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Transfarming agriculture in Bundelkhand through rainbow revolution...

Healthy millets: Mighty Millets

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From Vice Chancellor's Desk.....

Millets, a family of coarse grains and popular staples, are getting popularity at global level as these crops are nutritionally rich and climate resilient. Prime Minister Shri Narendra Modi recently inaugurated a global conference on millets, extolling them as the "door to prosperity" for India's marginal farmers, the "cornerstone of nutrition", and as a potential ally against "climate change". The United Nations declared 2023 as the "International Year of Millets" amidst climate uncertainty and the need to reduce agriculture's carbon footprint.

Millets such as sorghum, bajra ragi and others are strongly linked to Indian dietary traditions, which is why the country has for long been the largest producer of millets in the world. It is no surprise that this cereal family is popular because it is energy dense, can be grown with ease in arid soils, and relatively to other major cereals, is less susceptible to pests and is a store house of nutrients.

With average global incomes having risen, there is rising demand for 'sustainable agriculture', India is looking to market millet as a global panacea. However, competing with the rice-wheat-maize, which according to the Food and Agriculture Organization constitute 89% of global cereal production, means that millet production must be many times more than now. Hybrid varieties of jowar and bajra exist, and improved varieties of other nutri-cereals have also been developed however it would be challenging to realise gains in yield. Dietary shifts are slow processes and promoting millets only as nutritionally rich, may not be accepted by farmers until and unless it competes economically with other crops.

The present issue of Agri-Life, entitled, **"Healthy Millets: Mighty Millets"** is an endeavor to invite scientists and researchers to showcase their ideas dealing with various production, cultivation, processing, value addition, nutritional, nutraceutical, value chain and policy aspects of millet cultivation. I hope this issue of Agri-Life would cover some of the critical questions about millet revival in the Bundelkhand in particular and country in general and will open new vistas for research with many key researchable questions that need to be systematically investigated to bring back millet crops to mainstream.

(A. K. Singh)
Vice Chancellor

Editorial

Healthy Millets: Mighty Millets

The Food and Agriculture Organization of the United Nations (FAO) has declared 2023 as the "International Year of Millets" at India's initiative. Millets have special nutritive properties (they are high in protein, dietary fibre, micronutrients and antioxidants) and special agronomic characteristics (drought-resistant and suitable for semi-arid regions). Major millets include sorghum, pearl millet and finger millet, while minor millets include foxtail, little millet, kodo, proso, and barnyard millet. India's Millet Revolution is driven by growing awareness of the health and environmental benefits of millets, as well as efforts to revive traditional agricultural practices and support small-scale farmers. Nearly six decades after the Green Revolution, it appears that the wheel with respect to the general perception on millets is coming full circle. After being reduced to marginal status during the Green Revolution years, millets are slowly regaining favor among policymakers and consumers. Faced with a food shortage in the 1960s, India opted for an input-intensive push that yielded huge productivity gains in wheat and rice. But now the times have changed; India is self-sufficient in wheat and rice output.

Millets, with their iron, calcium and zinc content, can make a big difference in combating micro-nutrient deficiency in India, besides diabetes and heart disease. Meanwhile, farmers growing millets can make do with 20 cm of rain annually, against 120-140 cm needed for rice. Millets are by default organic since the crop does not rely on chemicals and pesticides and its essentially small growers lack the resources to use them actually makes it a big draw in a world where organic produce is in demand. What is not working for millets is its poor prices, low productivity, processing difficulties and above all, insufficient demand. Prices will rise and infrastructure will come up if demand improves, even as research on hybrids is expected to lift yields.

Government agencies at the States and Centre are trying out two approaches to lift demand. At first, efforts are being made to raise rural demand through awareness campaigns, while also distributing millet-based meals through mid-day meal programmes in schools and anganwadis, an approach that is likely to boost market prices, particularly if there is a procurement process to back this up. The second approach is to lift urban demand through promotional campaigns. Ready to cook millets can work for the young in particular. It is possible that as urban demand picks up, it will challenge the decades-old notion of millets being a non-aspirational food meant for the downtrodden. The Centre has raised MSP for millets, but in the absence of procurement and demand (the former being weak because of the latter), prices have not picked up.

I am very pleased that this ninth issue of Agri-life with theme **"Healthy Millets: Mighty Millets"** will present an overview to the readers about the prospects and benefits of millet crops.

(Anil Kumar)
Editor in Chief

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Millets as Super Foods for Nutritional and Health Security

Meenakshi Sahu[1], Anil Kumar[2] and Rumana Khan[2]

Millets have gained attention for their nutritional and health benefits, making them a potential solution to achieve nutritional and health security. These small-grained, drought-tolerant crops are rich in essential nutrients, including protein, fiber, vitamins, and minerals, with low glycemic index. They offer numerous health benefits, such as managing diabetes, weight control, reducing the risk of chronic diseases, and promoting gut health. Millets also have superior environmental adaptability, contributing to food and climate resilience. Thus, promoting millets as superfoods can enhance nutritional and health security, while ensuring sustainable agriculture and food production.

Introduction

For the origin of millets-Neolithic China, is been accepted but it still remains unspecified where the first domestication of common millet (*Panicum miliaceum*) or foxtail millet (*Setaria italic*) was done as well the era of its domestication along with travelling routes (dispersal) is also unknown. But is supposed to be excavated storage pits at the Neolithic Cishan site, China-dated between *ca.* 10,300 and *ca*. 8,700 calibrated years before present (cal. year BP). This data presents the phytoliths, bimolecular records through radiocarbon dating. After this time period, foxtail millet was found in quantity. Millets belong to the *Poaceae* family, they differ in color, appearance, and species. Many researches shows that millets are dry farming crops specially found in East Asia which is more probably excellently resistant to droughts and have the ability to survive in high temperatures with minimal water. Millet is a low maintenance and drought resistant grain and can be easily grown in dry conditions. Millets are a sustainable food source for combating hunger in today's changing global climate because they are resistant to climate stress, diseases and pests. Further, millets do not require much water or other resources, which makes them a long-term option for combating climate change and establishing climate-resilient agri-food systems for people.

Millets are said to have been first cultivated around 4,000 years ago in Asia and in the Middle Ages millets were the largely produced grains in Europe and the United States. Nowadays millets are cultivated and consumed around the global scale. Half of the population of Asia and Africa is dependent on millets, which are the customary and traditional grains. Millets are of group a small, round whole grains grown in India, Nigeria, and other Asian and African countries. Considered an ancient grain, they are used both for human consumption and livestock and bird feed. The United Nations, with the initiation of Indian government signified year 2023 is "*International Year of Millet* (IYOM)" to promote them as a solution to alleviating hunger.

Millets, which encompasses in a diverse group of cereals including pearl (bajra), little, proso, kodo, foxtail, barnyard, brown top and others, is an important source of nourishment and alleviating hunger for millions of people across Sub-Saharan Africa and Asia. In short, we can say that Millets, have several nutritional benefits and also ensures sustainable production. It has a low carbon and water footprint and also can be grown in adverse conditions. Prime Minister Narendra Modi stated that a once-in-a-century pandemic and upcoming future conflict have demonstrated that food security is still a global concern. "Millets have a glorious history of being among the most primitive earliest crops grown by humans," Modiji also stated in his address to the opening etiquette of the "International Year of Millets 2023," which was held at the headquarters of the Food and Agriculture Organization (FAO) in Rome, Italy. In the past, they were a prime source of food. However, there is an urgent need to provide them with a food option for the future. Modi also said while addressing, "A global movement related to millets is an important step since they are easy to grow, climate resilient, and drought resistant.

There is a need for diversity on the land and on our tables. If agriculture becomes monoculture, it impacts our health and the health of our lands. Millets are a good way to increase agricultural and dietary diversity," He also added to his speech. Jowar (sorghum), bajra (pearl millet), and ragi (finger millet) are the three main millet

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crops that are currently being grown in India. India is also a large producer of a wide variety of indigenous and biogenetically diverse "small millets" like kutki, kodo, sanwa and chena. Haryana, Rajasthan, Gujrat, Andhra Pradesh, Telangana, Maharashtra, Karnataka, and Tamil Nadu are the major producers of millet across the country. According to the report of PIB, the production of millets has risen from 14.52 million tonnes in 2015-16 to 17.96 million tonnes in 2020-21, which states about the consumption and production of millets on a large scale. There are three key actions, recommended to enhance the consumption of millets: providing knowledge on nutritional and health facts on millets, developing delicious products to satisfy the taste, and improving accessibility of millets in urban markets.

Initiatives steps taken by the government to promote millet consumption and production

The government raised MSPs for millets, providing farmers with significant price incentives. The government has also included millets in the public distribution system to ensure a secured and fixed market for the production. The government has made seed kits and other inserts available to farmers which help them in building value chains through Farmer Producer Organizations and make millets more marketable and available. The Ministry of Women and Child Development has been establishing various Nutri-gardens, promoting for research on connections between crop dietary and diversity, and running a behavior change campaign to enhance the consumer demands for Nutri-cereals.

As we know, grain, millets (magical millets) are from ancient times till today's new modern life styles. Now, therefore, Government of India has decided to celebrate IYOM, 2023 to make it peoples' movement so that the Indian millets, recipes, value added products are accepted globally. As an important movement for millets, the government is focusing on:

- Generating awareness regarding Health and Nutrition benefits i.e., "Eat Right Campaign".
- Promote the bio fortification of millets.
- Digital publication of Papers and articles on Millets.
- Awareness among mothers through Mothers Committees of Anganwaadi or likes.
- To commission studies by National and International reputed organizations (Task Force-II).
- Mid-Day Meal in schools & Anganwadis for at least one day a week.
- Buffets at hotels to have millet focus at least one millet dish in year 2023.
- Chefs to give online training modules- to build up, one platform for sharing dishes.
- Appeal to eat millets at least once or twice a week, food influencers to share best experiences with millets Promote "Vrat" recipes of millets and its compilation.
- Providing online platforms and delivery agents to popularize millets.
- Organize events in various groups (using NSS, NCC SHGs/FPOs), organizations, schools, colleges, universities, industry and civil societies.
- FSSAI to develop the standards.
- Organize monthly -Millet Challenge, by preparing various recipes.

Millets are directly affecting the human health if consumed in a proper manner. They have proven as a boon for the humans since ancient times till date. The various types of millets are advantageous for the different diseases and concerned health issues respectively. The blessings of these millets are as following:

Millets are a mainly versatile group of *small-seeded grasses*, which are widely grown around the world as cereal crops or grains for human food and fodder. Millets are highly *coarse-grains such as Ragi, Bajra, and Jowar etc*. They are filled with high amount of nutritious valuable nutrients and are generally used by rural populations. There are around 6,000 varieties of millet throughout the world wide. Some of them are Proso (Chena/Barr), Finger Millet (Ragi or Nachni), Fonio Millet, Sorghum (Jowar), Barnyard (Sanwa), Little Millet, Pearl Millet (Bajra), Kodu (Arke), Brown top (Sama), Amaranth Millet, Guinea, Foxtail Millet (Kora) and two Pseudo Millets (Buck-wheat (Kuttu) and Amaranthus (Chaulai).

There are two categories of Millets, listed below:

Husked grains - these are basically indigestible seed coated, which has to be removed before cooking, they require a separate hulling process to make it husk free before consumption. This process was earlier done by hand now it is carried out mechanically. Ideal examples of this category are- kodo, foxtail and Little Millets.

Naked grains –these millets are devoid of indigestible and hard husk. Examples of these millets are: bajra, ragi, jowar. This category millets do not require any processing after harvesting. They can be consumed followed by washing and cleaning, this is the main feature of such millets and so therefore are cultivated in today's date, widely.

Several health advantages of consuming millets (Superfood): Millets are high protein bundles, full of fibres, contains essential vitamins, and packets of minerals. They are chiefly acclaimed as a nutritional powerhouse for the beings. It supports immunity, helps in weight reduction, and overall health benefits. Being high in nutrient values such as dietary carbs, fiber, proteins, and healthy fats, as well as minerals like calcium, iron, magnesium, manganese, zinc, potassium, and phosphorus. Millets also step towards fitness and maintain energy levels, which also boost the immune system because they offer low-calorie content. Millets have also been shown to alleviate asthma, lessen migraines, and drain out toxins from our bodies, allowing our organs to work optimally.

Nutritional values: Like most cereals, millets are starchy grains and protein-rich grains but less as compared to other cereals - meaning that they're rich in carbs. Notably, they are also packed with several vitamins and minerals. Millets supplies more essential amino acids than most other cereals, which are essential for building blocks of protein. One cup (174 grams) of cooked millet pack contains: Calories: 207, Carbs: 41 grams, dietary Fiber: 2.2 grams, Protein: 6 grams, Fat: 1.7 grams, Phosphorus: 25% of the Daily Value (DV), Magnesium: 19% of the DV, Folate: 8% of the DV, Iron: 6% of the DV, zinc B Vitamins, Manganese, Potassium, Copper, Selenium and much more. They are the powerhouses of anti-oxidants, flavonoids, anthocyanins, saponins, and lignans, which all contribute to impressive health benefits. Moreover, finger millet boasts the highest calcium content of all cereal grains, providing 13% of the DV per 1 cooked cup (100 grams) .Calcium is important to ensure bone and teeth health, blood vessel and muscular contractions, and proper nerve functioning. They provide plenty of phosphorus and magnesium.

Benefits: Millets have a wide range of health benefits, including helping to lower our blood sugar and cholesterol levels. They are also gluten-free, so can be easily consumed and digested by people with celiac disease or gluten sensitivities and intolerances. Millets have procured popularity in western countries because of their gluten-free property and boast high protein, fiber, and antioxidant contents. They have multiple superiorities over the other crops, including drought, pest resistance and ably can survive in harsh environments and less fertile so, as well less or no biofertilizers are required. These benefits root millets from their genetic composition and physical structure — for example, its small size and hardness make them suitable to survive in extreme environment.

Millets are rich in nutrients and plant compounds. Therefore, they may offer multiple health benefits, are listed as follows:

Millets have a low glycemic index of 54-68. The presence of a high value of dietary fibres and proteins-containing all essential amino acids, minerals, vitamins and healthful fats, which altogether helps in stabilizing a balanced blood sugar level.

Rich in antioxidants: Millets are great bundles of phenolic compounds, especially ferulic acid and catechins, which are an excellent source of acting as antioxidants to protect our body from harmful oxidative stress. Some studies exhibit, in mice, link ferulic acid to rapid action of wound healing, skin protection, and anti-inflammatory properties**.** While other antioxidants, catechins bind to heavy metals in our bloodstream to prevent metal poisoning and other likely effects. Some studies reveals that all the millet varieties contain antioxidants, but those with a darker color, such as foxtail, finger and proso millets — have more antioxidants than the white or yellow counterparts.

May help control blood sugar levels: Millets are highly rich in fiber and polysaccharides (non-starchy), two types of indigestible carbs that help control blood sugar levels .These cereals also have a low glycemic index (GI), meaning that they are unlikely to spike blood sugar levels. Thus, millets are considered as a supreme food grain for people suffering with diabetes. Meanwhile, a study revealed with 105 people with type 2 diabetes determined that replacing a rice-based breakfast with a millet-based one lowered blood sugar levels after the meal. On the other hand, a study in 64 people for 12 weeks with pre-diabetics gave similar results. The study says that after eating 1/3 cup (50 grams) of foxtail millet per day, those people experienced a slight reduction in fasting and post-meal blood sugar levels, well as a decrease in insulin resistance. Insulin resistance is an important marker for type 2 diabetes, which occurs when our body stops responding to the hormone insulin,

which helps to regulate the blood sugar. All these studies mention us the importance of millets for the diabetes suffering population and how they are proven as a blessing for human health.

Metabolic effects of millets on humans: The prevalence of metabolic syndrome, which consists of a group of metabolic abnormalities associated with increased cardiovascular risk, has been on the rise in India. Unbalanced dietary habits have contributed to this. The cereal millets are thought to have beneficial properties in combating this illness. Hence, this study set out to compare the effect of millet versus non-millet-based diets on the parameters of metabolic syndrome.

Fights against the cancer cells: Millets such as porso and foxtail varieties are 'proven by researches to be effective in impeding the growth of cancerous and likely cells in various tissues. Phytochemicals in millets exhibit antiproliferative effects and lower the development and formation of cancer cells in the colon, breast, and liver without harming and causing any vandalization to normal cells.

May help lower cholesterol: Fibres in millets are soluble in nature, which produces a viscous substance in our gut. In turn, this traps fats and helps in reduction of cholesterol levels. A study of 24 rats found that those rats fed with porso and foxtail millet had significantly reduced triglyceride levels, compared with the control group. Adiponectin is a hormone which helps with an anti-inflammatory effect that supports heart health and stimulates the fatty acid oxidation as well maintains their regulation in a proper channel. It is found in a lower level usually people with obesity and type 2 diabetes. Additionally, the millet proteins are authorized to help in lower cholesterol maintenance.

Hyperlipidemia: However, the effects of millets on hyperlipidemia (high lipid levels) have been insufficiently known. A synchronized meta-analysis and review were conducted to collate availability for the evidence regarding the impacts of millets consumption on lipid profile, called as- total cholesterol (TC), triacylglycerols, very-low–density lipoprotein cholesterol (VLDL-C) or Intermediate- density lipoprotein (IDL), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), and or ultra-lipoproteins. Many of other studies make symbolic evidence which leads us to conclude that consumption of millets raises the levels of HDL-C (good cholesterol), reduces hyperlipidemia and controls hypertension, which can be helpful for managing the associated threat of developing hypertension and atherosclerotic cardiovascular diseases in ahead in life.

Fights and defeat the heart problems: Millets are loaded with an impressive silhouette of antioxidants such as tannins, lignans, beta-glucans, anthocyanidins, flavonoids, and policosanols. These are good antioxidants which play a crucial and vital role in lowering LDL cholesterol, total cholesterol and helps to maintain the blood vessels healthy as well clears off the clots, thereby defeating and lowering the risk of heart diseases, and strokes.

Regulates the hormones: The key regulator of metabolism in our body is Thyroid gland. Changes in thyroid results in the alteration of the lipolytic capacity in the adipose tissues, which results in the effects of thyroid hormones and results in alteration in signal transduction, apoptosis, inflammatory response and lipid metabolism. They also result in lipolysis, down- regulation of sterol and thus may cause thyrotoxicosis and insulin resistance. They all result in modulated expression of genes with a wide range of malfunctioning in human adipose tissues. Millets are also vouchsafe with a wealth of nutrients and fibre that supports boost metabolism for hormones also.

Balancing Diabetes: Millets (including sorghum) are known to be highly nutritious besides having a low carbon footprint and the ability to survive in high temperatures with minimal water. Millets are widely recognised as having a low Glycaemic Index (GI), helping to manage diabetes. This systematic review and meta-analyzes across the different types of millets and different forms of processing/cooking collated all evidence. Minimally processed millets were 30% more effective in lowering GI of a meal compared to milled rice and refined wheat. In conclusion, millets can be beneficial in managing and reducing the risk of developing diabetes and could therefore be used to design appropriate meals for diabetic and pre-diabetic subjects as well as for non-diabetic people for a preventive approach. Millets have many health benefits of (e.g., sorghum) that have been advocated, including their roles in preventing and managing diabetes.

Promotes the digestion: The good amount of dietary fibres of millets performs well to maintain the digestive system of our body. These fibres fights against the flatulence, bloation,crampings, constipation, irregular bowel function. Not only has this but also combated the

overall health of other vital organs in our body, like pancreas, kidneys and liver, as well boosts up the immune system along with the gut maintenance.

Fits with a gluten-free diet: Millets are excellently a gluten-free grain, and this makes them a viable choice for people with celiac disease or those who are following a gluten-free diet. Let's understand "Gluten'- is a protein that occurs naturally in grains like barley, wheat, and rye. People with celiac disease or non-celiac gluten sensitivity must avoid it because it triggers harmful digestive symptoms, such as malabsorption of nutrients, diarrhea and malfunctioning of digestive system. When shopping for millets, we should still look for a label that certifies it gluten-free to ensure it hasn't been contaminated with any gluten-containing ingredients.

Potential downsides: Despite the multiple health benefits of millets, they also contain few antinutrients - compounds that block or reduce our body's absorption of other nutrients and may lead to some specific deficiencies. Some of these antinutrients are listed below:

- Phytic acid – it interferes with potassium, calcium, iron, zinc, and magnesium uptake in the cells. However, if a person is with a balanced diet, isn't likely to experience adverse effects.
- Goitrogenic polyphenols- this can cause goiter and may adversely impair thyroid function, — an enlargement of your thyroid gland that results in neck swelling and disturbed metabolism of the body. This effect is associated only with excess polyphenol intake.

Method for better consumption: Millets must be used by soaking it overnight at room temperature, then draining and rinsing it before cooking. As well, sprouting also reduces the antinutrient contents. In market, certain health food stores sell sprouted millets, though we can also germinate it on our own. To do so, place-soaked millet in a glass jar and cover it with a cloth that's secured with a rubber band or tie the knot with the same cloth. Afterwards, turn the jar upside down, rinsing and draining the millet every 8–12 hours. Small sprouts can be noticed, beginning to form after 2–3 days. Drain the excess water from sprouts and they are ready to be consumed. While choosing millets for sprouts, it should be kept in mind that sprouts have a short shelf life and are more prone to food-borne illnesses, or likely diseases, so to ensure the safety:

- Always keep the sprouting container clean,
- Use bottled water or filtered water (do not use tap water),
- Rinse sprouts frequently carefully,
- no water must remain inside the used jar before storing - empty all remaining water,
- Store sprouts in a dry and cool place at room temperature,
- Before refrigerating, wait for 8 to 12 hours to ensure they are cool and dry.

Overall, we can say the anti-nutrients present in millets have adverse effects on our body by blocking the body's absorption of some specific minerals, this adverse effect can be controlled or reduced by consuming a balanced diet , sprouting the millets and soaking them Not only this but millets are also avaible in flour form, through which a variety of dishes can be prepared including porridge, salads, biscuits, cookies etc.

Conclusion

Millets are bestowed with a wealth of nutrients and are committed to an excellent source of protein, fibre, key vitamins, and minerals. Millets are a gluten-free grain which has been rich in antioxidants since ancient times, and therefore is consumed as food by our ancestors. The reason shows they were more fit and healthy as well. Recent studies had made these evidences more authentic by revealing, the potential health benefits of millet include protecting cardiovascular issues, augment heart health, preventing the onset of diabetes, reducing hyperlipidemia (they may lower cholesterol) and blood sugar levels (diabetes), supporting, balancing and regulating the boosted metabolism, control blood pressure, helping people achieve and maintain a healthy weight management, and managing inflammation in the gut and hence improved good digestive system Thus, they are a healthy addition to the diet- meal plan in routine. While it is also beneficial for the environment, as it is mainly a rain-fed crops as well do not attract pests and other harmful insects and can grow well without the use of pesticides.

Millet Cultivation: Scenario and Prospects

Huwishka Dutt and Dr. R. S. Sengar

With the aim to create awareness and increase production & consumption of millets, the United Nations, at the behest of the Government of India, declared 2023 the International Year Millets. The International Year of Millets (IYM) is a global initiative that aims to raise awareness about the nutritional and ecological benefits of millets and promote their cultivation, consumption, and trade. The initiative was launched by the Food and Agriculture Organization (FAO) of the United Nations in 2023 to help improve food security and nutrition, particularly in developing countries.Millets are a group of small-seeded cereal grains that have been cultivated for thousands of years in various parts of the world, particularly in Africa, Asia, and Europe. They are known for their nutritional benefits and are considered to be highly nutritious and healthy. They are rich in a variety of essential vitamins and minerals, including iron, potassium, magnesium, zinc, and B vitamins. They are also a good source of dietary fibre, which can help to promote healthy digestion and prevent constipation.Raw millet has 378 calories per 100 grams and is a good source (20% or more of the Daily Value) of protein, dietary fibre, several B vitamins, and a variety of dietary minerals, including manganese at 76% Daily Value. There are 9% water, 73% carbs, 4% fat, and 11% protein in raw millet. In addition, millets are gluten-free and can be a good alternative for people with celiac disease or gluten intolerance. They also have a lower glycemic index compared to other grains, which can help to regulate blood sugar levels in people with diabetes.Millets are also high in antioxidants, which can help to protect the body against damage from free radicals and reduce the risk of chronic diseases such as cancer and heart disease.The International Year of Millets is an important initiative that aims to promote the use of millets as a nutritious and sustainable food source, and to help improve food security and nutrition in developing countries. In summary, millets are a nutritious and healthy food that can be enjoyed by people of all ages and dietary needs. They are a good source of essential vitamins and minerals, fibre, carbohydrates, and protein. They are also gluten-free and have a lower glycemic index which can be beneficial for people with diabetes.

Introduction

Millets are a group of small-seeded grasses belonging to the family Poaceae that are drought-tolerant and can grow in challenging environments. They have been grown for thousands of years, and are an important staple food in many parts of the world, particularly in Africa and Asia. Some common types of millets include:

Pearl millet (*Pennisetum glaucum*): this is the most widely grown type of millet, and is a staple food in many parts of Africa and India; Finger millet (*Eleusine coracana*): also known as ragi, this millet is a staple food in parts of Africa and India and is rich in iron, calcium and other minerals; Foxtail millet (*Setaria italica*): this millet is popular in China and parts of Asia, and is often used to make porridge or fermented products; Proso millet (*Panicum miliaceum*): this millet is grown primarily in the United States and is used for feed and birdseed; Sorghum (*Sorghum bicolor*): this is a type of millet that is grown for grain, forage, and biofuel.

All millets are annual plants, and they typically have a short growing season, with most varieties maturing within 60-90 days. They have a shallow root system, which allows them to quickly absorb water in the soil. The leaves of millets are long and narrow, and are typically green or blue-green in colour. The flowers of millets are small and inconspicuous, and are typically wind-pollinated. The seeds of millets are small, round, and typically range in color from white to red or black, depending on the variety.

Millets are a type of cereal grain that are grown for their edible seeds, which are usually ground into flour or used whole to make porridge or fermented products. They are also grown as a cover crop, forage crop, and biofuel crop. They are well adapted to poor soil, low rainfall and high temperature. They can grow in a wide range of soil types, including sandy soils, clay soils, and saline soils. They are also tolerant to high temperatures and low rainfall, which makes them well-suited to growing in semi-arid regions.

