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# Rediscovering Millets: A Lost Treasure for Modern Times

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A R T I C L E I N F O

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A B S T R A C T

Conventional agriculture predominantly depends on the large-scale cultivation of a limited number of monocultures, posing significant risks to food security and contributing to considerable environmental degradation. Ensuring approach to adequate, safe, in addition with nutritive food for all has enhance a critical global imperative, with many individuals still lacking access to adequate diet. The United Nations has set a target to achieve universal food access by the year 2030. Before the Green Revolution, rice and millets were the dominant staple crops, exhibiting greater production volumes compared to wheat, barley, and maize. However, post-Green Revolution, millet production declined, shifting from a staple food to a fodder crop, reflecting changes in agricultural practices and diets. Cultivated in order to millennia, especially across Asia as well as Africa, millets are characterized as tiny seeded grasses. Also recognized as nutri-cereals, millets encompass a verity/diversity of tiny seeded grasses, including those that share this characteristic. bajra (Pearl millet), kangni (Foxtail millet), ragi (Finger millet), cheena (Proso millet), jowar (Sorghum bicolor), kutki (Little millet), and kodon (Kodo millet) among others. Millets are versatile, four-season crops cultivated worldwide and characteristically, millets possess elevated levels of dietary fiber, antioxidants, protein, carbohydrates, micronutrients, macronutrients, and fats. Recently, a growing focus has emerged on the revitalization of these previously underappreciated millet grains, particularly in the context of addressing pressing global issues like climate change, food insecurity, and malnutrition. The United Nations (UN) designated 2023 even as the International Year of Millets, underscoring their potential contribution to the advancement with regards to the acceptable Development Goal line. This initiative has reignited global interest in millets among researchers, policymakers, and consumers.

## Introduction

Global climate change is projected to exacerbate abiotic and biotic stresses, notably affect crop productivity and growth. Consequently, the development of stress-tolerant crop varieties and innovative improvement strategies has become imperative. However, disproportionate research focuses on major cereals (e.g., rice, wheat, maize) has resulted in a relative neglect of minor cereals, such as millets, despite their potential for resilience (Gupta et al., 2017). Millet' finds its etymological roots in the Latin word 'Milum,' signifying 'grain.' Millets, among the earliest domesticated crops, likely across diverse global regions, millet cultivation likely arose independently several millennia ago, making their precise origin difficult to pinpoint. The archaeobotanical record demonstrates that *Panicum miliaceum* (broomcorn millet) as well as *Setaria italica* (foxtail millet) stood under cultivation in northern-China by 8000 cal. BP, (Deng et al. 2017). Farmers in Africa, the Middle East, alongside their Asian counterparts, also cultivated millets around the same period. They recognized the advantages of millets, including their simple cultivation, quick maturity, excellent storage capabilities, and the ability to provide long-term nutritional support (Tripathi et al., 2016). Old Indian writings, called the Yajurveda, talk about different types of millets like foxtail, barnyard, and black finger millet. This proves that people in India ate a lot of millets a very long time ago, even before 4,500 BC. This shows millets were a key food in India for thousands of years, and were important in their way of life even before they had big farms. A reassessment of the chronological framework for millet cultivation in Europe reveals a shift from the previously posited Neolithic period to the Bronze Age. This revised understanding, supported by contemporary research, places the commencement of millet cultivation around 3,500 years ago, with a distinct prevalence in eastern and central Europe. Conventional agriculture predominantly depends on the large-scale cultivation of a limited number of monocultures, posing significant risks to food



