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REVIEW ARTICLE

Exploring the importance of millets in reference to NEH region in India: A key to food and nutritional security

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Abstract

Millets is a collective term used for several small-seeded grasses such as sorghum, pearl millet, finger millet, foxtail millet and little millet. Millets play a crucial role in Indian subcontinent as they provided food security, nutrition, cultural significance, livelihoods and environmental sustainability. India holds global leadership in promoting the benefits of millets. The success of the International Year of Millets depended on the active participation of role of Self-Help Groups (SHGs) and Farmer-Producer Organizations (FPOs). Millets have gained attention in recent years not only in India but also in other countries owing to their incredible nutritional composition and potential health-promoting properties. This review highlights status of millets, their importance, effects on health, nutritional value and their distribution in India, particularly in the Northeastern Himalayan (NEH) region. The review also discusses the association of millets with culture, culinary diversity and therapeutic versatility with scope for entrepreneurship via value addition. Additionally, the article also provided information on policies for millet improvement, expansion of area for cultivation, development of improved varieties and conservation of local landraces. Moreover, it emphasized the need for accelerating millet-based enterprises through SHGs and FPOs, linking them to markets etc. In conclusion, the review highlights the status of millet in the NEH region and need for efforts to increase their production.

Keywords: culinary diversity; millets; NEH region; policies; therapeutic versatility

Introduction

Millets are small-seeded grain plants, referred to as “miracle grains”. They have gained substantial attention because of their unique adaptability to thrive in dry conditions and their need for less irrigation as compared to other crops. These crops can tolerate harsh conditions found in semi-arid lands and drought-prone environments (1). According to the International Crop Research Institute for the Semi-Arid Tropics, more than 90 million people in Africa and Asia depends on millet for their nutrition (2). They belongs to the family of grasses (Poaceae) and were among the first crops to be cultivated and consumed during the Indus-Sarasvati culture, from 3300-1300 BCE (3). The major millet species includes finger millet (*Eleusine coracana*), kodo millet (*Paspalum scrobiculatum*), little millet (*Panicum sumatrense*), foxtail millet (*Setaria italica*), proso millet (*Panicum miliaceum*) and barnyard millet (*Echinochloa frumentaceae*). These millets offers various culinary applications and contribute to sustainable and nutritious diets worldwide (4).

Millets add diversity in the food basket. Some of them act as super foods and ensure nutrition security (5). These are used to prepare different traditional foods and beverages like idli, dosa, papad, chakli, porridges, bread, infant and snack foods (6). The nutritional value including protein and macronutrients of millets was comparable or higher to traditional cereals. They make a substantial contribution to both human and animal nutrition because of their high-calorific value minerals (such as calcium, iron, zinc), fat and protein content. They are also abundant in dietary fiber and trace minerals (micronutrients) (7).

Millets, including pearl millet, finger millet and foxtail millet, are traditional crops in India that had been vital for food security and sustainable agriculture for centuries. They are rich in essential minerals like iron and calcium, as well as vitamins, which help overcome dietary deficiencies. Millets also offer therapeutic benefits due to their unique phytochemicals, including flavonoids, phenolics and anthocyanidins, which have antioxidant properties, reducing oxidative stress, combating inflammation and promoted overall health, making them a vital component of India's food systems (8).

Before the Green Revolution, millets were produced in

larger quantities than wheat and rice, making up over 40 % of all agricultural grains; however, after the revolution, the cultivation of crops such as rice and wheat increased. Rice production doubled and wheat production tripled (9). To promote the production and consumption of millets, India declared 2018 as the National Year of Millets. The production of millet increased from 14.52 million tons in 2015-2016 to 17.96 million tons in 2020-2021 (10). Furthermore, to create awareness and increase the production and consumption of millets, the United Nations, at the behest of the Government of India, declared 2023 the International Year of Millets. The International Year of Millets 2023 mark a special occasion for us to recognize its significance, not only as a vital food source but also as a key player in addressing global challenges such as food security, nutrition, sustainable agriculture and climate change to promote biodiversity, transform agri-food systems and eliminate hunger (11).

Millets are considered a crop of food security owing to their adaptability in adverse agro-climatic conditions (9). Many challenges like climate change, water scarcity, Increasing population, increasing food costs and other socioeconomic impacts were expected to generate serious threats to agriculture and food security worldwide, especially for the poor people living in arid and sub-arid regions (12). Therefore, millets acted as best alternate crops for coping with the above-mentioned situations. Millets are hardy and show tolerance to tough weather conditions including low rainfall (13).

Status in India

Indian millets are a group of nutritious, drought-tolerant plants, mostly grown in the arid and semi-arid regions of India. They constitute an important source of food and fodder for millions of resources- poor farmers and play a vital role in the ecological and economic security of India. Millets are also known as "coarse cereals" or "cereals of the poor". Indian millets are nutritionally superior to wheat and rice as they were rich in protein, vitamins and minerals. They are also gluten-free and had a low glycemic index, making them ideal for people with celiac disease or diabetes. India ranks among the top five millet exporters globally.

The introduction of green revolution technologies led to a decline in the area and production of finger millet, minor millets, pearl millet and sorghum; however, it simultaneously increased their productivity, which is due to varietal improvement and improved agronomic practices (14). During the period of the 1960s, the area and production of finger millets, minor millets, pearl millet and sorghum declined due to the introduction of green revolution technologies in the country. At the same time, per capita per year millet consumption in India declined and consumption of wheat and rice increased. The millet area was diverted largely to soybean (Madhya Pradesh, Maharashtra, Rajasthan, Andhra Pradesh and Karnataka), maize (Andhra Pradesh, Gujarat, Karnataka, Maharashtra and Tamil Nadu), cotton (Andhra Pradesh, Gujarat and Haryana), sugarcane (Maharashtra, Tamil Nadu and Uttar Pradesh) and sunflower in Karnataka (14).

