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Review Article

Millets for Food Security: Reviving Nutri-Cereals for a Sustainable Future

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ABSTRACT

The fact that a substantial portion of India still lives below the poverty line and cannot afford enough nourishing food twice a day raises serious concerns about our nation's current policies, both domestically and internationally. First of all, the main causes that are identified include unemployment, which makes their lives in misery, unchecked government policies that deprive poor farmers of the value of their crops, the conversion of agricultural lands into industrial areas, and many more.The government undoubtedly has a lot of plans to deal with all of this, but in the conflict between the crooked and the impoverished, the corrupt appear to be winning for the time being. It goes without saying that the government's top priority should be to ensure that no one dies from starvation. Despite producing enough food to meet its own requirements, India's inflationary pressures on food prices are a striking tale that affects everyone, but especially the poor. The long term viability of India's existing level of self-reliance is also in doubt because of the country's growing population and shifting dietary patterns. The consequences of climate change and the quantity of land required to grow food grains are two other significant problems. Millets are an environmentally friendly food source that can aid in the fight against hunger. These offer an extra benefit in addressing nutrient deficits in third-world nations because nutrients are abundant in them. The grains are resistant to pests, diseases, and climate stress, and are easily stored for an extended period of time.

Keywords: Food Security, Millets, *Pennisetum typoides*, *Sorghum bicolor, Eleusine corocana, Panicum miliaceum, Setaria italica, Paspalum scrobiculatum*

INTRODUCTION

One of humanity's most fundamental rights is the right to nourishment. But hunger is still far too common, and many of the current food production systems are just not sustainable. With the rise of the population of nine billion on the earth by 2050, crop production must increase by 70% to satisfy the demand. Climate change is one of the main factors influencing food production and increasing food prices. It is the leader of variations in rainfall patterns, growing seasons and also the rise in events like floods and water shortage. According to the United Nations Environment Programme, land degradation, water scarcity, and climate change might cause up to 25% of global food production to disappear by 2050.[1]

Numerous organizations globally are striving to discover methods for sustainably producing the food required, while adhering to the ecological limits that can support both present and future generations. [(1)] Approximately 200 million children under five years old suffer from energy and protein deficits. Some developing nations have taken advantage of opportunities brought about by trade liberalization and strengthened their position in the market. Some nations with limited resources, however, have not been able to do so. These nations have benefited greatly from their involvement in the Doha Round of the World Trade Organization [1].

Security of Food Supply

Food security, according to the FAO, is "when everyone always has access to enough safe, nourishing food to sustain a dynamic and healthy life." The three elements of food security are "availability, access, and use of food," according to the World Health Organization. The phrase "availability of food" refers to the steady supply of adequate amounts of food, and the financial and material means to buy the right foods for a healthy diet is known as food access. The proper use of food is determined by an understanding of fundamental nutrition and care, as well as by access to enough water and sanitary facilities [1].

Proper nutrition is attained when all physiological requirements are met through a balanced diet, access to clean water, effective sanitation, and adequate medical care. For a population, household, or individual to be deemed food secure, they must consistently have access to sufficient food. Consequently, the aspects of availability and access regarding food security can also be referred to as stability. To achieve nutritional demands, a person should have enough money to purchase appropriate, safe, and nourishing food [1].

MILLETS

Millets are forage grasses and small-seeded cereals that are fed to livestock as well as humans. Since 2700 B.C., they have been cultivated in China and are resistant to drought. Eastern Asia is most likely where they first appeared. In terms of total output and cultivated area, India is the world's leading producer of millets. Besides India, millets are also widely cultivated in Russia and various African countries [2].

The government acknowledged millets as nutri-cereals in April 2018 because they are high in vitamins and minerals. In March 2021,

the UN General Assembly declared 2023 to be the International Year of Millets, and India's motion was endorsed by 72 nations. The government has created three Centers of Excellence (CoE) and is promoting nutri-cereals through research and development assistance [3]. Approximately 90 million individuals in Asia and Africa currently consume millets. Over 55% of the world's production comes from Africa, with Asia coming in second with over 40% and Europe representing about 3% of the worldwide market [2].