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security and contributing to considerable environmental degradation. A diverse array with regards to tiny seeded annual cereal crops, millets are 10 grown over marginal lands across arid, semi-arid, temperate, subtropical, and tropical climates. Emerging from the semi-arid tropical areas of Africa as well as Asia, millet, a cereal grain of the Poaceae family, has achieved widespread global cultivation. Its historical significance and ability to thrive under adverse conditions have secured its position as a crucial staple crop, particularly in its regions of origin (Ankita et al. 2025 and Hassan et al. 2021). Therefore, a key focus of current research is the development with regards to millet varieties exhibiting greater nutraceutical properties and enhanced tolerance to environmental stresses. Advanced crop improvement practices, including genomics-assisted breeding and genetic engineering, play a crucial role in grasp intricate mechanisms with regards to stress response along with tolerance, ultimately contributing to increased crop productivity. Although, the identification and improvement of native crops, inherently adapted to local climates, possessing high-nutritive value, and exhibiting resilience to abiotic and biotic stresses, represent a promising avenue for mitigating these challenges (Gupta et al., 2017). The rapid maturity and potential for year-round cultivation of millets present a significant opportunity to improve the efficiency of intensive cropping-systems and their integration as catch or relay crops. However, despite their critical role within the diets of populations in semi-arid as well as arid regions, millets have historically been under-researched, leading to their designation as 'orphan crops' or 'lost crops', While the term 'lost crops' is a misnomer, it reflects the relative underutilization of millets by developed nations and their comparatively low global production volumes compared to mainstream cereals. Nevertheless, these neglected crops are crucial contributors to biodiversity and serve as vital livelihood sources for impoverished populations in numerous regions worldwide (Gupta et al., 2017 and Belton and Taylor, 2004). The millet group comprises six key small-grained cereal species bajra (Pearl millet), kangni (Foxtail millet), ragi (Finger millet), cheena (Proso millet), jowar (Sorghum bicolor), kutki (Little millet), and kodon (Kodo millet). Each of these species is recognized for its distinctive characteristics and nutritive value (Kumar et al., 2016). Following a period of neglect, nutri-cereals, particularly millets, are experiencing a significant resurgence in India. As a leading cultivator, India contributes substantially to global millet production. Compared to many common cereals, millets exhibit a more advantageous nutritional composition, exhibiting three to five times higher concentrations of fiber, vitamins, proteins and essential minerals including iron along with calcium. Furthermore, their gluten free composition contributed to their recognition as 'superfoods' (Kaur et al., 2024 and Ashoka et al., 2020). The short growing season of millets facilitates multiple annual harvests. Their inherent resilience to pests, drought and diseases renders them an authentic crop option for farmers in areas characterized by limited water-resources and random weather patterns (Michaelraj et al., 2013).

**The shift away from millets towards modern staple grains**

Millets represent approximately of the most primitive domesticated crops, playing a critical role in the development of human civilization. Despite their historical importance as a primary food source, their prevalence declined significantly in favor of rice and wheat, particularly following the Green Revolution (Tripathi et al., 2023, Tripathi et al., 2023 and Ghoshe et al., 2024). Notwithstanding their considerable capacity to contribute to food and nutritional security, millets have remained underutilized. Recognizing this, India, the leading global producer of millets, has implemented various initiatives to revitalize their role as a staple food. Notably, millets were integrated into India's National Food Security Act. in 2013 along with subsequently included in the National Food Security Mission in 2018 (FASAR 2022). Underscoring its dedication, the Government of India declared 2018 as the National Year of Millets, and its continued efforts led to the United Nations' designation of 2023 as the International Year of Millets. Following a period of underutilization, millets are experiencing a significant resurgence in India's cereal production. In 2022, India's whole millet production reached 17.60 million metric-tons (Mn MT), comprising 4.40 Mn MT of sorghum and 13.20 Mn MT of other millet varieties (FASAR and APEDA, 2022), as compare to the estimated total pulses production for the 2022-23 period reached 260.58 lakh tonnes, representing a 5.7% increase over the preceding five-year average production of 246.56 lakh tonnes. (Mukesh et al., 2024).