In 1960, per capita per year millet consumption in India was 15.89 kg and it decreased to 8.54 kg by the year 2022. The millet consumption declined with a compound growth rate of -1.30 percent per annum during 1960-2022. However, the per hectare yield of millets increased globally due to the development and adoption of new HYV varieties of millets and agronomic practices. This resulted in an increased export of millets from India. The export of millets from India growing continuously with a compound growth rate of 14.10 percent per annum (15).

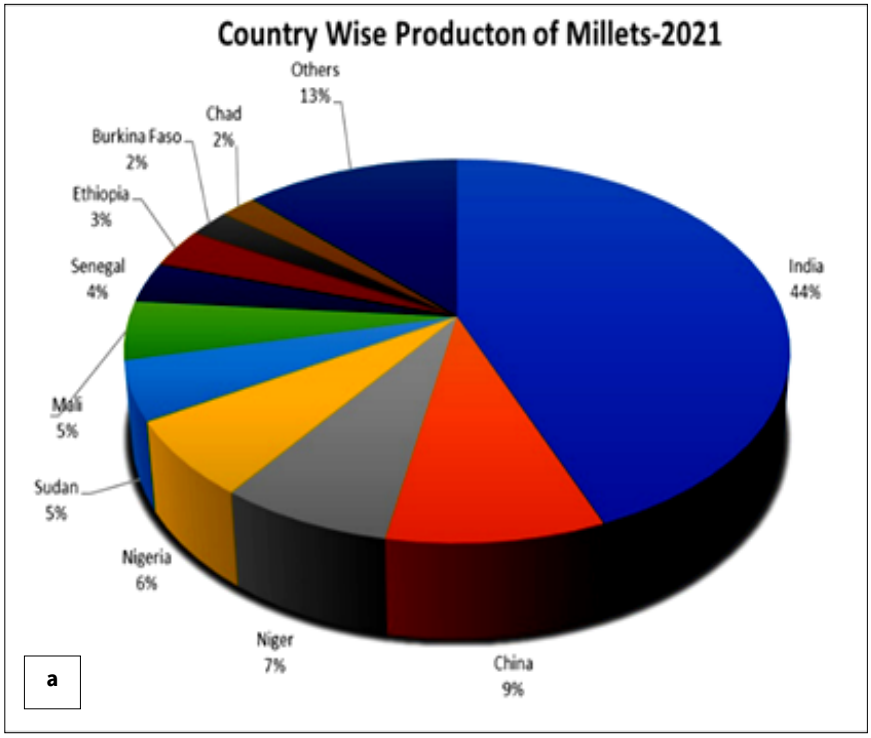
In 2021, the area under millet cultivation in the world was 30.94 million hectares, with a production of 30.09 million tonnes. In 2021, an area under millet cultivation in India was 9.76 million hectares with a total production of 13.21 million tonnes with an average yield of 13.53 quintals per hectare. The quantity of millet exports from India was 91287 tonnes worth 27.42 million USD during the year 2021 (11). Among the different states of India, Uttar Pradesh is the leading producer of millet followed by Karnataka (Fig. 1) (14). In India, millet production had been on the rise in recent years and farmers increasingly planting millets as a drought-resistant crop. Among the different millets, Bajra (62.0 %), Jowar (26.0 %) and Ragi (9.0 %) were produced the most; however, minor millets (3.0 %) contributed only a little share to total millets production during the year 2023-24 (Fig. 1) (16).

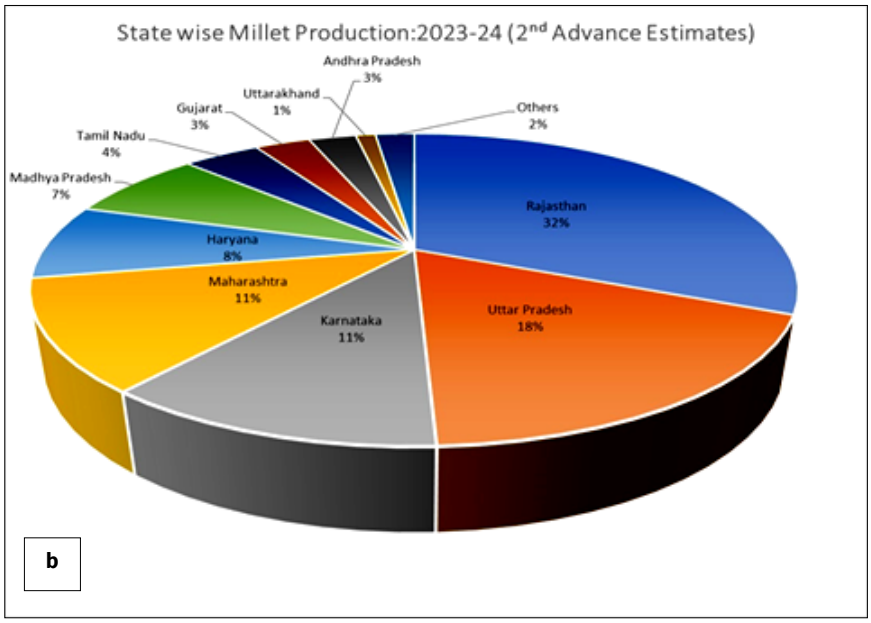
Global millet exports rose from $400 million in 2020 to $470 million in 2021 (16). India exported millets worth $64.28 million in the year 2021-22, against $59.75 million in 2020-21. The share of millet-based value-added products was negligible (15, 16). India's export of cereals stood at ₹96011.42 crore / $12872.64 million during 2021-22. Rice (including basmati and non-basmati) occupied the major share in India's total cereal exports, with 75 % (in value terms) during the same period, whereas other cereals, including wheat, represented only a 25 % share of total cereals exported from India (16).

