phenolic compounds and the high caffeic acid content of pearl millet grains may be useful in the suppression of LDL-C oxidation. Because pearl millet is gluten-free, it has a significant amount of potential in foods and beverages that are suitable for people with celiac disease. Pearl millet's lower GI value makes it possibly useful for treating diabetic patients' hyperglycemia and, to a lesser extent, for combating obesity (Jukanti *et al*. 2016; Nambiar *et al.*, 2011; Satankar *et al.*, 2020). They lower blood triglyceride levels and enhance immunological response, as well as brain and eye function and child development. Pearl millet has a high fiber content (1.2g/100g) and can be used extensively to produce nutritious foods for persons who need a high-fiber diet, especially for those who are obese or have constipation issues (Nambiar *et al*., 2011).

- **Finger millet:** The highest source of calcium (Ca) among cereals is finger millet (Maharajan *et al.*, 2021), which has a calcium concentration that is up to 10 times greater than that of brown rice, wheat, or maize and three times greater than that of milk cereals (Kumar *et al.*, 2016). The Ca plays a crucial part in maintaining several vital bodily processes, including the regulation of nerve excitability, maintenance of the skeletal muscles, contractility of the heart, blood clotting, and in allergic situations (Piste *et al.*, 2012), decreased chances of high blood pressure, colorectal cancer, and osteoporosis (Gao *et al.*,2005). In addition, it is high in fiber and iron, making it a more nutritional crop than the majority of other cereals (Kumar *et al.*, 2016). By including finger millet in our daily diet, we can combat the deficiencies that contribute to bone and teeth problems and anemia (Singh *et al*., 2012). Due to its abundant protein, essential amino acid, mineral, and vitamin content, finger millet may help the world's most vulnerable populations overcome hidden hunger (Maharajan *et al.*, 2021).

- **Little millet:** To make use of the health advantages of little millet, various value-added products have recently been created using millet. It is also a good source of micronutrients like Fe, P, and niacin (Gowda *et al.*, 2022). It is advantageous to vegans since it is high in methionine, cysteine, and lysine and includes amino acids in balanced quantities (Neeharika *et al.*, 2020). The millet's complex carbohydrates, phenolic compounds, and antioxidants aid in fighting off disorders such as diabetes, cancer, obesity, etc. (Srilekha *et al.*, 2019). Iron (9.3 mg/100g) and phosphorus (220 mg/100g) levels are high. It is particularly beneficial for those with low body mass (Sharma *et al.*, 2020).

V. CONCLUSION

Millet production has declined due to various reasons, yet they offer a solution for malnutrition and food security challenges. They are precious because of their low needs, flexibility, and superb nutrition—especially in considering the world's expanding population and changing climate. The significance of millet for health and food security has been highlighted by government initiatives, especially in India, and recent global recognition. Because of their abundance of nutrients, millet can help with a wide range of health problems. Millets present a wholesome and sustainable solution to the world's food security and health issues, with a focus on increased research and public awareness.

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