Health benefits of millets - The nutri-cereals

Given their highly nutritious content, millets are regarded as the next generation of superfoods or "nutri-cereals" worldwide. They may be helpful as a long-term solution for nutritional security. Millets are gluten-free and are a good source of dietary fibre, minerals and vitamins. They are also rich in antioxidants and the

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phytochemicals which may help to prevent chronic diseases. They are also considered as a good alternative to the traditional wheat and rice in terms of food security and climate change adaptability. According to ICAR-Indian Institute of Millet Research, Hyderabad, Millets contain 7-12% proteins, 2-5% fats, 65-75% carbohydrates and 15-20% dietary fibres. Niacin, which is abundant in millet, aids your body in controlling more than 400 enzyme reactions. Niacin is crucial for healthy skin and proper organ operation. In reality, it's a crucial substance that is frequently added to processed foods for enrichment. Darker kinds of millet are particularly good sources of beta-carotene. This organic pigment supports the health of your eyes and functions as both an antioxidant and a precursor to vitamin A, assisting your body in fending off free radicals.

They are both allergy-free and gluten-free. They are high in bioactive chemicals and essential amino acids and have a low Glycemic Index (GI), a measurement used to assess how much a particular diet raises blood sugar levels. They are beneficial for diabetics because of their low GI. Millets are three to five times more nutritious than wheat and rice in terms of proteins, minerals, and vitamins. They are also rich in micronutrients like calcium, iron, zinc, iodine, and others. Heart disease, anaemia, calcium insufficiency, and other conditions can all be fought using millets.

Nutritive value of millets (per 100g)

Crop/Nutrient	Protein (g)	Fat (g)	Minerals (g)	Iron (mg)	Calcium (mg)	Phosphorus (mg)	Fibre (g)
Rice	6.4	0.4	0.7	1.0	9.0	143	0.2
Sorghum	10.4	1.9	1.6	4.1	25	222	1.6
Pearl Millet	11.6	5.0	2.3	8.0	42	296	1.2
Finger Millet	7.3	1.3	2.7	3.9	344	283	3.6
Foxtail Millet	12.3	4.3	3.3	2.8	31	290	8.0
Proso Millet	12.5	1.1	1.9	0.8	14	206	2.2

World scenario of millet

Millets have been grown for thousands of years in many parts of the world, but in recent times they have lost popularity as a staple food crop due to the rise of wheat and rice. However, there has been a renewed interest in millets in recent years due to their potential to improve food security and adapt to climate change.

In India, pearl millet, sarghum and finger millet are the most widely grown types of millets and are a staple food for many people in the country. In Africa, pearl millet is also an important staple food crop, particularly in the Sahel region. In China and parts of Asia, foxtail millet is a popular food crop.

Globally, the area under millet cultivation has been decreasing over the last decades, but still, the total area of millet cultivation is around 42 million hectares. The major millet producing countries are India, Nigeria, China, Sudan, Niger, Burkina Faso, Mali, Chad, and Senegal. Despite the decline in production, there has been a renewed interest in millets in recent years due to their potential to improve food security and adapt to climate change. Millets are drought-tolerant and can grow in challenging environments, making them well-suited to growing in regions that are prone to drought and climate change. Also, the nutritional values and gluten-free properties of millets make them suitable for people with celiac disease, and other gluten-intolerance.

As the world's population continues to grow, and the effects of climate change become more pronounced, it is likely that the demand for millets will increase in the future. This could lead to an expansion in millet cultivation and an increase in the use of millets as a staple food crop in many parts of the world.

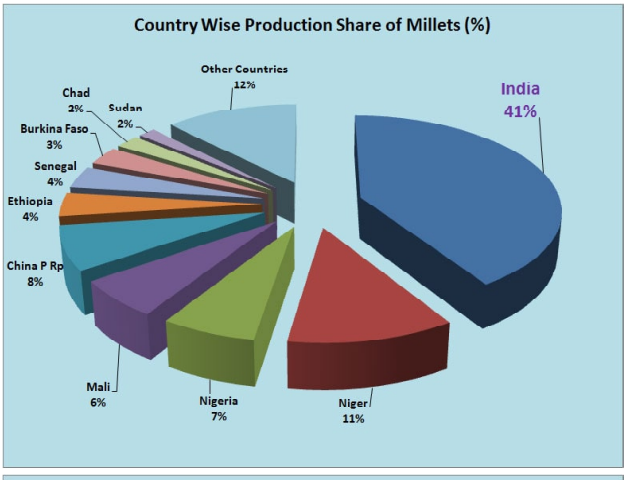
Millet production in India

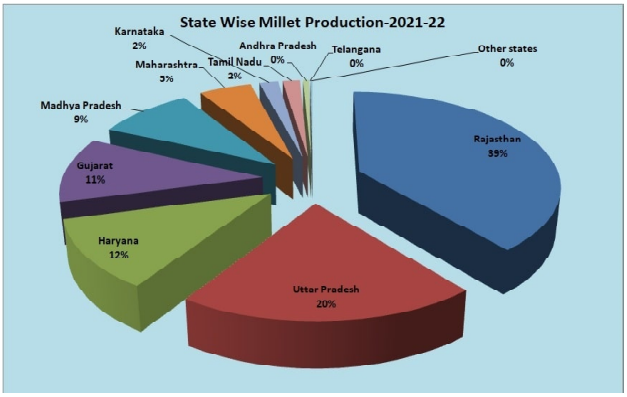
Millet production in India is a significant part of the country's agriculture sector. India is one of the world's largest producers of millets, with the crop being grown in several states including Rajasthan, Maharashtra, Andhra Pradesh, and Karnataka. The most commonly grown millets in India are pearl millet, finger millet, and foxtail millet. The government of India has been promoting millet cultivation in order to increase the production and consumption of these nutritious grains. This includes initiatives such as the National Millets Mission and the National Food Security Mission.

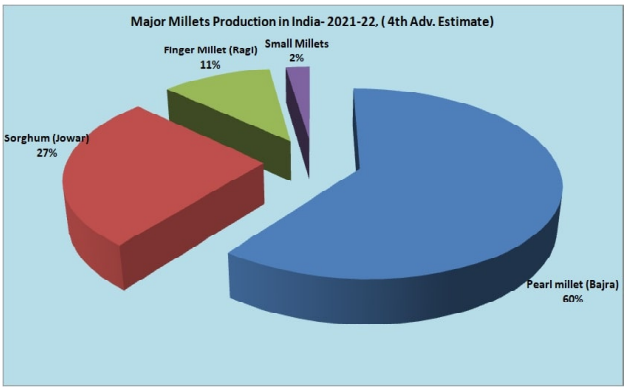
In recent years, there has been a renewed interest in millets as a nutritious and sustainable alternative to

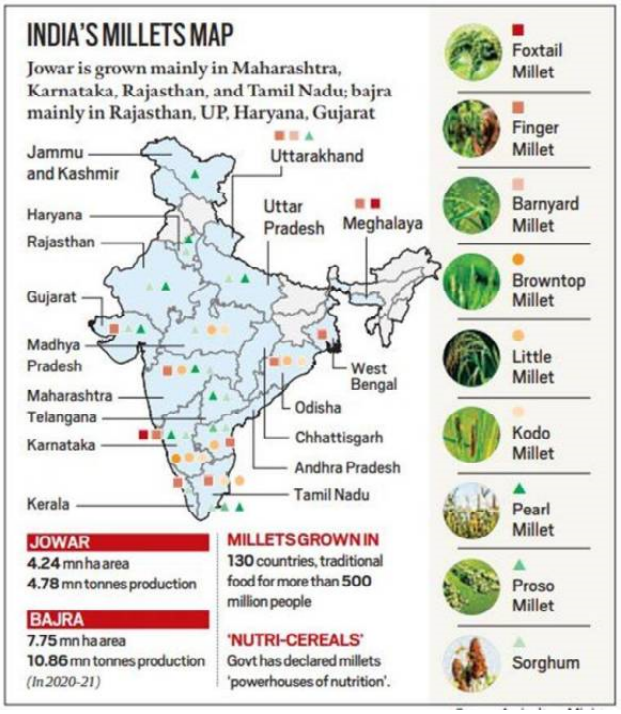
rice and wheat, and the government has been promoting millet cultivation and consumption as a part of its efforts to improve food security and reduce dependency on rice and wheat imports. According to the Food and Agriculture Organization (FAO), global millet production in 2019 was estimated to be around 17.8 million metric tons. India is one of the largest producers of millet in the world, with an estimated production of 7.5 million metric tons in 2019 and with a share of 41 percent in the year 2020.

Due to the millets' high nutritious value, the government designated them as nutri-cereals in April 2018. The millets have a low glycemic index and are a good source of protein, fibre, minerals, iron, and calcium. In 2018, the National Year of Millets was observed. The Indian government has requested the UN to declare 2023 the *International Year of Millets* in order to increase demand on a national and international level and to provide people with nourishing food (IYoM). In March 2021, the United Nations General Assembly (UNGA) declared 2023 to be the International Year of Millets after receiving support from 72 nations. Through funding for research and development and the establishment of 3 Centers of Excellence, the government is increasing public awareness of nutri-cereals (CoE). Additionally, start-ups are also offered support.









Challenges faced by farmers during millet cultivation

- **Drought:** Millet is a drought-tolerant crop, but it still requires a certain amount of water to grow. Drought conditions can reduce crop yields and make it difficult for farmers to produce a good harvest.
- **Pest and Disease**: Pests and diseases can also be a problem for millet farmers. The most common pests include stem borers, armyworms, and aphids, while diseases such as leaf spot and rust can also cause damage.
- **Soil fertility**: Millet is a crop that can grow in poor soil conditions, but it still needs a certain amount of nutrients to grow well. Poor soil fertility can lead to low crop yields and make it difficult for farmers to produce a good harvest.

- **Limited access to markets**: Small-scale farmers may face challenges in selling their millet due to limited access to markets, lack of information about prices and buyers, and lack of transportation infrastructure.
- **Lack of knowledge and technology:** Many farmers lack knowledge about the best practices for growing millet, including appropriate planting, fertilization, and pest management techniques.
- **Low priority**: Millet is often considered as subsistence crop and is grown by small farmers. It is seen as a low-priority crop, which is often neglected in terms of research and development, as well as extension and advisory services.

Actions to be performed to increase millet production

- **Manufacturing, processing and storage:** Cultivation of millet should be encouraged due to its climate resilience, short growing season and ability to grow in poor soils, mountainous areas and low rainfall. Millet farmers in rain-fed areas need to be empowered through capacity building and skills training.
- **Marketing:** For the entrepreneur's sourcing of quality millet and its stable marketing, small and marginal millet farmers should be connected to online marketing platform such as the Electronic Agriculture National Market (e-NAM).
- The setting up of farmer producer organisations (FPOs) can also enhance the millet producers' bargaining power in both the domestic and global markets. There is need to learn from the last-mile experiences of approximately 200 millet start-ups that have been incubated in the last few years by youngagri-entreprenuers.
- **Awareness raising and capacity building:** We need to work with multiple diverse stakeholders, including doctors, chefs, and nutritionists across the country. Both farmers and consumers need to be educated about the benefits of millet. To increase demand for millet, researchers need to put more emphasis on its nutritional benefits to consumers concerned about immunity and health, especially in a post-pandemic world. Solutions also need to be developed to improve the shelf life of millets (cereals, processed grains and flour) and bring it in par with competing crops.
- **Branding to spread:** Not only do we need to improve our marketing strategies to increase consumption, but we also need to improve the recipes for putting millet on people's tables and making it part of their daily diet. Companies like MTR, which makes breakfast mixes, are a good place to start.
- **Public procurement and distribution:** (a) Increase the amount of coarse grain procured for central pools and distributed under NFSA; According to the latest inventory data from Food Corporation of India (FCI), as of 1 November 2022, only 2.64 rough metric tonnes (LMT) of coarse grain were available in the central pool. In contrast, stocks of rice, wheat and unpolished rice were 265.97 LMT, 210.46 LMT and 263.70 LMT respectively. (b) Millet should be included in the Anganwadi lunch program or PDS to improve the nutritional status of preschool children and women of childbearing age. (c) Only Jowar, Bajra and Ragi qualify for the Minimum Support Price (MSP) set by the government. Other millet should also be included.
- **Other steps:**
  (a) The International Fund for Agricultural Development (IFAD) has supported the development of agriculture in Kodo and Kutuki, Dindri, Madhya Pradesh. Dindri models need to be replicated beyond one district and other millets.
  (b) Many millet cultivars suitable for different agro-ecological zones have been documented. A diverse seed bank should be created to facilitate this and ensure the availability of planting material.

Conclusion

It is a well-known truth that fibre-free foods are a major contributor to the global health problems. Additionally, it is evident to thousands of patients that all lifestyle disorders can be avoided by simply consuming millets for their meals and avoiding refined foods like rice, wheat, refined flours, processed meats, refined oils, packaged and ready-to-eat foods and milk. Efforts need to be scaled up to further improve millet acreage. Among the millets, the Union government declared a minimum support price for jowar, bajra and ragi. It is important to make people realize the importance of food by

introducing millets as a nutritious food, fulfilling the nutritional requirement of the global population and effectively reducing the problems of hunger, malnutrition and other health problems. It has multiple benefits in several diseases and disorders, and contains anti-oxidants. It is also considered as 'superfood' now-a-days due to its unending perks. Large-scale millet farming has the potential to help farmers secure their livelihoods in the face of climate change. Widespread use of mill*et al*so helps combat lifestyle diseases such as diabetes due to its nutritional value. The government has taken several commendable initiatives to promote millet production. Despite the challenges faced by farmers, they should be supported and a way forward should be paved for the increase in the production of the millets. The declaration of the year 2023 as the 'International Year of the Millets' should be seen as an opportunity and the right steps should be taken to grasp it by overcoming the problems faced till date. All the nutritional benefits should be exploited to the best of their use for the development and benefit of the humankind.

Pseudocereals: An Efficient Food Supplement

Shivam Yadav & Rumana Khan

Due to their outstanding nutritional profile and adaptation to various agroecological zones, pseudocereals, a category of non-grass plants, have attracted a lot of interest lately. This article gives a general review of the nutritional make-up and potential health advantages of some pseudocereals that have gained popularity as prospective replacements for conventional cereals, such as quinoa, amaranth, and buckwheat. Pseudocereals are abundant in vitamins, minerals, dietary fibre, protein, and other vital nutrients. Additionally, because they are gluten-free, they are excellent for people who have celiac disease or gluten sensitivity. The adaptability of pseudocereals in several culinary contexts, including as whole grains, flours, and processed goods, is discussed in the paper. Their inclusion in contemporary diets presents prospects for improving dietary diversity and treating nutritional issues, especially in areas where access to conventional sources of nutrition is limited.

Introduction

Pseudocereals encompass fruits or seeds derived from non-grass species, which are consumed in a manner akin to cereals. Pseudocereals have been found to be efficacious as supplementary sources to traditional cereals. Pseudocereals such as quinoa, amaranth, and buckwheat exhibit significantly elevated protein levels compared to traditional cereals. Moreover, the protein quality of these pseudocereals is notably enhanced, characterized by a greater abundance of lysine, an amino acid that is typically deficient in cereals. Pseudocereal proteins exhibit superior characteristics in terms of digestibility, bioavailability, accessible lysine content, and net protein consumption, as compared to cereals. The nutritional value of pseudocereals is highly comparable to that of conventional crops, and in many instances, it surpasses them.

Pseudocereals:

Exploring an alternative food resource, cereals are classified within the botanical family Poaceae and are primarily grown for their starchy seeds, which are consumed as a source of sustenance. Pseudocereals are cultivated for similar purposes, however they are taxonomically distinct from the grass family. As to the concept put forth by Shewry (2002), pseudocereals refer to a group of dicotyledonous plants that have no close genetic relationship with either one other or the monocotyledonous true cereals. Cereals and pseudocereals serve as the principal sources of dietary carbohydrates for the global human population. Approximately 50% of the annual cereal production is consumed by the global human population. The main cereals include rice, wheat, corn, sorghum, millet, oats, barley, and triticale. The term "millet" is used to denote a type of grain characterized by its small seed size. In addition to conventional cereals, the human food supply include a diverse range of plant resources, such as minor cereals and pseudocereals. While these crops may have limited cultivation and value, they should not be disregarded entirely. These plants provide several discernible benefits. Firstly, they exhibit adaptations to thrive in arid and challenging environmental conditions. Secondly, they demonstrate the capacity to flourish in infertile soils found in peripheral regions that are unsuitable for cultivating other primary crops. Lastly, the local rural communities possess extensive knowledge and expertise in cultivating and utilizing these plants. These particular plants offer superior nutritional value in comparison to the primary cultivated crops. The black fonio (*Digitaria iburua*) in Nigeria, the white fonio (*Digitaria exilis*) in other regions of tropical Africa, *Brachiaria deflexa* var. sativa and *B. ramose* in specific areas of Africa, and the staple cereal Teff grass (*Eragrostis abyssinica*) in Ethiopia have garnered significant significance and widespread recognition, making substantial contributions to food security, particularly within the African continent. Several dicotyledonous species, including *Amaranthus caudatus*, *Amaranthus cruentus*, and *Amaranthus hypochondriacus* from the Amaranthaceae family, *Chenopodium quinoa* (commonly known as quinoa) from the Chenopodiaceae family, and *Fagopyrum esculentum* and *F. tartaricum* (referred to as buckwheat) from the Polygonaceae family, possess seeds that are abundant in starch and can be consumed as cereals. These seeds are commonly referred to as pseudocereals.

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Floristic composition of India

India is ranked as the seventh-largest country and the tenth-most industrialized nation globally. It spans a geographical area of approximately 3,287,263 square kilometers, located between latitudes 8.04° N and 37.96° N, and longitudes 68.07° E and 97.025° E. The Indian subcontinent is geographically categorized into four distinct climatological zones based on longitudinal variance, namely equatorial, tropical, subtropical, and warm temperate. India has a remarkable proportion of approximately 11% of the global flora, despite its relatively modest land area accounting for merely 2.4% of the overall terrestrial expanse. India is home to two significant regions of high biodiversity, including the Eastern Himalaya and the Western Ghats. These areas are recognized as biodiversity hotspots, a term coined by Myers in 1990, and are among the 25 such hotspots discovered globally. These two regions exhibit a significant concentration of plant diversity within the geographical boundaries of India. In terms of species variety, India has been documented to have roughly 45,000 recorded plant species. India is home to a diverse angiosperm flora, with roughly 17,500 species. Among these, a significant proportion of 5,725 species are categorized as indigenous to the region. According to Nayar (1996), an alternative calculation reveals that approximately 28% of the overall flora in India and over 33% of the angiosperm flora found within the country are considered indigenous. According to Nayar and Sastry's research conducted between 1987 and 1990, it may be approximated that approximately 10% of the flowering plant species found in India are currently facing the risk of extinction. Furthermore, their study also identified a total of 34 plant species that have been officially proclaimed as extinct. India is widely recognized as a highly diverse hub for the cultivation of several plant species. The region has a significant range of landrace variety, which possesses valuable gene pools that confer tolerance to various physiological and ecological challenges, resistance to diseases and pests, and desirable quality features. The wild relatives and progenitors of cultivated plants hold significant value. India has been found to possess approximately 326 plants of this nature. Native tribal people have extensively utilized around 1000 edible wild plant species, as documented by many studies. The All India Coordinated Research Project (AICRP) on underused crops (UUC) was established in 1982, with its headquarters located at the National Bureau of Plant Genetic Resources (NBPGR) in New Delhi. The project encompasses 15 primary centers and 10 collaborating centers strategically distributed across various agricultural zones within the country. The Agricultural Innovation and Crop Diversification Research Program (AICRP) has identified a range of categories of underutilized crops that are recommended for further exploration and exploitation.

1. Pseudocereals – Grain amaranths, quinoa, buckwheat, Job's tear, etc.
2. Food legumes and pulses – Rice beans, winged beans, faba beans, etc.
3. Oilseed – Perilla, paradise tree, etc.
4. Vegetables – Kankora, winged bean, etc.
5. Fodder plant – Amaranth, salt bush, etc.
6. Energy, hydrocarbon and industrial plants – Jatropha, guayule, jojobe, etc.

Approximately 75% of India's cereal supply is derived from three primary cereal crops, namely wheat, rice, and maize. In contrast, the remaining 25% is contributed by minor cereals such as *Avena sativa, Eleusine coracana, Echinochloa* sp*., Hordeum vulgare, Panicum miliaceum, Pennisetum* sp., *Secale cereale*, *Setaria italica*, *Sorghum bicolor*, as well as pseudocereals like Amaranthus, Chenopodium, and Fagopyrum esculentum. A wide range of about 1200 herbaceous plants, both cultivated and wild, are utilized for their edible leaves. It is projected that by the year 2020, the demand for food grains is expected to increase to around 250 million metric tons. This would necessitate the procurement of an extra 72 million metric tons of food grains.

Nutritive value of pseudocereals

The nutritional value of pseudocereals surpasses that of traditional cereals. In terms of protein content and protein quality, it can be observed that the pseudocereals exhibit superior characteristics compared to cereal species. Amino acids such as tryptophan and lysine, with a particular emphasis on lysine due to its limitation in cereals, have been seen to be abundant in pseudocereals. Both arginine and histidine, which are amino acids, have been found to be crucial for the health of infants and children. These amino acids are available in substantial quantities in seeds, making amaranth and quinoa suitable food supplements for child nutrition. Net protein utilization (NPU), protein efficiency ratio (PER), protein digestibility, bioavailability of protein, and accessible lysine are among the key parameters used to

assess the nutritional quality of a protein. From this perspective, the protein levels of pseudocereals are notably higher when compared to cereals and are similar to those of casein. The protein content of pseudocereals is characterized by the presence of 2S albumins, as well as 11S and 7S globulins, which is consistent with the protein composition observed in dicotyledonous plants. Consequently, the protein composition of pseudocereals bears resemblance to that of legumes, crucifers, and composites, as noted by Marcone in 1999. The proteins found in pseudocereals are considered appropriate for individuals with celiac disease due to their comparatively decreased prolamine level. Pseudocereals exhibit a higher fat content in comparison to the majority of cereal species, with the fat being predominantly composed of unsaturated fatty acids, such as linolenic acid. The mineral composition of amaranth and quinoa is approximately twice as elevated compared to that of other cereals. The genus Amaranthus encompasses numerous edible species, as well as several weedy members that exhibit a global distribution with a preference for tropical climes. Amaranths, which have been cultivated and consumed by the Aztec civilization, hold the distinction of being one of the earliest known crop plants. The Aztec people, recognizing their nutritional value, regarded amaranths as a highly beneficial food source. The exploration of its remarkably high nutritious content occurred well in advance. In the African continent, the foliage of the amaranth plant is commonly ingested in a manner similar to the consumption of spinach. Archaeological investigations conducted at a cave located in Tehuacan, Puebla, Mexico have provided substantial evidence of the existence of amaranth seeds throughout the prehistoric era. The seeds of Amaranthus cruentus, which were obtained from Puebla, Mexico, have been dated to around 6000 years ago.

Cereals have been identified as containing enzyme inhibitors and allergens. Allergic reactions may be induced by proteins derived from wheat, rice, maize, and barley, whereas the specific gliadin fraction obtained from wheat has been identified as a causative agent for celiac disease. However, it should be noted that pseudocereals and legumes, such as soybeans and amaranths, do not possess these particular components. In addition, it is worth noting that pseudocereals possess a significant amount of dietary fiber, a characteristic that has been found to enhance lipid metabolism. The primary source of nutritional value in pseudocereals is attributed to their protein component. The inherent vegetable proteins found in leafy amaranths possess significant utility due to their notable biocompatibility, nutritional efficacy, and cost-effectiveness. The pseudocereals possess a prominent assemblage of 11S globulin storage proteins, with buckwheat and amaranth exhibiting lesser quantities of 2S albumin and 7-8S globulins. The Incas regarded *Chenopodium quinoa*, commonly known as quinoa, as the progenitor of all grains. This pseudocereal has its origins in the Andean area of South America. Currently, the production of [product] is taking place in Bolivia, Peru, and Ecuador. In contrast to most other cereal grains, this particular grain possesses a notable protein content and a balanced profile of amino acids, notably featuring a substantial concentration of lysine, an amino acid that is often found in low levels in most other cereals. The perception of its nutritional worth as a grain has remained rather consistent throughout the Inca era, and it is occasionally regarded as a "supergrain" in contemporary times. According to Taylor and Parker (2002), this particular plant has similarities to amaranths due to its notable protein content, significant nutritional value, and remarkable ability to thrive in arid environments. The potential application of quinoa as a food source has been investigated by multiple researchers, who have focused on its incorporation in the manufacturing of bread and cakes as well as pasta. Both amaranths and quinoa are known for their abundant production of edible grain, with amaranth being particularly recognized as the grain of the twenty-first century. Both amaranth and quinoa have higher mineral and vitamin content compared to the majority of cereals. The protein content of grain amaranths surpasses that of cereals and legumes both qualitatively and quantitatively. Amaranthus possesses a protein content of around 16%, with proteins exhibiting a notable enrichment of arginine, lysine, tryptophan, and sulfur-containing amino acids. The lysine content of amaranth is twice that of wheat and three times that of maize. Additionally, the nutritive value of amaranth is approximately 75, whereas maize, wheat, and barley have values of 44, 57, and 62, respectively. Previous studies have noted that the globulin fraction of oat and amaranth exhibits a high level of homogeneity and bears resemblance to the legume 11S storage protein. The examination of primary storage protein fractions, namely prolamins in cereals and globulins in pseudocereals, has been the subject of inquiry by multiple researchers. The analysis of the protein's nutritional value and amino acid content demonstrated a strong similarity between soybean and amaranth. The nutritional adequacy of amaranths as a viable alternative to cereals is strongly supported by their high protein content and diverse amino acid profile. Buckwheat, classified as a pseudocereal

Percentage based dry weight of chemical components of amaranth, quinoa and buckwheat

Components	Amaranth (*Amaranthus cruentus* L.)	Quinoa (*Chenpodium quinoa* L.)	Buckwheat (*Fagopyrum esculentum*)	Wheat(*Triticum aestivum* L.)
Protein	15.2	13.3	10.9	11.7
Fat	8.0	75.0	2.7	2.0
Starch	67.3	69.0	67.2	61.0
Ash	3.2	2.6	1.59	1.8

Comparative account of nutritive value of grain amaranths and other cereals

Crops	Protein	Fat	Carbohydrate	Calcium	Iron	Phosphorus	Food energy
Amaranth	16	3.1	60.0	0.49	17.5	0.6	391
Rye	12.1	1.7	73.4	0.38	10.5	0.37	334
Buckwheat	11.7	2.4	72.9	0.12	15.5	0.28	335
Chenopodium	12.0	5.0	68.0	0.20	12.6	0.5	342
Wheat	13.3	2.0	71.0	0.41	10.5	0.37	333
Maize	9.2	3.9	73.7	0.20	3.5	0.25	355
Rice	7.0	1.0	78.0	0.20	3.5	0.18	345

rather than a kind of wheat, has garnered significant interest as a potential agricultural crop. Additionally, the substance comprises protein with significant nutritional benefits, characterized by a relatively high content of lysine and other indispensable amino acids. The substance in question exhibits a notable concentration of phenolic compounds, iron, chromium, calcium, magnesium, selenium, and polyunsaturated fatty acids. The origin of buckwheat can be traced back to Middle Asia, where it was then introduced to Central and Eastern Europe through the migration of nomadic populations. During the 13th century, buckwheat experienced a period of significance in Germany, Austria, and Italy. However, its prominence gradually diminished as other cereal crops began to be cultivated. In contemporary times, the resurgence of interest in buckwheat can be attributed to the increasing popularity of gluten-free diets. (Tables 3.1a and 3.1b).

