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## Millets: Cultivating resilience and sustainability for the future of global agriculture

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### Abstract

Millets, a diverse group of small-seeded grasses, are gaining global attention for their resilience to climate change, nutritional benefits, and sustainability. This paper explores millet production trends, challenges, and future potential, emphasizing their role in food security and sustainable agriculture. Millets have been a staple food in many parts of the world for centuries. Their importance has been witnessed in recent years due to their resilience to harsh climatic conditions, nutritional benefits, and potential role in ensuring food security. This paper delves into the current state of millet production, examines the factors influencing its cultivation, and explores the future scope of millet cultivation in the context of global challenges such as climate change, nutritional security, and sustainable agriculture.

**Keywords:** Millets, climate resilience, food security, sustainable agriculture, nutritional value, millet production, agricultural policy

### Introduction

Millets are one of the oldest cultivated crops, traditionally grown in arid and semi-arid regions of Asia and Africa. They include varieties such as sorghum, finger millet, pearl millet, foxtail millet, and proso millet. With the rise in awareness about climate change, food security and the need for sustainable agricultural practices, millets have gained attention as a viable alternative to more water-intensive and less resilient crops like rice and wheat.

Millets have been a critical part of the diet in various cultures, especially in Asia and Africa. Historically, they were the primary grain in many regions before the Green Revolution shifted the focus to rice and wheat. Their role in traditional farming systems was significant due to their ability to thrive in poor soils and under limited water conditions.

The decline in millet cultivation is particularly concerning given the growing challenges of climate change, water scarcity, and the requirement for sustainable agricultural practices. Millets require less water, are more resistant to diseases and pests, and have a shorter growing season compared to other major cereals, making them ideal for regions facing climate variability. Furthermore, millets are nutritionally superior to some of main crops like rice and wheat, offering high levels of proteins, dietary fiber, and essential nutrients such as calcium, phosphorus, iron fibre and magnesium. These qualities make millet a crucial component of efforts to enhance food and nutritional security, particularly in developing countries where micronutrient deficiencies are prevalent.

In recent years, there has been a resurgence of interest in millet due to its potential to contribute to global food security and sustainable development. Governments, particularly in millet-producing countries like India and Nigeria, have begun to recognize the importance of these grains in their agricultural policies. The declaration of 2023 as the International Year of Millets by the United Nations has further highlighted the global importance of millets in addressing contemporary challenges in agriculture (FAO, 2023) <sup>[19]</sup>. This paper aims to provide a comprehensive analysis of the current state of millet production, the challenges faced by farmers, and the future scope of millets in global agriculture, with a focus on their role in promoting climate resilience, food security, and sustainability.

### Review of Literature

Historically, the diets of people throughout the world have included a large amount of these millets. India and Niger are the two countries with the most area cultivated for millet. Worldwide, 312.44 lakh hectares are used to grow millets, with Niger and India dominating the world in output. Switzerland and Uzbekistan have the highest millet yields per hectare.

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Millets are valuable because of their adaptability to a wide range of temperatures, moisture regimes, and input conditions, including shorter growing seasons (Dixit & Ravichandran, 2023) <sup>[5]</sup>.

Millets belong to multiple species. They are merely small-kerneled, farmed grasses, and that is the only thing that unites them. Millets don't contain gluten-forming proteins, but there are a plethora of diverse millet food and drink options available. Despite the growing urbanization of the population, millets are still very popular in the developing countries. To satisfy the demands of the expanding urban population, the number of sorghum and millets processors in the Sahel region of West Africa, as well as the quantities they process, are developing at a rapid pace. Millets are becoming a niche crop for organic farmers and specialty food corporations in industrialized countries (Taylor & Emmambux, 2008) <sup>[18]</sup>.

The majority of people who use grains as a food source are traditional farm and village customers who come from lower socioeconomic backgrounds. They are abundant in minerals, vitamins, phytochemicals, crude fiber, protein, and carbs. Several conventional methods, including soaking, germination, malting, fermentation, milling or grinding, boiling, roasting, and popping, are used to process them. Uses for millet grains and flours include porridges, chapati, dosas, biscuits, snacks, drinks, and pastas. To increase food security and avoid micronutrient shortages, new value-added products made from millets - an underutilized crop - are required (Ramashia *et al.*, 2021) <sup>[16]</sup>.

