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Mini Review Article

The world of Millets: A comprehensive overview of Millets and their Significance

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Abstract

Cereal grains and pseudocereals are served as key sources of food worldwide. However, other significant cereal crops, such as sorghum and millets, along with pseudocereals, are crucial for the daily sustenance of billions of people in Asia and Africa. Millets are among the ancient crops, a staple food in many parts of the world, unfortunately, the production and consumption of millets declined in recent decades but gained popularity with the increasing recognition of the importance of food security and the need for sustainable agriculture practices, due to their low glycemic index and high nutritional values. Often referred to as Nutri cereals or orphan crops, millets are small-seeded cereal crops belonging to the Poaceae family. "The word "Millet" derives from the French word "Mille, " meaning thousands". They are the 6th most important cereal crops cultivated worldwide and are among the first crops to be domesticated. Being C_4 plants, millets are also drought-resistant, disease and pest-resistant, hardy, and dry land crops that can adapt to various climate conditions, hence known as climate resilient crops. This review gives an overview of the different aspects like characteristics, historical account, geographic distribution, and importance of the different millet species. They are cultivated in extreme environmental conditions ranging from arid to semi-arid zones and are a primary food source in many Asian and African countries. They are used as both food and fodder with significant ecological, environmental, and ethnobotanical importance. Due to their higher nutritional value in proteins, vitamins, and minerals compared to wheat, rice, and maize, hence named "Nutricereal".

Keywords: Millets, Nutri-cereals, Importance, Nutritional benefits, Food security

1. Introduction

Millets are one of the oldest foods known to humans in the category of cereal crops commonly used for food, which are small-seeded cereal grains belonging to the grass family (Poaceae) family. "The word "Millet" is derived from the French word "Mille" which means thousands, implying a handful of millet can hold up thousands of grains" (Kumar et al., 2021). "They can be grown in a variety of tropical and subtropical climates and require minimal input. Major millet crops include sorghum (*Sorghum bicolor*), finger millet (*Eleusine coracana*), pearl millet (*Pennisetum glaucum*) foxtail millet (*Setaria italica*) or little millet, kodo millet, proso millet (*Panicum miliaceum*), and brown top millet. Depending upon their size, millets are divided into two categories: major millets and minor millets. Major millets include sorghum, pearl millet, and finger millet. While little millet, foxtail millet, proso millet, and barnyard millet are included in minor millets. Eight Botanists have counted two pseudo

millet too namely: Buckwheat and Amaranth" (Yadav & Singh, n.d.). Millets, also known as "Nutricereal" are often considered as last resort for cultivation due to their lower market demand and consumption, resulting in reduced profitability compared to other crops. Despite being termed "minor millet", which suggests they are less important, millets are actually significant for their high nutritional value, medicinal benefits, used as animal fodder, and role as a crucial food source during crisis (Kumar et al., 2021). Millets were among the first crops domesticated by humanity and have long been a lifeline for the dry regions of Asia and Africa, serving as both food and fodder. In some parts of the world, millets are a staple food and are also used as fodder. Overspread globally, becoming essential food sources for developing civilizations. Despite their importance, millets are often referred to as orphan crops because they receive less attention for cultivation due to their lower market demand and profitability compared to other crops (Bhat et al., 2019). Nevertheless, these neglected crops play a crucial role in sustaining livelihood and providing essential food and nutrition. About 97 per cent of the world's millet production is found in developing countries while India is the largest producer of millets (Scott, 2015). Today millets are the world's 6th most important cereal grains. The International Year of Millets, 2023 aimed to raise awareness about the importance of millets and their health benefit envisaging the theme, - "healthy millets - healthy people" (Kumar et al., 2021).

2. Characteristics

Millets are 6th dominating crop in the world concerning agriculture production and are resistant to drought. Also, millets exhibit resistance to pests and diseases, have a short life cycle, and have high productivity under drought conditions, as compared to major cereals (Saleh et al., 2013). Millets are climate-resilient, hardy, and dry land crops that can adapt to various climate conditions. Millets are crucial crops grown during the kharif season completing their life cycle within the monsoon period. They can thrive in poor soil conditions with minimal irrigation and can easily adapt to degraded saline, acidic, and aluminum-toxic soils (Kumar et al., 2021). Hence exhibiting strong adaptability to various ecological conditions makes them suitable for climate change. Being C_4 plants they are efficient with low input requirements but can also respond well to high input management. With unique nutritional properties of millets, i.e., high fiber, quality protein, and mineral composition, they are called "Nutri cereals" (Kumar et al., 2021).

