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Kiran Hingonia

Assistant Professor, Department of
Agronomy College of Agriculture,
Sumerpur, Pali, Agriculture
University Jodhpur, Rajasthan,
India

Priyanka

Assistant Professor, Department of
Plant Pathology, College of
Agriculture, Sumerpur, Pali,
Agriculture University Jodhpur,
Rajasthan, India

Seema

Assistant Professor, Department of
Soil Science, College of Agriculture,
Jodhpur, Agriculture University
Jodhpur, Rajasthan, India

Anita Sharma

Assistant Professor, Department of
Entomology, College of
Agriculture, Sumerpur, Pali,
Agriculture University Jodhpur,
Rajasthan, India

Corresponding Author:

Kiran Hingonia

Assistant Professor, Department of
Agronomy College of Agriculture,
Sumerpur, Pali, Agriculture
University Jodhpur, Rajasthan,
India

Nutritional and agronomic potential of minor millets: A sustainable approach

Kiran Hingonia, Priyanka, Seema and Anita Sharma

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Abstract

Minor millets, also known as small millets, represent a group of traditional grains that have been cultivated for centuries across various regions of the world, particularly in Asia and Africa. The United Nations General at its 75th session in March 2021 declared 2023 the International Year Millets (IYM 2023). FAO is the lead agency for celebrating the year in collaboration with other relevant stakeholders. Millets can grow on arid lands with minimal inputs and resilient to change climate. The theme of international year of millets is "Healthy Millets, Healthy People". Millets are an important source of nutrition and offer a range of health benefits. They are high in fiber which helps promote digestion and lowers cholesterol. These millets play a crucial role in the food and nutritional security of millions of people, especially in rural and marginalized communities. Despite their significance, they have often been overshadowed by major cereals like rice, wheat, and maize in terms of research, policy focus, and market demand. Minor millets are a group of small-seeded cereal crops that belong to the grass family Poaceae. They are termed "minor" primarily due to their lower global production compared to major cereals like rice, wheat, and maize. Despite this classification, they hold significant nutritional, ecological, and cultural importance, particularly in semi-arid and rain-fed regions.

Keywords: Finger millet, foxtail millet, proso millet, barnyard millet, little millet, nutritional composition, challenges, cultural practices

Introduction

Minor millets are a group of small-seeded cereal crops that belong to the grass family Poaceae. They are termed "minor" primarily due to their lower global production compared to major cereals like rice, wheat, and maize. Despite this classification, they hold significant nutritional, ecological, and cultural importance, particularly in semi-arid and rain-fed regions where they thrive. The United Nations General at its 75th session in March 2021 declared 2023 the International Year Millets (IYM 2023). FAO is the lead agency for celebrating the year in collaboration with other relevant stakeholders (Hay *et al.*, 2013) [7]. Millets can grow on arid lands with minimal inputs and resilient to change climate. The theme of international year of millets is "Healthy Millets, Healthy People". Millets are an important source of nutrition and offer a range of health benefits. They are high in fiber which helps promote digestion and lowers cholesterol. Minor millets have ancient origins, with evidence of their cultivation dating back thousands of years. Minor millets hold significant cultural and culinary importance in various regions across the world (Porwal *et al.*, 2023) [16].

Archaeological findings suggest that millets such as foxtail millet and proso millet were cultivated in China and other parts of Asia as early as 10,000 years ago, contributing to the development of settled agricultural societies (Sameer *et al.*, 2019) [18]. Over millennia, minor millets spread across Asia, Africa, and parts of Europe through trade, migration, and agricultural diffusion (Miller *et al.*, 2016) [13]. They adapted to diverse climatic and soil conditions, becoming integral to local farming systems. India is the major producer of minor millets such as finger millet (ragi), foxtail millet, and little millet. States like Karnataka, Tamil Nadu, and Andhra Pradesh are known for their extensive cultivation of these crops (Maitra *et al.*, 2022) [11]. In China, cultivation of foxtail millet and proso millet, primarily in northern and northeastern regions can be seen. In Southeast Asia, minor millets like little millet are cultivated in countries

such as Thailand, Myanmar, and Vietnam and in Eastern Africa; finger millet is a staple crop in countries like Uganda, Kenya, and Tanzania, where it is grown in highland regions. In Western Africa; millets such as pearl millet and sorghum dominate, but minor millets like fonio are cultivated in countries like Mali and Burkina Faso. In Southern Africa; minor millets like finger millet are grown in countries such as Malawi and Zimbabwe, contributing to food security in marginal areas. In South America; minor millets are cultivated in countries like Brazil and Argentina, particularly by indigenous communities, where they play a role in traditional diets and cultural practices (Fuller and Castillo *et al.*, 2022)^[5].