Conclusion

Pseudocereals have emerged as a promising alternative to traditional cereal grains due to their unique nutritional profile and diverse culinary uses. Quinoa, amaranth, and buckwheat are excellent sources of protein, fiber, and essential nutrients, making them highly beneficial for individuals with dietary restrictions or specific health needs. These pseudocereals have also gained popularity in the culinary world, with their versatile nature allowing them to be incorporated into various recipes such as salads, porridges, and baked goods. Moreover, their cultivation requires less water and land compared to traditional cereal grains, making them more sustainable and environmentally friendly. As pseudocereal awareness continues to grow, incorporating these nutritious grains into our diets can contribute to a healthier, more sustainable future.

Unlocking the Nutritional Power: Exploring the Impressive Health Benefits of Millets

D. Keerthana, D. S. Lagoriya, Sajan Kumar, Rumana Khan, Shailja Chauhan, Asif and Shani Kumar

Millets have been a traditional staple food in arid regions across the globe. In the case of India, millets cover approximately 17 million hectares with an annual production of 18 million tonnes. This contribution accounts for 10 percent of the country's food grain basket. Millets are often referred to as nutri-cereals due to their highly nutritious composition, rich in protein, essential fatty acids, dietary fibre, B-vitamins, calcium, iron, zinc, potassium, and magnesium. The millet grain contains about 65% carbohydrate, a high proportion of which is in the form of non-starchy polysaccharides and dietary fibre which help in prevention of constipation, lowering of blood cholesterol and slow release of glucose to the blood stream during digestion. Lower incidence of cardiovascular diseases, duodenal ulcer and hyperglycaemia (diabetes) are reported among regular millet consumers. Millet grains are also rich in important vitamins *viz*., Thiamine, riboflavin, folic acid and niacin. Millets are comparable to rice and wheat or rich in some of the minerals as well as fatty acids. Millets vary largely in composition of carbohydrates as proportion of amylose and amylopectin content vary from 16-28% and 72-84%, respectively.

Introduction

Millets, a type of grass with small seeds, are part of the Poaceae family and have been utilized as fodder and food for humans for approximately 10,000 years. In India, there are eight commonly grown millet species, including Sorghum, Pearl millet, Finger millet, Foxtail millet, Kodo millet, Proso millet, Barnyard millet, and Little millet, which are cultivated under rain-fed conditions. Moreover, in each millet-growing region, at least 4 to 5 species are grown either as the main crop or in conjunction with pulses, oilseeds, spices, and condiments. Millets play a crucial role in the semi-arid tropics of Asia and Africa (particularly in India and Nigeria), where 97% of millet production occurs in developing nations. Millets are highly significant in less developed countries due to their capacity to thrive in harsh weather conditions with limited rainfall. Millets has been recognized for its nutritional and medicinal benefits. Sorghum and millets have served as crucial staple foods in the semi-arid regions of Asia and Africa for many years. These crops continue to be the primary sources of energy, protein, vitamins, and minerals for numerous impoverished individuals in these areas. Millet outperforms rice and wheat in terms of several macronutrients, minerals (iron, zinc, phosphorus, calcium, potassium), and vitamins. Notably, millet possesses inherent features such as being hypolipidemic, having a low-glycemic index, and exhibiting antioxidative properties. Due to its nutritional value, millet is utilized worldwide in the production of noodles, nutritious soups, alcoholic beverages, pancakes, and cereal porridges.

Generally, millets are a good source of fiber, minerals, and B-complex vitamins. However, their high fiber content and the presence of certain substances like phytates and tannins can affect the absorption of minerals. Millets also contain beneficial compounds like polyphenols, lignans, phytosterols, phytoestrogens, and phytocyanin's, which have antioxidant and immune-modulating properties. These compounds help protect against age-related diseases such as cardiovascular diseases, diabetes, and cancer. Millets are safe for individuals with gluten allergies and celiac disease since they do not contain gluten. They are easily digestible, non-acidic, and non-allergenic. Overall, millets have the potential to help prevent age-related degenerative diseases.

Health benefit of millets

Consuming millets offers various health advantages that can help reduce the risk of heart disease and diabetes, enhance digestion, prevent cancer, detoxify the body, boost respiratory health, provide energy, and improve the muscular and neural systems. Millets also offer protection against degenerative diseases like metabolic syndrome and Parkinson's disease. These benefits are attributed to essential nutrients found in millets, including resistant starch, oligosaccharides, lipids, and antioxidants such as phenolic acids, flavonoids, lignans, avenanthramides, and phytosterols.

Malignant growth (Cancer): Cancer poses a significant hazard to humans, capable of causing severe

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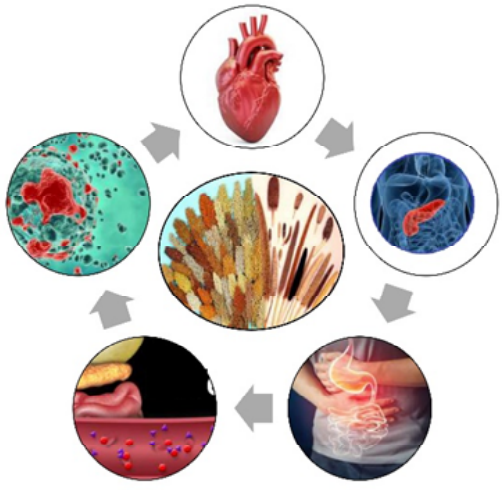
health complications, organ failure, and potentially leading to death if not detected and treated promptly. According to literature, millet grains are known to have high levels of phenolic acids, tannins, and phytate. These components have been linked to a decreased risk of colon and breast cancer in animals. The lower incidence of esophageal cancer among those who consume sorghum and millets, as opposed to wheat or maize, is thought to be due to the presence of fiber and phenolic compounds. Sorghum contains polyphenols and tannins that have properties to prevent mutation and cancer development. Additionally, these compounds can also fight against human melanoma cells and promote melanin production. Recent studies have shown that consuming more than 30 gm of fiber daily is one of the most effective and easiest ways for women to reduce their chances of developing breast cancer by over 50%.

Cardiovascular diseases (heart & blood vessels): Millets are abundant sources of magnesium and aid in lowering blood pressure and the likelihood of heart strokes, particularly in individuals with atherosclerosis. Additionally, the potassium found in millets functions as a vasodilator, contributing to reduced blood pressure and diminished cardiovascular risks. Furthermore, millets contain plant lignans that can be transformed into animal lignans when in the presence of microflora in the digestive system, shielding against certain types of cancer and heart ailments. Moreover, the substantial fiber content in millets plays a crucial role in reducing cholesterol levels by eliminating LDL (Low Density Lipoprotein) from the body and enhancing the effects of HDL (High Density Lipoprotein). Finger millet and proso millet may prevent cardiovascular disease by reducing plasma triglycerides.

Diabetes mellitus: Diabetes mellitus is characterized by high levels of sugar (glucose) in the blood. This chronic illness develops when the body either does not produce enough insulin or is unable to effectively use the insulin it produces. As a result, glucose cannot enter the body's cells and remains in the bloodstream, leading to elevated blood sugar levels. It is seen as the prevalent hormonal disorder and causes insufficient insulin production or a combination of resistance to insulin activity and the insulin-secretory reaction. The effectiveness of insulin and glucose receptors in the body is enhanced by the notable quantities of magnesium found in millets and aids in the prevention of diabetes. Diets centered on finger millet have demonstrated reduced glycemic response due to its abundant fiber content and its ability to inhibit alpha amylase, which decreases the digestibility and absorption of starch.

Gastrointestinal disorders: Gastrointestinal disorders refer to medical conditions affecting the digestive system, causing discomfort and hindering the normal functioning of the digestive organs. Eating gluten-free grains such as rice, corn, sorghum, millet, amaranth, buckwheat, quinoa, and wild rice can be beneficial for people who follow a gluten-free diet, including those with celiac disease. Millets contain fiber, which aids in preventing and relieving digestive issues such as constipation, excessive gas, bloating, and cramping.

Anti-oxidant properties: The antioxidants present in millet have substantial benefits in combating cancer-causing free radicals and eliminating toxins from the body, particularly in the kidneys and liver. Components like quercetin, curcumin, ellagic acid, and other beneficial catechins aid in effectively eliminating foreign substances and toxins by facilitating their proper expulsion and neutralizing enzyme functions in these organs. Because of their potential impact on human health, there has been significant focus on polyphenols. The soluble and insoluble bound phenolic extracts of various types of millets, such as kodo, finger, foxtail, proso, pearl, and little millets, have demonstrated antioxidant properties, as well as the ability to chelate metals and reduce their levels.



Millets and their health benefits

Conclusion

Millet is a versatile and nutrient-dense grain that offers numerous health benefits. From its high fiber content to its rich array of vitamins and minerals, including magnesium, manganese, and phosphorus, millet supports healthy digestion, bone health, and overall

wellbeing. Additionally, millet's gluten-free nature makes it a suitable choice for people with gluten intolerance or celiac disease. Its low glycemic index also makes it an excellent option for individuals who need to manage their blood sugar levels. Beyond its nutritional value, millet's potential role in reducing the risk of chronic diseases, such as heart disease and diabetes, further underscores its significance in maintaining optimal health. Incorporating millet into our diets can provide a wealth of benefits, making it a nutritious and wholesome grain to include in our everyday meals.

Importance of Millets in Human Health

Nitin Kumar[1], Kamaluddin[1], Vijay Sharma[1], Preeti Sonkar[1] and Rahul Rai[2]

Millets, a group of small-seeded grains, have gained significant importance in human health due to their nutritional benefits. Rich in fiber, vitamins, and minerals, millets promote cardiovascular health, aid in weight management, and reduce the risk of chronic diseases such as diabetes and cancer. Additionally, millets are gluten-free, making them suitable for individuals with celiac disease or gluten intolerance. Moreover, their low glycemic index helps regulate blood sugar levels, making them an ideal choice for diabetics. Incorporating millets into the diet plays a crucial role in enhancing overall human health and well-being.

Introduction

In recent years, there has been a significant shift in dietary preferences worldwide, with a growing number of individuals embracing millet as a staple food. Millets, a group of small-seeded grasses, grown as **cereal and fodder crops** have been cultivated for thousands of years and are gaining popularity due to their exceptional nutritional profile, environmental sustainability, and versatility in culinary applications. They are raised mainly as rain-fed ***Kharif*** **crops (sown with the onset of the monsoons)** in India. They have been traditionally cultivated and consumed in regions such as East Asia, South Asia, West Africa, and East Africa. Over time, the domesticated varieties have spread beyond their original territories. India is the largest producer of millets in the world, with a total production of 30.23 million tonnes. In India, the area under millet cultivation is 9.67 million hectares, and the annual production is 13.21 million tonnes. Rajasthan is the leading state in India for millet production, accounting for 39% of the total production. Other significant millet-producing states in India include Uttar Pradesh (20%), Haryana (12%), Gujarat (11%), Madhya Pradesh (9%), Maharashtra (5%), Karnataka (2%), and other states (2%).

Millets offer several health benefits compared to wheat and rice. They have a higher nutritional content, making them a nutritious powerhouse. Millets are naturally alkaline, which makes them easy to digest, particularly for young children. They are a good source of vital fatty acids, dietary fibre, B vitamins, antioxidants, and minerals such as calcium, iron, zinc, potassium, and magnesium. Millets are also high in protein, which is essential for building muscle. Additionally, millets have a low glycemic index and are gluten-free, making them suitable for individuals with gluten sensitivities or celiac disease. In India, there are various types of millets available, including sorghum (jowar), pearl millet (bajra), finger millet (ragi), foxtail millets, proso millet (cheena), kodo millet (kodo), barnyard millet (sawa/sanwa/ jhangora), little millet (kutki), and brown top Millet etc.

Importance and uses of millets

Millets hold great importance and offer a wide range of uses in various aspects. Here are some key reasons why millets are important and how they are used.

1. **Nutritional value**: Millets are highly nutritious and packed with essential vitamins, minerals, antioxidants, and dietary fibre. They are rich in proteins, complex carbohydrates, and healthy fats. Including millet in the diet can provide a diverse range of nutrients necessary for overall health and well-being.
2. **Health benefits**: Consuming millets has been associated with numerous health benefits. They can help in managing weight as they are low in calories and have a low glycemic index, which helps regulate blood sugar levels. Millets are also known to promote heart health, improve digestion, boost immunity, and reduce the risk of chronic diseases such as diabetes, obesity, and certain types of cancers.
3. **Gluten-free alternative:** Millets are naturally gluten-free, making them an excellent choice for individuals with gluten sensitivities, celiac disease, or those following a gluten-free diet. They can be used as a substitute for wheat and other gluten-containing grains in various recipes like bread, cookies, and pancakes.

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4. **Culinary uses**: Millets have a wide range of culinary applications. They can be used to make porridge, pilaf, upma, dosas, rotis, bread, muffins, and even beverages like millet-based smoothies. Millets have a versatile flavor profile, ranging from nutty and earthy to mildly sweet, allowing them to be incorporated into both savory and sweet dishes.

5. **Environmental sustainability:** Millets are considered environmentally sustainable crops. They require less water compared to other grains like rice and wheat, making them suitable for regions with water scarcity. Millets are also resilient to pests and diseases, reducing the need for chemical pesticides. Their cultivation contributes to biodiversity and can help in soil conservation.

6. **Economic importance**: Millets play a crucial role in the livelihoods of many small-scale farmers, particularly in developing countries. They provide income opportunities and food security for rural communities. Millets are often grown in marginal lands where other crops may not thrive, making them an important source of income for farmers.

7. **Animal feed**: Millets are not only consumed by humans but are also used as animal feed, especially for poultry, livestock, and birds. Millets offer nutritional benefits to animals, and their inclusion in animal diets can enhance the quality of meat, eggs, and milk.

8. **Food security and climate change adaptation:** Millets are known for their resilience to harsh climates, including drought and high temperatures. They have the potential to contribute to food security and climate change adaptation by providing a stable food source in regions prone to climate variability.

Overall, millets are important due to their nutritional value, health benefits, versatility in cooking, environmental sustainability, economic significance, and their potential to address food security and climate change challenges. Incorporating millets into our diets can promote sustainable and healthy food choices while supporting local farmers and communities.

Nutrient values of millets

Millets are a rich source of nutrients, containing 60–70% dietary carbohydrates, 6–19% protein, 1.5–5% fat, 12–20% dietary fibre, 2-4% minerals, and a number of phytochemicals.

Nutrient values in millets and compared with wheat and rice in 100 (g)

Crop/nutrient	Protein (g)	Fiber (g)	Minerals (g)	Iron (mg)	Calcium (mg)
Sorghum	10	4	1.6	2.6	54
Pearl millet	10.6	1.3	2.3	16.9	38
Finger millet	7.3	3.6	2.7	3.9	344
Foxtail millet	12.3	8	3.3	2.8	31
Proso millet	12.5	2.2	1.9	0.8	14
Kodo millet	8.3	9	2.6	0.5	27
Barnyard millet	11.2	10.1	4.4	15.2	11
Little millet	7.7	7.6	1.5	9.3	17
Brown top millet	11.5	12.5	4.2	0.65	0.01
Rice	6.8	0.2	0.6	0.7	10
Wheat	11.8	1.2	1.5	5.3	41

Source: Paschopur *et. al.* (2021)

Health benefits of millets

Millets have also been shown to have antibacterial, anti-tumorigenic, and antioxidant properties. Regular consumption of whole grain millets and their products helps prevent cardiovascular diseases, type II diabetes risk, gastrointestinal malignancies, and a variety of other ailments. Based on various epidemiological studies, eating millets enhances the immune system, detoxifies the body, lowers the risk of cancer, boosts energy, improves nervous system and muscular systems, and raises immunity in the respiratory system. In addition to Parkinson's disease and metabolic syndrome, millet consumption also offers protection from a number of degenerative illnesses. Some of the key health advantages of using specific millets in our daily diet include protection against metabolic syndrome and Parkinson's disease.

Millets can control blood sugar for combating diabetes: A chronic metabolic condition called diabetes mellitus causes hyperglycemia and changes how carbohydrates, proteins, and lipids are metabolised. It is a typical endocrine condition that negatively impacts the synthesis of insulin, leading to an imbalance in the body's sugar levels. Magnesium, which is abundant in millets, aids in raising the body's insulin levels and, as a result, improves the effectiveness of the glucose receptors. The risk of type I and type II diabetes is subsequently decreased as a result.

Millets help cure for coronary diseases: The millet grains are a nutritional powerhouse that helps reduce coronary artery blockage and improve heart

health. They include a higher concentration of magnesium, potassium, and plant lignins, which work as vasodilators to lower blood pressure and lower the risk of heart attacks and other cardiovascular diseases. Millets' high fibre content decreases cholesterol levels, clearing LDL (Low-Density Lipoprotein) from the body and boosting HDL's beneficial effects on the body.

Millets' antioxidant properties help in detoxification: Millets are full of beneficial catechins like quercetin, ellagic acid, and curcumin, which help the body eliminate toxins and xenobiotics by promoting proper excretion and inhibiting enzymatic activity. Various soluble and insoluble bound phenolic millet extracts demonstrate antioxidant, metal-chelating, and metal-reducing properties. Millets contain a high concentration of more than 50 phenolic compounds from various classes, including phenolic acids and their derivatives, dehydrodiferulates and dehydrotriferulates, flavonols, flavones, flavan-3-ol monomers and dimmers, etc. These compounds can be used as functional food ingredients and as natural antioxidant sources.

Millets aid with digestion and reduce digestive disorders: Regular and excessive eating of gluten-rich meals has been related to significant gastrointestinal conditions such as gastric ulcers and colon cancer as well as increased nutrient retention. In issues such as excessive gas, bloating, constipation, and cramping are eliminated by the use of millets rich in fibre and phenolics combined with their seed coat, gastrointestinal tract and decreases other kidney and liver disorders.

Millets protect the risk of cancer: phenolic acids, tannins, phytates, and dietary fibre content of millet grains have antimutagenic and anti-carcinogenic characteristics. Millets can lower the incidence of oesophageal, breast, and colon cancer when consumed regularly. A few recent studies have shown that women who consume 30 g of dietary fibre daily can reduce their risk of breast cancer by about 50%.

Conclusion

In conclusion, the importance of millets in human health cannot be overstated. These versatile grains not only provide essential nutrients but also offer numerous health benefits that can contribute to a balanced and well-rounded diet. By incorporating millets into our daily meals, we can take advantage of their fiber, vitamins, and minerals to support cardiovascular health, weight management, and reduce the risk of chronic diseases. Furthermore, their gluten-free nature makes millets accessible to a wider range of individuals, including those with celiac disease or gluten intolerance. Ultimately, embracing millets as a staple in our diets can greatly improve our overall health and well-being.

Future of Millets with Reference to Climate Change in Indian Scenario: A Brief Overview

Sajan Kumar, Rakesh Choudhary, Anshuman Singh, D. Keerthana, Rumana Khan, Subhaprada Behera and Shani Kumar

Millets are a group of small-seeded grasses that have been cultivated for time immemorial as a staple food crop in many parts of the world, including Africa, Asia, and Indian subcontinent. It provides numerous benefits as a food source since it contains numerous amino acids and pharmacologically active compounds. It is a rich source of protein fibres and low in fat as well as cholesterol making it a useful source of food for health conscious people. It is a crop that requires low amount of water and being a hardy plant can sustain extensive climate anomalies. In current changing climate scenario it will not only help to address such issues but also in a long run will help to address the SDG goals such as Food and Nutritional Security and combating hunger. But extensive research, demonstation, high yielding cultivar identification as well as breeding practices assisted by suitable policy formulation and proper implemention of such policy is utmost important for successful implementation and execution of such plan.

Introduction

Millets are a group of small-seeded grasses that have been cultivated for thousands of years as a staple food crop in many parts of the world, most prominently in Africa, Asia and India. These are highly nutritious and provide a range of health benefits owing to their unique composition of vitamins, minerals, fiber and other bioactive compounds.Millets are incredibly nutrient-dense, non-glutinous, and acid-free meals. Millets provide a variety of health-enhancing and nutraceutical benefits, particularly due to their high fibre content. Millets serve as a probiotic source of nutrition for the microflora in our internal ecology. Millets help us stay hydrated in the colon, which prevents constipation. Millet's niacin can aid in lowering cholesterol. Millets are a good source of dietary fibre and major and minor nutrients. For celiac sufferers, millets can replace wheat or other grains that contain gluten because they don't contain gluten. Sorghum, pearl millet, finger millet, foxtail, tiny, kodo, proso, and barnyard millet are among the nutrient-dense cereals known as millets. These are among the earliest foods that humans have ever consumed. One of the several varieties of coarse cereal grasses in the poaceae family, these are grown for their tiny edible seeds.

History of millets

In Africa, millets remain an important food source, mainly in the Sahel region where they are a staple crop. Millets are also grown in other parts of Africa. Tef and fonio are among those millets that were domesticated in the African continent and are still grown there almost exclusively, where teff, a type of millet, is used to make injera, a sour dough flatbread that is a national dish, and Fonio is considered to be the oldest West African cereal and its cultivation is thought to date back to 5000 B.C. Over time, millets were brought by traders, explorers, and settlers to various parts of the world, such as Africa, Asia, Europe, and the Americas, especially in areas with difficult growing conditions. In Asia, millets were brought to India and Southeast Asia, where they developed into significant crops throughout the continent. Early traders also introduced millets, which were cultivated in places like Greece and Italy, to Europe. European settlers brought millets to the Americas, where they were grown in areas like the southern United States and South America.

Millets production trend in India over the years: A brief overview:

Since 1966, India's estimated millet yield has increased by more than twofold. The average millet yield in India is 1208 kg per acre (2021–2022). Despite the fact that the area under millet plantation has been declining steadily in India since 1971–72, the production of millets has also increased by 7% between 1966 and 2022. Between 2006 and 2016, the area used for millet farming significantly decreased. Millets' per-person availability has changed over time as well. It has dropped significantly since reaching an all-time high in 2019. In 2021, each person had access to about 12.3 kilogramme of millet.

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Nutritional composition of millets: Each 100 gram (g) of cooked millet contains the following:

- 3.51 g of protein
- 23.7 g of carbohydrate
- 1.3 g of dietary fiber
- 44 milligrams (mg) of magnesium
- 0.161 mg of copper
- 100 mg of phosphorus
- 0.272 mg of manganese

Nutritional benefits of millets

Millets are an excellent source of protein, dietary fibre, iron, calcium, magnesium, and potassium, amongst many other nutrients. Furthermore, they are a good source of B-complex vitamins like niacin, thiamin, and riboflavin. Millets are a healthy food option for anyone wanting to maintain an appropriate diet because they are low in fat and almost completely free of cholesterol.

A protein rich food: Millets are a good source of plant-based protein, which is important for building and repairing tissues in the body. For example, one cup of cooked millet contains about 6 grams of protein. Each 100 gram (g) of cooked millet contains nearly 3.51 g of protein.

Rich fiber status: Millets are high in dietary fiber, which is important for maintaining a healthy digestive system. Fiber can also help in lowering blood cholesterol levels and hence reducing the risk of heart disease and assist in promoting satiety.

Low fat cereal: Millets are naturally low in fat and contain nearly no cholesterol, making them a good choice for people who are trying to maintain a healthy weight or reduce their risk of heart disease.

Rich sink of vitamins and minerals: Millets are a good source of several vitamins and minerals including iron, magnesium, phosphorus and potassium. These nutrients are important for maintaining healthy bones, muscles and organs.

A Gluten-free cereal: Millets are naturally gluten-free, making them a good choice for people with celiac disease or gluten intolerance.

Overall, millets are a nutritious and healthy food that can provide a range of benefits to people of all ages.

Nutraceutical benefits of millets

Millets contain several bioactive compounds that have been shown to have health-promoting properties. For example, millets are a rich source of antioxidants such as phenolic acids and flavonoids, which can help protect against oxidative stress and reduce the risk of chronic diseases, such as cancer and cardiovascular disease. Millets are not only a source of essential nutrients but also contain several bioactive compounds that have been shown to have health-promoting properties. Here are some of the nutraceutical benefits of millets:

Antioxidants properties: Millets are a rich source of antioxidants such as phenolic acids and flavonoids, which can help protect against oxidative stress and reduce the risk of chronic diseases such as cancer, heart disease and neurodegenerative diseases.

Anti-inflammatory properties: Millets contain several anti-inflammatory compounds that can help reduce inflammation in the body. Chronic inflammation is linked to several chronic diseases, including heart disease, diabetes and cancer.

Phytochemicals for healthy lifestyle: Millets are rich in several phytochemicals such as lignans, phytosterols, and saponins, which can help promote overall health and wellbeing.

A high Glycemic index: Millets have a low glycemic index, which means they release glucose into the bloodstream slowly. This can help regulate blood sugar levels and prevent insulin resistance.

Cholesterol-lowering properties: Millets have been shown to have cholesterol-lowering properties, which can help reduce the risk of heart disease.

Overall health benefits of millets: Millets have been shown to have several health benefits, including reducing the risk of type 2 diabetes, improving digestive health, and promoting weight loss. Millets have a low glycemic index, meaning they release glucose into the bloodstream slowly, which can help regulate blood sugar levels and prevent insulin resistance. Millets are also a good source of dietary fiber, which can improve bowel function and reduce the risk of constipation and other digestive disorders. Finally, millets are a low-calorie, nutrient-dense food that can help people maintain a healthy weight.

Benefits of millet consumption in current lifestyle scenario

Reduced risk of chronic diseases: Millets are rich in several bioactive compounds such as antioxidants and phytochemicals, which can help reduce the risk of chronic diseases such as cancer, heart disease, and neurodegenerative diseases.

Improving digestive health: Millets are an excellent source of dietary fiber, which is essential for maintaining digestive health and preventing constipation. Millets also contain several anti-inflammatory compounds that can help reduce inflammation in the digestive system.

Regulating blood sugar levels: Millets have a low glycemic index, which means they release glucose into the bloodstream slowly. This can help regulate blood sugar levels and prevent insulin resistance, reducing the risk of type 2 diabetes.

Healthy weight management: Millets are a low-calorie, nutrient-dense food that can help people maintain a healthy weight. The high fiber content in millets can help people feel fuller for longer, reducing the likelihood of overeating.