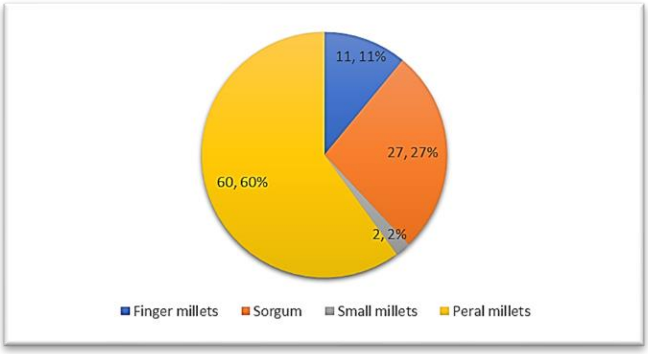


**Figure 1. Production status of millets in India according to production of major (FASAR and APEDA reports 2022).**

**The Nutritional Powerhouse**

Certain cereals have acquired popularity owing to their inherent gluten free nature, rendering them appropriate for those by means of celiac disease as well as gluten sensitivity. These grains typically boast rich nutrient profiles, providing a spectrum of vitamins, minerals, and antioxidants, which resonate with increasing health consciousness (Vashishth et al., (2024), Anonymous (2023), Shastri et al., (2019), Kumari et al., (2024), Gunathunga et al., (2024) Figure 1. It explores the potential well-being paybacks of millet-bran, encompassing its elevated fiber-content, positive impacts on gut health, blood sugar regulation, and cardiovascular health, as well as its antioxidant and anti-inflammatory properties. Furthermore, the distinctive fatty acid composition of millet bran, including omega-6 fatty as well as omega-3 acids, potentially contributing to general well-being. (Ahamed et al., 2019 and Shastri et al., 2019). Millets derived with significantly toward nutritional security worldwide by supplying key caloric and protein components of diets. Compared to conventional cereals, millets exhibit an enhanced nutritional profile characterized by higher levels of dietary fiber, calcium, protein and polyphenols. Recognized as a nutrient-dense food, millets possess a comprehensive nutritional profile, including 2-4% minerals, 60-70% carbohydrates, 12-20% dietary fiber, 1.5-5% fat, 6-19% protein and a diverse array of phytochemicals.

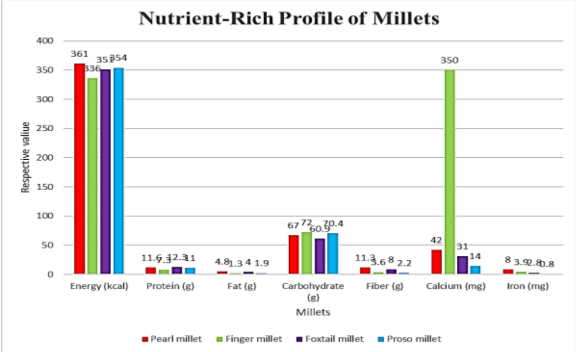


**Figure 2. Nutritional Value Comparison Across Millet Type**

The outermost layer of millet seeds/grains, referred to as millet bran, presents a heterogeneous nutritional composition, characterized by a substantial presence of macronutrients and micronutrients. Millet-bran, the pericarp of millet grains, presents a nutritionally diverse composition, notably in its macronutrient profile. Predominantly composed of complex carbohydrates, including dietary fiber, millet bran contributes to enhanced gut health and satiety, with carbohydrate content ranging from 30% to 60% depending on the variety (Ahamed et al., 2019 and Shastri et al., 2019). In comparison to other bran sources, it exhibits a relatively high protein content, typically within the range of 10% to 18%. Furthermore, millet bran is characterized by a low-fat content, generally between 3% and 9%, and exhibits a favorable ratio of monounsaturated as well as polyunsaturated fatty acids, along with omega-6 and omega-3, recognized for their positive impact on cardiovascular health (Kumari et al., (2024)). Millets represent a notable source of vital micronutrients, exhibiting an abundance of vitamins and minerals crucial for physiological functions. Notably, it offers a valuable source of vitamin-B (B1, B2, B3, B5 and B6), which are vital in order to energy metabolism as well as nerve function, along with vitamin E, a powerful antioxidant a certain protects cells against oxidative stress. Furthermore, millet bran is abundant in minerals namely iron, magnesium, phosphorus, potassium, and zinc., all of that are indispensable for diverse bodily processes such as bone wellbeing, muscle function, and energy production (Vashishth et al., 2024).