Minor millets are valued for their resilience to adverse growing conditions such as drought and poor soil fertility. They play a crucial role in food security and sustainable agriculture, particularly in regions susceptible to climate variability. Additionally, these millets are rich in essential nutrients like dietary fiber, proteins, vitamins, and minerals, contributing significantly to balanced diets and nutritional security (Singh *et al.*, 2022)^[20].

Nutritional composition of minor millets

Minor millets are nutritionally dense grains that offer a range of essential nutrients. Minor millets are rich sources of protein, ranging from 7% to 12% by dry weight, depending on the variety and growing conditions (Amadou and Gounga *et al.*, 2013)^[1]. For instance, finger millet (ragi) contains about 7.3-7.8% protein on a dry weight basis (Mane K, Kadam *et al.*, 2021)^[12]. They provide complex carbohydrates, contributing to sustained energy release. Carbohydrate content varies from 60% to 75% of the grain's dry weight. They provide complex carbohydrates that are slowly digested, aiding in sustained energy release. Foxtail millet, for example, is composed mainly of carbohydrates (67-73%). Minor millets are rich in dietary fiber, promoting digestive health and satiety. Barnyard millet has been reported to contain approximately 12-15% fiber. Minor millets are excellent sources of dietary fibre, with levels ranging from 2% to 12% depending on the variety. Fiber content contributes to digestive health and can aid in managing cholesterol levels. They are rich sources of essential minerals such as iron, calcium, magnesium, phosphorus, and potassium, which are vital for various physiological functions (Kaur and Singh *et al.*, 2023)^[7].

Minor millets contain vitamins such as B-complex vitamins (B₁, B₂, B₃ and B₆) and vitamin E, contributing to overall health and wellbeing. Some millets contain antioxidants like phenolic compounds, which help protect cells from oxidative stress. Foxtail millet has been found to have significant antioxidant activity. They contain various vitamins, particularly B vitamins important for energy metabolism and nerve function. Foxtail millet is known to be a good source of niacin (B₃) and pyridoxine (B₆). Minor millets are rich in minerals such as calcium, iron, magnesium, and zinc. Finger millet, for instance, is notably high in calcium (344 mg/100 g) and iron (3.9 mg/100 g). (Tripathi and Patel *et al.*, 2023)^[24].

Nutritional Highlights overview

- **Foxtail Millet:** High in carbohydrates and dietary fiber; contains significant protein.
- **Finger Millet:** Known for its high calcium content, making it beneficial for bone health.
- **Proso Millet:** Contains good protein levels and is a versatile ingredient in various dishes.
- **Barnyard Millet:** High in fiber and low in calories,

beneficial for weight management.

- **Kodo Millet:** A good source of iron and magnesium; helps in energy metabolism.
- **Little Millet:** Similar to Kodo millet in nutritional profile; also rich in fiber. (Saini and Saxena *et al.*, 2021)^[17].

Cultural and culinary significance of minor millets

Cultural Significance

Traditional Diets: Minor millets have been integral to the diets of many indigenous communities and rural populations for centuries. They are often considered sacred or auspicious and are used in religious rituals and ceremonies.

Cultural Festivals: In regions like South Asia, millets such as finger millet (ragi) are central to cultural festivals and traditional cuisines, symbolizing heritage and community identity. Minor millets have deep-rooted cultural significance in many societies. They are often associated with rituals, festivals, and ceremonies, symbolizing fertility, prosperity, and communal harmony. For example, finger millet (ragi) is central to the cultural practices of several ethnic groups in India, where it is used in religious offerings, traditional foods, and celebrations.

