



A Review of Millet Crops for Agricultural Sustainability in India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJAEES/2023/v41i102162

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://www.sdiarticle5.com/review-history/104251>

Review Article

Received: 15/06/2023

Accepted: 20/08/2023

Published: 08/09/2023

ABSTRACT

A major issue in India is the sustainability of agriculture due to population expansion, climate change, and mounting demands on natural resources. This review paper explores how millet crops might help India's agriculture become more sustainable. A family of small-seeded grains known as millets has been cultivated for millennia and has various distinctive qualities that make them appropriate for sustainable farming methods. The paper looks at the advantages of growing millet from an environmental, economic, and social standpoint, as well as the difficulties and potential solutions for their broad adoption. Additionally, millet contributes to improved soil health, water resource conservation, mitigation against climate change, and strengthening rural communities. The review's conclusions underscore the important part millet crops can play in achieving agricultural sustainability and offer suggestions for how politicians, academics, and farmers should encourage the development of millet crops.

Keywords: Millet; pearl; finger; Sorghum; Kodo; Proso, barnyard; pseudo; little.

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1. INTRODUCTION

The small-seeded grains known as millet crops have been grown for many years in India. Millets belong to minor cereals in the grass family Poaceae [1]. Millets are cereal crops grasses with small-seeded structures planted in diverse tropical and desert climates with the capacity to thrive in less rich soil. The millets are en route to becoming a worldwide phenomenon. The United Nations (U.N.) has decided to designate 2023 as the international year of millets, a resolution sponsored by India and supported by more than 70 [2]. decision recognizes the potentially critical role of millets in improving the health status of a sizeable portion of the world's malnourished population. They come in a variety of varieties, such as ragi (finger millet), bajra (pearl millet), kangni (foxtail millet), and kutki (small millet). Millets are well recognized for their adaptability to a variety of agroecological conditions, making them excellent for cultivation in areas that are subject to both drought and rain. By embracing millet crops, India may establish a more resilient and sustainable agricultural system that will support rural development, environmental protection, and food security [3].

The world's largest producer of millet is India. In 2020, the two millets grown in India, Pearl Millet (Bajra) and Sorghum (Jowar), would account for roughly 19% of global production. In 2020, India produced 40.51% of the world's pearl millet,

followed by 8.09% of the millet produced by sorghum. Rajasthan, Karnataka, Maharashtra, Uttar Pradesh, Haryana, Gujarat, Madhya Pradesh, Tamil Nadu, Andhra Pradesh, and Uttarakhand are the leading millets-producing states in India. Currently, these ten states collectively account for almost 98% of India's millet production in 2020–21 [4]. The production of millet is divided among six states—Rajasthan, Karnataka, Maharashtra, Uttar Pradesh, Haryana, and Gujarat—for more than 83% of the total. 28 % of India's total millet production comes from Rajasthan. India produces many different types of millets, including pearl millets, sorghum, finger millets, foxtail millets, kodo millets, barnyard millets, proso millets, little millets, and pseudo millets like buckwheat and amaranths. The three millets that make up the majority of India's overall millet production are Pearl millet (Bajra), Sorghum (Jowar), and Finger Millet (Ragi) [5].

India confronts many difficulties in establishing agricultural sustainability due to its expansive agricultural area and different climatic conditions. These difficulties include the effects of climate change, water scarcity, soil degradation, and the requirement to provide food security for the country's expanding population. In this situation, growing millet crops stands out as a potential answer to these problems and a means of advancing agricultural sustainability.