**Millet's importance in human health**

The diverse vitamin profile of millet bran confers a multitude of potential health benefits. B vitamins, abundant within millet bran, play a critical part within energy metabolism, acting as coenzymes within the conversion of food into usable energy, thereby promoting sustained energy levels. These vitamins, alongside vitamin E, are also integral to the maintenance of healthy nervous system function, contributing to mental clarity and cognitive performance by supporting neurotransmitter synthesis and protecting neural tissues from oxidative stress (Yadav 2010, Dykes, 2006 and Burton, 2000). While not all sources list vitamin C and A as abundant in Millet Bran, when present, they contribute to immune system fortification, aiding in the body's defense against pathogens. Additionally, vitamin C and E are essential for collagen synthesis, a crucial protein for the structural integrity of skin, bones, and connective tissues, thus supporting tissue health. Furthermore, folic acid, a B vitamin, is vital for cell growth and development, particularly during fetal development, and contributes to the maintenance of healthy cell division throughout an organism's lifespan. (Kumar *et al.,* 2010, Chavan *et al.,* 2014), Wankhade *et al.,* 2018 and Prakash *et al.,* 2019). Millet's constituents offer cellular protection through two primary mechanisms, free radical scavenging and DNA protection. The antioxidants efficiently counteract free radicals, thus preventing oxidative damage to cellular constituents and reducing the likelihood with regards to evolving chronic conditions alike cardiovascular diseases, cancer, as well as neurodegenerative disorders. Furthermore, these antioxidants contribute to the preservation of DNA integrity, potentially reducing the likelihood of carcinogenic mutations (Burton *et al.,* 2000, and Wankhade *et al.,* 2018). Omega-3 alpha-linolenic acid (ALA) may exert a significant effect in reducing inflammation, lowering blood pressure, and enhancing vascular function, potentially leading toward a reduced risk concerning cardiovascular disease, including heart disease as well as stroke. Additionally, the optimal omega-3 to omega-6 ratio found in millet bran further supports cardiovascular health by promoting a balanced lipid profile and reducing pro-inflammatory responses. Omega-3 alpha-linolenic acid (ALA) has been associated with cognitive function, memory, and learning, particularly during early childhood development. Emerging research suggests that omega-3 fatty acids may also provide neuroprotective benefits, potentially aiding in the management of neurological disorders and so on Alzheimer's disease. However, further studies are required to elucidate the specific health impacts of omega-6 as well as omega-3 fatty acids derived from whole wheat on human health. Additionally, processing methods can knowingly affect the content and bioavailability of these essential fatty acids. A well-balanced diet incorporating diverse sources of omega-6 as well as omega-3 fatty acids is crucial for keeping optimal neurological and overall-health (Prakash *et al.,* 2019 and Al-Taher *et al.,* 2023).

**Addressing Specific Health Considerations**

Despite the numerous potential health advantages of millet bran, it is crucial to consider individual health statuses and consult a healthcare professional before including it in one's diet. Key considerations include. The high fiber content of millet bran may support digestion and promote gut health. However, individuals with sensitive digestive systems should introduce it gradually to assess tolerance. Due through its fiber as well as protein content, millet bran may contribute towards improved blood sugar management, suggesting its potential as a dietary component for individuals with diabetes or prediabetes. Nevertheless, personalized dietary recommendations from a healthcare professional are advised. Regarding cardiovascular health, millet bran contains omega-3 fatty acids, antioxidants, and fiber, which may have a positive impact. However, its benefits are maximized when integrated into a holistic heart-healthy lifestyle encompassing regular physical activity and a balanced diet. Potential drug interactions, certain bioactive compounds in millet bran may interact with specific medications. Therefore, individuals taking prescription drugs should consult a healthcare provider before including millet bran in their diet. Concerning gluten sensitivities, although millet is inherently gluten free, persons along gluten intolerance or else celiac diseases should verify that millet bran originates from certified gluten-free sources to avoid cross-contamination.