Dietary Diversity

Minor millets have enriched dietary diversity in regions where they are cultivated. They provide alternatives to major cereals and contribute to a balanced diet due to their rich nutritional profile. Different millets are used in various culinary preparations, from porridges and bread to fermented foods and desserts, reflecting local tastes and preferences. (Tripathi and Vyas *et al.*, 2023)^[24].

Traditional Knowledge and Farming Practices

Cultivation and processing techniques of minor millets have been passed down through generations, embodying traditional ecological knowledge (TEK) and sustainable agricultural practices. Farmers have developed indigenous methods for soil fertility management, pest control, and water conservation specific to millet cultivation. (Yadav and Singh *et al.*, 2023)^[7].

- **Community Resilience:** Minor millets have historically served as a buffer against food insecurity and environmental fluctuations. Their ability to thrive in marginal lands and withstand droughts contributes to community resilience in times of adversity. They have been lifelines during periods of famine and scarcity, providing sustenance and nutritional security to vulnerable populations. (Ashoka *et al.*, 2023)^[3].
- **Food Security:** Minor millets play a crucial role in food security, especially in regions prone to climatic variability and where they serve as reliable sources of nutrition for rural communities. (Mehta *et al.*, 2024)^[4].
- **Cultural Importance:** They are integral to local cuisines and cultural practices, often featuring prominently in festivals, ceremonies, and traditional rituals.
- **Livelihoods:** Cultivation of minor millets supports livelihoods of smallholder farmers, providing income and employment opportunities, particularly in marginalized and rural areas. (Mehta *et al.*, 2024)^[4].

Culinary significance of minor millets

Versatile Cooking Methods: Minor millets are used in a variety of culinary preparations such as porridges, bread, pancakes, fermented foods, and alcoholic beverages.

Their mild flavors allow them to adapt well to different cooking techniques and flavour profiles. Minor millets are valuable

sources of nutrition and health benefits, offering a range of essential nutrients and promoting overall well-being. Incorporating these grains into diets can enhance dietary diversity, support sustainable agriculture, and improve food security globally. (Gowda and Siliveru *et al.*, 2022) ^[14].

Health Benefits of minor millets

Millets are recognized for their high nutritional value, contributing to health benefits such as improved digestion, management of diabetes, and enhanced immunity.

- 1. Gluten-free:** Minor millets are naturally gluten-free, making them suitable for individuals with celiac disease or gluten intolerance.
- 2. Weight Management:** High fiber content in millets promotes satiety, aiding in weight management by reducing calorie intake.
- 3. Digestive Health:** Dietary fiber in millets supports healthy digestion and prevents constipation.
- 4. Heart Health:** Millets contribute to heart health by lowering cholesterol levels and reducing the risk of cardiovascular diseases. (Tiwari *et al.*, 2022) ^[22].
- 5. Diabetes Management:** Millets have a low glycemic index, helping in better blood sugar control and management of diabetes (Jacob *et al.*, 2024) ^[18].
- 6. Nutritional Security:** In regions where millets are staple foods, they contribute significantly to nutritional security by providing essential nutrients that are often lacking in diets based on refined grains.

Cultural practices of minor millets

The agro-climatic requirements of minor millets vary depending on the specific type of millet and its adaptation to different environmental conditions.

1. Finger Millet (Ragi)

- **Scientific Name:** *Eleusine coracana*
- **Regions:** Widely cultivated in Africa and South Asia, particularly in India, Uganda, Kenya, and Ethiopia.
- **Characteristics:** Known for its small reddish-brown seeds and high nutritional content. It is rich in calcium, iron, dietary fiber, and essential amino acids.
- **Culinary Uses:** Used to make porridges, malted beverages, flatbreads (roti), and fermented foods like idli and dosa in South India.
- **Health Benefits:** Helps in managing diabetes, aids in weight loss, and is beneficial for bone health.
- **Temperature:** Finger millet grows well in a range of temperatures but prefers moderate temperatures around 20-30°C during its growth stages.
- **Rainfall:** It is suitable for regions receiving 600-1000 mm of annual rainfall, although it can tolerate lower rainfall conditions due to its drought tolerance.
- **Altitude:** Grows at altitudes ranging from sea level to 2000 meters above sea level, making it adaptable to varying elevations.

