

Sustainable Cultivation of Millets



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ABSTRACT: Millets, once considered as neglected crops, have gained significant attention due to their nutritional value, climate resilience, and suitability for sustainable agriculture. This review paper synthesizes current research on sustainable cultivation practices for millets, focusing on key aspects such as soil health, water management, pest and disease control, and socio-economic implications. It explores innovative approaches such as intercropping, organic farming techniques, and precision agriculture methods to enhance millet yields while minimizing environmental impact. Furthermore, the paper discusses the role of millets in enhancing food security, promoting biodiversity, and mitigating climate change. By critically evaluating existing literature, this review aims to provide insights for policymakers, researchers, and farmers to promote the adoption of sustainable millet cultivation practices, thereby contributing to global food security and environmental sustainability.

KEYWORDS: Sustainable, Climate resilience, Socio-economic, Biodiversity

I. INTRODUCTION:

The International Year of Millets will be observed in 2023, according to a resolution passed by the UN General Assembly. This highlights the significance of millets and how they improve food security.[1] These small-seeded grains called millets belong to the Poaceae family and are widely cultivated in tropical and arid regions of Africa and Eurasia. One of the earliest crops to be domesticated was millets is proof that millet was consumed as early as 3000 BC in the Indus Valley Civilization. These are regarded as the world's most important cereal grain crop, ranking behind only wheat, rice, maize, and barley.[2][3] Millets are more resistant to pests and diseases than other grains.[4] Although millets were once significant food crops, their promotion as the major food of the future is owing to the negative effects of climate change, which are more noticeable in ecosystems that are more sensitive.[5] Because of their many benefits, millets are referred to as "miracle crops." These benefits include their use as food and food products with added value, forage, contribution to agro-diversity, low nutrient requirements, greater C sequestration (C4 plants), ability to prevent erosion in arid regions, and confirmation that smallholders who live in harsh environmental conditions have an adequate supply of food and nutrition.[6] Among the crop's many positive traits are its quick maturity, resilience to stress and drought, and ability to be stored for a long enough period of time without suffering insect damage.[7][8] Millets are known as crop cereals or "penurious people's grains." [9] Because these grains are important for animal feed as well as food, they are cultivated. Due to shifts in consumer preferences and status symbols, the crop was formerly disregarded, but nutria crops are currently seeing a significant upturn in the global crop production industries.[10][11] Based on their importance in terms of cultivation, consumption, and economic significance, two categories of millets are sometimes distinguished using the names "major millets" and "minor millets." Sorghum (Jowar), Pearl (Bajra), and Finger (Ragi) are the major millets. On the other hand, the minor millets are composed of Kodo (Kodon), Barnyard (Sanwa), Little (Kutki/Shavan), Proso (Chenna/Barri), and Foxtail (Kakum).[12] Millets are a fantastic source of antioxidants, dietary Fiber, vitamins, and minerals. Two amino acids that are present in considerable amounts are cysteine and methionine. Unlike other cereals, millets have several bioactive minerals and bioactive components. Alpha-tocopherol, thiamine, riboflavin, niacin, and folic acid are among the vitamins that are remarkably abundant in millets, along with calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), iron (Fe), and manganese (Mn).[13][14][15] In the global food and nutrition business, millet is essential. Because of their special qualities like their quick maturity millets can be utilized in intensive cropping systems. They are long-lasting and can sustain you during a dry spell or a food crisis. In terms of macro and micronutrients, millets are quite nutritious compared to other crops.[16]

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II. NUTRITIONAL BENEFITS OF MILLETS:

Since most people on the planet consume plant-based diets, nutritional security is essential to enhancing global health. The main source of nutrients needed for healthy growth and development is plants. However, because they mostly rely on grain products for sustenance, half of the world's population particularly those from Asia and Africa suffers from nutritional deficiencies.[17] [18] Millets are an excellent source of proteins, vitamins, and minerals, millets are very nutrient-dense. The remaining 20% of millet grains are used to make alcoholic beverages and as animal feed. Approximately 80% of millet grains are utilized for food.[19] millet is a superfood because they don't contain gluten, people who are sensitive to or allergic to gluten can safely consume them. [20] Millets are a powerhouse of nutrition, offering a plethora of health benefits. These ancient grains are packed with dietary Fiber, essential minerals like iron, calcium, magnesium, and phosphorus, and are rich in antioxidants. Their gluten-free nature makes them suitable for those with gluten sensitivities, while their low glycaemic index helps in managing blood sugar levels. Millets also provide a significant source of plant-based protein, aiding in muscle function and overall well-being. Their high Fiber content promotes digestive health, prevents constipation, and supports weight management by inducing a feeling of fullness. Additionally, the antioxidants present in millets help combat oxidative stress, reducing the risk of chronic diseases. Incorporating millets into the diet can contribute to heart health by lowering cholesterol levels and supporting cardiovascular function. With their versatility in culinary applications, millets offer a nutritious alternative to traditional grains, making them a valuable addition to any balanced diet.[21]

III. ENVIRONMENTAL BENEFITS OF MILLETS:[22]

- A. **Drought Resistance:** Millets are hardy crops that require minimal water compared to other grains like rice and wheat, making them well-suited for arid and semi-arid regions.
- B. **Soil Health:** Millets have a beneficial impact on soil health, as they require minimal soil fertility and can even thrive in poor soil conditions, thereby reducing soil degradation.
- C. **Biodiversity:** Cultivating millets promotes biodiversity by diversifying crop cultivation, which can contribute to ecosystem resilience and sustainability.

IV. CULTIVATION OF MILLETS

Cereal crops have a substantial potential to contribute to global warming in addition to being a key supply of macronutrients including proteins, lipids, and carbohydrates. Of all the major cereal crops, wheat has the greatest potential to cause global warming (about 4 tons CO₂ equivalent per hectare), followed by maize (about 3.4 tons CO₂ equivalent per hectare) and rice. [23] Additionally, the carbon equivalent emissions of these crops are high 1000, 956, and 935 kg C/ha for wheat, rice, and maize, respectively.[24] Millets are often xerophilic capable of reproducing with little water input and thermophilic thriving at comparatively warmer temperatures. There are many distinct types of millets in different parts of the world, and each type of soil has certain requirements for healthy growth.[25] Due to the generations-long refinement of these traditional growing techniques to suit regional environmental circumstances and farming customs, millet agriculture has become more resilient and sustainable over most of the world. Depending on the particular millet type and the growing region, different traditional cultivation techniques are used for different millets. However, a few prevalent customs are as follows: [26]

- A. **Seed Selection:** In order to guarantee the crop's resilience and local adaptability, farmers typically choose seeds from robust, high-yielding plants for the upcoming planting season.
- B. **Land preparation:** In traditional methods, tillage is generally done by hand or with the help of animals to get the soil ready for sowing. This could entail leveling, harrowing, and plowing the ground to make an appropriate seedbed.
- C. **Planting (sowing):** Usually, millet seeds are spread, or manually scattered, onto the prepared soil, or they can be seeded with conventional seed drills or other tools. The local climate and rainfall patterns influence when to sow.
- D. **Water Management:** Conventional techniques for conserving water, including contour trenching or bunding (constructing little earthen dams), may be used in areas with variable rainfall to collect and hold rainwater for millet farming.
- E. **Weed Control:** To manage weeds that impede millet plants' access to nutrients, water, and sunshine, manual weeding with conventional instruments like hoes or hand-pulling is a popular technique.
- F. **Pests' management:** Natural means of controlling pests and diseases, such as intercropping with plants that repel pests, using biopesticides made from native plants, or utilizing cultural practices to reduce the load of pests and diseases, are frequently included in traditional knowledge.
- G. **Harvesting:** When the millets are completely dry and mature, they are usually picked. Using sickles or scythes to manually cut the millet stalks, then stacking them to dry in the field before threshing, are examples of traditional harvesting techniques.

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H. **Winnowing and Threshing:** Traditional threshing techniques involve pounding the harvested stalks with wood or trampling them with animals to separate the grain from the chaff after they have dried. The harvested millet is next cleaned by winnowing, which is the process of throwing the grain into the air to separate it from the chaff.