Improveing heart health: Millets contain several nutrients such as magnesium, potassium, and fiber that can help lower blood pressure and reduce the risk of heart disease. Millets also have cholesterol-lowering properties, reducing the risk of heart disease.

Millets as a wonder crop to address changing climate scenario

Millets are resistant to climate change because of their resilience to a wide range of temperatures and moisture regimes as well as their minimal input needs. They are hardy crops with minimal carbon and water impacts. Climate change is having a significant impact on millet cultivation in India like other crops. Rising temperatures and changing rainfall patterns are affecting the growth and yield of millets, particularly in the rain fed areas of the country. Droughts and water scarcity, which are becoming more frequent and intense due to climate change, are also affecting the cultivation of millets. The fact that millets have a deep root system that enables them to access moisture from deeper soil layers, making them resilient to droughts helps to address the concerns upto certain extent. These crops also require fewer inputs like water and fertilizers as compared to other crops.

As climate change continues to impact India, with more frequent and intense droughts and heat waves, millets are becoming increasingly important for ensuring food security and resilience in rural communities. The cultivation of millets can provide a sustainable source of food and income for farmers, as well as help to conserve water and improve soil health. The future of millets in India with reference to climate change is promising, as millets are well-adapted to the arid and semi-arid regions of the country and can thrive in conditions of water scarcity and high temperatures. Overall, the future of millets in India with reference to climate change is bright, and their cultivation and consumption can play an important role in ensuring food security and sustainable agriculture in the country.

Biotechnological Approaches for Improvement of Millets

Rashmi Malik[1], Manoj Kumar Tripathi[1], Sushma Tiwari[2], Rakesh Chaudhary[3], Shailja Chauhan[3] and Kuldeep Singh[4]

Different small-grained cereal grasses are collectively described as 'Millets'. These millets are nowadays consumed worldwide but cultivated marginally due to their nutritional benefits and climate resiliency. India is the largest producer of millets in the world and accounting for 20% of global production and 80% of Asia's production but the meager investments in research and genomic resource development have made the millets stand far behind other cereal crops, including rice, wheat, and maize. This article elaborates about the biotechnological interventions to expedite crop improvement programmes in the present scenario.

Introduction

Different small-grained cereal grasses are collectively described as 'Millets'. Millets are one of the oldest cultivated foods known to humans. Two main groups of millets are major millets (sorghum and pearl millet) and small millets based on the grain size. Both major and small millets have grown marginally but consumed worldwide. The group of small millets is represented by ten species, namely finger millet (*Eleusine coracana* L.), little millet (*Panicum sumatrence*), kodo millet (*Paspalum scrobiculatum* L.), foxtail millet (*Setaria Italica* L.), barnyard millet (*Echinocholoa frumentacea* L.), proso millet (*Panicum miliaceum* L.), teff (*Eragrostis* tef), fonio (*Digitaria exilis*), jobi tears (*Coix lacryma*-jobi), guinea millet (*Brachiaria deflexa*) and brown top millet (*Urochloa ramosa*) representing the area grown in that order. These crops have traditionally been the essential component of rainfed farming system in India as generally these are all C_4 crops**.** In addition to climate resiliency and nutritional quality, these crops also have low glycemic index unlike in rice and wheat. This further helps in control of Type -2 diabetics' condition. India is the largest producer of millets in the world and accounting for 20% of global production and 80% of Asia's production. The meager investments in research and genomic resource development have made the millets stand far behind other cereal crops, including rice, wheat, and maize. This article elaborates about the biotechnological interventions to expedite crop improvement programmes.

Whole-genome sequencing and pangenome analysis

With the advancements in nucleic acid sequencing technologies to the next-generation level, the draft genome sequencing, whole-genome resequencing, and genotype-by-sequencing platforms have accelerated the pace of genomic resource development in plant species. These genomic resources are being deployed to identify genomic region or gene(s) contributing trait of interest, which then could be introgressed to the susceptible/elite species either through breeding or genetic engineering technologies. The first released genome sequence for any flowering plant was of *Arabidopsis thaliana* in early 2000 which have prompted the avenues for other plants to be sequenced. Currently, the draft genome sequence of foxtail millet, finger millet, pearl millet, and broomcorn millet are available. Among the most cultivated millet species, foxtail millet (2n = 2x = 18) and pearl millet (2n = 2x = 14) are only diploid species, whereas, finger- (2n = 4x = 36), kodo- (2n = 4x = 40), little- (2n = 4x = 36) and proso millet (2n = x = 36) are tetraploid while barnyard millet is hexaploid (2n = 6x = 36) in nature. With approximately 400 Mb in size, foxtail millet possesses the smallest genome among millet crops, followed by broomcorn millet (~923 Mb), finger millet (~1.2 Gb), and pearl millet (~1.7 Gb). Additionally, low genome complexity, inbreeding nature, short life cycle, and availability of high-throughput genomic resources have established foxtail millet as an experimental model crop for the study of genetics and genomics of abiotic stress tolerance, the biochemistry of C4 photosynthesis and biomass production of panicoid biofuel crops. The

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pangenome analysis has recently gained significant attention as it comprises complete genomic information extracted from a large number of genetically diverse genotypes. Among cereals, the pangenome analysis is available only for rice and maize. It needs to be extended to the other cereals, including millets, to delineate their genetic complexity and overall gene pool.

Allele mining and collection of millet germplasm for diversity

To explore genetic diversities for identifying and harnessing abiotic stress tolerance determinants from millets, the collection of a large number of natural germplasms of each species is a prerequisite. *Ex-situ* conservation at different gene banks and national institutions globally is the most commonly used method for preserving millet genetic resources. The collection of wild and cultivated millet germplasm was initiated in the early 1970s by the Rockefeller Foundation of USA to expedite the breeding programs. Currently, an extensive collection of millets germplasm is being preserved at various global organizations, including the International Crop Research Institute for Semi-Arid Tropics (ICRISAT), Indian Council of Agricultural Research (ICAR), Consultative Group on International Agricultural Research (CGIAR), and others. More than 46,500 cultivated and 900 wild foxtail millet accessions are being maintained in gene banks across the globe. ICRISAT, NBPGR, and All India Coordinated Pearl Millet Improvement Project (AICPMIP) are the principal repositories of global and indigenous pearl millet accessions in India. More than 29,000 proso millet genotypes, 8000 accessions each of kodo- and barnyard and millets, and over 3000 little millet accessions have been preserved globally. Russia, Japan, and India have the largest collection of proso, barnyard, and kodo millet germplasm resources, respectively. The vast assemblage of germplasms and establishment of the core, mini core, reference, and composite collection sets have enormous applications in molecular breeding, pangenome analysis, and gene pool mining.

Identification of molecular markers and QTLs

Molecular markers uncover the genetic diversity within the population and are widely utilized in genomic-assisted breeding (GAB) programs. The recent progress of DNA sequencing technologies has advanced the development of high throughput global genomic markers associated with economically important agronomic traits. The application of single nucleotide polymorphic (SNP) markers has subsided the exploitation of simple sequence repeat (SSR) and insertiondeletions (InDels) markers in recent years. The noteworthy features of SNPs are their abundance throughout the genome and mostly biallelic in nature. A total of 17,417 SNPs from the sequence information of 181 foxtail millet genotypes have been identified, and marker-trait associations were established for several agronomic traits, including abiotic stress.

The SNPs could also be applied to segregate the accessions for a given trait following genotyping. Abiotic stress tolerance in a plant is a complex quantitative trait controlled by the synergic effect of many genes or small main-effect quantitative trait locus (QTLs). Since most of the millet species are naturally tolerant to different abiotic stresses, they might be an excellent source of environmental stresses-related QTLs or alleles for further crop improvement. The fine mapping of putative QTLs would provide the precise genomic regions associated with the desired phenotype, which may be engineered to the susceptible interspecific major cereal crops; however, to date, QTLs regulating abiotic stress response has not been explored.

Transcriptomic approach for candidate gene selection

Small millets comprised of a large number of stress-responsive genetic determinants, including genes and non-coding regulatory RNAs. The comparative transcriptome analysis is a widely accepted approach that facilitates identifying a large number of trait-associated genes in plants. The recent technological advancements have made it possible to analyse the global transcript profile of an organism through qRT PCR and NGS-based RNA sequencing (RNA-seq). For orphan crops like millets, with minimal genomic resources, RNA-seq can generate significant information regarding the global pattern of gene expression under different environmental constraints.

Omics approaches

Advanced omics have provided substantial genetic and genomic resources, which can be exploited for genetic manipulation using third-generation genome-editing tools. Clustered regularly interspaced short palindromic repeat (CRISPR)/CRISPR-associated protein 9 (Cas9) nuclease system is a powerful gene-editing tool, which is now successfully employed in various crops, including rice, wheat and maize. However, this gene-editing tool has not been used for most small

millet crops except foxtail millet. In this direction, a foxtail millet mutant, *xiaomi*, with a short generation time, was developed using the CRISPR system. This mutant provides an efficient C_4 model system, which can be utilized to study genes associated with important agronomic traits. Recently, a nano-particle based delivery system for plasmids, ribonucleo protein (RNPs) and and RNA is now developed for speedy trait improvement. However, this concept has not been utilized in millets, but this approach holds a promising future in these crops.

Genome Editing tools showed promising potential in QTLs editing to instigate desired alleles into several crops by eluding the requirement of excessive crossing. Further, the generation of double haploids (DH) drastically reduces the generation times, thereby speeding up breeding. Given this, the haploid inducer line of foxtail millet has been generated by CRISPR-Cas9 mediated manipulation of the *SiMTL* gene. These doubled haploid lines provide a platform to exploit complex traits, including climate resilience, in C_4 crops. This gene-editing assisted *de novo* domestication of polygenic traits such as climate resilience, and nutritional aspect is a new-generation breeding strategy for crops like small millets.

Developing an efficient transformation and regeneration method is necessary for the successful generation of transgenics by gene editing. Though millets lag on efficient transformation, few millet transformation reports are available. For example, *Agrobacterium*-mediated transformation and regeneration of transgenics have been performed in finger millet. Similarly, transgenic finger millet expressing rice chitinase (*chi11)* was developed through *Agrobacterium*-mediated transformation, which showed resistance against leaf blast disease. Few other studies reported the development of transgenic finger millet showing salt and drought tolerance through expressing serine-rich protein (*PcSrp*) and mannitol-1-phosphate dehydrogenase (*mtlD*). Successful transformation using the biolistic method is reported in pearl millet. Similarly, the biolistic method-based transformation has also been tested in barnyard millet. Recently, *Agrobacterium*-mediated transformation has been reported in kodo millet. Therefore, these successful attempts could set a platform to extend these studies to other small millet crops, accelerating their improvement.

Conclusion

In conclusion, biotechnology approaches have proven to be effective in improving millets through genetic modification, marker-assisted selection, and tissue culture techniques. These approaches have helped to increase yield, enhance nutritional content, and improve disease and pest resistance in millet crops. Additionally, biotechnology has enabled the development of drought-tolerant and salt-tolerant varieties of millets, making them resilient to environmental stresses. These advancements are crucial for ensuring food security and alleviating malnutrition, particularly in developing countries where millets are staple crops. Moving forward, continued research and investment in biotechnology approaches for millet improvement will be essential to further enhance their potential as a sustainable and nutritious food source.

Millet Technology: Revolutionizing Agriculture and Nutrition

Dinesh Pandey[1] and Anil Kumar[2]

Millets have become increasingly popular in recent years because of their great nutrition, eco-friendliness, and ability to grow in different conditions. Technology has played a crucial role in discovering and maximizing the benefits of millets. It has empowered farmers, researchers, and consumers to use millets in creative ways. Thanks to advancements in farming techniques and processing methods, millet technology is transforming agriculture and nutrition, leading us towards a healthier and more sustainable future.

Introduction

In recent years, there has been a growing interest in alternative crops that can address the challenges of climate change, food security, and nutrition. One such crop that has gained significant attention is millet. Millet, a term used to describe a group of small-seeded grasses, is a staple crop in many parts of Asia and Africa. It is known for its hardiness and ability to thrive in harsh environments, making it a resilient option for farmers facing unpredictable weather patterns. Millet requires minimal water and is resistant to pests and diseases, reducing the need for chemical inputs. This makes it an attractive choice for sustainable agriculture and resource-limited regions. Governments and international organizations have also recognized the significance of millet in addressing global challenges. The United Nations declared 2023 as the International Year of Millets, highlighting its contribution to food security, nutrition, and sustainable agriculture. This declaration aims to raise awareness, encourage research and development, and promote policies that support millet production and consumption. With advancements in millet technology, this humble grain is now revolutionizing both agriculture and nutrition. This article explores how millet technology is transforming agriculture and benefiting human nutrition.

Advancements in millet production technologies

1. Smart farming for improving millet cultivation

Smart farming is changing the way millet can now be grown by using advanced technology. One important aspect is precision farming, which uses sensors, drones, and satellite images to gather information about the soil, nutrients, and plant health. This helps farmers make better decisions based on data.

Sensors placed in the fields measure things like soil moisture, pH levels, and nutrients. This information is analyzed and shown in a way that farmers can understand. It helps them know what their millet crops need, like when to water or fertilize. Drones are like flying cameras that take pictures of millet fields from above. They can see things that are hard to notice on the ground, like signs of disease or nutrient problems. This helps farmers take action early to protect their millet plants and make them healthier. Satellites are used to monitor large areas of farmland. They take pictures and collect data to show the overall health of the millet crops. This helps farmers plan their work and make smart decisions to improve millet farming. Smart farming has many benefits for millet growers. It helps farmers know how much water their crops need, so they can use it efficiently and not waste any. It also helps them give the right amount of nutrients to the plants, which makes them grow better. Smart farming even helps with pest control by detecting pests early and taking action to stop them from causing too much damage.

2. Climate-resilient varieties for changing climatic conditions

In the face of climate change and its impact on agriculture, scientists have been working tirelessly to develop millet varieties that can withstand and thrive in challenging environmental conditions. They are employing a combination of genetic engineering and traditional breeding techniques to create climate-resilient millet varieties that possess exceptional traits like drought tolerance, disease resistance, and high yield potential. Genetic engineering allows scientists to introduce specific genes into millet plants, enhancing their natural

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ability to cope with adverse environmental conditions. By identifying and incorporating genes associated with traits like drought tolerance, these modified millet varieties can better withstand water scarcity and continue to grow even in dry spells. This is particularly crucial in regions where water availability is very low.

Traditional breeding techniques are also employed to selectively cross different millet varieties with desired traits. Through careful selection and cross-pollination, scientists can create new millet varieties that exhibit superior characteristics, including disease resistance. These varieties have built-in defense mechanisms that help them combat common diseases and pests, reducing the need for excessive pesticide use and promoting sustainable farming practices. The development of climate-resilient millet varieties focuses on improving their overall yield potential. Scientists aim to breed varieties that can produce higher yields while maintaining their resilience to environmental stresses. This ensures that farmers can achieve more abundant harvests, even under challenging climatic conditions, contributing to food security and livelihoods.

The introduction of climate-resilient millet varieties not only benefits farmers but also has broader implications for global food production. As extreme weather events become more frequent, these resilient varieties offer a buffer against crop failures and ensure a stable food supply. By enhancing the adaptability of millet to changing climates, these varieties contribute to the overall resilience of agricultural systems. It is important to note that the development of climate-resilient millet varieties is a result of rigorous scientific research and adherence to strict safety regulations. Scientists undertake comprehensive evaluations to ensure the safety and efficacy of these varieties before they are released for cultivation.

3. Digital farming tools for farmers' information and support

Nowadays, farmers can use special tools on their phones and computers to get important information and help with their farming. These tools are called digital farming tools. They can do a lot of useful things for farmers. One helpful feature of digital farming tools is that they give farmers advice on how to take care of their crops. They show step-by-step instructions on things like when to plant, how much water and fertilizer to use, and how to deal with pests. This helps farmers make better decisions and grow healthier crops. Another great thing about these tools is that they can tell farmers the weather forecast. Farmers can know if it will rain or be sunny, which helps them plan when to do certain tasks like planting or harvesting. By knowing the weather, farmers can be prepared and work at the right time.

Digital farming tools also give farmers information about the market. They can see what crops are in demand and how much they are selling for. This helps farmers decide what to grow and sell. By knowing the market, farmers can make more money and be successful. These tools also connect farmers with experts and other farmers. Farmers can talk to experts and get advice on how to improve their farming. They can also share their own experiences and learn from others. This helps farmers learn new things and become better at what they do.

Innovations in millet processing:

1. Millet grain dehulling:

In the past, removing the outer layer of millet grains, called dehulling, was a lot of work and took a long time. But now, thanks to new technology, we have machines that can do it quickly and efficiently. These machines make the process faster, save time, and reduce waste, which is really good for farmers and the quality of millet grains. Using these machines has many benefits. First, it makes farmers more productive. The machines can process a lot of millet grains in a short time. This is especially helpful for farmers who grow millet for business. They can process more grains quickly, which means more millet to sell. Second, these machines make sure that all the grains are the same. They remove the outer husk without damaging the grains. This makes the millet look and feel consistent. It's important because people like to buy millet that looks good and has a nice texture.

Another good thing is that these machines reduce waste. In the old way, some grains would get broken or not dehulled properly, so they couldn't be used. But with the new machines, fewer grains are wasted. They are designed to get the most millet grains possible, which means less waste and more millet to sell. Due to use of these machines, farmers can produce more millet in a better and faster way. They can provide high-quality millet grains that meet the demands of customers. This is good for the millet industry and for people who enjoy eating millet.

2. Value-added processing:

Thanks to technology, we now have many different millet products to choose from. Different ways of processing millet have led to the creation of special products that are even better for us. These products are made to meet the needs of people who want healthy and gluten-free options.

One exciting product is millet flour. Millet grains can be ground into flour, which can be used in many recipes. It can be used to make bread, cakes, cookies, and more. Using millet flour gives these foods a special taste and texture. What's great is that millet flour doesn't contain gluten, so it's a good choice for people who can't eat gluten. Another popular product is millet flakes. These are made by flattening millet grains. Millet flakes can be cooked and used in porridge, cereals, or even in snacks like granola bars. They're a nutritious and gluten-free option for people who want to start their day with a healthy breakfast or have a quick and easy snack. Puffed millet is made by heating millet grains very quickly, and they become light and crispy. You can eat puffed millet as a snack by itself, or add it to cereals, trail mixes, or energy bars. It's a fun and crunchy option that many health-conscious people enjoy.

We also have snacks made with millet. There are crackers, chips, and bars that are made with millet as the main ingredient. These snacks are made with other good things like seeds, nuts, and natural flavors. They taste great and are healthier than typical snacks. All these special millet products have become popular because more people are looking for healthy and gluten-free choices. As we learn more about the benefits of millet, the demand for these innovative products keeps growing.

3. Nutrient extraction from millets

Thanks to advanced extraction technologies, we can now get even more goodness from millets. These technologies allow us to extract important nutrients like proteins, fibers, and phytochemicals from millets. These extracted compounds can then be used to make a variety of food and drinks that are not only nutritious but also have added health benefits. One of the nutrients that can be extracted from millets is protein. Protein is an essential building block for our bodies, and millets are a good source of plant-based proteins. With extraction technologies, we can separate the protein from millets and use it to enrich other food products. This is especially important for people who follow vegetarian or vegan diets and need alternative sources of protein. Besides these proteins can be used to design other value added products. For example they can be used to make nanodelivery vehicles for delivery of important vitamins.

Fibers are another valuable nutrient found in millets. Fiber is important for our digestive system and helps keep us feeling full and satisfied. Through extraction techniques, we can obtain fiber-rich extracts from millets. These extracts can be used to fortify foods and beverages, making them more fiber-packed and promoting better digestion and overall health. Phytochemicals are natural compounds found in plants that have beneficial effects on our health. Millets contain various phytochemicals with antioxidant and anti-inflammatory properties. With advanced extraction technologies, we can isolate and concentrate these phytochemicals. They can then be incorporated into different food and drink products, providing added health benefits and boosting the nutritional value of the final product. By incorporating these extracted compounds into various food and beverage products, we can enhance their nutritional content and functional properties. For example, protein-rich millet extracts can be added to energy bars, shakes, or baked goods, making them more nutritious and suitable for athletes or those looking to increase their protein intake. Fiber extracts can be used in cereals, bread, or snack bars to promote better digestion and help regulate blood sugar levels.

Furthermore, the incorporation of phytochemical-rich millet extracts into beverages, such as juices or smoothies, can provide an extra dose of antioxidants and contribute to overall well-being. These extracts can also be used in the formulation of dietary supplements or functional foods designed to target specific health concerns.

Promoting millet consumption:

1. Consumer awareness:

Technology has revolutionized the way we spread awareness about the nutritional benefits of millets. Through digital platforms, social media, and mobile applications, information about the health advantages of including millets in our diets is disseminated widely. These platforms serve as powerful tools to educate consumers, sharing valuable insights, recipes, and tips related to millet nutrition. Digital platforms, such as websites and online forums, provide comprehensive information about the nutritional content of millets and their positive impact on health. Social media platforms facilitate the sharing of articles and recipes, reaching a diverse audience and

fostering discussions around millet-based diets. Additionally, mobile applications dedicated to healthy eating empower users with easy access to millet recipes, inspiring them to incorporate this nutritious grain into their meals.

Through technology, consumer awareness about millets is expanding rapidly, enabling individuals to make informed decisions about their dietary choices. By embracing these digital resources, consumers can unlock the numerous health benefits that millets offer, promoting a healthier and more diverse approach to nutrition.

2. E-commerce platforms:

Online marketplaces and e-commerce platforms have made it easier for consumers to find and buy millet-based products. With these platforms, consumers can conveniently explore and purchase a wide variety of millet items from their homes. This eliminates the need to physically visit stores or markets, saving time and effort. E-commerce also benefits millet producers, allowing them to showcase their products to a larger consumer base. The convenience and accessibility of e-commerce platforms promote the availability and consumption of millet products, making it easier for consumers to enjoy the nutritional benefits of millets.

3. Food Innovation:

Technology-driven food innovation has revolutionized the realm of millet-based products, bringing forth a plethora of enticing options that cater to contemporary dietary preferences. Through the integration of advanced technologies and culinary expertise, millets have paved the way for the creation of a diverse range of snacks, ready-to-eat meals, bakery products, and beverages that delight the taste buds while offering healthier alternatives to conventional processed foods. In recent years, the marriage of technology and culinary innovation has given rise to a new era of millet-based snacks. These snacks encompass a wide array of options, including savory crisps, crunchy granola bars, and delectable puffed millet clusters. With their satisfying textures and flavors, these snacks not only provide a delightful snacking experience but also pack a nutritional punch, offering the goodness of millets in every bite.

Ready-to-eat meals featuring millets have gained popularity as well, catering to the demands of busy individuals seeking convenient and nutritious options. From millet-based instant porridge to savory millet bowls, these meals are designed to provide a balanced and wholesome eating experience, infused with the inherent benefits of millets. They serve as a time-saving solution without compromising on nutritional value. In the realm of bakery products, technology has facilitated the creation of millet-based bread, muffins, cookies, and more. These innovative products offer a healthier twist to traditional baked goods by incorporating nutrient-rich millet flours. With their light and fluffy textures, these baked treats are not only a delight to savor but also contribute to a well-rounded and wholesome diet. Technology has also enabled the development of refreshing millet-based beverages, including millet milk, smoothies, and energy drinks. These beverages provide an alternative to conventional sugary drinks while offering the nutritional benefits of millets in a convenient and enjoyable form.

The emergence of these innovative millet-based products reflects the growing awareness and demand for healthier food choices. By harnessing technology-driven food innovation, we can transform millets into appealing and accessible options that cater to modern dietary preferences. These products not only enhance the diversity and nutritional value of our diets but also contribute to sustainable agriculture and the economic growth of millet farming communities.

Conclusion

Millet technology has transformed agriculture, improved crops, and promoted healthier food choices. By using advanced farming techniques and processing methods, we have unlocked the full potential of millets. These small grains are now grown sustainably, with higher yields and resistance to harsh conditions. Millets are also turned into nutritious products like flour, flakes, and snacks. Technology has spread the word about millets' health benefits through digital platforms and apps, influencing people to include millets in their diets. Investing in millet technology will ensure a resilient and nutritious future for farming and food.

Processing and Value-addition of Millets

Shubham Gangwar[1], Amit Kumar Singh[1*] and Ghan Shyam Abrol[2]

Millets are a group of highly nutritious and drought-resistant crops that are gaining popularity due to their health benefits and sustainability. It have a high content of fiber, protein, vitamins, and minerals, and also gluten-free.Millets processing for export purpose can add significant value to the crop and provide benefitsto the farmers, processors, and consumers. Millets are nutrient-dense, gluten-free grains that are widely grown and accepted in Asia and Africa. However, despite of their many health benefits, they have been largely overlooked in the global market. In recent years, there has been growing interest in millets due to their nutritional value and environmental sustainability. To tap into the potential of millets as an export commodity, it is necessary to focus on value addition through processing. Value addition of millets can involve several methods such as milling, fortification, and extrusion. These methods can enhance the texture, flavor, and shelf life of millet-based products. Furthermore, fortification with vitamins and minerals can improve the nutritional profile of millets, making them more appealing to health-conscious consumers. Extrusion technology can also be utilized to develop ready-to-eat snacks, breakfast cereals, and instant porridges that are convenient and easy to consume. The value addition of millets can create new opportunities for farmers, processors, and traders in the supply chain management of millets. It can also help to increase the income of smallholder farmers by providing a market for their produce. Additionally, it can create employment opportunities in the processing and packaging of millet-based processing industry. Due to above those reasons year 2023 are announced as International year of Millets.

Introduction

Millets are a group of small-seeded grasses that have been cultivated for thousands of years in various parts of the world, including Africa, Asia, and the Americas. They are highly nutritious and are considered to be some of the most drought-resistant crops in the world, which make them an important staple food in those regions with unpredictable rainfall and poor soil quality. Due to gluten-free in nature, it have a low glycaemic index which make them an ideal food for people with celiac disease, diabetes, and other health conditions. Despite of their many benefits, millets have largely been neglected in the global food system, with most attention being given to other grains such as wheat, rice, and corn. However, in recent years, there has been a growing interest in millets due to their health benefits, sustainability, and potential to improve food security in regions affected by climate change. Processing millets for export can add significant value to the crop and benefit farmers, processors, and consumers. Millets can be processed into various forms such as flour, flakes, and puffed grains, which can be used in a wide range of applications such as breakfast cereals, snack foods, and baked goods. Processing millets can also results in the production of higher value products that are more appealing to consumers and can command higher prices in the market.