Millets have been cultivated for thousands of years in Asia and Africa, among other parts of the world. It, once thought of as "poor man's food," is now acknowledged as an essential source of nutrients, specifically when taking food security and sustainable agriculture into account [4].

BIOLOGICAL DESCRIPTION AND ECOLOGICAL PERSPECTIVE OF SOME IMPORTANT MILLETS

Pearl Millet (*Pennisetum typoides*)

The most significant millet crop in India is pearl millet. It is the main grain in several regions of India, particularly Gujarat and Rajasthan. It is an annual plant with tall, linear, lanceolate, scabrous leaves with wavy margins and a sturdy, unbranched stem that reaches a height of one to two and a half meters. The inflorescence is a thick panicle that is roughly 2.5 cm in diameter and 8 to 16 cm in length. Each spikelet has two florets, the upper being hermaphrodite and the lower being typically male [2].

Because of its tasty and nourishing grains, it is produced practically everywhere in the nation, with the exception of Assam. During 2007-08 total area under pearl millet cultivation was 9.5 million hectares, nearly one-third of the entire acreage in the world under pearl millet cultivation [2].

It is a fast-growing crop that takes about 90 days to reach maturity. It can withstand heat and drought and has a high tillering rate. It is grown as a rainy season crop during kharif and as a summer crop under irrigation. Red and medium black soils, as well as sandy soils, can all be used to cultivate the crop. Sandy loam soil is ideal for its growth. The best condition for its growth is warm, dry weather with sporadic showers and bright sunshine [2].

Numerous better cultivars of pearl millet have been developed as a consequence of extensive breeding efforts conducted at different centers. Apart from their substantial potential output, these cultivars possess other appealing characteristics, including early maturity, resilience to disease, and a compact growth pattern. The most significant types of pearl millet that are cultivated throughout India are MH-179, PCB 138 in Punjab, T55, A 1/3, S.350, S.28 in Uttar Pradesh, RSK, RSJ, CM 46 in Rajasthan, Co 1, Co 2, Co 3, Co 4, Co 5, K 1 in Tamil Nadu AKP 1, AKP 2, Akanath 101, 14, Akanath 201, Balaji composite, BJ104, BX- 560, CHB CMS7703, ICH 501, MBH -110, WCC 75in Andhra Pradesh, etc.[2].

Sorghum (*Sorghum bicolor*)

In rainfed cultivable areas, sorghum is a significant crop. It was grown in Egypt prior to 2700 B.C. and is a major crop there now. The northeastern region of Africa has the most variation in both wild and cultivated sorghums. However, Linnaeus believed that sorghum originated in India. Many African nations (Nigeria, Somalia, Sudan), as well as the United States, China, India, Pakistan, and the Arab world, now cultivate it extensively. Sorghum output in India is among the highest in the world. Prior to the Green Revolution, sorghum was India's second-largest grain crop. It lost 346.4 thousand hectares between 1960 and 1990 and fell to third place behind wheat and rice [2].

The plant is an annual herb with alternating, sheathing leaves that grows to a height of 14.5 meters. A loose or thick panicle, referred to as the head, is the inflorescence. The spikelets are grouped in clusters, twos, or threes, with one being hermaphrodite and sessile and the others being sterile or staminate. The grain is circular, tiny, and has a pinkish-white hue. Sorghum is cultivated as a rabi and kharif crop in India. The ideal rainfall range for the crop is 40–100 cm per year. Farmyard manure is applied sparingly, and the field is prepared to a reasonable degree. Typically, grains are seeded 30 to 40 cm apart in rows. It is typically planted as a stand-alone crop or combined with safflower, vegetables, and legumes. The enhanced types typically reach maturity in 140 days. Threshing and harvesting are done by hand or with the help of bullocks. Before being stored, the harvested grains are sun-dried [2].

The primary goals of sorghum breeding are to increase protein levels, starch digestibility, and to increase oil content to provide a better calorific value. Co.4 to Co.10, Co.13, Co.14, Co. 23, Maldandi 35, Budh Perio 53, SPV 492, SPV 475, and Vidisha 60-1 are some improved sorghum varieties for grains. For fodder, there are Pusa chari (IS 6090), Haryana chari (JS 73/53), SL 44, and Meethi sudan (SSG 59-J) [(2)].