2. Foxtail Millet

- **Scientific Name:** *Setaria italica*
- **Regions:** Originated in China and widely grown in India, China, Japan, Korea, and other parts of Asia.
- **Characteristics:** Small, yellowish seeds arranged in compact, cylindrical spikes. Known for its drought tolerance and short growing season.
- **Culinary Uses:** Used in porridges, upma (a savory dish), pulao, and as a rice substitute in various cuisines.

- **Health Benefits:** Gluten-free, rich in carbohydrates, dietary fiber, and essential minerals like iron and magnesium.
- **Temperature:** Foxtail millet is adaptable to various temperature ranges, from 15-35 °C, but it thrives in warm climates with temperatures around 25-30 °C.
- **Rainfall:** It can grow in regions with 400-1000 mm of annual rainfall, making it suitable for both semi-arid and sub-humid conditions.
- **Altitude:** Suitable for cultivation at altitudes ranging from sea level to 2100 meters above sea level, with higher yields at lower elevations.

3. Proso Millet

- **Scientific Name:** *Panicum miliaceum*
- **Regions:** Originally from Central Asia, it is cultivated in Europe, Russia, China, and parts of the United States.
- **Characteristics:** Small, round seeds ranging in color from white, yellow, and red-brown. Fast-growing with a short growing season.
- **Culinary Uses:** Used in bread, porridge, couscous, and animal feed. It has a mild, nutty flavor.
- **Health Benefits:** Gluten-free, high in protein, and rich in B vitamins, minerals, and antioxidants.
- **Temperature:** Proso millet grows best in warm climates with temperatures ranging from 20-30 °C during the growing season.
- **Rainfall:** It prefers moderate rainfall conditions between 300-600 mm annually but can tolerate dry conditions due to its drought tolerance.
- **Altitude:** Cultivated at altitudes ranging from sea level to 2000 meters above sea level, adapting well to various elevations.

4. Barnyard Millet

- **Scientific Name:** *Echinochloa spp.*
- **Regions:** Cultivated in India, China, Japan, Korea, and parts of Southeast Asia.
- **Characteristics:** Small, white, round grains resembling tiny beads. It grows well in poor soils and is highly resilient.
- **Culinary Uses:** Used in porridges, upma, dosa, and rice preparations. It has a mild flavor and cooks faster than some other millets.
- **Health Benefits:** Gluten-free, low glycemic index, high in fiber, and contains essential amino acids.
- **Temperature:** Barnyard millet is adaptable to a wide range of temperatures, from 15-35 °C, with optimal growth occurring around 25-30 °C.
- **Rainfall:** It can thrive in regions with 500-1000 mm of annual rainfall but is known for its drought tolerance and ability to grow in lower rainfall areas.
- **Altitude:** Suitable for cultivation at altitudes ranging from sea level to 2300 meters above sea level, making it versatile in mountainous regions.

5. Kodo Millet

- **Scientific Name:** *Paspalum scrobiculatum*
- **Regions:** Native to India and grown in Nepal, Myanmar, and parts of Africa.
- **Characteristics:** Small, round grains with a reddish-brown husk. It has a short growing season and is resilient to drought.
- **Culinary Uses:** Used in porridges, idlis, dosas, and fermented beverages. It has a slightly bitter taste.
- **Health Benefits:** Gluten-free, high in fiber, protein, and antioxidants. It is known for its digestive and cardiovascular

health benefits.

- **Temperature:** Kodo millet prefers warm temperatures ranging from 25-35°C but can tolerate temperatures as high as 40°C during the growing season.
- **Rainfall:** It requires moderate rainfall between 500-800 mm annually but can grow in semi-arid conditions with adequate soil moisture.
- **Altitude:** Suitable for cultivation at altitudes ranging from sea level to 1800 meters above sea level, thriving in diverse elevations.