The Indian government was promoted the production of millets through its National Food Security Mission and the production of millets in India was expected to increase in the future (16). The International Year also aligned with the Sustainable Development Goals (SDGs), particularly SDG2 (Zero Hunger), SDG3 (Good Health and Well-being) and SDG13 (Climate Action). By promoting millets, the world moves toward healthier diets, improved nutritional outcomes and resilient agricultural systems (17). As of 2023, global millet production stood at approximately 30 million tons annually, with the majority produced in developing countries.

Status in the world

Millet production has remained relatively stable over the past few years, with an estimated production of 28 million metric tons in 2020. The majority of millets were produced in Africa, followed by Asia. In the Asia-Pacific region, India produced 12490 metric tonnes and occupied the first position with a share of 80 %, followed by China with 2300 metric tonnes. India is the largest producer of millets, followed by Niger and China. Other major millet-producing countries included Burkina Faso, Mali and Senegal (Fig. 1) (11). According to the World Food Programme, there are an estimated 1.2 billion people who consumed millet as a part of their diet. Millets served as a traditional staple for hundreds of millions of people in Sub-Saharan Africa and Asia (particularly in India, China and Nigeria) for 7000 years and were currently cultivated around the world. More than 90 million people in Africa and Asia were estimated to depend on millets in their diets. Africa contributed over 55 % of global millet production, followed by Asia with nearly 40 %, while Europe represented around 3 % of the world market (16). In recent years,





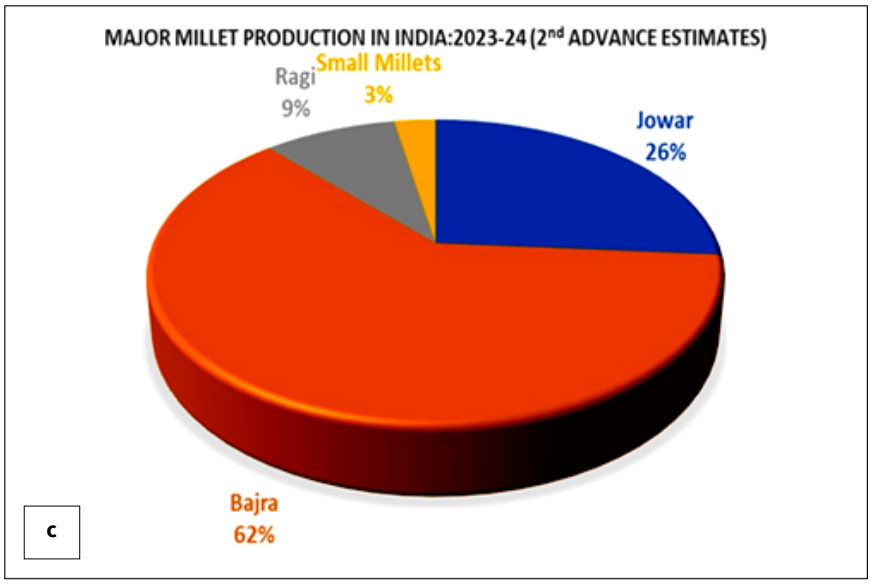


Fig. 1. (a) Millet production by country, (b) state-wise millet production in India and (c) major millet production states in India. (Source - GOI-APEDA, 2021 and 2023-24).

production gradually declined due to market distortions, a lack of appreciation of the benefits of millets and policies that favoured the production of the so-called Big Three cereals- rice, wheat and maize. Farmers switched to cultivating more remunerative crops for profit. They moved away from subsistence agriculture, responding to changing consumer preferences and market inputs. While millets were not a prominent food crop in the developed world, they played a vital role in the diets of many people in developing countries. Millets were also considered a drought-tolerant crop that could be grown in dry, arid climates where other crops might fail. Millets were expected to continue as an important food crop globally in the years to come because of their rich nutritional value (18).

Millet cultivation in the Northeastern Himalayan (NEH) region

The cultivation of millet holds significant importance in the NEH region of India, encompassing Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura. As traditional crops, millets had been cultivated for generations due to their resilience in adverse conditions, contributing to food security, biodiversity preservation the livelihoods of tribal communities. Despite the global trend towards fewer, more prolific crops, millets remained vital for sustainable agriculture in the NEH region. Government initiatives, NGOs and agricultural institutions actively promoted millet-based farming through training, extension services and research to enhance food security, farmer incomes and indigenous agricultural practices. While limited quantities of millet varieties were currently grown and consumed in Assam and neighbouring states. The farmers in NEH regions of India facing challenges like climate change, water scarcity and rising food prices and in such a scenario, millets offered a potential solution for food security, especially for vulnerable populations, particularly in arid and semi-arid regions. The popularization of millets had the potential to significantly uplift farmers' economic status. The NEH Programme was implemented across seven centres (Agartala, Gossaigaon, Namthang, Pasighat and West Garo Hills) and received Thirty lakh rupees in 2021-22. While millet utilization remained limited, it offered opportunities for value addition and climate change adaptation across the NEH region. Community members recognized the strong connection between millets, shifting cultivation and biodiversity, recalling a rich history of traditionally grown varieties. The region's Jhum cultivation practices promoted crop diversity, positioning it to champion food sovereignty nationally.