Additionally, 20 lines of high energy sorghum (HES) have been found with exceptional agronomic features, high total soluble solids, high juice extractability, moderate to high degrees of resistance to stem borer and shoot fly, and high biomass production potential

Finger millet (*Eleusine corocana*)

Finger millet is a tropical crop that grows well in a variety of climates and moisture levels. It is most likely native to Africa. For the tribal people of Ethiopia, Somalia, and East Africa, it is a staple crop. It is frequently grown in the 50 to 100 cm rainfall area of the tropics and sub-tropics on hilly lateritic soils. In Africa, it stretches from Nigeria to Ethiopia in the east and to Natal and South West Africa in the south. To a lesser degree, it is also grown in Malaysia and Sri Lanka. Four million hectares of the crop are cultivated in Karnataka, Andhra Pradesh, Tamil Nadu, Maharashtra, Bihar, Odisha, and the Himalayan foothills in India [2].

Approximately 75% of India's total production comes from this crop, which is grown from the eastern Ghats slope to the Deccan plains' border. The plant is an annual herb that grows to a height of 1.0 to 1.25 m. Its main stem has several tillers. A common place on a peduncle is the origin of the inflorescence's four to six thick spikes. Finger millet gets its name from the spike's similarity to a finger. Except for the terminal blossom, which could be sterile or staminate, all of the flowers are flawless. The tiny, spherical grains have a dull red hue [(2)].

Finger millet is typically produced on loam, red laterite, and black soils as a rainfed kharif crop. In South India, it is sown all year round as an irrigated crop, although it is sown in May or June. Sorghum,

green grams, sesame, or groundnuts are alternated with rainfed crops. The crop takes 130–140 days to reach maturity. The ears are removed, and it is trimmed near the ground. The cattle's feet do the threshing. Harvesting occurs between the 50% blooming and dough stages for high-quality green fodder. When the crop is left on the field after the ears are removed, the quality of the fodder declines [(2)].

Potential traits for choosing superior lines for ragi grain yield include ear weight, productive tillers, and straw weight and land harvest index. Sarada, EC 4840, EC 28, EC 593, AR 525, AR 325, EC 1540, K. I, H.22, PR 202 (Godavari), PR 722, HR 911, HR 374, PES 110, PES 176, PES 400, Indaf 5, Indaf 8, JNR 852, JNR 1008, RAU 8, and VL 204 are a few of the enhanced finger millet types currently being grown[2].

Foxtail millet (*Setaria italica*)

A high-yielding, drought-resistant millet that has been grown for ages, is foxtail millet. It is said to have come from eastern Asia, most likely China. It is extensively grown in North America, South and East Europe, China, India, Japan, and South Africa. In India, it is a significant crop in the highlands of Tamil Nadu, Karnataka, and Andhra Pradesh, as well as the lower Deccan plains [2].

The plant is an upright, frequently sturdy, tufted annual with culms that are fasciculate and clearly joined, growing to a height of 0.6 to 1.5 m. The linear, lanceolate leaves are 15–45 cm in length and 0.75–3.3 cm in width. A loose spike is formed by the arrangement of the flowers. The higher florets are hermaphrodite, while the lower florets are barren. The spikelets are broadly oblong to elliptic. The grain is smooth, shiny, globose ellipsoidal, and comes in a variety of colors [2].

It can be produced all year round and is mostly a rainfed crop. When there is insufficient rainfall, it is commonly planted in black cotton soils as a substitute crop for sorghum. It is often planted in June or July, when the south-west monsoon season begins. In 90 days, the crop reaches maturity. Fields are prepared modestly and frequently fertilized with animal manure 20. G.1, W.1, H.1, H.2, Co.1, Co.2, Co.3, Co.4, Co.5, Navane 1, Arjuna, Chitra, SiA 326, SiA 36, and ISC 377 are some of the improved foxtail millet types grown in India [2].