6. Little Millet

- **Scientific Name:** *Panicum sumatrense*
- **Regions:** Cultivated in India, Southeast Asia (Thailand, Myanmar), and parts of Africa.
- **Characteristics:** Small, round grains with a light brown husk. It has a short growing season and grows well in dryland conditions.
- **Culinary Uses:** Used in porridges, upma, idlis, and mixed with rice for making traditional foods. It has a nutty flavor.
- **Health Benefits:** Gluten-free, rich in dietary fiber, minerals (iron, zinc), and B vitamins. It aids in weight management and supports digestive health.
- **Temperature:** Little millet grows well in warm climates with temperatures ranging from 20-35°C, but it can withstand temperatures as high as 40°C.
- **Rainfall:** It prefers regions with 500-800 mm of annual rainfall but can tolerate both dryland and low rainfall conditions.
- **Altitude:** Suitable for cultivation at altitudes ranging from sea level to 2000 meters above sea level, adapting well to varying elevations

Cultivation Practices

- **Climate:** Minor millets are typically grown in semi-arid to arid regions where rainfall is unreliable or low. They are well-adapted to drought-prone areas and can thrive in poor soils.
- **Temperature:** They generally tolerate a wide range of temperatures, from hot summers to cool winters, depending on the variety.
- **Soil Requirements:** Minor millets are versatile in terms of soil adaptability. They can grow in a variety of soil types, including sandy, loamy, and even marginal soils that are low in fertility.
- They are known for their ability to improve soil health by enhancing organic matter content and microbial activity.

Traditional Cultivation Methods

- **Seed Selection and Saving:** Farmers traditionally select seeds from the best-performing plants each harvest. This practice helps maintain local landraces adapted to specific agro-climatic conditions (Tonapi *et al.*, 2015)^[23].
- **Crop Rotation and Intercropping:** Millets are often grown in rotation with other crops such as legumes or tubers to maintain soil fertility and manage pests and diseases naturally.
- **Water Management:** Traditional methods such as contour bunding, mulching, and rainwater harvesting are used to conserve soil moisture and manage water resources efficiently.
- **Pest and Disease Management:** Traditional farmers often rely on crop diversity and natural pest predators to control pests and diseases rather than synthetic pesticides.

Cropping Systems

- **Rotation:** In traditional farming systems, minor millets are often part of crop rotation cycles that include legumes or other cereals, helping to maintain soil fertility and pest management.
- **Inter-cropping:** In some regions, minor millets are inter-cropped with legumes or vegetables to optimize land use and enhance nutritional diversity.

Propagation and Harvesting

- **Seeding:** Minor millets are usually propagated through seeds, which are sown directly into the soil either by broadcasting or in rows, depending on local practices.
- **Harvesting:** Harvesting methods vary but typically involve cutting the mature plants and threshing the grains to separate them from the chaff. Traditional methods like hand harvesting and threshing are still prevalent in many regions.

Modern Cultivation Methods

1. Improved Varieties and Hybridization

Modern Approach: Modern agriculture incorporates improved varieties through breeding programs and hybridization to enhance yield potential, disease resistance, and nutritional quality.

2. Mechanization and Precision Farming

Modern Approach: Mechanization of planting, irrigation, and harvesting processes increases efficiency and reduces labour dependency. Precision farming techniques optimize inputs such as water and fertilizers.

3. Synthetic Inputs

Modern Approach: The use of synthetic fertilizers, pesticides, and herbicides is common in modern agriculture to maximize yield and manage pests and diseases effectively.

4. Irrigation Practices

Modern Approach: Modern cultivation often relies on irrigation systems such as drip irrigation and sprinklers to ensure consistent water supply, especially in regions with erratic rainfall.

Comparative Analysis

- **Benefits of Traditional Methods:** Traditional cultivation methods promote biodiversity, maintain soil health, and preserve local agricultural knowledge and practices.
- **Benefits of Modern Methods:** Modern techniques can increase productivity, improve crop resilience to climate change, and reduce labour intensity, meeting the demands of growing populations.

Role in sustainable agriculture and climate resilience of minor millets

Minor millets play a crucial role in sustainable agriculture and climate resilience due to their inherent characteristics and cultivation practices.

Role in Sustainable Agriculture

1. Biodiversity Preservation

Diverse Genetic Resources

Minor millets contribute to agricultural biodiversity by preserving a wide range of genetic resources adapted to various agro-climatic conditions.

2. Soil Health and Fertility

Crop Rotation: Traditional cultivation practices of millets involve crop rotation with legumes and other crops, which enhances soil fertility and reduces the dependence on synthetic fertilizers.