3. Historical Account

Millets are ancient crops to be domesticated or familiar to mankind. The proof of millet utilization and cultivation was first to be found in the Indus Valley civilization (3000BC). Millets are recognized as one of the essential cereal crops along with wheat, rice, maize, and barley (Memmott et al., 2021). Millets have been considered an important staple food in human history. For the last 10,000 years, the cultivation has been done in East Asia (Bhat et al., 2018). "Different millet species were initially domesticated in several parts of the world like Southeast Asia, and West Africa. However, they spread well beyond their initial area of domestication. The earliest record of millet domestication and cultivation is that of foxtail millet and proso millet from China around 3000-2000 BC and the Indian valley of Kashmir is regarded as a place of integrated networks, where major trade of millets took place between Asia, Europe, and Africa. Cultivation of millets in China and Africa covers the major history of world millet cultivation" (Kumar et al., 2021). Pearl millet is a valuable cereal food crop of Asia and Africa and ranked 4th in the world as an important tropical food grain crop (Kumari et al., 2022). First, it was found to be domesticated in dry savannah from Sudan to Senegal (Tripathi & Vyas, 2023). Sorghum is a cultivated tropical cereal grass considered to have been first domesticated in North Africa. Possibly in the Nile, sub-Saharan or East Africa region as recently as 1000 BC (Dahir et al., 2015).

4. Geographic Distribution

Millets are a significant source of food for humans and fodder for animals, especially in the arid and semi-arid regions of Africa and Asia. In Asia, it is mainly grown in south and east Asia and Africa mainly in the Sahel (Singh et al., 2017). They can be cultivated under extreme abiotic environments (poor soil quality, limited irrigation, high salinity) as well as biotic stresses (*viz.* pests and diseases) (Mohan et al., 2023). According to the FAO (Food and Agriculture Organization) 2014, the mostly grown varieties of millets across the globe include Pearl, Proso, Foxtail, Japanese barnyard, Finger, and Kodo millets (Saxena et al., 2018). Sorghum is another important crop of African

origin and is especially important in the semi-arid tropics of Africa and South Asia" (Dahir et al., 2015).

Pearl millet is 6th maximal widely cultivated crop. It is a traditional crop in regions of central, eastern, and southern Africa, particularly the Sahel region of western Africa as well as in India, Pakistan, and the southern coast of the Arabian Peninsula (Saxena et al., 2018). Pearl millet the major millet that is grown in India accounts for nearly 75 per cent of the total area under millet. Largely concentrated in Rajasthan, North and Central Maharashtra and northern Karnataka (Bhagavatula et al., 2013).

Finger millet commonly known as Ragi in India, is important millet grown extensively in various regions of Africa and Southern Asia constituting a large segment of the population in these countries. In India, it is mainly grown in Uttar Pradesh, Bihar, Tamil Nadu, Karnataka, Andhra Pradesh, and Himachal Pradesh. It ranks sixth in production after wheat, rice, sorghum, and bajra in India (Devi et al., 2014; Dida & Devos, n.d.).

Proso millet also known as broomcorn millet or common millet, is grown in Asia, Australia, North America, Europe, and Africa and is important as bird and livestock feed in developed countries as well as for food in some parts of Asia (Vetriventhan et al., 2019). Being a short-season crop, it is cultivated for 60 to 75 days. With average annual precipitation requirement of less than 600 mm and average temperature of 17 °C (Zarnkow et al., 2010).

Seeds of foxtail millet have been found in Neolithic sites (in eastern and central Asia, Europe, and the Middle East). It is cultivated in Europe, China, India, Indonesia, the Korean peninsula, and the former USSR (Union of Soviet Socialist Republics) (Taylor & Taylor, 2023). It is drought tolerant at the seedling stage but most sensitive to drought at the inflorescence and spikelet development stage (S. Dwivedi et al., 2012)

Barnyard millet (*Echinochola spp.*) is an age-old variety, that is cultivated in warm and temperate regions across the globe with widespread cultivation in Asian countries notably India, China, Japan, and Korea. It ranks as the fourth most extensively produced minor millet. India being the largest producer of barnyard millet (Renganathan et al., 2020). The crop is valued for its drought tolerance, short growth period, and superior nutritional value (Wallace et al., 2015).

Kodo millet known to originate in India, is grown on poor soil and is widely distributed in arid to semi-arid regions of India and Africa. In India, it is significant to the plateau of Deccan, and cultivation is limited to Gujrat, Karnataka, Chhattisgarh, East Madhya Pradesh, and parts of Tamil Nadu (Bunkar, 2021).