They are beneficial as C4 crops because they boost the conversion of carbon dioxide into oxygen. Because millets provide food and feed to smallholder farmers in arid regions, they have the potential to support food and nutritional security. The review paper's research scope offers insightful suggestions for developing millet-based agriculture, broadening the variety of food options, and achieving complete food and nutritional security in a world free from hunger (Dixit & Ravichandran, 2023) <sup>[5]</sup>.

Food security is a persistent issue, as the staple foods of today are insufficient to combat problems like the current COVID-19 pandemic. Here, we suggest that small millets, particularly in areas of extreme need, have the potential to emerge as new staple crops. Crop output is now constrained by the need to optimize supply chains and storage, the paucity of genetic tools being used for trait development, and the lack of millet farming intensification.

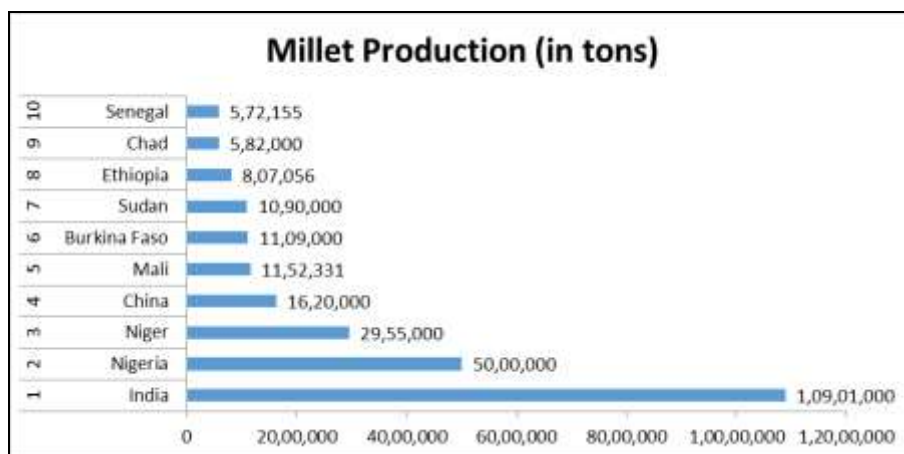
We outline a road map for bolstering small-scale millet production, including figuring out which cultivars are best suited for specific conditions and utilizing genetic and genomic methods to improve specific traits. In addition to providing economic support to farmers and other small-scale millet farming stakeholders in the midst of the epidemic, these strategies will aid in the fight against hunger and malnutrition (Muthamilarasan & Prasad, 2021) <sup>[13]</sup>.

Millets are in short supply because, in the next five years, the WMO predicts a 1.5-degree Celsius rise in global temperature. This will affect cereal productivity, jeopardizing billions of people's access to food. Millets are a wonderful substitute because they are hardy crops that can withstand high temperatures and drought. The war between Russia and Ukraine has had a significant impact on wheat and edible oil shortages, primarily in Africa. Africa can cultivate millet since it is a productive crop under such conditions. Reliance on the mono-cropping of the rice-wheat system must be reduced, and other crops should be planted following the potential of the region. Since cereal prices are rising as well, millets are light in the dark to make nourishment more affordable (Sandhu *et al.*, 2022) <sup>[17]</sup>.

As the world's largest producer of millets, India's small and marginal farmers stand to benefit greatly from increased global demand and awareness for millets, which could lead to substantial profits both in domestic and international markets. Additionally, because of millets' high nutritional content and high input efficiency, which contribute to global nutritional security, as well as their resilience to various stresses and C4 pathways, millets are a golden crop of the future. Millets are effective enough to combat hidden hunger in developing nations, and while cereal-legume intercropping is more common, intercropping with small millets is gaining attention due to its many advantages (Sandhu *et al.*, 2022) <sup>[17]</sup>.

**Global Production**

Millet production is concentrated in India, Nigeria, Niger, and China, which together account for a significant portion of global output. India is the largest producer, with Rajasthan, Karnataka, and Maharashtra being the leading states. Despite their resilience, millet cultivation has seen a decline in some regions due to the preference for rice and wheat, supported by government policies and consumer preferences.