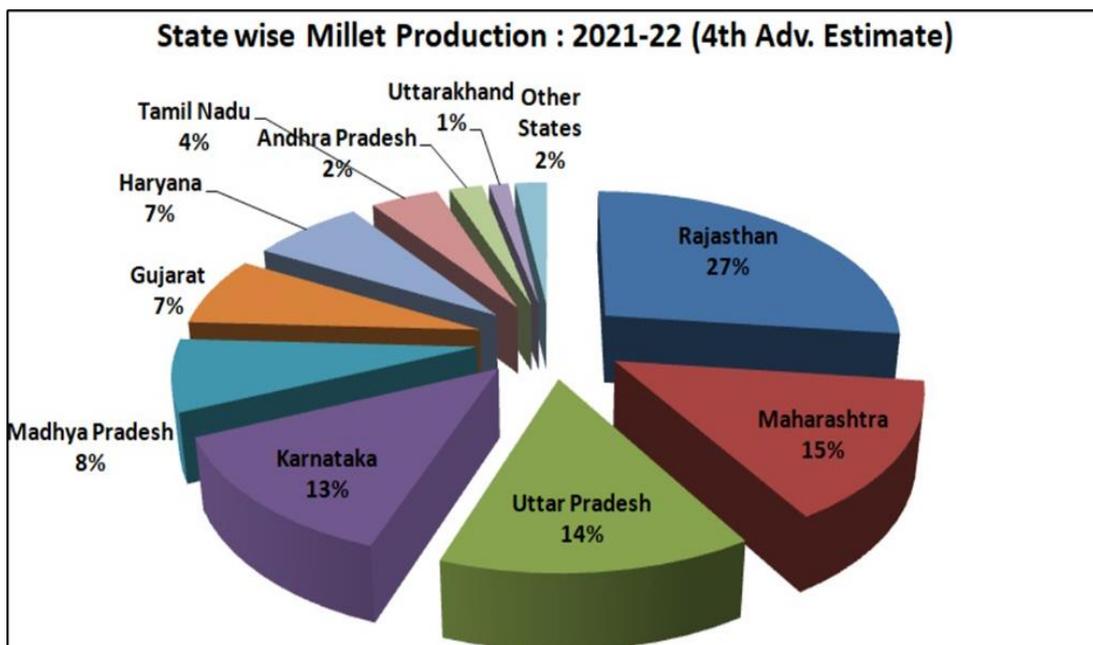


Fig 1. Millet Production: 2021-22 Per State.

SOURCE: [6]

The Objective: This paper aims to investigate how millet crops might help India's agriculture become more sustainable. The objective of the paper is to provide a thorough grasp of the advantages of millet farming from an economic, social, and environmental standpoint. Additionally, it looks to pinpoint the issues and limitations preventing the broad use of millets and suggests solutions. This review intends to shed more light on the significance of millet crops in attaining agricultural sustainability in India by exploring the function of millets in promoting food security, improving soil health, conserving water resources, mitigating climate change, and empowering rural communities.

2. METHODOLOGY

A thorough examination of the literature was conducted to find pertinent research, reports, and academic papers on millet crops and their effects on India's agricultural sustainability. To ensure a thorough and current analysis, several databases, including academic publications, research databases, and official reports, were investigated. To present a comprehensive overview of the topic, the information was then synthesized and examined.

The numerous facets of millet cultivation and its potential to support agricultural sustainability in India will be explored in more detail in the next sections of this review study. A thorough understanding of millet's role in sustainable agriculture will be provided by the examination of the advantages of millet crops from an environmental, economic, and social standpoint as well as the difficulties and promotion tactics.

Millet Crop Overview: Millet is a small-grained cereal plant in the Poaceae family. They stand out for their tenacity, adaptability, and nutritional quality. The resilience of millets to extreme environmental circumstances, such as drought-prone areas with poor soil fertility, is well known. They are suitable for small-scale and subsistence farming due to their short growing season and ability to be grown as rainfed crops.

Because of their extreme adaptability, millet crops are suitable for a wide range of uses, including industrial processes, human consumption, and animal feed [7]. Due to their lack of gluten and low glycemic index, they are suitable for people with dietary restrictions or health issues. Additionally abundant in dietary fiber, antioxidants, and minerals (iron, calcium,

and phosphorus), millet supports a healthy diet [8].

Millets Cultivated in Different Regions of India: India has a wide variety of millet crops, and different varieties are grown there. The principal varieties of millets cultivated in India include:

Finger Millet (ragi): One of the most extensively grown millets in India is called finger millet (ragi), which is also known by its scientific name, *Eleusine coracana*. It is generally grown in hilly and southeastern states. Ragi is used to make a range of foods, including porridge, roti, and malted beverages. Ragi is noted for its high nutritional value, particularly calcium and iron.