The list of millets grown around the world with their centers of origin and cultivation in major countries is as follows:

Table 1: List of millets grown around the world, their origin, cultivation in major countries (Memmott *et al.*, 2021)

Crop name	Center of origin	Cultivation	References
		Major Millets	
Sorghum (*Sorghum bicolor*)	Abyssinian (Ethiopia)	USA, Nigeria, Mexico, Sudan, India Ethiopia, Pakistan, Thailand, China	(Dahir et al., 2015; Duodu & Dowell, 2018)
Finger millet (*Eleusine coracana*)	Western Uganda and Ethiopian Highlands	Nepal, Ethiopia, India, Sri Lanka, Uganda, Kenya, Eritrea, China, Sudan, Zimbabwe, Burundi	(Goron & Raizada, 2015)
Pearl millet (*Pennisetum glaucum*)	Western sub-Saharan and Sahelian zone of Africa	India and Africa	(Winchell et al., 2018)
		Minor Millets	
Foxtail millet (*Setaria italica*)	China	India, China, Myanmar, Eastern Europe, North America, North Africa	(Vetriventhan et al., 2012)
Proso millet (*Panicum miliaceum*)	Northeast China	India, Russia, The USA, Iran, Ukraine, South Korea, France, Kazakhstan, Belarus	(Memmott et al., 2021)

Barnyard millet (*Echinochola esculenta*)	Japan	Japan, India, China, Malaysia Korea	(Renganathan et al., 2020)
Kodo millet (*Paspalum scrobiculatu*)	India	India	(Bunkar, 2021)
Little millet (*Panicum sumatrense*)	Eastern Ghats of India	India	(Memmott et al., 2021)

5. Importance

At present the world is facing agrarian and nutritional challenges due to the changing climatic conditions and increase in population, which has further increased the demand for agricultural land and food (Kumar et al., 2018). "Millets are a very important climate change-compliant crop in terms of marginal growing conditions and are highly nutritious due to the presence of proteins, essential fatty acids, dietary fibers, vitamins B, and minerals such as calcium, iron, potassium, and magnesium" (Dayakar Rao et al., 2016). Besides this, millet is also important for fodder, feed, bird seed, industrial material, medicine, etc. (Bhat et al., 2019).

5.1 Importance of Millet as food and fodder

Millets serve as a major food source in many Asian and African areas (Saleh et al., 2013) grown around the world as cereal crops or grains for fodder and human food due to their adaptability to semi-arid and dry climates, with 97 percent of millet production in developing countries (Dayakar Rao et al., 2016; Scott, 2015). Millets also grow at a rapid pace and can be grazed around 5 to 7 weeks after sowing (Scott, 2015).

5.2 Nutritional and health benefits of millets

Millets have higher nutritional values in terms of proteins, vitamins, and minerals than wheat, rice, and maize. "They contain 60 to 70 percent carbohydrates, 7 to 11 per cent proteins, 1.5 to 5 per cent fat, and 2 to 7 per cent crude fiber and are also rich in vitamins and minerals" (Sarita & Singh, 2016). They are rich in phytochemicals like phenolics, tannins, lignans, phytate, sterols, resistant starch, dietary fibers, and carotenoids, and also have powerful antioxidant activity which is important in healthy aging, and metabolic syndrome (Sarita & Singh, 2016). Being a rich source of magnesium millet helps in reducing blood pressure and the risk of heart stroke. Potassium present in millet helps in keeping blood pressure low and reduces risk of cardiovascular diseases (Dayakar Rao et al., 2016). The presence of phenolics, tannins, and phytate in millet reduces the risk of cancer (Dayakar Rao et al., 2016; Sarita & Singh, 2016). Millets are gluten-free and suitable for individuals suffering from celiac diseases (Kk, 2023).

Millets are a good source of essential amino acids except for lysine and threonine but are relatively high in methionine. While foxtail millet is rich in lysin. Pearl millet was significantly found rich in resistant starch, soluble and insoluble dietary fiber minerals, and antioxidants (Saleh et al., 2013). Millets have higher amounts of methionine and other amino acids. Finger millet is rich in polyphenols and other essential amino acids (Numan et al., 2021). Finger millet is also a rich source of calcium and millet is an energy rich nutritious food, recommended for the health and well-being of infants, lactating mothers, elderly, and convalescent (Scott, 2015). The two millets highest in fat are pearl millet and little millet. Finger millet contains the lowest fat (Scott, 2015). Kodo millet is rich in calcium, dietary fiber, polyphenols, protein, vitamins, and minerals, and also contains significant amounts of essential amino acids, particularly sulfur-containing amino acids, and also has higher fat content than maize, rice, and sorghum (Chauhan et al., 2018).