Furthermore, millets can be fortified with essential vitamins and minerals during processing, such as iron, calcium, and zinc, which can enhance their nutritional value and make them even more appealing to health-conscious consumers. Processing millets for export can open up new markets for farmers and processors, helping to diversify their income streams and reduce dependence on traditional crops. Ultimately, processing millets for export can help increase the value of the crop, improve the livelihoods of farmers, and provide consumers with a nutritious and sustainable food option. Here are some potential value additions of processing millets for export:

Improved shelf life

Processing of millets can increase their shelf life and prevent spoilage. This can increase their marketability and reduce food waste.

Higher value products

Processing of millets can result in the production of higher-value products such as millet flour, flakes, and puffed grains. These products can be used in various applications, such as breakfast cereals, snack foods, and baked goods.

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Value addition through fortification

Millets can be fortified with essential vitamins and minerals during processing, such as iron, calcium, and zinc. This can enhance their nutritional value and make them even more appealing to health-conscious consumers.

Market diversification

Processing of millets for export can open up new markets for farmers and processors. It can help to diversify their income streams and reduce dependence on traditional crops.

Increased income for farmers

Processing of millets for export can result in higher prices for farmers. That can provide them with a better income and improve their livelihood.

Improved shelf life of millets

Processing of millets for export can improve the crop's shelf life, which can benefit farmers, processors, and consumers. Millets, like other grains, are susceptible to spoilage due to their high moisture content and vulnerability to pests and microorganisms during handling, storage and processing. However, by processing millets, such as through milling or roasting, the moisture content can be reduced the level of moisture, and the crop can be made more resistant to pests and microorganisms, thereby increasing its shelf life or storability. Additionally, the processing of millets can result in the production of value-added products such as flour, flakes, and puffed grains, which have a longer shelf life than whole millets. For instance, millet flour can be used to make bread, cakes, and other baked goods, which have a longer shelf life than whole millets. Millet flakes, which are made by flattening the grain, can be used to make cereals and granolas, which also have a longer shelf life.

Improved shelf life can benefit farmers by reducing post-harvest losses due to spoilage and enabling them to store and sell their millets for longer periods. Processors can benefit from longer shelf life by reducing the need for frequent processing and storage, which can reduce costs and improve efficiency. Additionally, consumers can benefit from longer shelf life by having access to millets that are fresher and less prone to spoilage, thereby reducing food waste. Processing of millets for export can improve the crop's shelf life, which can benefit various stakeholders in the value chain. It can increase marketability, reduce post-harvest losses, and improve efficiency and profitability for farmers and processors, while also providing consumers with access to fresher and more nutritious millets.

I. Millets processing

Millets are small-grained, annual, cereal crops that are grown in different parts of the world. The processing of millets involves a series of operations such as cleaning, grading, de-hulling, milling etc. However, to increase their export potential, value-added techniques can be employed to improve their quality, diversify product range, and increase shelf-life.

A. Cleaning and grading

The first step in millet processing is cleaning, which involves the removal of dirt, stones, and other foreign materials. Grading is done to separate the different sizes of grains, ensuring consistency and uniformity in the final product.

B. De-hulling and decortication

De-hulling is the process of removing the hard outer layer (hull) of the grain, which is usually indigestible. Decortication is the removal of the seed coat or testa, which is rich in fiber and minerals content. Removing the hull and seed coat makes the grain more digestible and improves its nutritional value.

C. Milling

Milling is the process of converting the de-hulled and decorticated grain into flour. This involves grinding the grain into various particle sizes to meet the desired end-use. Milling can be done using various techniques, such as stone milling, hammer milling, and roller milling.

D. Value addition techniques

Value-addition techniques can be used to enhance the nutritional value, taste, and texture of millet products. These techniques include:

- **Fortification:** Adding essential micronutrients such as iron, zinc, and vitamins to improve the nutritional value of the product.
- **Extrusion Cooking:** A process that involves high temperature and pressure to produce extruded products such as breakfast cereals, snacks, and noodles.
- **Roasting:** A process that involves heating the grains in an oven to produce a nutty flavor and aroma.

- **Puffing:** A process that involves heating the grains to high temperature and pressure to produce a light and crispy product.
- **Flaking:** A process that involves passing the grains through a roller mill to produce flattened flakes that can be used in breakfast cereals and snack foods.

Value-addition techniques not only to enhance the nutritional value and sensory properties of the product but also to increase its shelf-life andto make it more suitable for export purpose.

Higher value products

Processing millets for export can produce higher value products such as flour, flakes, and puffed grains, which have a wider range of applications than whole millets. These products can be used in a variety of food applications such as breakfast cereals, snack foods, and baked goods, which can increase the demand and value for millets. Millet flour instance can be used as a substitute for wheat flour in many recipes, particularly in gluten-free products due to its rich in nutrients such as protein, fiber, and minerals, making it an ideal ingredient for health-conscious consumers. Millet flour can be used to make bread, cakes, and other baked goods, as well as other products such as pasta and porridge. Millet flakes are made by flattening the grain and can be used to make breakfast cereals, granolas, and snack bars. They are a convenient and nutritious option for consumers and can be flavored and sweetened to appeal to a wide range of tastes.

Puffed millet grains are made by heating the grain at high pressure, which causes it to expand and become crispy. Puffed millets can be used as a snack food, added to trail mixes, or used as a cereal topping. They are low in fat and calories, making them an ideal choice for health-conscious consumers. Producing higher-value products through millet processing can benefit farmers and processors by allowing them to command higher prices for their products. These products are also more appealing to consumers and can open up new markets for millet-based products, thereby increasing demand and driving up the value of the crop.The processing millets for export can result in the production of higher-value products, which can increase demand and value for the crop. Millet flour, flakes, and puffed grains can be used in a wide range of food applications, which can appeal to a wider range of consumers and open up new markets for farmers and processors.

Value addition through fortification

Processing millets for export can increase the income of farmers by providing them with access to new markets and higher prices for their products. By processing millets into higher value products such as flour, flakes, and puffed grains, farmers can sell their crops for a higher price than they would receive for selling whole millets.Additionally, by processing millets for export, farmers can expand their customer base beyond local and regional markets, and access international markets. This can help to mitigate the risks associated with relying solely on local markets and provide farmers with access to higher-paying markets.

Furthermore, processing millets can help to reduce post-harvest losses by increasing the shelf life of the crop, which can result in less spoilage and waste. This can help to improve the efficiency and profitability of millet production, which can in turn benefit the farmers. Moreover, by processing millets for export, farmers can increase the value of their crop without necessarily having to increase their quantity. This can be particularly beneficial for smallholder farmers who may not have the resources or land to increase their production levels.

The processing millets for export can increase the income of farmers by providing them with access to new markets and higher prices for their products. It can also help to reduce post-harvest losses, improve efficiency and profitability, and provide smallholder farmers with an opportunity to increase the value of their crop without necessarily increasing production.

II. Export potential of millets

Millets have been traditionally grown and consumed in various parts of the world, including Africa, Asia, and South America. However, in recent years, there has been a renewed interest in millets due to their quality and sustainable farming practices. Millets are rich in protein, fiber, minerals, and vitamins and are suitable for individuals with gluten intolerance.

A. Current export scenario

Despite the numerous health benefits and potential for export, the current export scenario for millets is limited. According to the Food and Agriculture Organization (FAO), the global trade of millets is less than 1% of the global cereal trade. India is the leading exporter of millets, followed by China, Nigeria, and Niger.

State/Millet	2017-18			2018-19			2019-20			2020-21			2021-22		
Crop	A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y
Pearl millet	74.81	92.09	1231	71.05	86.64	1219	75.43	103.63	1374	76.52	108.63	1420	67.03	96.24	1436
Sorghum	50.24	48.03	956	40.93	34.75	849	48.24	47.72	989	43.78	48.12	1099	38.08	48.12	1110
Finger millet	11.95	19.87	1662	8.91	12.39	1390	10.04	17.55	1747	11.59	19.98	1724	12.11	16.96	1401
Small Millet	5.46	4.39	804	4.54	3.33	734	4.58	3.71	809	4.44	3.47	781	4.23	3.75	885

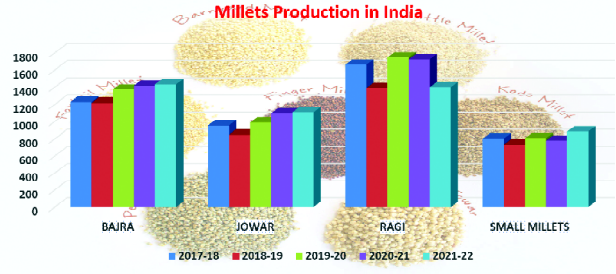
A-Area in lakh ha;**P**-Production in lakh tonnes and **Y**-Yield kg/ha

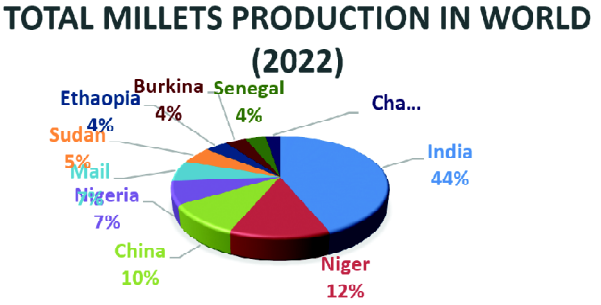
B. Potential export markets

The potential export markets for millets include both developed and developing countries. The developed countries are interested in millets due to their gluten-free and sustainable properties, while developing countries are interested in millets due to their affordability and suitability for smallholder farmers. Some of the potential export markets for millets include the United States, Canada, the European Union, Japan, Australia, and the United Arab Emirates.

C. Constraints and challenges

Despite the potential for export, several constraints and challenges hinder the growth of the millet processing and their export potential. These include limited awareness about the nutritional benefits of millets, lack of processing facilities, inadequate infrastructure, and limited access to credit facilities. Additionally, trade policies and regulations, such as tariffs and phytosanitary standards, can hinder trade in millets.





Market diversification

Processing and exporting millets can contribute to improving food security and nutrition by increasing access to diverse and nutritious foods. Millets are a rich source of essential nutrients such as protein, fibre, vitamins, and minerals, and are therefore an important component of a healthy diet.by processing millets into higher value products such as flour, flakes, and puffed grains, they can be made more accessible and appealing to a wider range of consumers, including those who may not be familiar with or have limited access to whole millets. This can help to increase consumption of millets, which can improve the nutritional status of individuals and communities.

Moreover, processing millets can also help to address issues related to food safety and hygiene. By processing millets, potential contaminants and impurities can be removed, thereby ensuring that the food is safe for consumption. Additionally, processed millets can be packaged and stored in a way that helps to preserve their quality and freshness, reducing the risk of spoilage and contamination. Furthermore, the processing and export of millets can also have economic benefits that contribute to improving food security and nutrition. By increasing the income of farmers and processors, it can provide them with the resources and means to invest in improving their farming practices, accessing healthcare, and purchasing nutritious food.

The processing and exporting of millets can contribute to improving food security and nutrition by increasing access to diverse and nutritious foods, improving food safety and hygiene, and providing economic benefits to farmers and processors. These benefits can help to promote the sustainable development of millet production and contribute to achieving global goals related to food security and nutrition.

Conclusion

In conclusion, the value addition of processing millets for export has immense potential to contribute to the global food market. Millets are highly nutritious, drought-resistant, and adaptable to various agro-ecological zones. However, to tap into their full potential, entrepreneurs must employ value addition techniques to improve quality, diversify product ranges, and increase shelf-life. Recommendations for entrepreneurs looking

to invest in the millet processing and export industry include embracing new technologies, collaborating with research institutions to develop new products, and conducting market research to identify new markets and emerging trends. It is also essential to adhere to food safety and quality standards to ensure the products meet international standards. The future prospects of millet processing and exports look promising, considering the increasing demand for healthy and sustainable food products globally. Moreover, the growing interest in alternative and gluten-free grains presents an opportunity for millets to gain a foothold in the global market. In conclusion, the value addition of processing millets for export is not only beneficial to entrepreneurs but also contributes to global food security and the promotion of healthy diets.

Millets in Tribal Agriculture

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Millets are one of the oldest crops grown in tribal areas, and are known as small seeded crops. Millets are nutritionally superior to wheat and rice in order to protein, mineral, and antioxidant levels and contain 60-70% carbohydrates, 7-11% protein, 1.5-5% lipids along with 2-7% crude fibers and vitamins. As we facing food insecurity, millets have proven its adaptability to diverse agro-climatic conditions such as poor soils, water scarcity and significant variations in weather. This review attempts to assess the cultivation strategy and consumption of diverse millet grains in the tribal communities of India. Tribal agriculture is considered inefficient due to various factors such as limited land ownership, inadequate land use, outdated farming methods, limited financial resources and limited access to modern production inputs. At the time of the Green Revolution, millets were excluded from several governmental schemes, policies, irrigation facilities, marketing campaigns and minimum support price. But now, India focuses on millet importance, and domestic and global demand of food because of increasing population and less arable land of the country and as well as nutritional quality of the crops. The farmers and tribal communities of the country are being adapting both conventional and advance approaches of millets cultivation to fulfill the food demand and nutrient requirement of the people. Still, knowledge of effective technological inventions to develop various strategies for empowerment of the livelihood of millet farming is still required in villages and tribal communities of India. Hence, a proper strategy focused on revamping millet cultivation and consumption would be beneficial in the fight against food insecurity and climate change, particularly in tribal regions of the country.

Introduction

Tribals are the true conservators of crop diversity and ancient knowledge of growing crops under aberrant weather conditions. The introduction of high-yielding cultivars of major cereals (rice, wheat, maize, etc.) and non-traditional crops in millet growing areas resulted in the loss of millet biodiversity and growing area. The traditional cutlivars of these crops are still conserved by tribal community due to their harmony with nature which is inherited in the culture. There is an urgent need to collect, conserve and document neglected germplasm resources with community involvement that could play an important role in sustainable agriculture. However, tribal agriculture is considered inefficient due to various factors such as limited land ownership, inadequate land use, outdated farming methods, limited financial resources and limited access to modern production inputs. Millet is one of the oldest crops grown in tribal areas. They are nutritionally superior to wheat and rice owing to their higher protein, mineral, and antioxidant levels. They contain 60-70% carbohydrates, 7-11% protein, 1.5-5% lipids along with 2-7% crude fibres and vitamins. Moreover, they are gluten free and have low glycemic index; hence suitable for people suffering from gluten allergy. They are considered to be future crops because of their higher resilience to pests and diseases under a changing climate. In the last few years, the interest of Indian people increased in millet farming due to land access to rural families, assets, labor and income opportunities. Knowledge of effective technological inventions to develop various strategies for empowerment of livelihoods for millet farming is still required in villages and tribal communities in India.

Farmers in India are rediscovering and reclaiming the value of millets that were once central to their culture and are now viewed as an ideal adaptation to ensure nutritional security in the present scenario of climate change. Millet gained a reputation as a coarse grain that the underprivileged ate and used as fodder. Since the Green Revolution, millets have largely remained excluded from the government's food grain research, policy, minimum support price, irrigation facilities and marketing campaigns. But now this time, India pushed for the recognition of millet's importance and the creation of domestic and global demand, as well as the provision of nutritious food to the tribal communities.

Connection of millets with tribes

Cultivation of millets is a crucial aspects of farming among the tribal communities in India.

For instance, tribal community "Soligas" inhabitants of BR hills in Chamarajnagar district of Karnataka, celebrate a festival (*Ragi* Habba) with the harvesting of

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millets. Dongriakonth community from orisha cultivates the indigenous native cultivars of millets that can grow well in dry weather. Their self-sufficient farming that depended on local resources was drastically affected by the introduction of high-yielding paddy and wheat varieties which resulted in the loss of several landraces with important attributes. Nowadays efforts involving govt policies with active participation with the community, landraces and uncultivated food systems are being resuscitated to ensure nutritional and food security in dongrias. Indigenous Adivasi community's *baiga* and *gond* from Dindorisamnapur block (M.P.) are traditionally used to cultivate two minor millets; kodo millet (*Paspalum scrobiculatum)* and kutki (*Panicum sumatrense*). They stopped cultivating Kodu and Kutki due to their low price (5-6 Rs. kg^{-1}) but now due to their proven nutritional properties (high protein, dietary fibre, antioxidant and mineral content), they again started growing these two millets with good market value. The union agriculture ministry apprises kodu and kutki along with eight other millets – jowar (sorghum), bajra (pearl millet), ragi (finger millet), kangani/kakun (foxtail millet), cheena (proso millet), jhangora (barnyard millet), kuttu (buckwheat) and chaulai (amaranthus) – as "Nutri-cereals"

In Korku tribe of Maharashtra and Madhya Pradesh, a nutrition disaster arrived back in the 70s, due to deviation from millet cultivation and they favored the production of wheat and soybean. This deviation from millet farming worsens the health and created severe malnutrition in the indigenous population. Indian government through its SABAL project helped Korku tribes to resuscitate the traditional crops and millet. More than 1896 Korku farmers in arid Madhya Pradesh and Maharashtra have adapted to climate change by switching from water-intensive crops to drought-resistant millets. Mayurbhanj is the highest tribal populated distinct in Orissa and has increased millet cultivation from 771.9 ha to 1690.5 ha in 2022. The

Cultivation of millets by tribal communities in difference states of India.

State	Tribes	Millet
Andhra Pradesh	Savara, Gadaba, Koya, Konda reddis	Finger millet, Foxtail millet, Sorghum, Pearl millet
Arunachal Pradesh	Apatani, Nyishi, Idu-Mishmi, Memba, Hill-Mirri, Singpha, Tusta, Lisu, Deori	Finger millet, Kodo millet
Assam	Santali, Bodo, Karbi	Finger millet, pearl millet, Foxtail millet and Proso millet
Bihar	Santhal, Oraon, Kharwar, Kharia, Bhumij, Pahariays	Finger millet, pearl millet
Chhattisgarh	Gond, Baiga,Muria, Bhunjia, Halba	Kodo and Kutki, finger millet, foxtail millet, Proso millet, Barnyard millet
Gujrat	Bhil, Ghamit	Kodo (*Paspalumscrobiculatum*), Finger millet, *Panicum miliare*, Pearl millet, Foxtail millet
Himanchal Pradesh	Gaddi, Kinnaura, Lahaule and Gujjar	Finger millet, Proso millet, Italian Millet, and Foxtail millet
Jharkhand	Asur, Banjara, Birhar, Chera, Gond, Kharia, Munda, SauriPaharia	Pearl millet, Sorghum, Finger millet, Kodo millet
Karnataka	Soligas, Siddhis	Finger millet, Pearl millet
Kerala	Irula, Muduga	Sorghum, Pearl millet, Horsetail millet, Barnyard millet and finger millet
Madhya Pradesh	Korku, Baiga and Gonda	Kodu, Kutki, Sikiya, Pearl millet and Sorghum
Manipur	Paite tribe and Thadoukuki	Finger millet, Kodo millet
Maharashtra	Koli, Korku, Varli, Kathodias	Sorghum, Pearl millet, Barnyard millet and Finger millet.
Meghalaya	Khasi, Garo, Jaintia	Finger millet, Barnyard millet, Foxtail millet and Raishan (*Digitariacruciata* var, *esculenta*)
Mizoram	Mara tribe	Pearl millet, Sorghum, Small millet
Nagaland	Angami, Aos, Changs, Konyak	Peral millet, Finger millet, Sorghum, Foxtail millet
Odisha	Kutiakondh,Bonda, Gadabas, Paroja, Saura, Bhumia, Darua, Bhottadas	Kodo millet, Foxtail millet, Finger millet, little millet, Pearl millet,
Rajasthan	Bhil, Kathodi, Kokna	Pearl millet, Foxtail millet, Proso millet, Sorghum, Kodo millet, Barnyard millet, Finger millet, Kutki
Tamil Nadu	Irula, Muduga, Kurumba	Barnyard millet, finger millet, little millet (*Panicum*sumatrense), Proso millet
Tripura	Lepcha	Foxtail millet, Finger millet, Proso millet
Uttar Pradesh	Baiga, Kol	Pearl millet, Sorghum, Finger millet, Kodo millet
Uttarakhand	Bhotia, Jonsari, Buksa, Raji	Barnyard millet, Finger millet, Amaranth, Foxtail millet
West Bengal	Birhors, Lodhas, Totos	Sorghum, Pearl millet, Finger millet, small millet

state government produced 3,415 quintals of millet in the years 2021-2022, helping the Mayurbhanj farmers to produce 11.5 million rupees of income. Koraput, a drought-prone district in Orissa dominated by Bhumia, Paroja, Gadaba and Kandha grow finger millet as a major crop. Tribal communities; Irulas, Mudugas, and Kurumbas from Attapaddy (Kerala) used to grow millets in their fields but after the 1970s they switched to other crops mainly rice and wheat. The effect of this was shocking, there were many cases of child mortality, maternity deaths, and anemia among the scheduled tribes. In 2018, the government of Kerala initiated a program called the "Millet village project," in which a total of 1465 ha of land were used for growing millets. Within two years of this project, the health of tribal people improved significantly.

Millets in tribal tradition and culture

Tribal festivals play important role in preserving millet as it is an integral part of their culture and festivals. Yimchunger Naga tribe of Nagaland celebrate 5day auspicious festival namely "Metumniu festival" after millet harvesting as it is a staple food crop for them. They have deep respect for agriculture and the harvested yield. Hence, they express their deep gratitude to God through festival celebrations. The wancho cultural society (WCS), Shillong, organized a three day millet festival called "Pungzm". Since millets have been a staple crop in the wancho tribe for generations hence local millet based dishes and products are featured in their stalls. Kutiakondh community of kandgamal distict of Orissa celebrates burlang yatra (indigenous biodiversity festival) in the spring season, which brings together millet farmers from various villages of district to exchange heirloom seeds and share knowledge about millet farming.

Millet is integral parts of rural agricultural farming thus various dishes are prepared with millet in different parts of India. In the various part of Maharashtra, Madhya Pradesh, Uttar Pradesh, Karnataka, and Rajasthan, roti is prepared from Jowar known as jowar roti or bhakri. In Punjab, Haryana, Rajasthan, Tamil Nadu and some parts of Uttar Pradesh, Bajra (pearl millet) roti is prepared. Mudde is prepared from ragi (finger millet) in Karnataka and some parts of Andhra Pradesh and Tamilnadu. In Tamilnadu a porridge called kambamchoru is made from boiled pearl millet. In hilly area of Uttarakhand people used barnyard millet as paleu or chencha (savoury porridge) cooked in buttermilk and finger millet as ragi roti and badi (made from ragi powder with warm water). Tribes of koraput and dasamantpur block (Orissa) make various finger millet dishes i.e. Mandiapitha (ragi flour in banana leaves), Mandiatampa (ragi flour with rice and warmwater), mandiakandulraav (ragi flour with whole arhar dal with some masala), mandiasukuaraav (ragi with dried fish). Similarly, in Arunanchal Pradesh a famous dish called 'Zan' is prepared with finger millet porridge with vegetable. Bhile community in Rajasthan use finger millet for making bread and porridge. In hilly regions of Uttarakhand, finger millet is used to prepare ragi roti, savoury porridge (made in buttermilk,) and badi (made with ragi powder and warm water). Kodedambu (millet ball), belnapetha (millet based roti) and sunumpitha (millet malpuva) are traditional finger millet dishes in boro tribe (Assam). Panchkuti Khichdi, a himanchali pearl millet recipe prepare with different pulses in one pot. Poumainaga tribe of Manipur makes sticky cake from foxtail millet

Millet based fermented drinks are popular among tribal communities of Arunanchal Pradesh. Sur, Maduaapong are common local beverages consumed by nyishi tribes (Arunanchal Pradesh). The Nyishi celebrates its annual NyokumYullo Festival in February in which "Apong" is served as a staple drink and distributed to all attendees during the festival, it is a sacred occasion to seek the blessing of the Nyokum goddess. Similarly, Khowa tribes make a starter drink with rice and millet. Chhage or kodo ka jaar a traditionally made finger millet based drink served in bamboo by Gurung, Limbu, Sapa,rai gorkha, bhutia, Lepcha and Monpa communities. The Local Lepcha community of Sikkim offers the Chhang drink as "chi" to their deity during religious ceremonies. Angaminaga tribe celebrates the tssinyi millet festival in which millet khichdi and millet apong are common dishes. A popular drink "Themsing" prepared by monpa tribes (Arunanchal Pradesh) with finger millet or barley. Rakshi is an alcoholic beverages used by tribes such as Monpa, mismis and miji, this drink is either prepared with finger millet, rice and barley. Mingri/ lohpani/ bhangchung, fermented drinks prepared by monpa tribe of tawang (Arunanchal Pradesh) prepared with finger millet,rice,maize and barley. Koozh a fermented porridge made with millet (kezhvaragu) or broken rice in Tamil Nadu and without fermented, hot koozh is offered at mariamman temple festivals across rural Tamil Nadu. India had a deep connection with the millets it can see in its culture. Vishakhapatnam based tribal community celebrates a community festival in which ragi based dishes are offered to bullocks. Similarly, in some parts Andhra Pradesh of after Diwali celebration, ragi pancakes are prepared before entering the house.

People from southern part of India offered ragi dishes to snake God on Naga Panchami. On the occasion of the popular fast "JitiyaVrat" in eastern Bihar, Uttar Pradesh and Jharkhand It's inescapable to eat Maduaki roti after the fast.

Apart from food, Indian tribes are greatly associated with millet through medicinal uses and other household uses. The tribal community of Bastar Plateau Zone of Chhattisgarh is using kodo millet straw ash as fertilizer in the onion field to increase the yield, kodo millet strawin paddy field to control blast disease and pest (leaf folder) and seeds of kodo millet for treatment of ranikhet disease of poultry. They use kodo millet grain as cattle feed to cure the tympani disorder and to increase milk production. To build termite-resistant house walls, they use Kodo millet straw mixed with mud. During wedding rites in Madhya Pradesh, madiah (ragi) and turmeric are blended and applied to the bodies of the bride and groom. In tribal groups, millet seeds are often utilized to ward off evil spirits. To ensure successful hunting and a plentiful harvest, the Pahadi Korwatribe of Chhattisgarh drapes millet stalks in their courtyards. As a further check to ward off bad omens, some respondents also mentioned that finger millet grain is wrapped in cloth with ash and salt and fastened around the neck, according to Taabiz (2.2%). An important festival for the tribal people of Bastar is Gaadi, during which finger millet grains are distributed as "Prasaad".If these grains of finger millet are sprinkled on mango and or tamarind trees that aren't yet bearing fruit, those trees begin to grow fruit the very next season. Madhya Pradesh tribal groups prepare paye using Kodo rice (cooked and fermented Kodo rice) and pooped grain also used as snacks. In its early stages, the plant is used as green

Medicinal uses of millets by different tribal communities in India.