Pearl Millet (Bajra): Also known as *Pennisetum glaucum*, pearl millet is a drought-tolerant millet crop that is mostly grown in India's arid and semi-arid regions. In states like Rajasthan, Gujarat, and Haryana, it is a vital staple meal. For rotis (flatbread), porridge, and animal feed, pearl millet grains are utilized

Foxtail Millet (Kangni): The scientific name for foxtail millet is *Setaria italica*, and it is a common crop in the states of Andhra Pradesh, Tamil Nadu, and Karnataka. It is utilized in the making of many foods, including upma, pulao, and dosa, and is renowned for its high protein content.

Little Millet (Kutki): Little millet (Kutki) is a small-grained millet crop grown in the arid parts of India. Its scientific name is *Panicum sumatrense*. It is often used in the southern states to make traditional cuisines like idli, dosa, and Pongal.

Other millets grown in India aside from these major varieties include proso millet (Chena), barnyard millet (Sanwa), and Kodo millet (Kodra). Each kind of millet has distinctive traits and a different nutritional profile, which add to the total variety and adaptability of millet crops in India [9].

Historical Importance of Millet Crops in Indian Agriculture: Millet crops have a rich history and are very important to Indian agriculture and culture. They have been raised for many centuries and have been vital to the nation's food supplies. For many people, especially those in rural and desert areas where they supplied food and nutritional security, millets were traditionally considered staple crops.

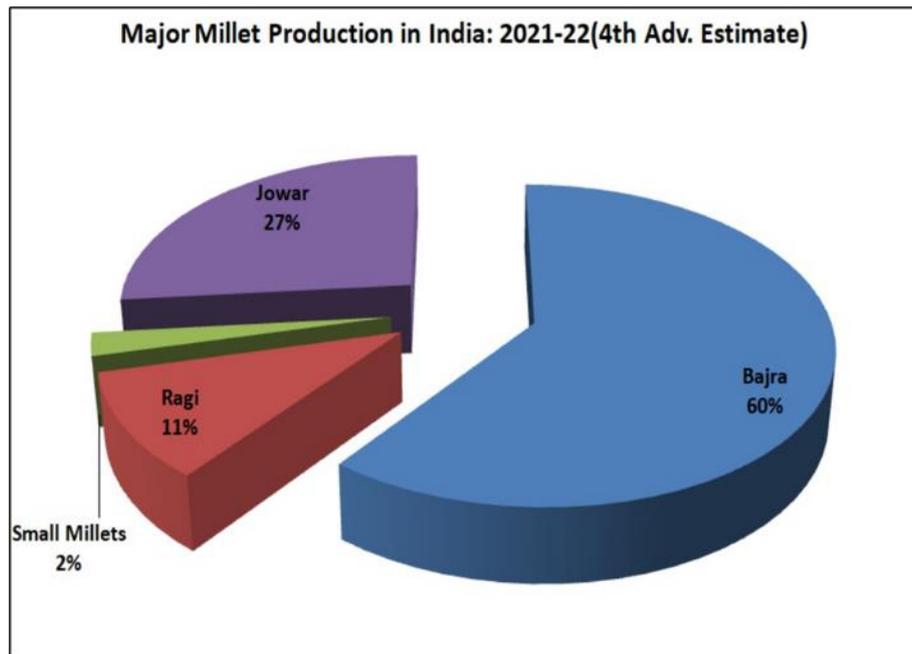


Fig 2. Major millet Production in India:2021-22

SOURCE: [6]

In the past, millets were a crucial component of India's native farming practices. They were prized for their capacity to flourish under many agro-climatic conditions with little management or input. Millets have been ingested traditionally in a variety of ways, such as whole grains, flour, malted beverages, and fermented dishes. They have been a crucial dietary element, enhancing the health of populations' diets.

Additionally, millets have long been used as a form of protection from unpredictable weather and failed crops. They have become a dependable source of food security for small-scale farmers thanks to their resistance to drought and capacity to generate respectable yields even under challenging circumstances [10].

Despite the Green Revolution's impact on the reduction of millet production, there has recently been a resurgence of interest in bringing back millet crops. There are initiatives to encourage their production and consumption in India due to their nutritional value, climatic resistance, and potential for sustainable agriculture.

The historical relevance of millets in Indian agriculture offers a solid foundation for recognizing their potential as sustainable crops and emphasizes the significance of their restoration and promotion for the country's agricultural sustainability.