V. MODERN AGRICULTURAL TECHNIQUES FOR MILLETS

A. **Crop Rotation:** To increase soil fertility and lower insect and disease levels, alternate millet crops with legumes or other unrelated crops. Millets grow well on a wide range of soil types, from rich, medium-loam to poor, shallow soils, with a typical pH of 7.5–8.0. The ideal soils are shallow, loamy, red, medium, and well-drained. Some millet crops, such as kodo millet, can be produced in soil that is stony and gravelly. A medium to fine tilth is essential for healthy crop establishment and germination.

B. **Precision Farming:** To maximize the use of water and fertilizer, apply precision farming techniques including drip irrigation, soil moisture monitors, and GPS-guided equipment. For the duration of the growing season, millets require between 450 and 650 mm of water overall. In the early stages of growth, little water is needed. Therefore, it is usually not beneficial to irrigate before planting, especially if there has been enough rainfall during that period. It is best to schedule irrigation for later development phases. The amount of water supplied should be raised in tandem with the crop's growth and peak during the transition from the vegetative to the reproductive phases. The biggest boost to production occurs when the soil is adequately hydrated during the peak time.

C. **Weed Management:** Employ various weed control methods such as manual weeding, herbicides, mulching, and cover cropping to suppress weed growth and competition with millet plants. It takes four to five weeks for millets to outcompete weeds in their early stages of growth, thus during this time the crop needs extra care. Weeds are suppressed by the adoption of preventive measures such as adequate spacing between plants to create uniform stands, good seed-bed preparation to guarantee uniform stands, covering the soil surface with cover crops or intercrops, and following a proper crop rotation with densely growing legumes. Hand weeding at 20–25 DAS after applying a single pre-emergence spray effectively suppresses the first flush of weeds.[27]

D. **Improved Varieties:** Select and cultivate improved millet varieties that are resistant to pests, diseases, and environmental stresses, and have higher yields. Grain and fodder yields were the most crucial factors for small millet; the latter was a feature that conventional breeders occasionally disregarded. Crop duration, panicle size and variety, disease resistance, and drought tolerance were other crucial features. Farmers' enjoyment of these traits in the local and improved varieties served as the foundation for their selection. [28]

E. **Integrated Pest Management (IPM):** Use IPM techniques to reduce the negative effects on the environment by controlling pests and illnesses using a mix of chemical, cultural, and biological means. Millets react favourably to fertilizer, particularly N and P. The amounts of fertilizer that are advised differ depending on the season and the state. Utilize 10 t/ha of farmyard manure along with the necessary fertilizer dosage. The use of organic and inorganic manures by judges improves the effectiveness of fertilizer.

F. **Conservation Agriculture:** Practice minimum tillage or no-till farming to reduce soil erosion, improve soil health, and conserve moisture.

G. **Fertilization:** Apply balanced fertilizers based on soil testing to provide millet crops with essential nutrients for optimal growth and yield.

H. **Post-Harvest Management:** Implement proper post-harvest handling practices including drying, cleaning, and storage to maintain millet quality and reduce post-harvest losses. Harvesting millets and pulses for fodder and reducing harvest losses through improved timing and technology are two things that should be developed and implemented. Scientific storage can assist in maximizing the nutritional value and shelf life of millets and pulses.

Harvesting, threshing, shipping, storing, milling/polishing, packing, and other processes should be coordinated and shouldn't raise costs unduly.[29]

I. **Marketing reform:** Farmers may overcome asymmetric knowledge, boost income, and save input costs by exchanging real-time information. The option to choose should be granted to the farmer by the consumer. The choice to sell directly to him without using an APMC's services should be offered if that's what he wants. Pulses and millets should also be able to benefit from e-marketing.