Millet	Parts used	Tribe	Medicinal use	State	References
Finger millet	Grain flour mixed with ghee	Tolcha, Marcha subtribe of Bhotia	For cut and wounds	Dhauli Ganga Uttarakhand	Kandari *et al*., 2012
Finger millet	Grain flour	Gond, Muriya	Instant relief from burning sensation	Bastar,Chattishgarh	Shahu and Sharma, 2013
Finger millet	Fruit and leaves	Adiyan, KurumanIrular and vitolia	Dysentery, wound healing, measles, small pox, fever, ulcers and diabetes	Andhra Pradesh, Kerala, Karnataka, Tamil Nadu	Sreeramulu *et al*., 2013 and Latheef *et al*., 2014
Finger millet	Fermented seeds	Lepcha	In body ache and gastric problem	Sikkim	Pradhan and Badola(2008)
Finger millet	Grains	Apatani	Stomach disorder and cold	Arunachal Pradesh	Kala, 2005
Foxtail millet	Whole plant	Kattuanaicka, Kurichya, Kuruma and Paniya tribes	Rejuvenation of nervous system, epilepsy, dyspepsia, poor digestion	Kerala	Dileep and Naiyer(2015)
Foxtail millet	Whole plant	Adiyan, KurumanIrular and vitolia	Shivering, poor digestion, diuretic, bone fracture and dyspepsia	Andhra Pradesh, Kerala, Karnataka, Tamil Nadu	Maloles *et al*. (2011)
Barnyard millet	Stem and seeds	Kharka and Chani	Jaundice	Uttarakhand	Singh *et al*., 2017
Barnyard millet	Grain	Bhotia	Jaundice	Uttarakhand	Phondani *et al*., 2010
Kodo millet	Grain	Bhil and Patliya	Corneal obesity, wounds, indigestion, infection, diabetes	Rajasthan	Lohar *et al*., 2019
Kodo millet	Root and rhizome	Kurichya	Diabetes and wounds	Kerala	Dileep and Nair (2015)
Kodo millet	Stem, root, rhizome and seed	Adiyan, Kuruman, Vitolia and Irular	Diabetes, diuretics, bowel cleanser, vitamin supplement and reduce inflammation	Andhra Pradesh, Kerala, Tamil Nadu and Karnataka	Maloles *et al*. (2011), Dileep and Nair (2015)
Proso millet	Grain	Bhotia	Curing measles	Uttarakhand	Phondani *et al*. (2010)

fodder. When combined with green fodder, a stover is used as cattle feed. In addition to being utilized as a roofing material, stover is also made into native beds, pots, and earthenware in Madhya Pradesh's rural districts. The potential for using the grains industrially is still being investigated.

Revolution of millet farming in India

Cultivation and consumption of millet has significantly declined due to polices centered around the green revolution which is primarily focused on food security. Nutritional security was not a primary focus of this revolution. This results in the current situation of malnutrition and various non-communicable diseases in tribal communities. Millet role in tackling the various diseases and vast potential for export markets makes them an immune booster and super food owing to their rich nutrition profile.

The Government of India has prioritized millets because of their huge potential and alignment with numerous UN Sustainable Development Goals (SDGs). Millets were renamed "Nutri Cereals" in April 2018, and the year 2018 was proclaimed the National Year of Millets to generate greater demand. The CAGR for the global millets market is predicted to be 4.5% between 2021 and 2026. To kick off the International Year of Millets (IYoM) - 2023, the Food and Agriculture Organization (FAO) of the United Nations hosted an inauguration ceremony in Rome, Italy, on December 6, 2022. A group of senior Indian government officials attended the occasion. Next in the series, the Department of Agriculture and Farmers Welfare sponsored a special "Millet Luncheon" for the Members of the Parliament at the Parliament building preparatory to the year-long celebration of "The International Year of Millets (IYoM) 2023.

Even though having several benefits, millets are only used as food by traditional rural populations. This is primarily due to the lack of consumer friendly ready-to-eat millet products. Millets have recently received more recognition to obtain their value-added processed goods due to their higher nutritional values. Tribal women self-help groups in the Eastern Ghats are capitalizing on the rising popularity of millets and the urban population's growing awareness of their health benefits. Tribal women are developing their cookery talents and learning how to make delicious millet products that would appeal to urban consumers in 15 villages in Odisha's Koraput district. Similarly, the Kathirimalai tribe in Erode, Kerala is using the support provided by the state government project "VaazhndhuKattuvom" to make various value-added products from millet and as a result, they can improve their standard of living.

Now, the Indian government has refocused its attention on millet farming and encouraged tribal and rural populations in this sector. There are various programs and schemes for helping farmers in millet farming including the following:

- ICDP-CC Programme (Integrated Cereals Development Programmes in Coarse Cereals) under macro-management of agriculture
- RADP (Rainfed Area Development Programme) under Rastriya Krishi Vikas Yojana (RKVY)
- Initiative for Nutritional Security through Intensive Millet Promotion under Rastriya Krishi Vikas Yojana.

Conclusion

Millet cultivation in tribal areas after green revolution had declined drastically, thus farmers shifted to more commercial crops to improve their living standards. However, later they faced severe health issues and malnutrition due to the absence of millet in their diets. They used to grow more than 80 varieties of millets, but now the majority of the germplasm is no longer available due to their focus on other crops. Millets have long been excluded from government research policies, minimum support prices, and marketing campaigns, but in recent years the revival of millet farming not only addresses the issue of malnutrition amongst tribes, but they can also generate reasonable income from it. Millets could be the better option for farmers in times of global warming and climate change because they have better tolerance to heat, drought and pests. Millets due to their climate resilient property rich nutritional profile considered as super food and future crop.

Proso millet: Germplasm Resources, Genomics and Breeding

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Proso millet is one of the small millets grown since ancient times in India. It is well adapted to a changing climate and possesses many nutritional and nutraceutical properties. The germplasm resources of Proso millet, conserved in various national and international gene banks, provide valuable resources for unlocking the repository of genetic diversity and trait discovery. The breeding methods followed in self-pollinated crops such as pure line selection, pedigree selection, mass selection, heterosis breeding and mutation breeding, are also applicable to proso millet. Now the information on the nuclear and chloroplast genome sequences of the proso millet is available for molecular breeding. Recent high-throughput phenotyping and genotyping platforms along with robust statistical tools can be utilized for identifying underlyinggenes/ QTLs for useful traits in proso millet. Genomics-assistedbreeding approaches such as marker-assisted backcross breeding (MABB), marker-assistedrecurrent selection (MARS), and genomic selection (GS) are helpful in developing improved the proso millet cultivars. Moreover, genome editing tools can further accelerate the improvement of proso millet for desirable traits.

Introduction

Proso millet (*Panicum miliaceum*) is one of the most important small millets grown in India. It is known by different names in different languages of India such as Cheena (Bengali), Cheno (Gujarati), Vari (Marathi), China Bacharibagmu (Odia), Bagaru (Kannada), Panivaragu (Tamil) and Variga (Telugu). Proso millet is consumed as food and also used as poultry and livestock feed in different parts of Asian countries. In India, the area under proso millet is 0.41 lakh hectares with a production of 0.22 lakh tonnes. The major proso millet producing states are Madhya Pradesh, Bihar, Tamil Nadu, Uttar Pradesh, Karnataka, Andhra Pradesh and Maharashtra. Proso millet is a C4 crop that can be grown on a variety of soils including low fertile soils and thrives well under drought stress. The grains of proso millet are good source of carbohydrates and are rich in protein, dietary fiber, minerals, vitamins and essential amino acids.Proso millet, like other small millets, has significant nutraceuticalproperties and health benefits.

Germplasm resources

Proso millet is a tetraploid crop (2n = 4x = 36) belongsto the tribe *Paniceae* and family *Poaceae*. Presence of genetic variability and its conservation is considered essential for crop improvement and stable production. The largest collection of proso millet is conserved in Russia (34%) followed by China (33%), Ukraine (19%), India (11%) and USA (3%) (Rajasekaran and Francis, 2021). In India, proso millet germplasm is maintained by two ICAR institutes, NBPGR, New Delhi (994 accessions) and AICRP-small millets, Hyderabad (920 accessions) along with one international institute, ICRISAT, Hyderabad (849 accessions).

These three institutions are actively engaged in collection, evaluation, characterization and documentation of proso millet germplasm. Through the qualitative and quantitative characterization of 833 accessions of 30 countries, ICRISAT has developed a core set of 106 accessions of proso millet that represent the valuable genetic resources for proso millet improvement.

Nutraceutical properties of proso millet and their health benefits.

S. No.	Responsible factor	Health benefits
1.	Low glycemic index	Prevent type-2 diabetes and cardiovascular disease
2.	High cholesterol level	Reduced obesity
3.	High adiponectin	Improved lipid metabolism and insulin sensitivity
4.	Absence of gluten protein	Prevent celiac disease
5.	High fiber content	Reduced constipation
6.	Phenolics, flavonoids, anthocyanin and phytic acid	Antioxidants advantage
7.	Anti-proliferative action	Reduced risk of breast and liver cancer

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Proso millet improvement approaches

A. Conventional breeding approaches

The breeding methods followed in self-pollinated crops such as pure line selection, pedigree selection, mass selection, heterosis breeding and mutation breeding are also applicable to proso millet. In India, the majority of proso millet cultivars are developed by selection from landraces and local cultivars. Of the 24 varieties of proso millet, about 65% are developed by selection from landraces. Pedigree selection involving hybridization followed by selection in segregating population is also an important breeding method used in proso millet. About 29% of the released varieties of proso millet in India are developed using pedigree selection. However, hybridization in proso millet is not easy due to its floral morphology and anthesis behaviour. For hybridization in proso millet, the panicles of selected plants are enclosed in a parchment bag before flowering and controlled hybridization is made by hand emasculation and pollination. The use of heterosis breeding in proso millet is limited due to difficulties in hybridization. Thus, developing male sterile lines would be a viable option to use heterosis. Mutation breeding also plays an important role in self-pollinated crops like proso millet to create variability.The most effective dose of gamma irradiation in proso millet is 20 krad for isolating high yielding mutants, while 40 or 50 krad is effective for early maturing mutants. At Department of Agricultural Botany, College of Agriculture, Dapoli (Maharashtra), two early maturity (20krad-21-1 and 60krad-101-19) and two high yielding (40krad-194-9 and 50krad-156-6) proso millet mutants has been developed by gamma irradiation.

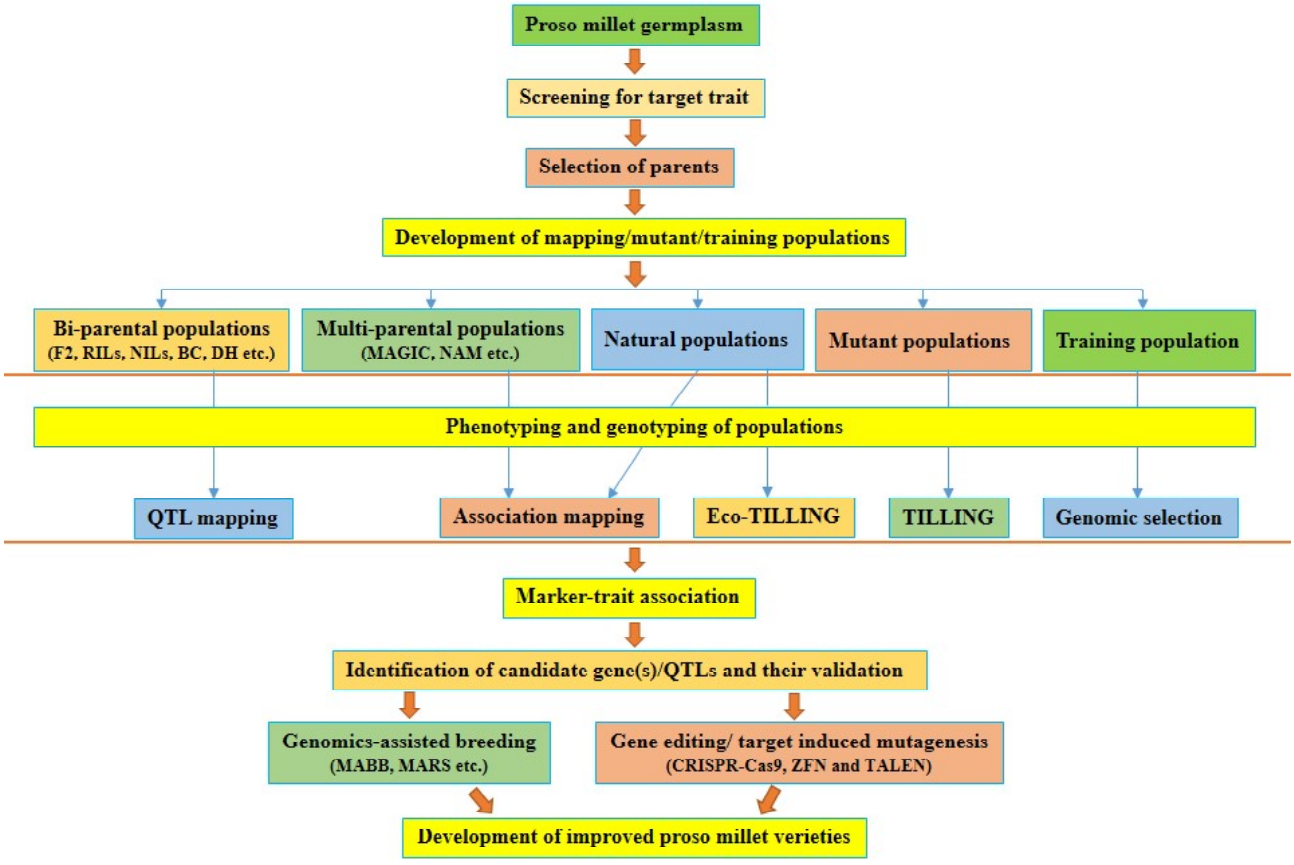
B. Genomics-assisted breeding approaches

(i) Genome sequence

The genome of proso millet was sequenced by Dr. Zhang Heng and Dr. Zhu Jiankang of the Chinese Academy of Sciences, China. The assembled genome sequence of proso millet contains 5541 contigs and has a contig N50 of 369 kb. The estimated size of proso millet genome is 923 Mb. The sequenced genome predicted 55,930 protein coding genes, 55,527 pseudogenes and 9643 noncoding RNAs. It contains 339 miRNAs, 1420 tRNAs, 1640 rRNAs and 2302 snRNAs(Krishna *et al*. 2022). The genome sequence of proso millet exhibited 58.2% repetitive elements, of which 92.1% are transposable elements. The chloroplast genome of proso millet was sequenced by Dr. X. Nie group. The size of the chloroplast genome is 139,826bp, which contain 108 genes. Of the 108 genes, 76 were protein coding, 28 were tRNA and 4 were rRNA genes.

(ii) Gene mapping and marker-assisted selection

Marker-assisted selection (MAS) helps in reducing the time and effort required for genetic improvement of complex traits. The identification of markers tightly linked to target traits is the first step in MAS. Prior to the emergence of genome sequence approaches, low-throughput markers, including RAPD, RFLP, AFLP and SSRs were developed and used for diversity analysis of proso millet germplasm. QTL mapping and genome-wide association studies (GWAS) are two useful approaches for identification of markers linked to target traits in proso millet. QTL mapping involves development of mapping populations either bi-parent (F_2, $F_{2:3}$, RILs, NILs, DH etc.) or multi-parent (NAM, MAGIC etc.) followed by finding marker-trait association using appropriate statistical tools.Rajput *et al*. (2016) mapped SNP markers associated with important agro-morphological traits using RIL population in proso millet. GWAS is a robust and powerful tool that can be used for mapping of the complex traits in proso millet. GWAS performs statistical associations between genotyping and phenotyping data for the trait of interest in a diverse set of germplasms or multi-parent populations. Boukail *et al*. (2021) using GWAS approach mapped SNP markers for agronomic and seed traits in proso millet. Genomic selection (GS) is another promising strategy with great potential to explore and increase genetic gain per selection in proso millet breeding. In GS, prediction models are developed based on the information obtained from genotyping and phenotyping of training population. This data is used to predict the genomic estimated breeding values (GEBV) for the breeding materials.TILLING and Eco-TIILING approaches can be used in proso millet for identifying allelic variants for useful traits using mutant population and natural population, respectively. The marker(s) identified through various mapping approaches can be utilized in marker-assisted backcross breeding (MABB) and marker-assisted recurrent selection (MARS). In MABB, foreground, background, and phenotypic selection is carried out in segregating backcross and selfed progenies to introgress desired traits into elite high-yielding and most popular varieties. MARS is a method to accumulate large number of QTLs within a population using subset of markers significantly associated with target traits. This method involves the mapping of early F_2 and F3 generations using genotyping and phenotyping



Integration of various genomic approaches for proso millet improvement

data and then followed by the recombination of selected individuals based onmarker index only for three generations to develop the population with a high frequency of favorable alleles. The advanced bio-technological tools such as CRIPSR-Cas9, ZFN and TALEN can also be applied in proso millet for targeted alteration in genome sequence. The integrated scheme of various approaches for genetic improvement of proso millet is illustrated in Figure.

Conclusion

The changing climate and nutrients poor cereal-based diet challenges food and nutritional security. The grains of proso millet possess many nutritional and nutraceutical properties that help in improving health status and prevent many health disorders in humans. It is also adapted to varying soil and climate conditions, thus can help in mitigating the effect of climate change. Unlocking the repository of genetic diversity of proso millet and their efficient utilization in pre-breeding programs is considered imperative now. In India, the majority of proso millet cultivars have been developed by selection from landraces/local cultivars followed by pedigree selection. Mapping of useful genes/QTLs followed by the use of genomics-assisted breeding approaches such as MABB, MARS, and GS can accelerate the pace of proso millet breeding. Moreover, genome editing tools can further speed up the improvement of proso millet.

Pearl Millet: Food, Feed and Fodder

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Pearl millet [*Pennisetum glaucam* (L) R. Br. Syn. *Cenchrus americanus* (L.) Morrone] is the world's sixth most important cereal and the primary food source in the dryland farming systems of semi-arid and tropical environments. India and Africa, it is primarily grown for food and forage, while in the American continents it it's a main component of the poultry and livestock sector. Pearl millet was domesticated over 4000 years ago in the West African Sahel. Spread later to east Africa and India. It is now being cultivated over 30 million ha. Worldwide, with the majority of the crop grown in Africa (<10 million ha.).

Introduction

Pearl millet is often considered to be "super cereal" with respect to its rapid growth even with the least input, high photosynthetic efficiency, inheritably good and balanced nutritional profile, tolerance to extreme climatic conditions and biotic stresses. India has the distinction of being the largest producer of the crop, both in terms of area and production in the world. It's grown in 7.41 million hectares area with a production of 10.3 million tons during 2020-21. The major pearl millet growing states are Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana, which account for more than 90% of pearl millet acreages in the country. It's known by a variety of names viz., Bajra/Bajri (Hindi), Sajje (Kannada) and Sajjalu (Telugu). Further, Pearl millet is the first crop to develop biofortified variety "Dhanashakti with high iron and zinc.

Nutritional profile

Composition of pearl millet grain in comparison with rice, wheat, and maize

Grain	Protein (%)	Fat (%)	Ash (%)	Carbohydrates (%)	Total dietary fiber (TDF)	Energy (Kcal)
Pearl millet	10.96	5.43	1.37	61.8	11.5	347
Rice, raw, milled	7.9	0.52	0.56	78.24	2.81	356
Wheat, whole	10.59	1.47	1.42	64.72	11.2	321
Maize, dry	8.8	3.7	1.17	64.7	12.2	334

Important minerals present in pearl millet in comparison with rice, wheat, and maize

Grain	Ca (mg)	P (mg)	Mg (mg)	Zn (mg)	Fe (mg)
Pearl millet	27.4	289	124	2.8	6.4
Rice, raw, milled	7.5	96	19	1.2	0.6
Wheat, whole	39.4	315	125	2.8	3.9
Maize, dry	8.9	279	145	2.3	2.5

Important B- vitamins present in pearl millet in comparison with rice, wheat, and maize

Grain	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)	Folic acid (µg)
Pearl millet	0.25	0.20	0.9	36.1
Barnyard millet	0.33	0.10	4.2	*
Rice, raw, milled	0.05	0.05	1.7	9.32
Wheat, whole	0.46	0.15	2.7	30.1
Maize, dry	0.33	0.09	2.69	25.8

Advantages of growing pearl millet

- It's a short duration crop, which completes its life cycle within 3-5 months.
- Resource use efficient crops which can be grown in marginal lands with low inputs.
- Hardiest, resilient and adaptable to harsh climate.
- Fodder crops in arid and semi-arid regions.
- Pearl millet popular fodder for the summer season (lean period for green fodder availability)
- Multicut bara provides long-term green fodder as farmers can take upto 3-5 cuts

Value added products from pearl millet

The millets have diversified high food value, but the consumption of these millets has declined for want of standardized processing techniques to compete with

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fine cereals. Hence an effort was made to increase the utilization of millets in a popular foods which would find ready acceptability with the tag of 'HEALTH FOODS'. Millet-based value-added products including traditional recipes, bakery products, pasta products, flaked and popped products instant food mixes were developed and popularized in India. Major value added products developed in pearl millet include pearl millet puffs, chapati, pasta, dhokla and biscuits.

Pearl millet as fodder

The livestock sector contributes 4.11% GDP and 25.6% total agricultural GDP. Increasing in population, urbanization and health consciousness has resulted in increasing demand of livestock products. The projected demand for milk and meat will be 400 and 14 million tonnes respectively by 2050. However, at present the country is facing a net deficit of 31% of green fodder and 12% of dry fodder (Roy *et al*., 2019). Furthermore, the average cow milk yield in India is 1014kg/animal/ year which is 52% lesser than world average and 84% lesser than developed countries like USA, Israel and Canada. Pearl millet is a major forage crop of arid and semiarid regions and is able to produce more leafy biomass silage yield under limited moisture regimes than forage sorghum and corn (Harinarayana *et al*., 2005). Multicut bajra is becoming more popular and emerging as popular summer season forage crop for in the northern and western parts in India. By growing multicut bajra, farmer can take upto 3-6 cuts in an interval of 20 to 30 days between two cuts of green forage. Further, bajra being the most drought and heat tolerant, nutrient use efficient crop can be grown in summer season (march to June) where other forage crops fail to give better yield. The summer season is also considered as lean period for green forage availability in the Indian farming system. Forage with low fibre and high crude protein and digestibility favour better animal intake and assimilation of energy, minerals, and vitamins.

- Average bajra contains 7-10% crude protein, 56-64% NDF, 38-41% ADF, 33-34%cellulose and 18-23% hemi cellulose on a dry matter basis.
- Single cut forage pearl millet and multicut forage pearl millet
- Multicut forage pearl millet varieties are popular summer season forage crop for in the northern and western parts of India. This can be cut and fed at any growth stage of the crop as it has no HCN content.
- Bajra being most drought and heat tolerant, nutrient use efficient crops can be grown in the summer season where other forage crops fail to give better yield.
- Bmr pearl millet forage genotypes contain less lignin, more crude protein, have higher DM degradability and digestibility

(a) Fodder pearl millet at vegetative stage

(b) Pearl millet field at seed set stage

Important fodder cultivars of pearl millet

Name of Cultivar	Nature of Cultivar	GFY (q/ha)	DFY (q/ha)
APFB-2	Multi cut variety	350	55
AVKB–19	Single cut variety	380	88
BAIF Bajra-1	Single as well as multicut	380-400	80-100
Giant Bajra	Multi cut variety	550	110
GFB-1	Multi cut variety	595	350
PAC-981	Single cut variety	584	128
APFB 09-1	Multi cut variety	302	69
Moti Bajra	Multi cut variety	811	277
TSFB 15-4	Single cut variety	426	84.7
TSFB 15-8	Single cut variety	420	86

Value addition in fodder pearl millet

Silage

- The single cut pearl millet varieties – harvested at between the milk and dough grain stage suitable for silage making.
- Stay green genotypes after the grain harvest can be harvested and converted into silage
- High sugar genotypes used mostly for silage. Quality and yield are stable near harvest with a balance between stem sugar content and grain yield.
- Specially bred BMR pearl millet lines will have 40 to 60% less lignin, their digestibility is higher by 15 to 30% are suitable for silage making.
- Current climate change scenario fodder millets would be the best alternative to corn in silage making

Millets as poultry feed

Replacement of corn with pearl millet in broilers' diets has led to significant enhancements of growth and feed efficiency. Pearl millet could replace 25–50% of maize in a broiler's diet without affecting its performance. Feeding pearl millet to laying hens is believed to have additional benefits because the eggs contain higher omega-3 fatty acids and lower omega-6.

Total mixed ration (TMR)

TMR, chopped green fodder and silage are blended with cereals, cereal by-products, protein sources, minerals, vitamins and feed additives in order to provide balanced ration to the dairy animals. Total Mix Ration (TMR) is an efficient system of delivering nutrients to dairy cattle and buffaloes. Crop residue based TMR (also referred to as 'dry TMR') is more popular among small hold dairy farmers. Millet based TMR can be prepared utilizing millet grains and straws of jowar and bajra. Bajra straw and Sorghum straw can be included up to 20-30% and 20-60% in the TMR preparation.

Advantages of TMR

- Improved feeding efûciency of livestock
- Perfect balance of all nutrients including minerals.
- Increased intake of dry matter (DMI)
- Lowers the risk of digestive upset, stabilizes rumen pH, and optimizes rumen feed digestion
- Increased milk production (5-8%) as compared to conventional ratio
- TMR increases milk fat content.

Conclusion

In current scenarios of climate change and increasing demand for foodgrains, milk and meat, a climate change-ready smart crop like pearl millet offers exciting opportunities towards improving the human nutrition and livestock production for different agro-ecologies globally. It can be grown easily during kharif and summer season in marginal soils. By any nutritional parameter, Pearl millet is ahead of rice and wheat in terms of their mineral content, compared to rice and wheat. This has low glycaemic index, which is higher in dietary fibre and antioxidants. Value-added products like pearl millet puffs, biscuits and other popular bakery products are attracting urban markets as healthy snacks. The consuming pearl millet prevents life style disease and improves immunity. This is the best crop to cultivate during summer season to meet fodder requirements. High sugar and bmr genotypes will be suitable for silage and TMR preparation as feed to the livestock. Overall, pearl millet is gifted to earth as a food, feed and crop.