Proso millet (*Panicum miliaceum*)

Proso millet is an ancient grain crop that is also mentioned as ordinary millet. Since the plant is unknown in its wild state, its origin is uncertain. However, some have proposed an eastern Mediterranean or Indian origin. It is the Romans' actual millet, or milium. Central or eastern Asia is where it was initially domesticated. It is now extensively grown in parts of the Middle East and Europe, as well as Russia, China, Japan, and India.

It is primarily grown south of the Krishna River in Southern India. It is also grown in isolated areas of northern hill country and central India [2]. The plant grows yearly and to a height of 0.5 to 0.9 meters, with an open, branching, compact, or one-sided panicle. The spikelet's scales closely encircle the grains, which come in a variety of colors. It is only cultivated on poor soils as a late monsoon crop. Seeds are either drilled or dispersed. The crop takes 90–100 days to reach maturity. Plants are uprooted or cut near the ground and threshed right away when the crop is a little immature (because ripe grain sheds rapidly from ear heads) to prevent grain loss due to shedding [2].

Grain yields average 900–1,000 kg/ha. N was 2.78, HCL fat was 3.70, starch was 74.65, sugar was 0.93, ash was 0.93 g/100 g, and energy was 451.5 Kcal, according to the dry basis analysis of the dehusked grains [2]. Some of the improved varieties include Pv. 14, Pv. 36, Pv. 1595. In rainfed highland regions, certain cultivars, such as MS 4872, PV 1685, and K 1, are appropriate for higher yields. They vary in length, growth time, vegetative traits, and the color of the glumes that encase the grain [2].

Kodo Millet (*Paspalum scrobiculatum*)

It is a minor cereal. It is widely grown in the country's southern regions. They are extremely coarse grains. The husks and young grains form an arc. The crop, which thrives in rain-fed areas, is extremely drought-tolerant. In late June, shortly after the monsoon season begins, the crop is sown. It is a member of the Poaceae family [6]. It is a crop that grows every year. Numerous tillers that are 50–75 cm tall are produced by the plant. The leaves (upto 18) are either lanceolate or linear. Two to eight spikes form a panicle in the inflorescence. Two series of spikelets alternately organize themselves. Self-pollination occurs in the plant. It takes 35 days for the grain to flower before it is completely mature. It is a single-seeded caryopsis grain [5].

Little Millet (*Panicum miliare*)

It is grown in Burma, Southeast Asian nations, and Pakistan. Due to its extremely small grain size, the crop is restricted to little millet. India is the primary country where the crop is grown.MP and U.P. are the chief growing states in India. Even very poor soils can support the plant's growth. The crop endures waterlogging and is extremely resistant to drought [5]. GPUK 3, RBK 155, RK 390-25 are some of the varieties grown in Karnataka and TNAU-86KMV, etc., are the varieties grown in Tamil Nadu [6].

Barnyard Millet (*Echinocloa frumentacia*)

Barnyard millet, an annual weed found in rice fields and moist regions of Africa, Asia, and America, is thought to be the ancestor of the Japanese barnyard millet. China, Japan, Korea, Malaysia, Indonesia, India, some regions of Africa, and the United States all grow this millet. The southern states of our nation are where the majority of the crop is farmed. The plant is cultivated for both fodder and food. The crop ripens in 45 days and expands rapidly [5].

It is a herb that grows every year. It reaches a height of four feet. Its tillers are scarce. There aren't many leaves on the thin stem. An extended panicle with up to fifteen branches makes up the inflorescence. Every spikelet has one beautiful blossom and one stele. It is cultivated as a rain-fed crop in warm climates. On the banks of rivers, the crop can even be grown on submerged soil [5].

ADVANTAGES OF DIFFERENT MILLETS FOR NUTRITION AND HEALTH:

All millets are known to provide health benefits, but because they include variable amounts of proteins, fats, carbs, dietary fibers, vitamins, minerals, and other components, their nutritional value and health benefits tend to vary. The following are some health and nutritional advantages of various millets:

Pearl millet

It has the same nutritional value as wheat and rice. To make bread, grains are pounded into flour. It can also be eaten after drying out or added to oatmeal. Malt can also be made from grains. Green fodder is another reason it is grown. Straw is used as fuel, for thatching, and as roughage for animals. Pearl millets are high in protein and energy. The grain contains 67% carbohydrates, 11.6% proteins, 5% lipids, 2.7% mineral matter, and 12.4% moisture [2,7].