**Antioxidant's status in Millet**

Millet bran is characterized by a rich composition of phenolic compounds, potent antioxidants that contribute to its potential health benefits. Among these, ferulic acid is found in high concentrations, acting as a free radical scavenger and enhancing the stability of other antioxidants. Vanillic acid and p-coumaric acid further contribute to the overall antioxidant activity and may provide anti-inflammatory effects. Additionally, millet bran contains tannins, which exhibit both antioxidant and antimicrobial properties, potentially contributing to improved gut health (Wankhade et al., 2018), it also contains a diverse array of flavonoids, another class of potent antioxidants. Notably, pigmented millet varieties, such as finger millet, contain anthocyanins, which exhibit anti-inflammatory and potentially cardioprotective properties. Furthermore, myricetin and quercetin, two additional flavonoids present in millet bran, contribute to free radical scavenging and may play a role in mitigating inflammatory responses (Ahamed et al., 2019).

**Culinary Versatility: Bringing Millets to the Modern Plate**

A renewed emphasis on millet cultivation is evident in India's cereal production sector, marking a departure from decades of relative neglect. The global millet sector experienced a remarkable surge in 2021, with production reaching 94.45 million tonnes, reflecting a 20.98% growth compared to the previous year (FAO, 2021). India maintained its position as the foremost producer, accounting for 19.1% of the global supply, although United States as well as Nigeria held the second and third positions, respectively (Bhat et al., 2018, FASAR 2022 and Rao et al., 2017). The temporal evolution of global millet production, specifically for the five leading producers between 2017 and 2021, is depicted graphically in. Despite their potential to mitigate nutrition-related challenges in India, the integration of millets into consumer diets faces demand-side obstacles

(Table 1). Specifically, consumer adoption remains limited, even with low-cost availability, without heightened awareness of their nutritional and health benefits. Economic demand models, utilizing secondary analysis of Indian food expenditure and consumption patterns, predict negative income elasticity and a decrease in coarse grain consumption (Mittal 2010; Minocha et al 2019). The historical perception of millets as a subsistence food contributes to their limited demand. However, millets exhibit potential as value-added products, particularly when incorporated into blends with rice and wheat. Notably, health-conscious consumers in metropolitan areas are increasingly adopting millet-based products, such as multi-grain flour and ragi-based dosa batter. The observed shift in urban consumption patterns suggests a nascent trend with the potential to influence demand beyond metropolitan areas. Rural populations, often inclined to emulate urban dietary habits, may contribute to a broader reversal of millet consumption trends. To facilitate this, the development of innovative millet-based recipes and the integration of millet-based complementary foods, such as khichri, upma, and roti, into feeding programs are essential (Makkar et al., 2019).

**Table 1. Regional Millet-Based Cuisine of India (Ankita et al., 2025)**

| Ethnic food as well as beverage traditional name | Millet used for preparations | Other ingredients use | Region/area |
|---|---|---|---|
| Bajre ki khichdi | Pearl millet | Pulses, rice | North-India |
| Gatka (porridge) | Sorghum | Cornmeal, salt | South-central India (Gond community) |
| Kodo roti and chilra | Kodo millet | - | Himachal Pradesh |
| Soup | Foxtail millet | Foxtail millet flour | North India |
| Ragi hurihittu | Finger millet | Foxtail millet flour | Karnataka |
| Ragi Mudde | Finger millet | Foxtail millet flour | Karnataka |
| Chilra or Iwar | Buckwheat | - | Himachal Pradesh |
| Ambli | Finger millet | Rice, buttermilk | South India |
| Rabdi | Pearl millet | Bengal gram flour, buttermilk | Rajasthan, Haryana |
| Koozh | Finger millet; Pearl millet | Broken rice, buttermilk, onion, garlic | Tamil Nadu |