VI. CHALLENGES IN MILLETS CULTIVATION

A. **Low Demand and Awareness:** As a result of their low demand and lack of promotion relative to other grains millets are frequently regarded as the diet of the poor farmers receive low prices. The lack of access to improved agricultural equipment,

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like better-quality seeds, fertilizers, pesticides, and irrigation systems, limits farmers' ability to increase crop yields and improve crop quality. Usually, marginal grounds unsuitable for other crops like rice, wheat, and maize are used to cultivate millets. However, the advent of more contemporary kinds of these crops has boosted their appeal to farmers, which has resulted in a recent drop in millet farming.[30]

- B. **Climate Change:** Although millets are generally more weather-resistant than other cereals, their cultivation can nevertheless be impacted by harsh weather events, unpredictable rainfall, and shifting climatic trends. Millets are frequently grown in arid and semi-arid regions that are vulnerable to the effects of climate change, including droughts and erratic rainfall, according to the FAO. Climate change and global warming will cause storm surges and cyclones to occur more frequently and with greater intensity. Flood plains and char lands will degrade somewhat to severely due to storm surges.[31]
- C. **Pests and Diseases:** Millets are vulnerable to a number of pests and diseases, which, if not well controlled, can drastically lower output. Integrated pest management techniques are essential to farming that is sustainable. The susceptible nature of millet crops to pests and diseases can drastically lower production. According to the survey, one of the biggest problems facing farmers is the absence of efficient methods for managing diseases and pests. It is important to note that the incidence of illnesses and pests has sharply increased recently due to the detrimental effects of climate change, particularly the rise in temperature. [32][33]
- D. **Limited Research and Development:** Millets have received less funding for research and development than other cereals like rice and wheat, which has resulted in a shortage of high-yielding varieties and effective farming methods.[34]
- E. **Land Degradation:** The cultivation of millet is severely hampered by nutrient depletion, soil erosion, and land degradation. It takes sustainable land management techniques to preserve the productivity and fertility of the soil.
- F. **The Lack of Water:** Although millets are typically thought to be drought-tolerant, their growth can still be impacted by a lack of water, particularly in areas with unpredictable rainfall patterns or inadequate irrigation systems.
- G. **Market Access:** Farmers may face financial difficulties if they are unable to sell their millet produce at fair prices due to limited access to markets, transportation, and storage facilities. One such issue is that millets have limited access to markets. It is claimed that because of their low price and restricted market appeal, millets are frequently seen as a traditional and specialized crop. According to the study, this reduces farmers' ability to cultivate millet profitably, which may deter them from making the investment in these crops. In order to bargain for fair prices for their commodities, these farmers do not belong to a farmer's cooperative or farmer's association. As a result, businesses have to charge low prices to middlemen for their goods.

VII. SUSTAINABLE SOLUTIONS

Sustainable cultivation of millets can be achieved through various practices such as following:

- A. **Organic Farming:** Avoid synthetic fertilizers and pesticides, opting for organic alternatives to maintain soil health and biodiversity. Fertilizers replenish the nutrients that crops require that have been taken up by the plants or that have not been lost due to washing, erosion, or retrogradation. It is crucial to confirm that these goods are of high quality because their primary purpose is to nourish plants and enhance soil properties.[35]
- B. **Agroforestry:** Integrate trees into millet fields to enhance soil structure, provide shade, and diversify income sources. The scientific soil testing documented in Soil Health Cards (SHCs), which assist farmers in determining the field-to-field requirement prior to sowing, can be the basis for a logical decision on the amount of chemical fertilizers and FYM to be employed. SHCs are being distributed widely; to date, over 18.93 crore cards have been provided, making it easier to determine the quantity of various nutrients that are accessible in the fields
- C. **Seed Diversity:** Promote the use of diverse millet varieties to increase resilience to pests, diseases, and climate variability. When it comes to seed size, shape, color, and nutritional makeup, millets are remarkably diverse. Pearl millet, finger millet, foxtail millet, proso millet, and barnyard millet are a few common varieties. Because each variety has distinct qualities, it can adapt to different environmental factors and culinary tastes. Food security, climate change resistance, and nutritional diversity in diets around the world all benefit from this diversity.[36]
- D. **Community Engagement:** Involve local communities in decision-making processes and traditional knowledge exchange for sustainable millet farming practices. Consumers, farmers, and the general public should all be made more aware of the nutritional benefits and adaptability of millets through ongoing initiatives. The promotion of millets as a sustainable and healthful food choice can be aided by media partnerships, educational initiatives, and promotional campaigns.