Cultivating the Past, Nourishing the Future: The Significance of Sorghum in Tamilnadu

K Rajarajan[1], E Priyadarshini[1], Neha Gangwar[1], Rumana Khan[2], AK Handa[1] and A Arunachalam[1]

Sorghum (*Sorghum bicolor*) holds a paramount position in the agricultural landscape of Tamil Nadu, India. This study explores the multifaceted significance of sorghum in the region, considering its historical, cultural, nutritional, and economic dimensions. The significance of sorghum in Tamil Nadu extends beyond its agrarian role, encompassing cultural, nutritional, and economic dimensions. Recognizing and supporting the cultivation of sorghum is crucial for preserving the region's rich agricultural heritage, ensuring food security, promoting a diverse and nutritious diet, and sustaining the livelihoods of numerous small holder farmers. This study advocates for continued research and policy measures aimed at enhancing the prominence and productivity of sorghum in Tamil Nadu's agricultural landscape.

Introduction

Sorghum (*Sorghum bicolor*) originated in Africa, specifically in the northeastern part of the continent. Its domestication likely occurred around 8,000 to 10,000 years ago in the Nile Valley region of northeastern Sudan. It is a versatile and ancient cereal grain that has been cultivated for thousands of years, making it one of the world's oldest crops. It belongs to the grass family, Poaceae, and is primarily grown for its seeds, which are used as a staple food source, animal feed, and for various industrial purposes. Sorghum is a highly adaptable crop and is grown in various regions around the world, particularly in areas with semi-arid and warm climates. Its distribution extends beyond its African origin to encompass many continents. Key regions for sorghum cultivation include: Africa, especially in sub-Saharan Africa, Asia, United States of America, South and Central America and Australia. India is distributed in almost all states like Maharashtra, Karnataka, Andhra, Telangana, Tamilnadu, Gujarat, Madhya Pradesh, Rajasthan, Uttar Pradesh, Bihar, Haryana and Punjab. It is also grown in smaller quantities in states like Chhattisgarh, Jharkhand, Odisha, West Bengal, and Assam. In this article, we will explore the multifaceted significance of sorghum in Tamilnadu.

Sorghum cultivation in Tamilnadu

Sorghum, known locally as "Cholam" in Tamilnadu, holds a unique and vital place in the state's agricultural heritage. This hardy, drought-resistant grain has been cultivated in the region for centuries, and its importance goes beyond just being a staple crop. Sorghum, known as "Cholam" in Tamil, has been an important staple and forage crop in the state for centuries. Sorghum has a rich historical background in Tamilnadu, dating back to ancient times. It was one of the primary cereals cultivated during the Sangam period, and its role in sustaining ancient civilizations cannot be understated. The cultivation practices have been passed down through generations, contributing to the preservation of traditional agricultural knowledge.

Sorghum is not just a crop; it's deeply embedded in Tamilnadu's culture and cuisine. Traditional dishes like "CholamKuzhiPaniyaram" and "CholamIdli" are beloved by locals and showcase the versatility of sorghum in South Indian cooking. Additionally, it is often used to make "Cholam Maavu," a flour used in various dishes, including bread and porridge. Sorghum is a powerhouse of nutrients. It's rich in fiber, antioxidants, and essential minerals like iron and magnesium. Its gluten-free nature makes it a preferred choice for those with dietary restrictions, contributing to the state's health and well-being.

Tamilnadu, like many other parts of India, faces challenges related to climate change and water scarcity. Sorghum's ability to thrive in arid conditions makes it a resilient crop choice for farmers. It requires less water compared to other grains, reducing the strain on water resources.Sorghum cultivation plays a significant role in the state's economy. It provides livelihoods for numerous farmers and contributes to food security. The production and sale of sorghum products also generate income and employment opportunities, particularly in rural areas. Geographical distribution of sorghum in Tamilnadu as; Northern districts: Dharmapuri, Krishnagiri, Salem, Erode, and Namakkal. Southern districts: Ramanathapuram and Tirunelveli. Sorghum is also cultivated, mainly in rain-fed areas as Madurai, Dindigul, Theni, Ramanathapuram, Tirunelveli, Thoothukudi, Virudhunagar, Sivagangai, Tiruchirapalli, Erode, Salem, Namakkal, Coimbatore and Dharmapuri.

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Nutritive value of Sorghum

Food	Energy Kcal	Protein (g)	Fat (g)	Carbohydrates (g)	Calcium (mg)	Iron (mg)	β-Carotene (mg)	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)
Jowar	349	10.4	1.9	72.6	25	4.1	47	0.37	0.13	3.1

Exploring the rich culinary heritage of sorghum: Delectable dishes in Tamil Nadu

Sorghum being used to prepare a variety of dishes, here are some traditional and popular sorghum-based dishes in Tamil Nadu:

- **Cholam pongal:** This is a popular breakfast dish made with sorghum and split green gram (moong dal). It's cooked similarly to traditional rice pongal and is often seasoned with black pepper, cumin seeds, and curry leaves.
- **Cholam biryani:** Sorghum is used as a substitute for rice in biryani preparations. Cholam biryani is cooked with aromatic spices, vegetables, and sometimes with chicken or mutton for a flavorful one-pot meal.
- **Cholam roti:** Sorghum flour is used to make flatbreads or rotis. These are often enjoyed with various vegetable curries and chutneys.
- **Cholam dosai:** Sorghum flour can also be used to make dosai (pancakes). Cholamdosai is a gluten-free alternative to traditional rice-based dosai and is often served with coconut chutney or sambar.
- **Cholam kanji:** Sorghum is used to make a nutritious porridge or kanji. It's a comforting dish, especially during times of illness or as a simple and wholesome breakfast.
- **Cholam koozh:** This is a fermented sorghum porridge. Sorghum flour is mixed with water, salt, and sometimes buttermilk to create a slightly tangy and cooling summer drink.
- **Cholam upma:** Sorghum grains can be used to prepare upma, a savory and nutritious breakfast dish. It's cooked with vegetables, spices, and sometimes grated coconut for added flavor.
- **Cholam sundal:** Sundal is a South Indian snack made from legumes or grains. Sorghum sundal is prepared by boiling sorghum grains and then tempering them with mustard seeds, curry leaves, and grated coconut.
- **Cholam kozhukattai:** Similar to rice kozhukattai, sorghum kozhukattai is a steamed dumpling made from sorghum flour and served with coconut chutney.
- **Cholam laddu:** Sorghum flour is used to make laddu, a sweet and nutritious snack. It's often mixed with jaggery, ghee, and roasted nuts.

These are just a few examples of the many ways sorghum is used in Tamil Nadu's culinary traditions. Sorghum's versatility, nutritional value, and ability to thrive in dry regions make it a valuable ingredient in traditional Tamil cuisine.

Challenges of sorghum cultivation in Tamilnadu

Sorghum production in Tamilnadu, like in many other regions, faces several challenges that can affect yield and productivity. Some of the key challenges of sorghum production in Tamilnadu include:

Water scarcity, climate ariability, pest and disease, low adoption of improved practices, post-harvest losses, market access and price and changing consumer preferences.

Conclusion

In a changing climate, sorghum's resilience and adaptability make it a crop of the future. Research and innovation in sorghum farming techniques and processing methods can further enhance its significance in Tamil Nadu's agriculture. Sorghum, or Cholam, in Tamilnadu isn't just a grain; it's a symbol of cultural heritage, resilience, and sustenance. Its historical, cultural, nutritional, and economic importance makes it an integral part of the state's identity, both in the past and for generations to come. As we move forward, recognizing and preserving the significance of sorghum is essential for the sustainable development of Tamilnadu's agricultural landscape.

Production and Maintenance of Nucleus and Breeder Seed System in Sorghum

Indu*, N. Dikshit, Rajesh K.Singhal, Mahendra Singh, Adarsh Shrivastav and Shahid Ahmed

Seed is the most basic and vital input for enhanced productivity in any crop. Breeder and nucleus seed production are essential components of modern agriculture that play a pivotal role in maintaining the genetic purity, quality, and consistency of plant varieties, ultimately leading to increased agricultural productivity and sustainability. By maintaining genetic purity and producing seeds with improved traits, breeder and nucleus seed production contribute to sustainable agriculture. These seeds can help reduce the need for chemical inputs, increase crop resilience, and improve overall agricultural efficiency. All-India Coordinated Sorghum Improvement Project (AICSIP) plays a vital role in monitoring the production and maintenance of nucleus and breeder seeds by providing support for both fundamental and strategic research aspects related to sorghum crop. In development of sorghum hybrids, production and maintenance of genetic purity in nucleus and breeder seeds of three lines (A, B and R) is critically important.

Introduction

Sorghum (*Sorghum bicolor* L.), the fifth most important cereal crop in terms of production and planting area is emerging as a crop with diverse end-uses as food, feed, fuel and forage. The real impact of any variety on farmer's field depends on the extent of coverage and the level of performance. Developer of any variety, the plant breeder plays key role in making availability of authentic quality seeds of required quantity for its wide adoption, popularity and real benefit to the farmer. Sometimes, even a best performing variety may also fail to get popularize because of lack of availability of quality seeds.

Classes of Seeds

Botanically seed is the matured ovule consisting of an embryonic plant together with a store of food surrounded by a protective coat. They are primarily a way of reproduction. Seeds perform a wide variety of functions and provides the basic and most essential input for enhanced productivity in crop plants. Sorghum seed multiplication follows a three-generation system, consisting of breeder seed, foundation seed, and certified seed stages. This approach is employed due to the crop's susceptibility to cross-pollination, which increases the risk of genetic contamination. The All-India Coordinated Sorghum Improvement Project (AICSIP) was established in December 1969, and its current headquarter is at ICAR-Indian Institute of Millet Research (IIMR) in Hyderabad. AICSIP functions as a nationwide network aimed at fostering cooperative, interdisciplinary research collaborations between ICAR Institutes and the SAUs, all with a primary focus on sorghum. This project has effectively harnessed the country's limited resources by promoting inter-institutional and interdisciplinary cooperation, leading to joint assessments of emerging technologies and the formulation of collective recommendations. Moreover, AICSIP plays a vital role in enhancing the research capabilities of each agricultural university by providing support for both fundamental and strategic research endeavours related to sorghum. The All-India Coordinated Sorghum Improvement Project plays a vital role in the supervision and coordination production of sorghum nucleus and breeder seed and their supply network, thereby indirectly helping in production of required quantity of foundation and certified seed in the country.

Nucleus Seed: The initial handful of seeds is the result of meticulous selection and breeding by the breeder. This class of seeds, known as nucleus seeds, has a unique characteristic of self-regeneration and is produced in very limited quantities, closely monitored by the originating breeder or a qualified designee. The varietal purity of subsequently multiplied breeder seeds, foundation seeds, and certified seeds relies heavily on the purity of nucleus seeds, demanding utmost care during their production. Nucleus seed production in sorghum, like in many other crop plants, involves the careful selection, maintenance, and production of high-quality seed stock. Nucleus seed production is the initial stage of a seed multiplication system and plays a crucial role in ensuring the genetic purity and uniformity of the seed supply for sorghum farmers. Nucleus seed production is a critical component of sorghum breeding programs,

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as it serves as the foundation for the production of certified seed for farmers. Careful attention to maintaining genetic purity, preventing contamination, and following best practices throughout the production cycle is essential for successful nucleus seed production in sorghum. Sorghum, as a predominantly self-pollinated crop, experiences minimal inbreeding depression. However, the extent of outcrossing, ranging from 5 to 25%, varies based on climatic conditions and the genotype or panicle type, be it compact or loose. The presence of stable cytoplasmic-nuclear male-sterility (CMS) in sorghum, as demonstrated by Stephens and Holland in 1954, offers the opportunity to develop commercial hybrids.Top of Form For the hybrid seed production, three distinct lines are necessary: A-line (the seed parent/male-sterile line), B-line (the maintainer/to maintain A-line), and R-line (the restorer) which restores fertility in hybrids when crossing the A-line with the R-line. The A and B lines are the isogenic lines except for male sterility in A line. The nucleus seed of A and B lines is produced and maintained through paired plant to plant crossing between A and B lines and their uniformity should be examined critically. Before the anthesis, any off-type should be discarded. Male-sterility in A-lines may be compromised when exposed to high temperatures, particularly those exceeding 38°C during the flowering stage. Therefore, it is advisable to avoid production of nucleus seeds for A-lines in regions where the temperature surpasses 38°C during the flowering season, especially in the summer months. In case of pure line variety, maintenance and production of nucleus seed is carried out by head-to-row method. In this method, seeds obtained from selected individual self-pollinated panicles that accurately represent the designated variety, all of which come from plants previously cultivated in the nucleus stock. In the next season, these seeds will be grown in head-to-row progenies. Each row is meticulously examined to ensure it aligns with the established characteristics of the particular variety. In any progeny rows showing variations or deviations from the variety's descriptors will be discarded. Only the self-pollinated progeny rows that express uniformity and purity to the characteristic traits of the designated variety are to be used for the nucleus seed. This nucleus seed then serves as the foundation for producing breeder seed.

Breeder Seed: Breeder seed production is a critical link in the seed supply chain, as it provides the foundation for the development of improved forage sorghum varieties that can benefit farmers by increasing forage quality and yield, ultimately contributing to livestock health and productivity. This is the progeny of the nucleus seed is multiplied in large areas under the supervision of plant breeders and monitored by a committee. It provides a cent per cent physical and genetic pure seed for the production of foundation class. A golden yellow coloured certificate is issued for this category by the producing agency. Forage sorghum is a valuable forage crop used for livestock feed, and producing high-quality breeder seeds is essential to ensure the availability of improved and genetically stable varieties for farmers. The process requires careful planning, attention to detail, and adherence to quality control measures to ensure the success of breeding programs for forage sorghum. Breeder seed production for A-lines involves cultivating both the A-line and its corresponding B-line within an isolated field. To ensure proper isolation, a distance of more than 300 meters is maintained between the A-line and B-line production fields. The planting ratio typically follows either 4A:2B or 6A:2B, and the borders of the field are sown with the B-line. A-lines and B-lines usually flower simultaneously. The pollen produced by the B-line fertilizes the A-line plants, thereby preserving the A-line's purity. During the seed production process for A-lines, it is crucial to rough out (removing off-type or unwanted plants), particularly pollen shedders, as distinguishing between A-lines and B-lines becomes challenging after flowering. Identifying and uprooting pollen-shedding plants in A-lines must be carried out daily during the flowering period. Careful labelling and harvesting of A-line and B-line rows are essential. Harvesting should begin with the B-line rows and then followed by the A-line. Maintaining the purity of the A-line is of utmost importance, as any lapses in this regard can result in significant time and resource losses during the production of hybrid seed (A x R) in

Field Standards for isolation in sorghum are as follows:

Contaminants	Minimum distance (m)	
	Foundation	Certified
Fields of other varieties of grain and dual purpose sorghum	200	100
Fields of the same variety not confirming the varietal purity requirements for certification	200	100
Johnson grass (*Sorghum halepense*)	400	400
Forage sorghum with high tillering and grassy panicle	400	400

Seed standards for each class should have the following seed quality characters for both certification and labelling:

Field standards	Foundation	Certified
Pure seed (maximum)	98%	98.00%
Inert matter (maximum)	2.00%	2.00%
Other crop seeds (maximum) (by number)	5/kg	10/kg
Total weed seed (maximum) (by number)	5/kg	10/kg
Other distinguishable varieties (maximum)	10/kg	10/kg
Ergot, sclerotia, seed entirely or partially modified sclerotia, broken or ergotted seed (maximum)	0.02%	0.04%
Germination (minimum)	75%	75%
Moisture (maximum)	12.00%	12.00%
For vapour proof container (maximum)	8.00%	8.00%

subsequent generation. It is advisable to retain an adequate quantity of carry-over seeds as a precaution against unforeseen crop losses. To ensure the smooth progress in seed production and monitoring of seeds, it is recommended to conduct annual joint meetings involving representatives from seed growers, foundation seed agencies, and national seed agencies.

Some of the common constraints of nucleus & breeder seed production in sorghum include:

- **Genetic purity**: Maintaining genetic purity is crucial in nucleus seed production. Cross-pollination from nearby sorghum varieties can lead to contamination of the seed stock, reducing its genetic purity.
- **Pest and disease management:** Sorghum is susceptible to various pests and diseases, which can affect seed quality and yield. Effective pest and disease management strategies are needed to prevent losses.
- **Weed control**: Weeds can compete with sorghum plants for nutrients, water, and sunlight. Weeds need to be controlled to ensure the healthy growth of sorghum and prevent contamination.
- **Environmental stress**: Sorghum can be sensitive to environmental stresses such as drought, heat, and extreme weather events. Adequate irrigation and management practices are necessary to mitigate the impact of such stressors.
- **Labor intensity**: Nucleus seed production often requires labor-intensive activities like roguing, where off-types are manually removed. Finding and training skilled laborers can be challenging.
- **Isolation distance**: Maintaining isolation between different sorghum varieties to prevent cross-pollination can be difficult in regions with a high density of sorghum cultivation.
- **Seed quality assurance**: Ensuring the genetic purity and quality of the seed stock requires regular testing and monitoring, which can be costly and time-consuming.
- **Infrastructure and equipment**: Adequate infrastructure for seed processing and storage, as well as access to appropriate equipment, is essential for maintaining seed quality.
- **Market access:** Access to a reliable market for nucleus seed is crucial for the sustainability of the production system. Seed producers need assurance that their seeds will be sold at fair prices.
- **Regulatory compliance**: Compliance with seed certification and quality standards set by regulatory authorities can be a constraint, as producers must adhere to specific regulations and standards.
- **Varietal development**: Developing and selecting suitable parental lines with desirable traits can be a challenge. This requires ongoing breeding efforts to improve sorghum varieties.
- **Climate change:** Changing climate patterns can impact sorghum production, affecting both yield and quality. Adaptation strategies may be required.
- **Seedborne diseases:** Diseases carried in the seeds themselves can be a constraint, leading to reduced germination rates and poor seedling health.

Conclusion

Addressing these constraints in nucleus and breeder seed production for sorghum often requires a combination of research and development efforts, improved agricultural practices, access to resources and training for farmers, and strong collaboration among stakeholders, including government agencies, research institutions, and the private sector. By tackling these challenges, sorghum seed producers can enhance the quality and availability of sorghum seeds for farmers, contributing to food security and agricultural sustainability.

Sorghum as Biofuel

Mahendra Singh[1], Indu[1], Rumana Khan[2], Rajesh Kumar Singhal[1], Aadarsh[1], Nilmani Dikshit[1], Shahid Ahmed[1]

Global demand for renewable energy sources is rising, which has accelerated the quest for sustainable fossil fuel substitutes. Due to its natural qualities of high biomass yield, adaptability to a variety of climates, and exceptional drought tolerance, sorghum (Sorghum bicolor) has emerged as a promising contender for the generation of biofuels. This research offers a thorough examination of sorghum's potential as a biofuel feedstock.The first part of the article discusses the agronomic benefits of sorghum, emphasising its effective photosynthetic capacities and low input needs. Furthermore, its capacity to flourish in water-strapped marginal lands makes it an essential bioenergy crop, potentially lowering rivalry with food production.

Introduction

A biofuel is a fuel produced from living organisms, most often referring to plants or plant-derived materials. Biofuels can be used to replace fossil fuels in transportation, heating, and electricity generation. Sorghum, a key biofuel crop, requires further research to identify efficient processes and cost-effective solutions. Lifecycle analysis and collaboration between private and public sector researchers and multidisciplinary teams are crucial for developing comprehensive biorefinery models. Sweet sorghum is a promising target for biofuel production.

Types of biofuels

There are many different types of biofuels, but the most common are:

- **Ethanol:** Ethanol is a liquid biofuel that is produced from the fermentation of sugars orstarches from plants. It is commonly blended with gasoline to create a fuel that is more environmentally friendly than pure gasoline. Ethanol can also be used as a pure fuel in some vehicles.
- **Biodiesel:** Biodiesel is a liquid biofuel that is produced from the trans-esterification of vegetable oils or animal fats. It can be used in diesel engines without any modifications. Biodiesel is a good alternative to diesel fuel because it produces lower emissions of greenhouse gases and particulate matter.
- **Biogas:** Biogas is a gaseous biofuel that is produced from the anaerobic digestion of organic materials. It can be used to generate electricity, heat homes, or power vehicles. Biogas is a good alternative to natural gas because it is a renewable resource and produces lower emissions of greenhouse gases.

Benefits of biofuels

Renewable fuels, produced from non-depleted resources, emit lower greenhouse gases than fossil fuels, reduce dependence on imported oil, and create jobs in agriculture and manufacturing sectors. Biofuels, such as manure, corn, switchgrass, soybeans, and plant waste, are renewable and sustainable, making them an efficient alternative to fossil fuels. Biofuels, made from renewable resources, reduce pollution and are being encouraged for their environmental benefits. One of the primary benefits of using biodiesel is energy efficiency Reducing foreign oil dependency, health benefits, positive economic impact reducing greenhouse gases sustainability high-quality engine performance are other potential benefits.

Properties and biochemical composition

Sweet sorghum is a promising biofuel due to its unique biochemical characteristics. The stalk contains high levels of fermentable sugars, including sucrose, which makes it an attractive feedstock for bioethanol production. Sweet sorghum also contains cellulose and hemicelluloses, which can be broken down into bioethanol. Its low lignin content makes the bioconversion process more efficient. Sweet sorghum's fast growth rate and drought tolerance make it suitable for regions with limited water resources, making it a promising biofuel crop.

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Sweet sorghum carbohydrates

Sweet sorghum is a high-carbohydrate crop with starch and sucrose in its grains and stalks, which can be fermented to produce ethanol. Factors like temperature, time of day, cultivar, and fertilization affect its carbohydrate content. Sweet sorghum is suitable for biomass production and can be used as a sugar crop or biofuel source.

Cultivation and agronomic considerations:

Sorghum cultivation is suitable for various agro-climatic conditions, thriving in rain-fed and irrigated areas. Its short growing season and minimal water requirements make it suitable for arid and semi-arid regions. Modern agricultural practices, like hybridization and genetic engineering, have improved productivity and stress tolerance. Sweet sorghum requires high temperatures and can tolerate various soil conditions. To grow, seeds should be planted deep enough for moisture to germinate and roots to grow. The aim of agronomy in sweet sorghum is to increase productivity and improve feedstock supply duration for biofuel production. This can be achieved by

Biofuel production processes:

Several biofuel production processes can utilize sorghum as a feedstock. The primary methods include:

a. **Bioethanol production:** Sorghum's high starch content can be fermented into bio-ethanolthrough enzymatic hydrolysis and yeast fermentation.

b. **Cellulosic ethanol:** Lignocellulose biomass from sorghum can undergo biochemical or

Thermochemical processes, such as enzymatic hydrolysis or pyrolysis, produce cellulosicethanol.

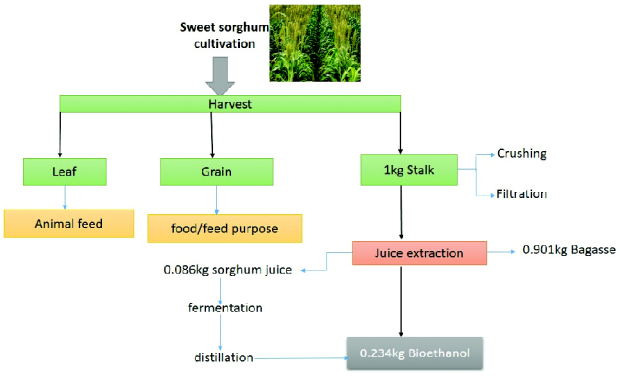
c. **Biodiesel:** Sorghum oil can be extracted and transformed into biodiesel throughtrans-esterification, similar to other oilseed crops.

Processing sweet sorghum stalk for ethanol production

The process of extracting plant juice involves milling, screening, sterilizing, clarifying, filtering, and concentrating. The juice is sterilized by heating to kill bacteria, clarified using a clarifying agent like bentonite, filtered, and evaporated to concentrate it. The concentration can be adjusted for specific uses, such as ethanol production or off-season storage.

- **Fermentation:** Fermentation is a yeast-based process that converts sugar into ethanol, carbon dioxide, yeast biomass, and other minor end products like glycerol, fuel oils, aldehydes, and ketones.
- **Distillation and dehydration: The** distillation process concentrates alcohol to 95% v/v, producing ethanol with a minimum concentration of 99.6%. The resulting vinasse can be composted or used as liquid fertilizer, depending on the treatment method.

Sweet sorghum grain undergoes similar processing to corn, including washing, crushing, milling, gelatinization, liquefaction, scarification, fermentation, distillation, and dehydration to produce high-purity ethanol.



Processing of Sweet Sorghum Stalk for Ethanol Production

Environmental Benefits and Sustainability

Sorghum, a biofuel, reduces greenhouse gas emissions, and requires fewer chemical inputs and water, making it a sustainable alternative. It can also be grown as part of crop rotation, improving soil health and preventing erosion.

Challenges and future prospects

Sorghum-based biofuels face challenges like optimizing conversion processes, developing cost-effective technologies, and promoting globally through market penetration and policy support, despite their potential. Biofuels currently cost the same as gasoline, but increasing demand may necessitate more efficient extraction methods, potentially making them more affordable in the future. Gasoline is derived from non-renewable crude oil, and while current gas reservoirs may last for years, they may eventually end in the near future. Countries with limited oil reserves face economic

challenges due to oil imports. However, increasing biofuel production can reduce dependence on fossil fuels, boost agriculture, and create jobs, thereby ensuring economic security. Growing a single crop over large land poses numerous challenges, including altering the environment for pests, allowing them to destroy entire crops, and affecting food availability. Scientists are working on improving the efficiency of current biofuel production technology to extract this fuel more effectively.

Conclusion

A strong argument is made for the use of sorghum as a biofuel feedstock in the transition to sustainable and renewable energy sources. Sorghum stands out as a robust and effective crop for the generation of bio-energy due to its outstanding biomass yield, adaptability to a variety of conditions, and notable drought tolerance. Additionally, its capacity to flourish in marginal lands reduces rivalry with food crops, resolving a crucial issue in the biofuel sector. Increases in conversion technology, including pretreatment techniques, enzymatic hydrolysis, and fermentation procedures, have greatly increased the output and viability of biofuel production. These changes represent an important step in making sorghum a competitive competitor in the bioenergy industry. Sorghum provides a practical and long-lasting option for the manufacture of biofuel, supporting the worldwide initiative to lessen dependency on fossil fuels and slow down climate change. Sorghum has the potential to play a key role in influencing a more sustainable and resilient energy future with continuous research and focused efforts.

Silage Production from Forage Sorghum: A Comprehensive Review

Aadarsh, Indu, Rajesh Kumar Singhal, Mahendra Singh, Nilmani Dikshit, Shahid Ahmed

Silage production is a crucial method for preserving forage crops for livestock feed. Among the various forage options, forage sorghum stands out as a popular choice due to its adaptability to diverse climates and soil conditions. This review article provides a comprehensive overview of silage production from forage sorghum, covering topics ranging from cultivar selection and crop management to ensiling techniques and nutritional value. It also highlights recent developments and research in the field.