3. ENVIRONMENTAL BENEFITS OF MILLET CULTIVATION

Drought Tolerance and Water Use Efficiency: Growing millet has substantial environmental advantages due to its outstanding drought resistance and water-saving capabilities. Because millet crops have evolved to flourish in arid and dry environments, they are suited for cultivation in areas with scarce water resources. Compared to other main cereal crops like rice and wheat, they require very less amount of water.

Crops of millet have evolved water-saving techniques and water scarcity adaptations. They are less reliant on surface water supplies thanks to their thick root systems, which allow them to absorb water from deeper soil layers. Millets' capacity to retain output even with minimal irrigation or under rainfed circumstances helps to conserve water and ease the strain on water supplies.

Improvement of Soil Health: Millet cultivation is essential for enhancing the fertility and health of the soil. These plants have fibrous roots that improve soil structure and raise the level of organic matter. The large root system of millet plants aids in soil agglomeration, prevents soil erosion, and increases the soil's ability to retain water.

Additionally, millets are regarded as crops with modest nutrient requirements. They are appropriate for cultivation on nutrient-deficient soils because of their capacity to effectively utilize the available nutrients in the soil [11]. Millets may also scavenge nutrients from deeper soil layers, which lowers nutrient leaching and enhances nutrient cycling in the agroecosystem.

Biodiversity Preservation: Millet crop farming helps to preserve biodiversity in agricultural environments. Millets are frequently cultivated using conventional and organic farming methods, which support biodiversity by sustaining conventional seed variants and the diversity of agroecosystems.

The cultivation of millet helps to preserve traditional landraces that are adapted to particular agro-climatic conditions as well as the diversity of local crops. The conservation of several millet types increases genetic diversity and makes agricultural systems more resistant to pests, illnesses, and climate change.

Fewer Chemical Inputs: Millet production often requires fewer chemical inputs, such as fertilizers and insecticides, than other conventional cereal crops. Because millets naturally resist pests and diseases, there is less need for synthetic pesticides.

In addition, compared to other major cereal crops, millets are less susceptible to infestations of pests and diseases. This lessens the need for chemical pesticides and promotes an eco-friendly method of insect control.

Millet farming helps to mitigate the harmful effects of excessive chemical use in agriculture on the environment and human health by using fewer chemicals, which helps to prevent soil erosion and water pollution.

The environmental advantages of millet production, such as their resistance to drought, efficient use of water, enhancement of soil health, preservation of biodiversity, and need for fewer chemical inputs, make them a sustainable option for agricultural practices. Promoting and emphasizing millet farming can help India's agriculture industry be more environmentally sustainable overall.

4. ECONOMIC AND SOCIAL BENEFITS

Economic Viability of Millet Cultivation: Especially in marginalized and resource-constrained agricultural settings, millet cultivation

gives farmers economic viability and the possibility of income generation. When compared to other major cereal crops, millets are comparatively inexpensive to grow since they require fewer inputs like water, fertilizer, and pesticides. This lowers production costs and raises the profitability of farmers.

Additionally, millets have a shorter growing season than crops like wheat or rice, which enables farmers to have several cropping cycles throughout the year. Diversification and more options for income are made possible by this. Additionally, millets are in high demand in both the domestic and global markets thanks to growing consumer interest in their nutritional and medical advantages.

Market Possibilities and Value Chains: New commercial prospects have emerged as the nutritional value of millets and their potential for sustainable agriculture have come to light. Millets are being used more frequently in a variety of foods, including breakfast cereals, snacks, baked goods, and gluten-free goods. Market diversification results in value addition and higher market pricing for goods made from millet.

Strengthening millet value chains and fostering farmer access to markets are priorities. Improvements to the millet processing, storage, and marketing infrastructure are being made through government efforts, farmer-producer organizations, and non-governmental organizations. Through these measures, farmers are better able to access larger markets and generate money at fair rates.

Improvement of Small-Scale Farmer's Livelihoods: Small-scale farmers, who frequently encounter difficulties because of climate variability, a lack of resources, and market restrictions, may benefit from millet production. Because they require little input and are resistant to environmental challenges, millets are a good choice for small-scale farming systems.