It contains 11.5% dietary fiber, which lowers the risk of inflammatory bowel disease by slowing down the speed at which food passes through the digestive system. Niacin content is highest in pearl millet out of all the grains.[8] Minerals like potassium, phosphorus, magnesium, zinc, iron, manganese, copper, and vitamin B are also abundant in them. High fiber content can help to address health issues, including obesity and constipation [8-10]. Pearl millet's phylates and polyphenols help prevent metabolic disorders and slow down aging. Furthermore, it is known that the phenolic chemicals found mostly in pearl millet, such as ferulic and p-coumaric acids, have anti-cancer qualities [11].

Sorghum

Sorghum grains are very nutrient-dense. They can be used to make sweets, cereal, or bread. In Africa, sorghum and common beans (*Phaseolus vulgaris*; 40:60) are combined to make tempe, a fermented food that is used as an additional meal to alleviate anemia and malnutrition. Crystalline sugar and jaggery can also be made from sweet sorghum. Grain germination produces sorghum malt. It works well as cattle feed as well. Only the edible and juicy stalks are used as feed [2].

In addition to a number of minerals and vitamins, the grain has 70 carbohydrates, 2.8 to 3.2% lipids, 10 to 13% moisture, and 9 to 10% and proteins 80%[2,7]. Calcium, iron, potassium, copper, phosphorus, salt, zinc, dietary fiber, protein, and vitamins (mostly B) are all abundant in sorghum. Because of its high content of dietary fiber, it is an excellent option for those who suffer from obesity and digestive issues. Because vital elements like iron and copper improve the growth of red blood cells, they increase blood circulation and prevent anemia. The complex carbohydrates in sorghum have antidiabetic qualities because they break down slowly and assist to keep blood sugar levels steady. Furthermore, it possesses anti-carcinogenic properties and could reduce the incidence of esophageal cancer [11].

Finger millet

Finger millet is a highly sustaining and nutrient-dense crop. Typically, it is pounded into flour and used to make cakes, puddings, porridge, and breads. Additionally, the grains are utilized in malting and the manufacturing of alcoholic beverages. They are astringent and tonic, beneficial for biliousness and a healthy snack for diabetics. Grain with high fiber content prevents bowel cancer, total cholesterol level and fecal impaction [2,13].

Finger millet has an average protein level of 8 to 9% and a well-balanced essential amino acid composition, including phosphorus, vitamin A, and vitamin B [7]. Among all the millets, they are an excellent source of calcium and are known to help older adults regain optimal bone density, which strengthens bones and reduces the symptoms of osteoporosis. Because finger millet contains dietary fiber and phenolic chemicals, numerous studies have demonstrated its anti-inflammatory and antidiabetic benefits.[12,14-16] Because it contains calcium and iron, it has enormous advantages for pregnant and nursing mothers, including promoting milk production, regulating hormone balances, and preventing anemia. Finger millet's high quantities of the amino acid tryptophan may help with chronic and non-communicable diseases, lifestyle issues, and nervous system function [4].

Malted ragi, malted horse gram (*Dolichos biflorus*), and roasted peanuts are combined to provide a cheap and wholesome weaning snack [65:25:10]. Vaginal bleeding is lessened by drinking a decoction of leaves and stems. The resistant starch included in cooked (freeze-dried) finger millet contributes significantly to dietary energy, promotes growth, and increases fat deposition. The straw makes a nice feed for cattle [2].

Foxtail millet

The thin, green straw is a valuable source of feed for cattle. The dehusked grain contains (dry basis): Caloric value: 4112 Kcal/kg; nitrogen: 2.57; HCL-fat: 4.58; starch: 72.07; sugar: 4.38; ash: 1.42%. The plant is also used medicinally as a sedative for gravid uteri [2].