## The Future of Millets

The intertwined challenges of climate change and escalating global-population growth pose a significant substantial risk to food security. To adequately nourish the projected 9–10 billion individuals by 2050, a substantial increase in food production, estimated between 60–110%, is imperative. This must be achieved concurrently with mitigating the impacts of complex and unpredictable climatic fluctuations (Arindam et al., 2024, Rockström et al., 2017). While millets exhibit climate resilience, their production is constrained by domestication-related challenges, including seed shattering, low yields, lodging, and suboptimal agronomic practices. These limitations have impeded their widespread adoption. The limited availability of well-characterized molecular information has restricted our ability to fully understand and leverage millet's unique traits for enhanced productivity and climate resilience, thereby limiting yield improvements (Arindam et al., 2024). The emergence of genomic data and progress in omics technologies presents substantial opportunities for enhancing millet through marker-assisted selection and the utilization of variations associated with specific traits. This method has the potential to broaden the available pool of genetic resources (Weckwerth et al., 2020). Data driven crop improvement holds significant promise for the future of millet cultivation. By systematically exploring and combining desirable variations, we can develop high-nutrient cultivars tailored to specific needs.

**Table 2. Global Millet Area, Production, and Yield Statistics (2021), (FAOSTAT 2023)**

| Regions | Area (MHA) | Production (MT) | Yield (T/H) |
|---|---|---|---|
| Africa | 46.7 | 38.4 | 0.8 |
| Americas | 6.6 | 24 | 3.6 |
| Asia | 17.3 | 25.7 | 1.5 |
| Europe | 0.7 | 1.7 | 2.7 |
| Oceania | 0.6 | 1.7 | 2.8 |
| World | 71.9 | 91.5 | 1.3 |

## Role of government policies and initiatives in encouraging millet production

The Green Revolution precipitated a reduction in millet consumption, despite their potential relevance to contemporary health challenges. In an era characterized by fast-food culture and sedentary lifestyles, millets provide a beneficial dietary option. The impact of millets on health and well-being, alongside their potential in alleviating lifestyle-related conditions like diabetes and obesity, deserves further investigation. The farming and dietary inclusion of millets can support the achievement of crucial global goals related to food and nutrition security, aligning with specific targets within the Sustainable Development Goals (SDGs) 2, 3, 12, and 13 (Anonymous (2023), Recognizing the nutritional benefits of millets, the Indian government has implemented numerous Central and State initiatives to enhance millet production, productivity, and producer income. Key initiatives encompass the Initiative for Nutritional Security through Intensive Millet Promotion (INSIMP), now integrated into the National Food Security Mission, as well as the National Mission on Sustainable Agriculture, the Rainfed Area Development Project (RADP), the National Food Security Act (NFSA) 2013, and the Rashtriya Krishi Vikas Yojana (RKVY). Acknowledging the significant nutritional value of millets, the Indian government officially recognized them as nutri-cereals in April 2018. Subsequently, during the 2018-2019 fiscal year, the Department of Agriculture and Farmers Welfare (DAandFW) implemented a Sub-Mission on Nutri-Cereals (Millets) under the National Food Security Mission (NFSM) to enhance millet acreage, production, and productivity (Jadhav et al., 2023).

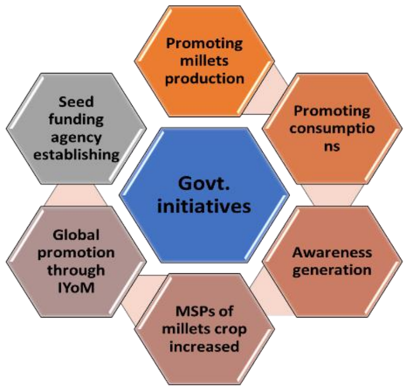


**Figure. 2. Initiatives taken by government for millets promotion**

## Conclusion

Millets, ancient grains with a rich history, are experiencing a resurgence due to their remarkable nutritional profile, resilience towards harsh environmental conditions, as well as potential to contribute food and nutritional security. Despite a period of neglect following the Green Revolution, India is leading a global effort to reinstate millets as a vital food source. Their superior nutritional content, gluten-free nature, and health-promoting properties, particularly those of millet bran, position them as 'superfoods' with significant benefits for human health, including improved digestion, blood sugar regulation, and cardiovascular well-being. Recognizing their importance, governmental initiatives in India are actively promoting millet production and consumption. Furthermore, advancements in genomics and breeding technologies hold promise for enhancing millet yields and climate resilience, paving the way for their increased integration into modern diets and agricultural systems to address the challenges with regards to food security as well as climate alteration.

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