Cultural affiliation of millets in NEH

Millets have long been deeply ingrained in the cultural history of northeastern India, especially within tribal regions, where they have held significant importance in various ceremonies and celebrations. These grains have been integral to events such as weddings, crop harvest festivals, offerings to traditional gods, worship rituals and death commemorations, symbolizing unity, joy and sorrow. Beyond their role as a food source, millets have been closely tied to the origin, habitat, religion and overall way of life in these communities, which is why they have been considered an essential part of India's cultural heritage (19). In the northeastern states, millets have been woven into the very fabric of religious ceremonies, festivals, traditional medicine and even art, literature and folklore, serving as symbols of fertility, prosperity and the connection between society and agriculture (20). Scholars agree that the strong cultural attachment to millets has helped preserve them and has protected valuable germplasm from extinction, reflecting the deep-rooted relationship between local traditions and the land (21).

The cultural significance of millets has been further exemplified in various regional celebrations and practices. In Nagaland, the Yimchunger ethnic tribe has celebrated the Metumniu festival in August and the Tsungkamniu festival in January to honour the millet harvest (22). In Meghalaya, the Wangala harvest festival, known for its vibrant dance performances and drumbeats, has involved the worship of Lord Sun, the deity of fertility. Similarly, in Manipur, the Sajibu Nogma Panba Cheiraoba festival has been marked by religious offerings of millet, fruits, vegetables and other foods to Meitei deities, followed by a communal celebration with friends and family (23). In Tripura, a millet harvest festival known as Tsiinyi has further underscored the grain's cultural importance (24, 25). The incorporation of 43 plant species, including millets, into Meitei socio-cultural practices has highlighted the integration of local ecological knowledge into the region's gastronomy, promoting biodiversity conservation and presenting opportunities for culinary tourism (26). Furthermore, millets have also played a role in traditional crafts; the seeds of var. lachrymal-jobi, used as beads, have been key components in creating the 'Vakiria' headgear worn by Mizo women during festive occasions (27).

Culinary diversity of millets in NEH region

Millets are processed in traditional ways to made exquisite millet dishes for consumption, enhancing their nutritional value and sensory characteristics (28). They had been utilized for decades for the preparation of a wide variety of traditional value-added foods, non-traditional value-added foods/post-harvest value-added foods and ethnic beverages (29). In NEH states, many ethnic tribes preserved and promoted culinary traditions of millet-based food recipes, which not only benefited the local communities but also contributed to the global movement towards a more sustainable and diverse food future (Fig. 2). In these areas, finger millet were predominantly used to prepare food recipes, followed by sorghum and kodo millet. Various ingredients, including local vegetables, milk, eggs, ghee, coconut and sugar were used along with millet flour for food preparation. Various cooking techniques, such as steaming, frying and boiling were adopted to prepare these dishes (30) (Fig. 2). In addition, millet was a key component and an important ingredient in the local wine making process of most of the Northeastern states. These drinks, having high nutritional and caloric values, were often used in ceremonies and occasions for celebrations (Table 1). NEH wines are nationally appreciated for their taste and health benefits.

Effect of millets on health

Millets have been observed to have numerous documented health benefits. They are rich in minerals and vitamins with low fat, dietary energy and low glycemic-index value. Epidemiological evidence showed that millet consumption decreased the incidence/risk of cardiovascular disease, diabetes and certain cancers (42). Magnesium present in the millets not only helped to reduce the severity of asthma and migraine attacks but also reduced high blood pressure, diabetic heart disease, atherosclerosis and heart attacks. Niacin has been used for ages

Zan: Zan is a common breakfast among the 'Monpa' tribe of Arunachal Pradesh. It was made up of finger millets, vegetables and had high nutritional value, containing dietary fiber, protein, calcium, iron and essential amino acids (31).

Millet pancake: Finger millet flour was incorporated with some traditional flavoring agents like coconut, sugar or jaggery. The steamed product made from these ingredients had richness in calorific values (32).

Finger millet steamed ball with tomato sauce: This was an all-rounder dish that could eaten at any time- breakfast, lunch or dinner. This recipe was made by incorporating tomato sauce, spinach and pumpkin to enhance the texture (33).

Miri: It was a semi solid-slurry dish made from the whole finger millet grain (Sese) and was a staple breakfast among the Apatani tribes (34).

Mirung Gakir: It was a mixture of lukewarm milk (Gakir) with finger millet powder (Mirung) (35).

Fig. 2. Traditional millet-based food recipes in NEH region of India.