Millet from foxtail helps regulate blood sugar levels, increases hemoglobin levels, and prevents anemia. Moreover, it contains antioxidants that combat oxidative stress and reduce the incidence of chronic illnesses. They are perfect for those with diabetes and cardiovascular disorders since they have a low glycemic index and contain chemicals like alpha-glucan that speed up the metabolism of sugar and cholesterol [4, 8, 16, 17].

Proso millet

The dehusked grains contain phytochemicals and many micronutrients, including iron, zinc, copper, and manganese. Therefore, adding it to the regular diet could help people who are deficient in certain nutrients. It has high lecithin content, which is crucial for the general health of the nervous system. They work well to prevent some types of cancer, including liver, breast, hormone-dependent, and colon cancer [4, 7, 8, 18, 19].

Kodo millet

Kodo millets are of nutritional and health advantages due to their high protein, carbohydrate, mineral, crude fiber, polyphenol, and antioxidant content. It has high fiber content (14.3%), little fat content (4.2%), and substantial protein content (11%). In addition to niacin, pyridoxine, and folic acid, kodo millet is rich in minerals like calcium, iron, lecithin content, potassium, magnesium, and zinc. It helps to strengthen the nervous system [6].

For postmenopausal women with high cholesterol and cardiovascular disorders, kodo millet is beneficial [6,18,19]. Because of its high phytochemical and antioxidant content, kodo millet is useful in preventing oxidative stress and lowering the risk of a number of illnesses, including cancer.

Little millet

Little millets are rich in protein, fiber, iron, magnesium, zinc, phosphorus, and a considerable amount of vitamin B. This is a healthy diet to combat pollutants and boost immunity for general health because of its strong antioxidant content. Apigenin, one of

the several bioactive compounds in small millet, has antidiabetic and anti-cancer qualities [20]; luteolin, which has anti-inflammatory and antioxidant [7,8,20].

Barnyard millet

It has the highest concentration of dietary fiber and iron. Beta-glucan and gamma-aminobutyric acid (GABA), an antioxidant that decreases blood cholesterol, are also found in its grains [7]. Barnyard millet is low in carbohydrates, high in protein, iron, dietary fiber, and phosphorus, and it helps to keep the heart healthy by controlling blood pressure, cholesterol, and blood sugar levels. It also aids in preventing celiac disease because it is gluten-free.

The low glycemic index and polyphenol compounds, which slow down the digestion of sugars and avoid a blood sugar spike, give them antidiabetic qualities.

Because they contain iron and fiber, respectively, they are believed to combat anemia and aid in the management of gastrointestinal issues like constipation, bloating, and acidity. Barnyard millet has a vanillin component that may lower the risk of cancer, particularly breast cancer [8,23].

FUTURE PROSPECT

Millets may be able to help fight malnutrition, particularly in areas where staple grains are deficient in vital elements. Its high quantity of iron, zinc, and protein can help cure dietary deficiencies, especially for vulnerable groups like children and expecting mothers. Public health could be enhanced by incorporating millets into school meal programs and government nutrition programs [24].

CONCLUSION

Millets have a C4 photosynthetic system, which helps them to survive high temperatures and low moisture. Most millet is grown in India, which is the world's largest producer. Millets are 3–5 times more nutrient-dense than most other grains in terms of vitamins, fiber, proteins, and minerals (calcium and iron). Millet is a good addition to diets because it is a good source of essential nutrients.

It has a shorter growing season, uses less water to develop, and can withstand drought. Their resilience to drought and reduced susceptibility to weather-related catastrophes make them a safe source of income for farmers. There is very little initial capital required to manufacture millet. Once thought of as "poor man's food," millets are now acknowledged as an essential source of nutrients, especially when considering sustainable agriculture and food security. When most other important crops fail, these can survive in the 21st-century climate's unusual weather circumstances. These are rich in nutrients, hence helps in overcoming food instability and malnutrition. World food security is in danger, so it is imperative that current millet crops be used effectively to provide a product that is affordable, delicious, and nutrient-rich.

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