VIII. POLICY AND INSTITUTIONAL SUPPORT

A key component of our all-encompassing strategy is the policies that are necessary to encourage the expansion of best practices and seek effects that go beyond the project's intended locations. Little millets, no matter how much rural farmers and their

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communities come to cherish them, will not gain official backing unless the policy climate changes. The manner that official business and public sector agricultural enterprise's view millets represents a second set of policy considerations. For minor millets, for instance, there is no official seed supply industry; therefore, one project's goal was to increase local populations' capacity to generate and disperse high-quality seeds.[37]

- A. **National Food Security Mission (NFSM):** Established in October 2007 it aims to promote the comprehensive growth of agriculture and related industries. Millets are cultivated as one of the components of the NFSM. In order to boost food security and farmers' incomes, it seeks to raise millets and other crop productivity.
- B. **Rashtriya Krishi Vikas Yojana (RKVY):** It was introduced in 2007 as a broad initiative to guarantee the comprehensive growth of the agricultural sector and related industries. reorganized as the RKVY Cafeteria Scheme starting in 2022–2023 and combining other programs, including as the Crop Diversification Program and the Paramparagat Krishi Vikas Yojana (PKVY). RKVY offers states financial support to encourage the cultivation of millets and other crops. It encourages the adoption of better farming techniques, technological advancements, and the construction of infrastructure for millet growing.[38]
- C. **National Mission for Sustainable Agriculture (NMSA):** It was developed with the goal of increasing agricultural productivity, particularly in rainfed areas. It focuses on integrated farming, water efficiency, managing soil health, and conserving synergistic resources. The goal of NMSA is to advance sustainable farming methods, which includes millets. It seeks to protect the environment, increase productivity, and assist farmers in adjusting to climate change.[39]
- D. **International Year of Millets:** To encourage the production and consumption of millets worldwide, 2023 has been designated as the International Year of Millets.
- E. **Promotion at Government Canteens:** To encourage staff members to make healthier dietary choices, the Department of Food and Public Distribution has ordered all of its offices and central public sector companies to introduce and promote millets in their canteens.[40]

IX. FUTURE DIRECTIONS AND RECOMMENDATIONS

- A. **Research and Development:** Make research and development investments to create millet varieties with higher nutritional value and resistance to diseases, pests, and climate change.[41]
- B. **Promote Organic Farming Methods:** By reducing the use of chemical pesticides and fertilizers, organic farming methods help to minimize their negative effects on the environment.[42]
- C. **Promotion and Awareness:** Raise consumer knowledge of millets' nutritional advantages by implementing marketing and educational initiatives that encourage their use.
- D. **Policy Support:** To encourage farmers to cultivate millets, governments should offer policies such as subsidies, incentives, and insurance plans.
- E. **Value Addition and Market Development:** To make millets more marketable and profitable for farmers, support value addition projects like turning them into flour, flakes, or ready-to-eat goods.[43]
- F. **Genetic Conservation:** To preserve the genetic diversity of millet species for upcoming breeding and research, set up gene banks and conservation initiatives.[44]

By focusing on these future directions and recommendations, sustainable cultivation of millets can be promoted, contributing to food security, environmental conservation, and economic development.

X. CONCLUSION

Millets can be cultivated sustainably as a multipurpose response to today's environmental and agricultural problems. Millets, which include a variety of species such as sorghum, finger millet, and pearl millet, have intrinsic qualities that are consistent with the concepts of sustainable agriculture. These can be grown sustainably for a variety of reasons, such as better soil health, water conservation, biodiversity preservation, and climate change adaptation. Agroecological techniques like crop rotation, intercropping, and sparing use of pesticides can help farmers strengthen rural livelihoods, increase food security, and improve the sustainability of millet production. First of all, compared to traditional crops like rice or wheat, millets are hardy crops that can grow in a variety of climates and soil types with less water and input requirements. This characteristic lessens the burden on irrigation systems, conserves water, and lowers the chance of crop failure in areas vulnerable to drought or irregular rainfall patterns. Furthermore, millets are nutrient-dense, resistant to drought, and input-light, which makes them an important part of global sustainable agriculture systems.

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