Table 1. Fermented millet-based ethnic beverages in NEH region of India

S. No	Name of local wine	Ingredients	Producing state	Reference
1	Ra-Chan, Kiad-kari, Sadhair	Pearl Millets (*Pennisetum typhoides*) and Thiat (Natural yeast cake)	Meghalaya	(36)
2	Madua Apong	Finger Millet (Eleusine coracana) and sige (local yiest made by grinding of rice)	Arunachal Pradesh	(37)
3	Kodo ka Jannr, Chyang	Finger millets and Marcha (Local yeast)	Sikkim	(38)
	Jnard	Finger millet	Sikkim	
4	Themsing	Finger millets or Barley and Pham (yeast tablet of indigenous rice paste and leaves of *Solanum khasianum*)	Arunachal Pradesh	(39-40)
5	Rakshi	Finger millets and Pham	Arunachal Pradesh	(39)
6	Tongba	Pearl millet/Finger millet + Kheusang (traditionally cultured microbial colony)	Sikkim	(36)
7	sithu	Fermented sesame seeds	Manipur	(40)
8	Chhi-um	Fermented sesame seeds	Mizoram	(41)

to reduce high cholesterol levels in the body (43). Phosphorus present in millets was an important mineral for energy production and was an essential component of Adenosine Triphosphate (ATP) (44). It also forms an essential part of the nervous system and cell membranes. A cup of cooked millet provided 26.4 % daily value for magnesium and 24 % daily value for phosphorus. Millets also contained lignin, which is converted to mammalian lignans by the healthy gut microflora in our body and thought to protect against breast cancer. The insoluble fiber of Millet aids in gallstone prevention. This gallstone protection from the fiber was dose-related, with every 5 g increase in insoluble fiber, the risk dropped by 10 %. Millets helped to lower blood glucose levels and improved insulin response (45). Finger millet is a humble grain with a low glycaemic index, which made it more suitable for diabetic patients (46).

Additionally, millets are a rich source of calcium (344 mg/100 g) and helped in supplementing calcium in human body (47). Postmenopausal women with signs of cardiovascular disease like high blood pressure, increased cholesterol and obesity could benefit from eating whole millet grains, particularly six times a week. Whole grains like millet may have had health-promoting effects equal to or even in higher amounts than fruits and vegetables and had a protective effect against insulin resistance, heart diseases, diabetes, ischemic stroke, obesity, breast cancer, childhood asthma and premature death (48) (Table 2).

Table 2. Nutrient profile of different millets and its therapeutic application

S. No.	Name of millets	Common name	Macronutrient/ phytochemical	Vitamins	Minerals	Uses	Reference
1	Kodo millet (*Paspalum scrobiculatum var. auriculatum* (J.Presl & C.Presl)Merr.)	Kodra	Highest dietary fibers, the high amount of protein low-fat content, Lecithin	Folic acid (B9), niacin (B3), pyridoxine (B6)	Calcium, iron, magnesium, potassium, zinc	Post-menopausal women that were suffering from high cholesterol problems or dyslipidaemia, cardiovascular diseases and diabetes	(49)
2	Little millet (*Panicum antidotale* Retz.)	Gajrao	37 %-38 % of dietary fiber, protein, apigenin	Vitamin B	Phosphorous and iron	Diabetes, celiac disease, cardiovascular disease, high cholesterol level and is anti-cancerous	(50)
3	Pearl millet (*Pennisetum*	Bajra	Unsaturated fatty acid	Vitamin B complex,	Copper, zinc, iron, magnesium,	Anemia, migraines, respiratory problems	(51)
4	Foxtail millet (*Setaria italica* (L.) P.Beauv.)	Kangni	Protein, dietary fiber, catechin, quercetin, apigenin, kaempferol	Vitamin B	Calcium, vitamins, iron, copper and magnesium	Diabetes, cardiovascular disease, maintaining dyslipidaemia, antimicrobial, antiulcer	(52,53)
5	Barnyard millet (*Echinochloa* spp.)	Swank or Shyama	Dietary fiber, protein, carbohydrate, linoleic acid, palmitic acid, oleic acid, phenolic compounds, flavonoids, serotonin derivatives, serotonin and tricin	-	Iron, zinc, calcium, protein, magnesium	Celiac diseases, diabetes, antioxidative activity, anti-cancerous, anti-rheumatic and antidiabetic	(54,55)
6	Finger millet (*Eleusine coracana* Gaertn)	Ragi	Protein, dietary fibers,	Vitamin A and vitamin B	Calcium, phosphorous	Blood cholesterol, constipation, intestinal cancer, Antimicrobial	(56)
7	Quinoa (*Chenopodium quino*a Willd.)	Quinoa	Protein, dietary fiber flavonoids, polyphenols, phytosterols, lysine and methionine amino acids, omega-6 fatty acid	Vitamin E and vitamin B	Rich in iron, magnesium, copper, phosphorus, potassium and zinc	Protein-energy malnutrition, celiac disease, maintaining dyslipidemia, cardiovascular disease and intestinal health	(57)
8	Sorghum (*Sorghum bicolor* (L.) Moench)	Jowar	b-carotene, folic acid, fiber thiamine, riboflavin, tannins, flavonoids and phenolic acids	Vitamins B1, B2 and B9	Calcium, iron, potassium, phosphorus, sodium and zinc	Anti-carcinogenic and lowers esophageal cancer, arthritis, heart-related diseases, malnutrition, obesity	(58)
9	Proso millet (*Panicum miliaceum* L.)	China	Caffeic acid, chlorogenic acid, ferulic acid and syringic acid	-	-	celiac disease, maintaining dyslipidemia, cardiovascular disease	(59)

Initiatives for increasing millet production in India

Policies/schemes for millets by the Government of India

Several schemes have been implemented and other initiatives have been undertaken by the Government of India to promote millet production. These mainly include the following;

Submission of Nutri-Cereals under the National Food Security Mission (NFSM): Recognizing millet's high nutritional value, the government designated them as Nutri-cereals in April 2018. From 2018 to 2019, the Department of Agriculture and Farmers Welfare (DA&FW) carried out a Sub-Mission on Nutri-Cereals (Millets) under the National Food Security Mission (NFSM) to increase the area, production and productivity of millets.