3. Water Use Efficiency

Drought Tolerance: Minor millets, such as finger millet and pearl millet, are known for their drought tolerance, requiring less water compared to major cereals like rice and wheat.

Climate Resilience

1. Adaptation to Climate Variability

Temperature and Rainfall Variability: Minor millets are adaptable to a wide range of temperatures and rainfall patterns, making them suitable for cultivation in marginal and rain-fed agricultural lands.

2. Mitigating Climate Change

Carbon Sequestration: Millets contribute to carbon sequestration in agricultural soils, helping mitigate climate change by reducing greenhouse gas emissions.

3. Resilience to Extreme Events

Extreme Weather Events: Their short growing seasons and drought tolerance enable millets to withstand extreme weather events such as droughts and floods, ensuring food security in vulnerable regions.

Challenges and Future Prospects of minor millets

Challenges: Despite their historical and cultural significance, minor millets face challenges such as low market demand, limited research investment, and the dominance of major cereals in global food systems. Changing dietary preferences, urbanization, and globalization pose threats to the preservation of traditional millet-based diets and farming practices. (Dogalli *et al.*, 2024) ^[6].

- **Market Access:** Limited market demand and low prices relative to major cereals pose challenges for farmers.
- **Research and Development:** Insufficient investment in research and development hinders improvements in yield, pest resistance, and value addition.
- **Climate Change:** Increasing climate variability and extreme weather events threaten production stability.

Future Prospects

Efforts are underway to revive and promote minor millets through initiatives that focus on nutritional education, culinary innovation, value addition, and market development. Governments, NGOs, and grassroots organizations are advocating for policies that support sustainable millet farming, enhance market access, and empower smallholder farmers. (Islam and Manaloor *et al.*, 2021) ^[19].

- **Promotion and Awareness:** Efforts to promote minor millets through awareness campaigns, nutritional advocacy, and culinary innovation are gaining momentum.
- **Research and Technology:** Investments in research to enhance productivity, resilience, and nutritional quality could unlock their full potential.
- **Policy Support:** Policies that prioritize sustainable agriculture, biodiversity conservation, and food security can facilitate the revival and mainstreaming of minor millets in global food systems. (S.A. Kheya *et al.*, 2023) ^[21].

Conclusion

The International Year of Millets 2023 served as a platform to promote sustainable development through the increased production and consumption of millets, contributing to food security, nutrition, and environmental sustainability. Minor millets exhibit adaptability to diverse agro-climatic conditions, making them suitable for cultivation in semi-arid and dryland regions where other crops may struggle. Their resilience to drought and varying temperatures underscores their importance in sustainable agriculture and food security, particularly in regions prone to climate variability. Minor millets encompass a diverse group of cereal crops that are characterized by their small seed size, adaptability to harsh environments, and nutritional benefits. Their classification based on botanical characteristics helps in understanding their genetic diversity and agricultural potential. Emphasizing their role in sustainable agriculture and food security is crucial for promoting their cultivation and consumption globally. Minor millets are nutritionally rich grains that offer a diverse array of essential nutrients, making them valuable components of balanced diets. Their nutritional composition supports health benefits such as improved digestion, enhanced energy levels, and overall well-being. Incorporating minor millets into regular diets can contribute significantly to nutritional security, especially in regions where they are staple foods. Minor millets play a crucial role in promoting ecological sustainability in agriculture. Their cultivation supports biodiversity conservation, improves soil health, enhances water use efficiency, and contributes to carbon sequestration. By integrating minor millets into agricultural systems, farmers can mitigate environmental degradation and build resilient food systems in the face of climate change. The historical and cultural significance of minor millets underscores their importance beyond mere sustenance. They represent a nexus of biodiversity, traditional knowledge, and community resilience, embodying sustainable agricultural practices that are increasingly relevant in the face of global challenges such as climate change and food insecurity. Preserving and promoting minor millets not only safeguards cultural heritage but also contributes to sustainable development goals, ensuring food sovereignty and nutritional security for future generations. Both traditional and modern cultivation methods of minor millets have their advantages and challenges. Integrating sustainable practices from both approaches can enhance agricultural resilience, improve food security, and ensure the preservation of genetic diversity for future generations.

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