Millets can help small-scale farmers diversify their planting systems and increase their income and food security. Millets are more tolerant of droughts and other climate ambiguities, making them a safety net during crop failures. Additionally, the shorter millet cultivation period enables farmers to devote more of their time and resources to other sources of revenue, enhancing their overall standard of living.

Women's Empowerment and Nutritional Security: Millet farming can be extremely important for women's empowerment and nutritional security. Women are frequently in charge of managing nutrition and food preparation in rural homes. Millets can help enhance household nutrition thanks to their high nutritional content and variety of culinary applications.

By giving them chances for revenue generating and active engagement in decision-making processes, millet farming empowers women. In the cultivation, processing, and marketing of millet, women frequently play a key role. Women's economic and social empowerment can be improved by acknowledging and encouraging their participation in millet value chains.

Millets are rich in micronutrients and can be used to vary diets, thus encouraging them can also address issues with malnutrition and food security. Millets provide needy communities with an affordable and nourishing food option, enhancing nutrition security in both the family and the community.

The promise of millet as a sustainable agricultural choice is highlighted by the economic and social advantages of millet cultivation, including its economic viability, market prospects, livelihood improvement for small-scale farmers, and women empowerment. India can accomplish economic growth while addressing social issues like secure nutrition, gender equality, and livelihoods by promoting millet.

5. CHALLENGES AND CONSTRAINTS

Lack of Awareness and Limited Customer Demand: The promotion of millet crops faces considerable obstacles due to a lack of awareness and limited customer demand. When compared to wheat and rice, millets have long been seen as inferior or underutilized crops. The consumption of millet has decreased even further as people turn to more contemporary and processed food options, especially in urban regions.

Consumers need to be made aware of the nutritive content, health advantages, and adaptability of millet. Promoting millet-based goods and raising customer demand can be accomplished through advertising campaigns, educational initiatives, and lobbying activities [12].

Technical and Marketing Restrictions: Farmers of millet have difficulties due to inadequate infrastructure and marketing resources. The quality and shelf life of millet grains and products are impacted by the absence of adequate storage facilities, processing facilities, and value-added infrastructure. For small-scale farmers in particular, lack of market access makes it difficult for them to sell millets for fair rates.

Investing in post-harvest infrastructure, creating effective supply chains, and helping farmers add value and diversify their product lines are all necessary to address infrastructure constraints [13]. Millets can be more competitive in the agricultural sector by improving market ties, forming farmer cooperatives, and enabling market integration.

Policy Support and Research Investment: Another difficulty in developing millet crops is a lack of sufficient policy support and research investment. Major cereal crops are frequently given precedence in policy frameworks, but millet's potential for sustainable agriculture is ignored. The acceptance and development of millet cultivation are hampered by a lack of adequate government support in the form of research money, subsidies, and incentives.

Policy Support and Research Investment: Inadequate policy support and research investment are other challenges in the development of millet crops. Policy frameworks usually prioritize major cereal crops while ignoring millet's potential for sustainable agriculture. The lack of sufficient government funding for research, subsidies, and incentives hinders the acceptability and growth of millet production.

Additionally, it is important to record and disseminate traditional millet-cultivating knowledge and methods. This can aid in the preservation of native millet types and encourage their development in certain agroclimatic areas.

Governments, academic institutions, and other interested parties can support the sustainable expansion of millet farming in India by putting these promotion tactics for millet cultivation into practice. These initiatives would improve the millet crop's social well-being, environmental sustainability, and economic viability, ultimately resulting in a more resilient and inclusive agricultural industry.

Furthermore, it is crucial to preserve and share conventional millet cultivation knowledge and techniques. In some agroclimatic regions, this may help to preserve local millet varieties and promote their growth.

By using these promotion strategies for millet cultivation, governments, academic institutions, and other interested parties can aid in the long-term growth of millet farming in India. These programs would enhance the social well-being, environmental sustainability, and economic viability of millet crops, which would ultimately lead to a more robust and inclusive agricultural sector.

6. STRATEGIES FOR PROMOTING MILLET CULTIVATION

Policy Interventions: Promoting millet farming requires the use of policy interventions. Millets should be given priority in government agricultural plans, and growers should get incentives and support. Input subsidies, price support measures, and insurance plans to reduce millet farming-related hazards can all fall under this category [14].