PLI scheme on millet: On March 31, 2021, the government approved a central sector program called the "Production Linked Incentive (PLI) Scheme for Food Processing Industry" with a budget of INR 10900 crores. The program was being implemented over 7 years from 2021-2022 to 2026-2027. The main goals were to encourage the development of global leaders in the food manufacturing industry and to promote Indian food product brands in foreign markets. The strategy was designed to promote specific food product areas, notably millet-based goods that had a strong potential for growth.

Promoting millets in the Public Distribution System (PDS): The government included millets in the Public Distribution System (PDS) to improve their accessibility and affordability and to facilitate their transportation. To meet the advance demand placed by the consuming state before the start of procurement, the provision of interstate transportation of surplus millets through the Food Corporation of India (FCI) was incorporated.

Promotion of millet by the Ministry of Women and Child Development (MWCD) in supplementary nutrition program (SNP): The MWCD advised all states and UTs to include millets in their recipes to improve the nutritional value of the food served as part of the Anganwadi Services' SNP. It was mandated to provide millet-based recipes at least once a week under the SNP component of Mission Saksham Anganwadi & Poshan 2.0 and to integrate millet into Take Home Ration (THR) made available to beneficiaries.

Support to states: The Department of Agriculture and Farmers Welfare also offers assistance to the states through the centrally sponsored scheme "Support to State Extension Programme for Extension Reforms" for a variety of extension activities, including farmers' training, exposure visits, demonstrations, kisan mela, kisan goshthi, farmers-scientists' interaction, mobilization of farmers interest groups and setting up of farm schools in the field of awardee/progressive farmers (2).

Recognizing millet's nutritional benefits, the Indian government declared 2018 the National Year of Millets, spearheading awareness efforts (60). This initiative led the United Nations General Assembly to declare 2023 the International Year of Millets, acknowledging their potential to address global challenges. This global campaign was designed to raise awareness about the benefits of millets and encourage actions to increase their production, consumption and utilization (61).

Policies/schemes for millets by the State Governments on Millets

Different state governments have also launched different policies for promoting the production of millets and popularise the superfoods.

Assam: In Assam, the ICAR launched the Small Millets-North East Hill Programme, introducing minor millets such as finger millet, foxtail millet and proso millet. The programme aimed to increase the productivity of minor millets by promoting their cultivation through the provision of improved varieties, equipment and necessary inputs. Additionally, the state has initiated a comprehensive mission called the Assam Millets Mission (AMM), set to span seven years starting from 2022-23. Under this mission, activities were undertaken in a value chain mode, covering production (including seed production), post-harvest processes, processing, value addition and market linkages. The total area targeted for millet cultivation under this mission was approximately 25000 hectares. Considering adoption by a similar number of farmers, the total area under millet cultivation was expected to reach around 50000 hectares. The current area under millet cultivation in the state was only about 6000 hectares but eightfold increase in expansion was targeted. Initially, interventions were proposed in 15 priority districts, namely Nagaon, Bongaigaon, Dhubri, Morigaon, Barpeta, Tinsukia, Kokrajhar, Baksa, Goalpara, Karbi Anglong, Kamrup Rural, Sonitpur, Jorhat, Golaghat and Udalguri (11, 16).

Nagaland: Millet is one of the important cereal crops grown in Nagaland and was used for the preparation of unique wine, food items and taken as a meal. There is no mission dedicated for millets in Nagaland. The state government may emphasize improving the sustainability and efficiency of small millet cultivation.

Sikkim: Sikkim lacks a specific millet mission; however, ICAR-supported training programs have supported finger millet cultivation practices and boosted yields.

Tripura: There is no dedicated mission on millets in Tripura. The Department of Agriculture, Government of Tripura, is attempting to utilize all the cultivable land by increasing cropping intensity and productivity with the best natural resources and diversified farming. The Dabbari village is considered one of the production hubs of minor millets under Salema Agri. Sub-Division, Paschim Champamura ADC Village of Mandwai Agri Sub-Division. The sub-division of Tripura was selected based on a Participatory Rural Appraisal (PRA) exercise. Extension activities and high-yielding varieties significantly influenced farmers' adoption of millet production. Currently, farmers were ready to take up millet cultivation if the milling facility was made available in the district (16).

Policy intervention for area expansion

No matter how much rural farmers and their communities have considered millets valuable, these crops need to receive official support from the authorities and a change in the policy environment. One of the greatest challenges faced by agriculturists today is to convince decision-makers that minor millets deserve a place in mainstream agricultural, nutritional and food policies. Till now policy makers have kept millets largely out of the scope for both research and development and price support agreements. Persistent neglect accelerates the erosion of

genetic diversity and traditional knowledge related to millet production, processing and utilization. The millets production is very low owing to the lack of suitable higher-yielding varieties, poor-quality seeds and better cultivation practices. Moreover, traditional processing methods followed by women who prepare dishes using millets for daily labour were condemned. In addition, there is a lack of attractive recipes for millets, lack of awareness about their nutritional value, poorly organized marketing strategies and unfavourable environmental policy (61).