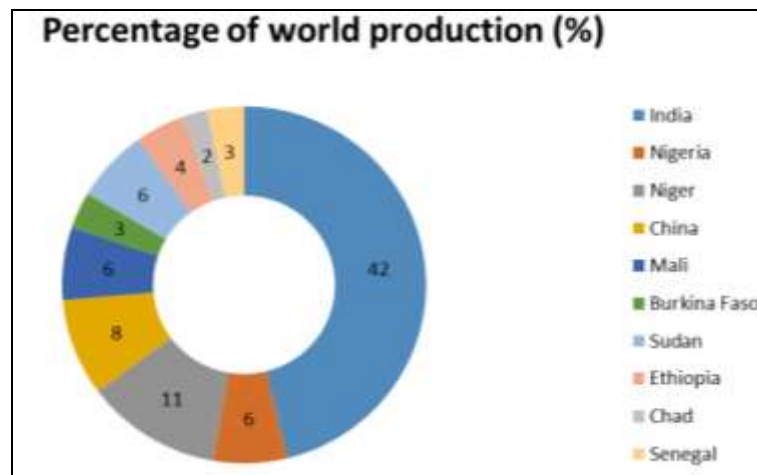


Source: Arora (2024) <sup>[1]</sup>

Fig 1: The World's Top 10 Millet-Producing Countries, 2024

In Figure 1, it can be seen that India is a major producer of millet with 1,09,01,000 tons followed by Nigeria and Niger with 50,00,000 tons and 29,55,000 tons respectively. This

figure shows that India is standing tall with a very significant margin and it still has a chance to grow further even in serious changes in climatic conditions.



Source: Millet Explorer. (2024) [12]

Fig 2: Contribution of countries in the world production of millets (%)

In Figure 2, it can be seen that India contributes 42 percent of the millet production in the total world production in an aggregate sense. India is followed by Niger and China with 11 percent and 8 percent respectively. India is the major contributor to millet production in the world. India has lots of potential even to grow further in terms of production volume as well as productivity. India has diverse climatic conditions even though it is a major producer of millets, this shows that even worse climatic conditions India still has the potential to even grow further.

**The Nutritional and Environmental Benefits of Millets**

Millets are rich in essential nutrients such as protein, fiber, vitamins, and minerals, making them a highly nutritious food source. They are gluten-free, have a low glycemic index, and are beneficial for managing conditions like diabetes and cardiovascular diseases.

From an environmental perspective, millets are highly drought-resistant and require less water and chemical inputs than other staple crops. They have a shorter growing season, making them an ideal crop for regions facing erratic rainfall patterns due to climate change.

Table 1: Nutritive value of millets (per 100 grams)

Crop/Nutrient	Protein (gram)	Calcium (milligram)	Fibre (gram)	Minerals (gram)	Iron (milligram)	Phosphorus (milligram)
Sorghum	10.4	25.0	1.6	1.6	4.1	222
Finger Millet	7.3	344.0	3.6	2.7	3.9	283
Pearl Millet	11.6	42.0	1.2	2.3	8.0	296
Foxtail Millet	12.3	31.0	8.0	3.3	2.8	290
Little Millet	7.7	17.0	7.6	1.5	9.3	220
Proso Millet	12.5	14.0	2.2	1.9	0.8	206
Kodo Millet	8.3	27.0	9.0	2.6	0.5	188
Barnyard Millet	6.2	20.0	9.8	4.4	5.0	280

Source: Gopalan et al., 2009 [6]; Pushpavalli, 2015 [15]

Table 1 shows different types of millets and their respective nutrient values. Proso millet has the maximum protein component (12.5 gram/ 100 gram) as compared to other millets. Finger millet has having maximum proportion of calcium with 344 milligrams per 100 grams as compared to

other millets. Similarly Barnyard contains 9.8 grams of fibre/ 100 grams, as compared to other millets. Pearl millet contains a maximum amount of Iron (8.0 milligram/100 gram) with a maximum amount of phosphorus i.e. 296 milligrams/ 100 gram of same millet.