5.3 Ecological and agricultural importance of millets

Formerly millets were an important food crop but it is promoted as the important food of the future due to the detrimental impacts of changing climate which are most pronounced in vulnerable ecosystems, they are described as a miracle crop and climate-smart crop because of their numerous advantages contributed to agro-diversity, low nutrient requirements, greater C sequestration (C_4 plant), ability to prevent erosion in arid regions (Memmott et al., 2021). Millet is also a drought-stand crop resistant to heat stress and can survive at very low soil moisture content, water logging tolerant species have been observed as finger millet and proso millet. Their yield is limited by multi-environmental stresses and the looming climate change (Numan et al., 2021).

Table 2: Important millets and their medicinal values (Kumar *et al*., 2021)

Millets	Medicinal values	References
Finger millet	It helps in lowering blood sugar level and cholesterol, sprouted seeds improve hemoglobin level in infants, increase the synthesis of collagen, tryptophan lowers appetite and keeps weight in control, high amount of calcium strengthens bone and high amount of iron protects from anemia, Suitable diet for lactating mothers, and infants. The rich amount of dietary fiber and gluten-free property maintains blood sugar levels and is more suitable for diabetic patients.	(Chandra et al., 2016; Kk, 2023)
Proso millet	The high amount of copper facilitates the body to form red blood cells and helps maintain healthy bone, nerves, and immune function. Sufficient copper in the diet prevents osteoporosis and cardiovascular diseases.	(Devi et al., 2014; Kumar et al., 2021)
Foxtail millet	The High amounts of protein and essential amino acids in foxtail millet can help in building body tissues. reduced bioavailability of calcium, magnesium, zinc and iron, reduce toxicity.	(Dayakar Rao et al., 2016)
Kodo millet	The presence of magnesium and potassium control blood pressure and relieve heart disease. Phenolic compounds have antioxidant properties and lower blood sugar levels and cholesterol.	(Kumar et al., 2021)
Barnyard millet	Barnyard millet rich in dietary fiber, iron, zinc, calcium, protein, magnesium, fat, vitamins, and some essential amino acids, and ideal for anemic patients, High amounts of dietary fiber reduce the risk of colon cancer. Phosphorous helps in bone growth and development in kids.	(Kumar et al., 2021; Renganathan et al., 2020)
Pearl millet	Pearl millet is a rich source of iron that helps prevent iron deficiency, especially in pregnancy, gluten-free property makes it suitable for celiac diseases, and it helps in lower cholesterol.	(Kk, 2023)

5.4 Ethnobotanical importance of millets

Millets are often used to make bread porridge and other traditional dishes in Asia and Africa. They play many important cultural, traditional, and medicinal roles in many regions of the world. In traditional Chinese medicine, millets are used for digestive problems, urinary tract infections, and insomnia. In India millets are used in Ayurvedic medicine, and religious and cultural practices for example millets are used in offerings to gods and goddesses during festivals and other ceremonies (Tripathi & Vyas, 2023).

6. Future Prospects

Most importantly millets provide food and economic security in areas with challenging environmental conditions such as climate change and global warming (Memmott et al., 2021). In present days climate change is an inducible fact, changes in precipitation patterns, rapid melting of glaciers, and rise in temperature will drastically shrink or reduce the yield of major staple food, millets are a wonderful alternative to fight the battle against climate change, for their adaptation to a wide range of environmental conditions (Kumar et al., 2018). Growing millets can maintain the productivity of arid land and guarantee future food and national security. Millets are an unexplored source of nutricereal, they hold vast scope to study and research for scientific rationalization of their health-healing properties. Millets can also transform into superfoods using various Agri-processing and other modern technologies like genomics, bioinformatics, biotechnology, and nanotechnology (Kumar et al., 2021). Yet millets are not common to our diets so incorporating them into various food products can reduce the chance of various life-threatening diseases such as obesity, diabetes, osteoporosis, cardiovascular diseases, and even age-associated diseases (Kumar et al., 2021). Millets have high nutritional value, which can help to eradicate nutritional challenges(Kumar et al., 2018). The promotion of millet cultivation maintains a sustainable production system and helps to attain sustainable development goals (SDGs) mainly SDG 2(zero hunger), SDG 3(good health and well-being), SGD 12(sustainable consumption and production), and SDG 13 (climatic action) (Tripathi & Vyas, 2023).

Conclusion

The above review paper "Millets: The Future Food" shows the characteristics, geographical distribution, and

importance of millets. Millets are known as nutricereal, climate-resilient, dry land crops, that can adapt to a wide range of climatic conditions. Several millet species are cultivated all over the world. Millets are also drought-resistant and can be grown in drought conditions.

Author contributions

The review was written and enriched by DK, NT and SU. All authors read, edited, and approved the final manuscript.

Conflict of interest

No

Declaration

The authors declare no conflict of interest.

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