Other methods for increase in millet production

Different types of millets cultivated across Northeast India

Finger millet (*Eleusine coracana*) is widely cultivated in Nagaland, Manipur, Meghalaya and Assam. Foxtail millet (*Setaria italica*) is another significant crop cultivated in Mizoram, Manipur, Arunachal Pradesh and parts of Nagaland, mainly under jhum or shifting cultivation systems. Barnyard millet (*Echinochloa* spp.) is traditionally grown in Sikkim, Meghalaya, Nagaland and Arunachal Pradesh, particularly in higher elevation and sloped lands. Likewise, little millet (*Panicum sumatrense*) is found in smaller patches in Assam, Manipur and Meghalaya (62). Proso millet (*Panicum miliaceum*) has limited cultivation in Meghalaya and Arunachal Pradesh. Sorghum (*Sorghum bicolor*), although not dominant in hill regions, was cultivated in dry pockets of Assam and Tripura. Kodo millet (*Paspalum scrobiculatum*) is grown in Assam, Meghalaya and parts of Nagaland, particularly in dryland areas. Pearl millet (*Pennisetum glaucum*) is the least cultivated among the eight major millets in the Northeast, with limited presence in Assam and Tripura due to high rainfall in the region (63).

Introduction of improved varieties

Of all the small millets such as finger millet, little millet, kodo millet, foxtail millet, barnyard millet, proso millet and brown top millet, finger millet stands out as the most crucial crop cultivated extensively throughout India. Its cultivation ranged from sea level to a high altitude of 8000 ft in the Himalayan region. The launch of a programme named All India Coordinated Research Project on Small Millets (AICRP-SM) in 1986 increased the focus on small millets. Following the launch of AICRP-SM, numerous improved varieties with higher yields, varying maturity and tolerance to various diseases and insect pests were developed and released for widespread cultivation across the country (Table 3) (64). These improved varieties contributed to increasing the production of millets in India. Enhanced millet varieties with high yield, better nutritional profiles and climate resilience has recently been introduced across the NEH region. A multi-year evaluation trial conducted in the Eastern Himalayan foothills demonstrated that Finger Millet (VL Mandua 352) achieved yields of 1.43 t/ha, outperforming several local landraces. Among local cultivars, Nagaland-2 and Sikkim-1 showed yields of 1.31 and 1.25 t/ha respectively and exhibited superior root architecture traits, including greater root length and surface area- key for adaptation in rain-fed, upland organic systems.

Table 3. Data related to millets varieties released over the years (64)

Crop	No of varieties released		Total
	From 1986-2022	Before 1986	
Finger millet (1918-2022)	97	45	142
Foxtail millet (1942-2022)	26	12	38
Little millet (1954-2022)	26	6	32
Proso millet (1954-2022)	19	8	27
Barnyard millet (1949-2022)	18	4	22
Kodo millet (1942-2022)	30	11	41
Total	86	216	302

Conservation of local landraces

The initial and crucial step for developing strategies to breed new varieties capable of addressing future challenges is to collect and conserve the germplasm of indigenous landraces. Plant genetic resource (PGR) conservation ensures a steady flow of input for crop advancement (65). Among the millets, sorghum (168500), pearl millet (20844) and finger millets (36873) are the major millets with the highest total number of cultivable germplasms worldwide. The minor millets, such as foxtail millet (44761), proso millet (29308), barnyard millet (7923), shama millet (707), kodo millet (4780) and little millet (3064), also had a significant number of available germplasms. Globally, gene banks conserved 133849 cultivated germplasm of millets, with the majority of genotypes being conserved 64.4 % in Asia, 13.8 % in Africa and 13.5 % in Europe (66).

The largest collection of millet germplasm in India is found at ICRISAT, making up 27.4 % of all crop accessions in the gene bank. The collection majorly included pearl millet, which was represented by 23092 accessions, comprising breeding lines, landraces, cultivars, genetic stocks and wild relatives. Around 665 accessions were accounted for by the primary collections of kodo millet from the United States and India. India was the primary source of little millet germplasm, with 473 accessions (67).

Scopes for entrepreneurship development through value addition

Importance of encouragement for rural entrepreneurs, including adolescents, women and farmers, due to their lack of self-confidence and challenges in balancing financial support and family responsibilities (68). Recent developments, such as self-help groups (SHGs) and NGOs, along with technical support and loans, have enhanced the independence of rural women. The utilization of finger millet, a nutritious cereal crop, through processing and value addition, held the potential to improve living conditions in production regions (69). The establishment of a millet processing business requires government support, including training and tie-ins with financial and marketing institutions. Value addition to millets is a highly strategic intervention in the popularization of nutritionally rich crops (70). Appropriate food processing technologies boosts agricultural production, enhanced product quality and value addition and generated employment opportunities. Such an approach was thus strategic in supporting both economic progress and industrial development in rural areas of India (71). As women are the main actors behind the knowledge, production and consumption of genetic resources of small millets, the enhanced use of these crops also provides an opportunity for the empowerment of this marginalized sector of Indian society (72).

The Indian government stated that in the current system of agricultural marketing, most farmers sold their produce for a fraction of the amount paid by the final consumer, which needed to be addressed. Small and marginal farmers were provided with

a platform by farmer-producer organizations to facilitate effective marketing and production. This platform enabled them to reduce the transaction cost of input access and to receive a consistent flow of market information, enabling them to act accordingly to maximize profits and access high-value markets (73).

The role of FPO is such that it offered its member farmers discounted prices for renting machinery and supplying inputs like seed. In addition, it is also involved in obtaining produce from farmers at a fair price when compared to the open markets. The value chain actors and the role of FPO in value chain actors were well explained in Fig. 3 (74).