Table 2: Millets and their health benefits

Millets	Benefits
Sorghum	Antioxidants reduce the risk of CVD and colon cancer, as well as high in soluble fiber, and reduce the risk of diseases such as type 2 diabetes.
Pearl Millet	It is a rich source of Vitamin E, as well as it protects body tissues from radical damage.
Finger Millet	Helps in the strengthening & development of bones and helps in fighting against anemia.
Foxtail Millet	Rich in calcium, it helps fight diseases such as osteoporosis and reduces the risk of fractures.
Proso Millet	Controls depression, lowers blood pressure, and also acts as an anti-inflammatory.
Kodo Millet	Excellent for strengthening the nervous system.
Little Millet	Helps improve heart health & an ideal food for diabetes as it prevents abnormal spikes in blood sugar levels.
Barnyard Millet	Contains high amounts of iron, and helps in the production of hemoglobin.

Source: International Year of Millets: India Leading The Way (2023)

Table 2 shows the health benefits of the consumption of different types of millet.

### Challenges in Millet Production

- a. **Low Yield:** Millets typically have lower yields compared to major cereals like rice and wheat.
- b. **Market Infrastructure:** Lack of robust market infrastructure and value chains hampers the growth of millet production.
- c. **Policy Bias:** Historical agricultural policies have favored the production of rice and wheat, leading to the neglect of millets.
- d. **Changing Dietary Patterns:** Urbanization and changing dietary preferences have led to a decline in millet consumption.
- e. **Market Access:** Inadequate market infrastructure, such as storage facilities and transportation, has hindered the growth of millet production. This is particularly evident in regions where millets are still grown primarily for subsistence.
- f. **Policy and Subsidies:** The agricultural policies of many countries have historically favored the cultivation of rice, wheat, and maize through subsidies, research, and market support. This has led to the marginalization of millets.

### Future Scope of Millets

- a. **Climate-Resilient Agriculture:** As the global climate continues to change, millets are emerging as a key crop for climate-resilient agriculture. Their ability to withstand extreme weather conditions makes them an important tool in mitigating the effects of climate change on food production.
- b. **Food and Nutritional Security:** With the increasing prevalence of lifestyle-related diseases, there is a growing demand for healthier food options. Millets, with their rich nutrient profile, are well-positioned to play a critical role in enhancing global food and nutritional security.
- c. **Government Initiatives and Policy Support:** A growing number of nations are including millets into their agriculture programs. For example, India proclaimed 2018 to be the "National Year of Millets" and introduced a number of programs to encourage the growing, processing, and eating of millet. The United Nations' proclamation of 2023 as the International Year of Millets has intensified efforts to raise millet consumption and production around the globe.
- d. **Market Development and Value Addition:** The future scope of millets also lies in market development and value addition. There is potential for expanding the market for millet-based products such as snacks, ready-to-eat foods, and beverages. Developing a robust value chain, improving processing technologies, and creating awareness about the benefits of millets can significantly enhance their market appeal.
- e. **Research and Innovation:** Ongoing research in millet breeding, agronomic practices, and post-harvest technologies is crucial for enhancing millet yields, improving resistance to pests and diseases, and extending shelf life. Innovations in millet processing and product development are also key to increasing consumer acceptance and marketability.

### Conclusion

The future scope of millets is also being shaped by supportive government policies and international initiatives. The Indian government's Millet Mission and the United Nations' designation of 2023 as the International Year of Millets are pivotal steps towards mainstreaming these grains in global food systems. Such initiatives not only promote millet cultivation but also aim to enhance research and development, improve processing technologies, and strengthen market linkages. These efforts are crucial for overcoming the challenges associated with millet production, such as low yields, market access, and consumer preferences.

However, realizing the full potential of millets will require a multi-faceted approach. Governments, research institutions, the private sector, and civil society must collaborate to address the challenges that have historically hindered millet production. Investments in research and development are needed to improve millet yields, develop pest-resistant varieties, and innovate in processing and storage technologies. Additionally, raising consumer awareness about the nutritional and environmental benefits of millet is essential for increasing demand and supporting the growth of millet markets.

In conclusion, millets are more than just a crop; they represent a pathway toward a more resilient, sustainable, and nutritionally secure future. By integrating millets into mainstream agriculture, we can build food systems that are better equipped to withstand the challenges of climate change, reduce the environmental footprint of food production, and provide healthier dietary options for populations around the world. The renewed global interest in millets, supported by strong policy frameworks and innovative market strategies, positions these ancient grains at the forefront of the global agricultural agenda, with the potential to transform the way we produce and consume food.

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