Introduction

Forage sorghum (*Sorghum bicolor* L. Moench) is a versatile and robust forage crop used in livestock feeding worldwide. With its remarkable drought tolerance, adaptability to various soil types, and capacity for high biomass production, forage sorghum has emerged as a cornerstone in modern livestock production systems. Silage production from forage sorghum has witnessed a surge in popularity among farmers and livestock producers, thanks to its role as a dependable year-round source of high-quality feed.

The preservation of forage sorghum through the silage is pivotal in bridging the nutritional gap in animal diets, especially during periods of scarcity. Ensuring the success of this preservation process requires a multifaceted approach, encompassing cultivar selection, meticulous crop management, and effective ensiling techniques. Additionally, an understanding of the nutritional value that forage sorghum silage provides is vital to optimize its inclusion in livestock rations.

Although maize is widely used as a silage worldwide, there are specific problems associated with maize silage that can be addressed or mitigated by using sorghum silage. Maize typically requires high nitrogen inputs to achieve optimal yields, which can be costly and have environmental implications. Sorghum has a lower nitrogen requirement, making it a more sustainable choice in terms of fertilizer use. While maize silage is known for its high energy content, it may have lower fiber content, potentially impacting rumen health. Sorghum silage, with its higher fiber content, can help provide a more balanced diet for livestock, especially when combined with other feeds. Repeated maize cultivation can lead to disease buildup in the soil. Sorghum can serve as an effective rotation crop, breaking disease cycles and reducing the need for excessive pesticide use.

It seeks to elucidate the key factors involved in achieving successful silage production, while also shedding light on the challenges faced and the evolving landscape of forage sorghum silage production. As the global agricultural sector continuously strives for sustainability, it is crucial to explore the cutting-edge developments and future directions in this field to ensure the resilience and efficiency of forage sorghum silage production systems.

Cultivar selection

Choosing the right sorghum cultivar is the first critical step in successful silage production. Factors to consider when selecting a cultivar may include early, intermediate, or late-maturing cultivars and can be chosen based on the length of the growing season. High-yielding cultivars can maximize silage production per acre. Selecting disease-resistant varieties can mitigate potential losses. Consider cultivars with quality traits such as high digestibility, sugar content, and nutritional value. Some sorghum varieties contain anti-quality factors such as tannins and prussic acid, which can impact palatability and animal health.

Planting and growth

Forage sorghum planting and growth requires careful consideration. The optimal planting density typically ranges from 8 to 15 pounds of seed per acre, depending on the chosen cultivar. It is crucial to ensure that the soil has adequate fertility for optimal growth. Nitrogen, in particular, plays a vital role in increasing biomass production. Additionally, effective weed management is of utmost importance to prevent competition for resources during the growth phase. When it comes to harvesting forage sorghum, targeting the boot stage is recommended to achieve optimal quality and digestibility. Timing is critical during this stage, and

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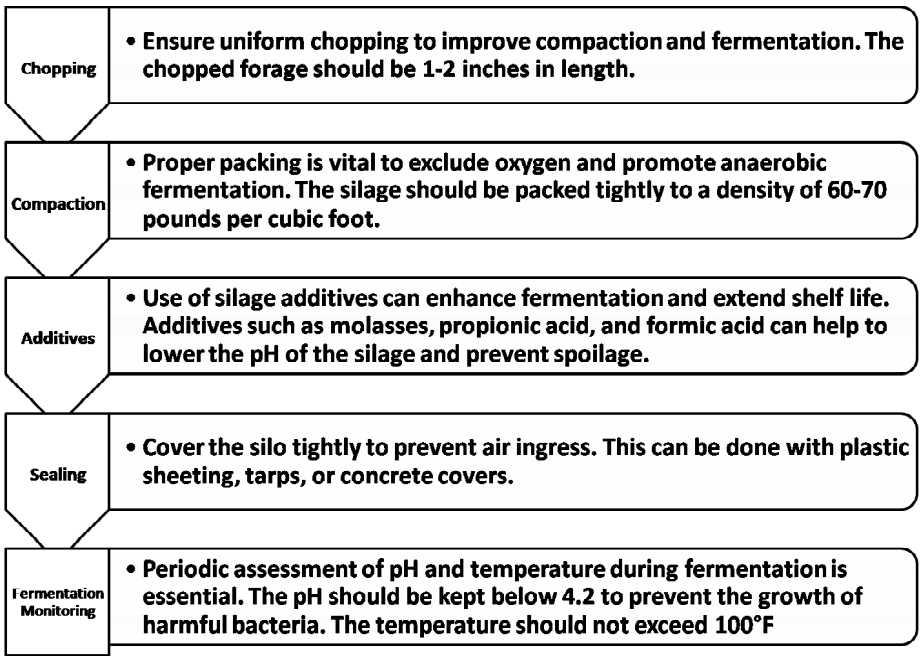


Ensiling Techniques

it's essential to aim for the right moisture content, ideally between 60% and 70%, and a sugar content ranging from 10% to 15%. These considerations are essential for successful forage sorghum cultivation and silage production.

Advantages of Forage Sorghum over Maize

Advantage	Forage Sorghum Silage	Maize Silage
Moisture content	60-65%	65-75%
Susceptibility to mold growth	Less susceptible	More susceptible
Starch content	Lower	Higher
Protein content	Higher	Lower
Tannin content	Higher	Lower
Yield	Similar	Similar
Adaptability to climate	More adaptable	Less adaptable
Drought tolerance	More tolerant	Less tolerant
Salt tolerance	More tolerant	Less tolerant
Insect and disease resistance	More resistant	Less resistant

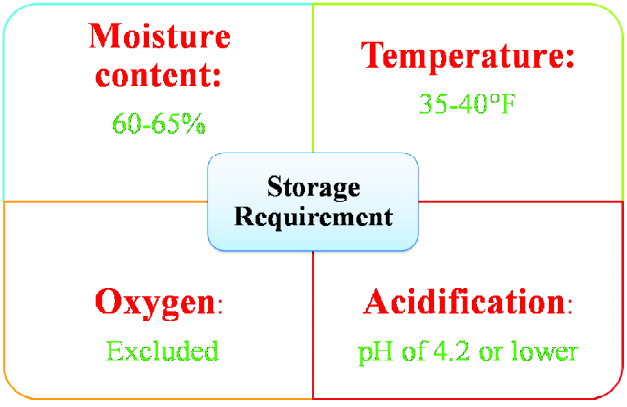
Nutritional Comparison between Forage Sorghum and Maize

Nutrient	Sorghum	Maize
Energy (TDN)	55-65%	65-75%
Protein	7-9%	8-10%
Fiber	30-40%	25-35%
Digestibility	60-70%	70-80%
Non-structural carbohydrates	25-35%	20-25%
Acid detergent fiber	20-25%	15-20%
Neutral detergent fiber	35-45%	40-45%
Lignin	10-15%	5-10%

Challenges and future developments

Despite its many advantages, silage production from forage sorghum is not without challenges.

- **Mycotoxins:** Forage sorghum silage can be contaminated with mycotoxins, which can be harmful to livestock. Mycotoxins are produced by molds that grow on the silage during storage.



Storage Requirement

- **Storage Losses:** Silage can lose nutrients and quality during storage. This can be due to a number of factors, including oxygen exposure, temperature fluctuations, and mold growth.
- **Climate Change:** Climate change is expected to have a negative impact on silage production in forage sorghum. Increased temperatures could reduce yields and quality.

Conclusion

Silage production from forage sorghum is a valuable component of modern livestock feeding systems. Careful cultivar selection, crop management, and ensiling techniques are essential for maximizing silage quality and nutritional value. Ongoing research and development efforts in sorghum breeding and silage management will continue to improve the sustainability and efficiency of forage sorghum silage production, ensuring a reliable feed source for livestock in various agricultural settings.

Potential of Millet Markets in India

V. David Chella Baskar, Rumana Khan and Anil Kumar Rai

The millet market in India holds immense potential for growth and development. With its rich genetic diversity and nutritional benefits, millets have long been a staple crop in India. The country's large collection of finger millet germplasm showcases the importance of the crop in Indian history, culture, and medicine. Additionally, millets have superior nutritional and health benefits compared to other cereals, making them a suitable crop for tackling the nutritional challenges faced by communities in India. India is already the largest producer of various types of millets, with finger millet accounting for 85% of total production in the country Moreover, finger millet has the highest productivity among small millets in India. Given these factors, there is immense potential for the millet market to thrive in India. Increasing global interest in millets, the potential to increase agricultural productivity, and the need for diverse food options all contribute to the positive outlook for the millet market in India . Furthermore, millets are drought-resistant crops that can be cultivated in low rain-fed areas, making them ideal for regions where major cereals struggle to yield substantial harvests. The Indian government's recognition of millets as "nutri-cereals" for production, consumption, and trade further solidifies the potential of the millet market in India.

Introduction

Millets include an abundance of nutrients such as fibre, proteins, and vitamins. Millets are a source of essential fats, which are vital for the functioning of the body. They give the exact amount of fat intake required. This helps to prevent excessive fats from being stored in the body, which may contribute to an increase in cholesterol levels as well as other health problems such as obesity and heart disease. Worldwide there is a trend to lose obesity. The amount of money spent on weight loss programmes all around the world is picking up speed. Many people are making an effort to eat more healthy meals. The combination of this momentum and the accessibility of nutritious food alternatives like millets has resulted in the creation of a promising possibility for this sector.

The increase in smartphone users is causing more and more availability of e-Commerce platforms. The proliferation of e-commerce platforms is inspiring businesses across a variety of sectors to launch their products in an online format. As a result, there is a growing amount of rivalry in the online format. Also, the distribution costs through online mode are comparatively less. As a result, many businesses are now in a position to offer appealing discounts because of the additional cushion made available by the drop in prices. More customers are making purchases through online marketplaces as a result of these price reductions. As a result, demand through online platforms is also operating as another major driver for this millet market. This market is also affected by a number of factors that act as limitations. The shelf life of millets is very little. This results in an increased rate of efficiency in the preservation and processing processes. As a direct consequence of this, the costs are elevated. The price hike is making it more difficult for businesses operating in this industry to attract a large number of customers. However, highly developed scientific methods are frequently put into practice, and efforts are currently being made to discover straightforward and uncomplicated means of extending the product's shelf life. This product is in extremely high demand, and as a result, there is promising commercial potential here.

Millet market segmentation at global level

Pearl Millet, Foxtail Millet, Sorghum, Finger Millet, and Others are the categories that make up this market's

Millet market segmentation

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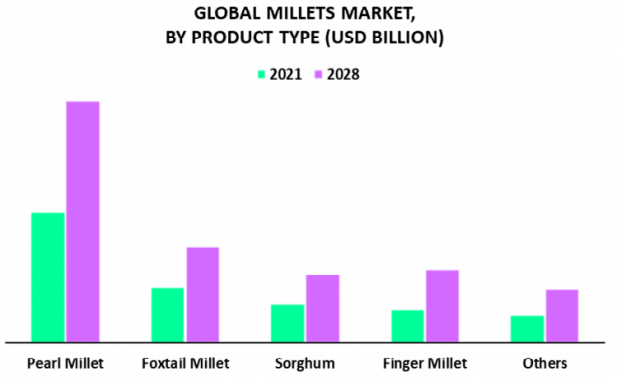
divisions. The market share held by pearl millet is now the greatest of any in the world. This high market share is mainly due to the high rate of consumption and the high rate of production. Pearl millet is the most common type of millet grown in India. Other types of millet are also grown there. The output of millets is higher in India compared to any other country in the globe. Regular millets are also grown but they require insecticides and proper fertilizers. The majority of organic millets make up nutritious dishes that use millet as an ingredient.

Based on End-Use, the market is segmented into ready-to-eat food, bakery, beverages, breakfast, and others. The segment of the market known as ready to eat, which is based on millets, now has the largest share. This is because the high protein content of these products provides a good option for consumers. On the other hand, the breakfast market is the market that is expanding at the quickest rate.

The market is divided into the following categories: trade associations, supermarkets, grocery stores, online platforms, and others, based on the end user of the product. This is how the distribution system works: Middlemen play a crucial role in the agricultural process by acting as a medium. Processors interact with farmers and purchase crops directly from them in order to fulfill their processing needs. After that, these materials go through processing to become the final goods. The finished goods, such as cereals and bakery products, may be found at grocery stores. In this day and age of rapidly advancing technology, online platforms are giving producers with a platform that is both lucrative and cost-effective. As a result, the internet platform acts as a significant Distribution Platform for the Millet Market.



Global millet market

The global market for millets may be broken down into the following regions: North America, Europe, Asia Pacific, and the rest of the world. When it comes to production and export, the Asia-Pacific area contributes the most, followed by African regions. In the Asia-Pacific Region, India has the highest share of production and consumption. India has the highest Millet Production in the world. Countries in Africa such as Nigeria, Mali, and Niger, amongst others, have maintained a healthy level of output for quite some time. The dry climate of these regions acts as a conducive environment for the growth of Millets.

The "Global Millets Market" study report provides valuable insight with an emphasis on the global market. Mayoora Foods, Navan Foods, LLC, Sydler India Pvt. Ltd., Nestle S.A., Nature's Logic, Sresta Natural Bioproducts Pvt. Ltd., Dharani FaMCooP Ltd., Dharmapuri District Minor Millet Farmer Producer Company Limited, and Janadhanya are the primary competitors in this market. The major development strategies, market share, and market ranking analysis of the aforementioned companies all over the world are broken down and analysed in the section on the competitive landscape.

Conclusion

In several domains, government initiatives are used to promote millets. For the numerous stakeholders, the government has offered a variety of supports, including financial, infrastructural, and technological. Most states have already established the Minimum Support Price (MSP) for key millets, which has greatly increased the potential for millet production. The processing facilities are situated in closer proximity to the manufacturing sites where primary processing and quality control checks are conducted initially. Following this, secondary processing, quality control checks, packing, and branding are carried out on a larger scale at the central level. This will lead to higher financial returns for millet farmers as well as agricultural opportunities and a decrease in the factory gate price of millet goods.

AGRI-INNOVATION

1. **Technology on orange-spotted grouper farming in marine cages by** Dr. Sekar Megarajan *et al.,* ICAR - CMFRI

   This is a landless production method, for high-density culture of reed fish in confined cage culture system. The method facilitates ease of harvesting without stress. This technology produces premium quality and required quantity of single fish species to meet the demanded in live fish trading.

2. **A rapid colorimetric LAMP assay for detection of *Rhizoctonia solani* AG-1 IA causing sheath blight of rice by** Dr. Hillol Chakdar *et al.,* ICAR-NBAIM, Mau.

   This technique can be performed in field conditions within a very short period (30-45 min) and the pathogen can be detected even when there is no visible symptom.

3. **Gin Trash Treatment System to Destroy Pink Bollworm from Cotton Ginneries by** Dr. V G Arude *et al.,* ICAR-CIRCT, Mumbai

   The gin trash treatment system destroys and breaks down the Pink Bollworm (PBW) life cycle and prevents its dissemination from ginneries to neighborhood cotton fields and damage to the cotton crop in subsequent seasons. The developed system has a capacity of 2.5 tons of trash per hour and comprises a centrifugal trash fan, cyclone, compactor, and ducting. Achieves 100% mortality rate of PBW larva and pupae. Technology has been commercialized.

4. **The seed village advocates village self-sufficiency in multiplication and distribution of quality seeds by** Dr. Dheeraj Singh *et al.,* ICAR-CAZRI, KVK Pali

   The technology deals with the concept of seed production at farmer's level under the guidance of scientist/agriculture department. Quality seeds of improved varieties of prominent crops of the area were distributed by the Krishi Vigyan Kendra (KVK), CAZRI, Pali to the identified farmers in the area as per annual programme. The farmers used these quality seeds and took their own seed multiplication in operational area which showed a considerable spread of improved variety in nearby villages. Seed village for ensuring seed availability under saline conditions of arid zone

5. **CARI Portable Poultry incubator by** Dr. Jagbir Singh Tyagi ICAR-CARI, Izatnagar

   Availability of quality chicks in smaller quantities in remote villages is a real challenge. This technology offers a potential alternative to the costly incubators utilizing the scrap produced in the form of discarded consumer durables such as refrigerators with required modifications. This low budget incubator is capable of hatching 300 chicken eggs and can be easily fabricated on DIY (Do It Yourself) basis. Hatchability up to 90% on fertile egg basis.

6. **Tank based pearl production from freshwater mussel by** Dr. Shailesh Saurabh *et al.,* ICAR-CIFA

   Traditionally, the production of pearls in freshwater mussels is done in the pond. For a farmer/ stakeholder, producing this priceless commodity in a tank is the stuff of dreams. Through this technology pearls can be produced from the freshwater mussels in FRP tanks at high density without compromising the quality of pearls. It reduces time as well as space with higher per unit production.

7. **Poultry maize feeder by** Dr. Debojyoti Borkotoky *et al.,* ICAR-NRCM

   Self-dispensing & easy refilling: Birds can self-dispense the grain while pecking, reducing fighting and aggressive pecking behavior. A funnel is also provided for easy pouring of the grain, simplifying the refilling process. Fungal growth prevention & reduced labor: By exposing shelled maize to sunlight and air, the feeder hinders fungal growth, eliminating the need for regular shelling and saving time and effort. Versatile and sustainable: The feeder can accommodate 12-15 birds, making it cost-effective. It is also portable, easy to handle, and eco-friendly. Additionally, the system facilitates easy medication and supplementation for the birds' health.

8. **Integrated Management of Nematode in pomegranate orchard by** Dr. Akath Singh *et al.,* ICAR-CAZRI, Jodhpur

   Nematodes are a serious problem across pomegranate orchard in light sandy soils of arid regions. Integrated module including combined application of Neemcake 500 g + Pacilomyces lilacinus 25 ml + Carbofuran 20 g + Fluensulfone

20 g per plant in April and August effectively controls this problem in two successive years of treatment..

9. Aqueous formulation of Spilosoma obliqua nucleo poly hedro virus for the management of Bihar hairy caterpillar *Spilosoma oblique*

   Spilosoma obliqua nucleopolyhedro virus is host specific and is effective against polyphagous Bihar hairy caterpillar. 68% pest reduction was recorded when the technology was evaluated under field conditions.

10. **A technique for the rearing of parasitoid Nesolynx thymus (Girault) and their use in the housefly, *Musca domestica* management by** Dr. K. Subaharan *et al.,* ICAR-NBAIR

    A rearing technique for Nesolynx thymus (Girault) a pupal parasitoid and assess its potential for the management of housefly, *Musca domestica*. Innundative release of the parasitoid will help to bring down the population of houseflies and thereby also decrease the level of dependence on the pesticides. The technology has been commercialized.

11. **Mechanized system for PRIMARY ROASTING of butter by** Dr. Rajesh Kumar Vishwakarma *et al.,* ICAR-CIPHET, Ludhiana

    The Makhana primary roaster efficiently handles 10 kg batches, ensuring precise roasting. It's a cost-effective system with high throughput capacity, making it economically viable. Capable of roasting all makhana grades, it operates with a 1kW energy requirement and uses 8 kg of LPG gas per 100 kg of makhana for heating, with key components including the Roasting Pan, Heating System, Power Transmission, Agitation System, and Discharge Mechanism.

12. **Mass production technology for parasitoid *Encarsia guadeloupae* for the suppression of rugose spiraling whitefly (RWS) by** Dr. A.S.K. Selvaraj *et al.,* ICAR-NBAIR, Bengaluru

    The mass production protocol for potential parasitoid, *Encarsia guadeloupae* to manage the invasive RSW was standardized. The technology has been commercialized

13. **Shatpada wettable powder formulation of *Heterorhabditis indica* strain NBAIIH38 for management of white grubs and fall armyworm by** Dr. A.S. According to Jagadeesh Patil *et al.,* ICAR-NBAIR, Bengaluru

    The wettable powder formulation of *Heterorhabditis indica* strain NBAIIH38 formulation can be used in difficult locations in the soil, galleries of boring insects or even against insect pests which developed resistance to chemical insecticides. Apart from white grubs and fall armyworm, this nematode strain can be used for the management of other soil-dwelling life stages of insect. Field application of the formulation is able to reduce 70-75% of pest population, but it may vary with insect pest species.

14. **Easy PCR Diagnostic Kit for common detection of MYMIV and MYMV by** Dr. Anirban Ray *et al.,* ICAR-IARI, New Delhi

    Used for a generic detection of two virus species, mungbean yellow mosaic India virus and mungbean yellow mosaic virus causing yellow mosaic disease of grain legumes (mungbean, blackgram, cowpea, soybean). User are diagnostic companies and seed companies. Breeders and Seed companies his kit will help in quick detection of any of the two or both viruses from infected samples. For regular suveillance purpose such kit will be useful.

15. **Technology for preparation of Milk-millet based protein rich dairy dip by** Dr. Devaraja H. C. *et al.,* ICAR-NDRI

    Nutri-cereal incorporated composite product. Contains goodness of milk and millets Contains Cheese and dairy cream which rich in high quality milk protein and milk fat. Contains 27% protein. Fiber content -270mg/100g.

16. **Arunachali gets the tag**

    Yak Churpi, a naturally fermented milk product made from Arunachali yak milk, has been given recognition as a Geographical Indication (GI) of Arunachal Pradesh. ICAR- National Research Centre on Yak initiated the application process for seeking GI tag to boost its conservation.

17. Raj-Himani

India's First horse foal produced through the combination of frozen semen and Embryo transfer technologies. Equine Production Campus, Regional Station, ICAR-National Research Centre on Equines, Bikaner.

18. Organic sunflower production in rainfed areas of Southern Telangana by Dr Gopinath, K.A, *et al.,* ICAR-CRIDA

The organic sunflower production protocol has been developed by conducting field trials during the last 10 years. This protocol helps in enhancing the yield of sunflower with the additional benefits of better soil health and quality of sunflower. The protocol has the potential to be upscaled in the rainfed areas of Telangana and other similar agroclimatic regions.

19. DMRO-1072 by Dr. Anil Kumar *et al.,* ICAR-DMR

High yielding strain of paddy straw mushroom (*Volvariella volvacea*). DMRO 1072 is whitish in color with solid pileus, high average fruit body weight (19.59g) and high yielding potential. DMRO 1072 has high acceptability in the paddy-growing regions and it is in the seed supply chain of ICAR-DMR, Solan.

20. Mechanized system for primary roasting of makhana by Dr. Rajesh Kumar Vishwakarma *et al.,* ICAR-CIPHET, Ludhiana

The Makhana primary roaster efficiently handles 10 kg batches, ensuring precise roasting. It's a cost-effective system with high throughput capacity, making it economically viable. Capable of roasting all makhana grades, operates with a 1kW energy requirement and uses 8 kg of LPG gas per 100 kg of makhana for heating.

Compiled by: Dr. Govind Vishwakarma
TRA, Fruit Science

INTERNATIONAL YEAR OF
MILLETS
2023

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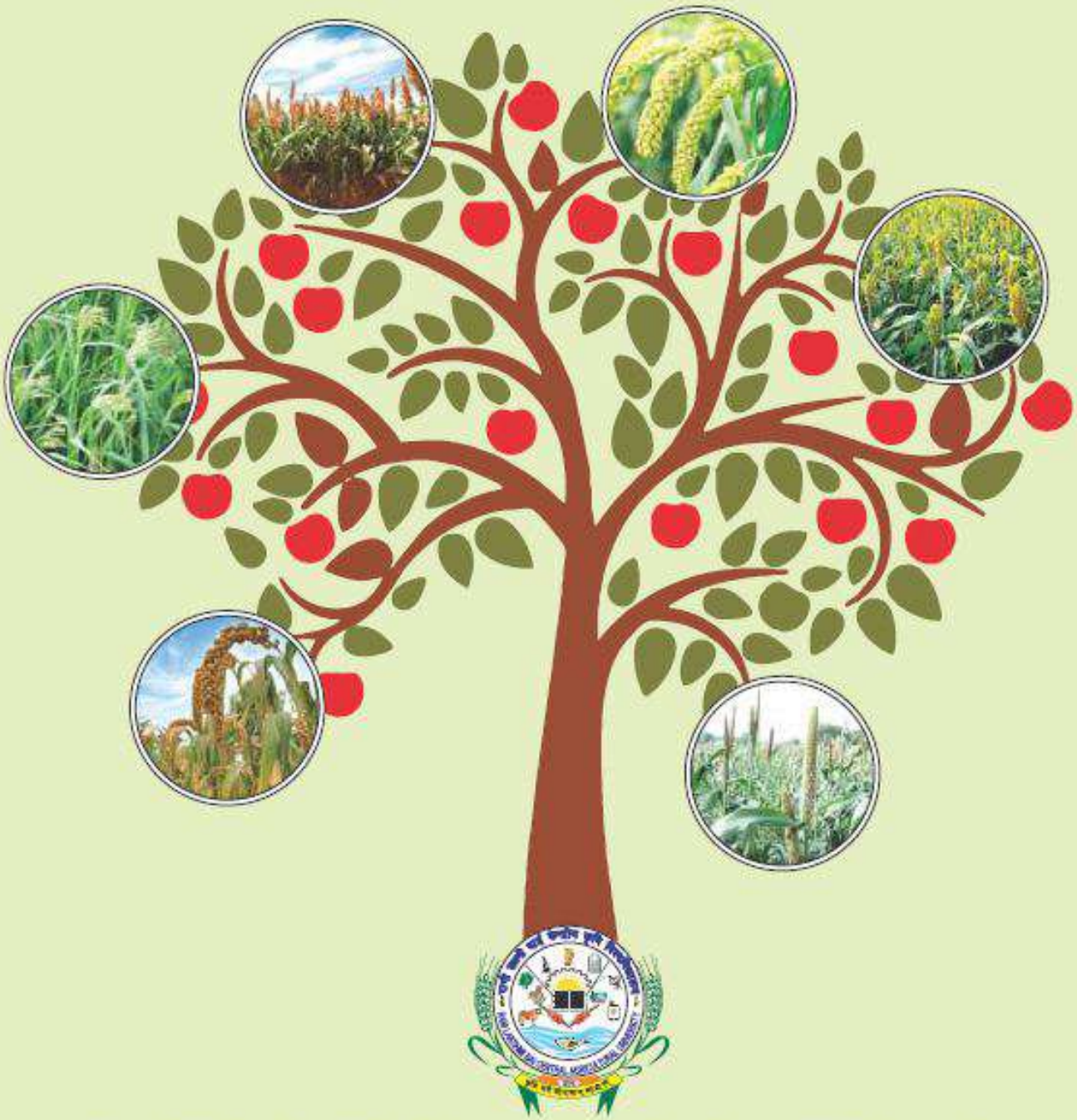

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PARAMPARAGAT KRISHI VIKAS YOJANA
ORGANIC FARMING GAINS MOMENTUM

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