In partnership with KVKs and state universities, ICAR-IIMR established a primary processing unit to assist small and marginal farmers through FPO at the farm gate, where KVKs serve as a lighthouse for ranchers in disseminating the technology. ICAR-IIMR is serving as CBBO for 41 FPOs in four states (Andhra, Telangana, Karnataka and Madhya Pradesh). Primary processing benefited approximately 25000 farmers across several FPOs, including Aland, Hulsoor, Shopur, Vizianagaram, Anantapur and Vishakhapatnam (75).

This initiative has been started by ICAR-IIMR to improve the millet value chain by providing practical training on the preparation of value-added goods and their delivery through the GeM portal, ONDC, SFAC and online platforms to FPOs/SHGs/ rural women/unemployed young (76) (Fig. 4).

Conclusion

Millets have a long history as both a staple cereal and a valuable source of bioactive compounds with diverse health benefits. In this review, we focused on the culinary diversity, status and millet distribution in the NEH region. The information related to nutritional aspects of varieties of millet with their therapeutic potential; and cultural affiliation was also highlighted. Proper standardization and clinical trials were needed to exploit their therapeutic utility to combat various diseases, such as cataracts, gastrointestinal disorders and cardioprotection. Technology and policy played essential roles in the cultivation and production dynamics of different food crops, including millet, which eventually influenced the demand and supply of individual food crops. Over the period, the land used for millet cultivation was diverted to other crops due to a lack of policy support, market-driven demands, adequate incentives to produce more and technical advancements to increase productivity, resulting in declined cultivation of millet. Policy interventions and support for millet-based enterprises through SHGs and FPOs are required to promote millet cultivation and create employment in both rural and urban areas.

Fig. 3. Various sectors in the value chain (38).

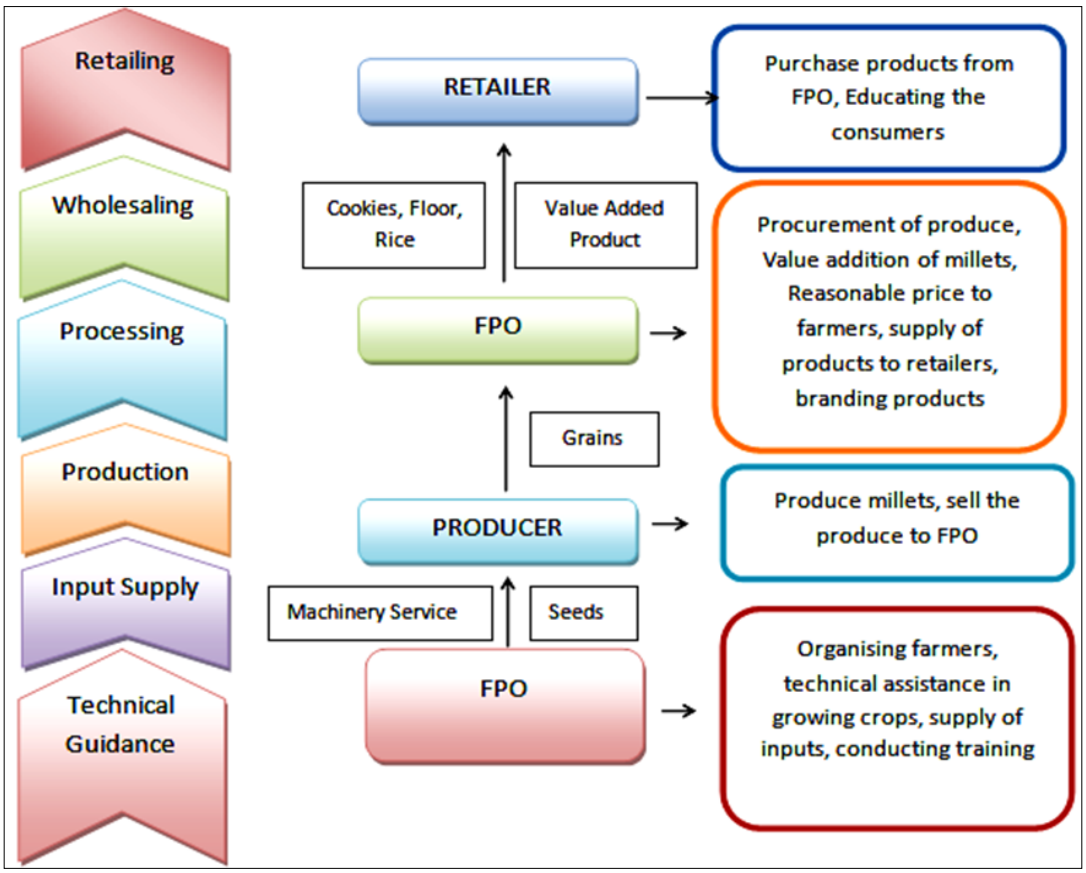


Fig. 4. Value chain map of millets.

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Authors' contributions

HCK conceptualized the manuscript and prepared the initial draft. SKB reviewed and edited the manuscript. SB contributed resources and provided supervision. AKM[1] performed corrections. HK contributed resources and reviewed and edited the manuscript KR reviewed and supervised the work. AK offered resources and participated in the review. AKM[2] analyse the therapeutic data. All authors read and approved the final manuscript. [AKM[1] stands for Amulya Kumar Mohanty and AKM[2] stands for Ashok Kumar Mahawer].

Compliance with ethical standards

Conflict of interest: The authors declare that they have no conflicts of interest related to this article. All authors have given their consent to submit this manuscript for publication.

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