Policies should also put an emphasis on fostering an environment that facilitates millet production, processing, and commercialization. This entails creating infrastructure including storage spaces, processing facilities, and market connections. The incorporation of millet in government nutrition programs, school feeding programs, and public procurement activities should be emphasized in policy frameworks as well.

Research and Development Initiatives: To boost millet varieties yield potential, invest in research and development, and address agronomic issues. The development of better millet varieties with characteristics like increased yields, disease resistance, and drought tolerance should be the main emphasis of research institutions [4]. The development of climate-smart millet farming techniques and technology should also be prioritized.

Research should concentrate on millet-based food product development, processing methods, and value addition. This could broaden the millet market and boost customer acceptance of them. Collaboration among academic institutions, farmers, and businesses in the private sector can

hasten innovation and technology transfer in millet farming.

Strengthening Value Chains and Market Linkages: Market linkages and millet value chains should be strengthened. The creation of farmer cooperatives, initiatives for group marketing, and the creation of millet producer organizations can all help with this. These organizations can facilitate farmers' access to markets, better pricing negotiations, and fair-trade practices.

Post-harvest infrastructure should be developed, including storage facilities, processing facilities, and packaging facilities. This would make it easier to add value to millet grains and retain their quality. Market opportunities for millet farmers can be created by promoting millet-based products in both home and foreign markets.

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The distribution of knowledge ought to include policymakers, extension agents, and agricultural experts in addition to farmers. Campaigns, conferences, and seminars that raise knowledge of millets' nutritional worth, health advantages, and commercial possibilities are helpful. Farmers should be effectively informed about government programs, subsidies, and assistance available for millet growing.

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7. CONCLUSION

The research report underlined the potential for millet crops in India to support agricultural sustainability. Millets have a long history of cultivation in the nation and offer a number of advantages in terms of the environment, the economy, and society. Environmental benefits of millet farming include its ability to withstand drought, use water efficiently, enhance soil quality, protect biodiversity, and use fewer chemicals. These characteristics make millets resistant to climate change, aid in water conservation, improve soil fertility, and encourage the diversity of agroecosystems.

In terms of the economy, millet farming offers small-scale farmers, in particular, chances for market expansion, income generation, and livelihood development. Millets have the potential to improve food security, diversify cropping systems, and lower production costs.

In terms of society, millet cultivation encourages women's empowerment, food security, and neighbourhood well-being. Millets provide women more power by generating income, allowing them to actively participate in decision-making, and enhancing household nutrition. Along with reducing malnutrition and enhancing food security, millets provide inexpensive and nutrient-dense food options [15]

Suggestions for Upcoming Activities: The following suggestions are given to further encourage millet production and improve India's agricultural sustainability:

1. Increase customer demand by promoting millets' nutritional worth and health advantages through advertising campaigns, outreach initiatives, and educational initiatives. By showing their adaptability and merging them into a variety of food products, millet-based products can be made in more demand by consumers.
2. Infrastructure and Market Development: To preserve millet grain quality and promote value addition, invest in post-harvest infrastructure, storage facilities, processing facilities, and packaging facilities. Develop effective supply chains and strengthen market ties to connect millet producers to larger markets, assuring fair prices and income generation.
3. Policy Support: Supportive policies should be created and put into place to

acknowledge and encourage millet cultivation, processing, and commercialization. This covers tools for maintaining prices, money for research, payments to millet growers, and incentives. Include millets in government nutrition programs, school feeding initiatives, and government procurement programs.

4. Research and Development: Spend money on research and development to enhance the yield potential of millet cultivars and tackle agronomic issues. Put your attention on creating climate-smart practices, pest and disease management plans, and millet value-adding methods. Encourage collaboration for innovation and technology transfer between research organizations, farmers, and the corporate sector.
5. Building Capacity and Knowledge Dissemination: Hold training sessions, field trips, and workshops to provide farmers, extension agents, and policymakers with the information and abilities required for millet farming. To preserve native millet types and encourage their cultivation, record and disseminate traditional millet farming knowledge and techniques.

Implementing these suggestions will enable all parties involved to advance millet cultivation, broaden consumer acceptance of it, and improve the general agricultural sustainability and well-being of Indian farming communities. The nation's food systems can be made more resilient and sustainable by reviving and promoting millet crops.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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