MILLETS: THE NOURISHING SOLUTION TO FOOD SECURITY CHALLENGES OVERCEREAL-BASEDCROPPING SYSTEMS

ABSTRACT

A heightened emphasis on augmenting millet production and accentuating their nutritional benefits is pivotal in mitigating reliance on conventional crops, fostering dietary diversity, and enhancing food security, particularly in times of natural calamities when food scarcity is prevalent. The United Nations General Assembly has designated the year 2023 as the International Year of Millet. Millets hailed as 'superfoods,' boast high levels of protein, fibre, vitamins, and minerals. India stands as a major contributor, producing 80% of Asia's millets and 20% globally, as reported by the Ministry of Agriculture and Farmers Welfare. Statistics reveal that over 90 million individuals in Africa and Asia incorporate millets into their diets, with Africa accounting for more than 55% of global production, followed by Asia at nearly 40%, while Europe constitutes approximately three per cent of the worldwide market. Specifically in India, West Bengal adheres to a predominantly monocultural cropping system, predominantly focused on rice. Monoculture systems are highly susceptible to blights and pests due to their lack of diversity, leading to reduced soil fertility and compromised soil structure. Cultivating millets not only offers a viable solution by diminishing reliance on synthetic fertilizers and pesticides but also facilitates a transition towards sustainable agriculture. This involves diversifying crop rotations and steering clear of the pitfalls associated with mono-cropping systems. Introducing various millet types into cropping systems can significantly enhance food security. Each millet variant possesses unique qualities that enable them to withstand extreme climatic conditions, making them particularly relevant as adaptive measures in the current context of global warming and climate change issues.

Keywords:*food security, mono-cropping, climate change, sustainable agriculture*

1. INTRODUCTION

“Agriculture is undoubtedly the backbone of any developing country like India. It is the prime source of food-fodder-fibre-fuel-fruit-flower-fish and timber and provides raw materials to many large- and small-scale industries. A lion’s share of the country’s mammoth population depends directly or indirectly on agriculture. Being the largest private enterprise in India it contributes 17.4% of national GDP” (G.O.I,2016).Tackling hunger and feeding the world population are two of the biggest challenges of the modern world. Reasons contributing to this issue range from deficiencies in the supply of micro- and macro-nutrients, shortages in the production of foods leading to supply–demand imbalances, and conflicts destabilising various parts of the world. Although several of these triggers for hunger can be addressed leading to a slight reduction in the population suffering from hunger and malnutrition from almost one billion in 1990–1992 to 850 million in 2010–2012, the threat of climate change and global warming still lingers” (FAO,2012).“Millets – often called “Nutri-Cereals” due to their high nutritional value – are a group of small-seeded grasses grown mainly in dry zones of Asia and Africa. These include sorghum (or great millet), pearl millet, finger millet, fonio, proso millet, foxtail millet, teff and other smaller varietals.Millets are one of the oldest foods known to humans & possibly the first cereal

grain to be used for domestic purposes. Millets are small-seeded grasses that are hardy and Millets are hardy crops grown in arid and semiarid environments and are resilient to higher temperatures and drought-prone environments require 350 mm of water compared to 1200 mm for rice. They offer food, fodder, fuel, and nutrition security and can be grown in intercropping (or maybe under mixed cropping with pulses and oil seeds)" (ACCII,2022). "Millets are also unique due to their short growing season. They can develop from planted seeds to mature, ready-to-harvest plants in as little as 65 days. This is important in heavily populated areas. When properly stored, whole millets will be kept for two or more years" (Michaelraj and Shanmugham,2013)."India is one of the leading producers of millets in the world with an estimated share of around 41 per cent in the global production. As per FAO(2020), world production of millets in the year 2020 was 30.464 million metric tonnes (MMT) and India's share was 12.49 MMT, which accounts for 41 per cent of the total millet production. India recorded a 27 per cent growth in millet production in 2021-22 as compared to millet production in the previous year was 15.92Mmt.India's top five millet-producing states: Rajasthan, Maharashtra, Karnataka, Gujarat and Madhya Pradesh.In recent times, climate change has been one of the great constraints to crop production and productivity including cereals. Among the various adaptation strategies is the choice and diversification of crops" (Sood et al., 2018). "Climate change and increasing global average temperatures are reported to have a direct impact on crop yields, crop productivity and the overall sustainability of our food systems. Although some estimates show that a few regions could benefit from climate change due to increased productivity and yields, this will not be sufficient to feed the higher number of inhabitants globally" (Kang et al.,2009). "Furthermore, most of the scientific community agrees that the current rates of global warming and emissions of greenhouse gas would significantly reduce overall crop productivity. Thus, reducing greenhouse gas emissions to control global temperatures plays a crucial role in achieving food security. However, the agricultural sector is one of the primary contributors to greenhouse gases such as methane into the atmosphere. Higher emissions are generally caused by intensive agricultural practices which are being followed in different locations around the world" (Downing et al.,2000 and Olesen et al.,2002). "Millets possess several morpho-physiological, molecular, and biochemical characteristics which confer better tolerance to environmental stresses than major cereals" (ACCII,2022).

2. LITERATURE REVIEW

"Millets are a highly varied group of small-seeded grasses, widely grown around the world as cereal crops or grains for fodder and human food.They can grow in the harshest,most arid regions"(Varshney et al., 2006)."Millets are low-input intensive crops making them a marginal Farmer's first choice.In the future, millets can be our insurance in times of climate change. Millets are resilient to extreme conditions including high temperatures and drought. They can grow in the harshest, most arid regions. Currently, around 55% of millets are grown in arid regions of Africa,40% in Asia, and 3% in Europe. In India, the demand for millets has grown by 140% but the production is less than 50%"(Kumar et al., 2022).As shown in Figure-1, there are 9 types of millets grown in India. They are- Sorghum(*Sorghum bicolor*), Pearl millet(*Pennisetum glaucum),*Fingermillet*(Eleusine coracana),*Barnyard

millet*(Echinochloacolona),*Proso millet*(Panicum milaceum),*Foxtail millet*(Setariaitalica),*Little millet*(Panicum sumatrense),*Kodo millet*Paspalum scrobicultum),*Brown top millet*(Urochloaramosa)* (source-Indian express).

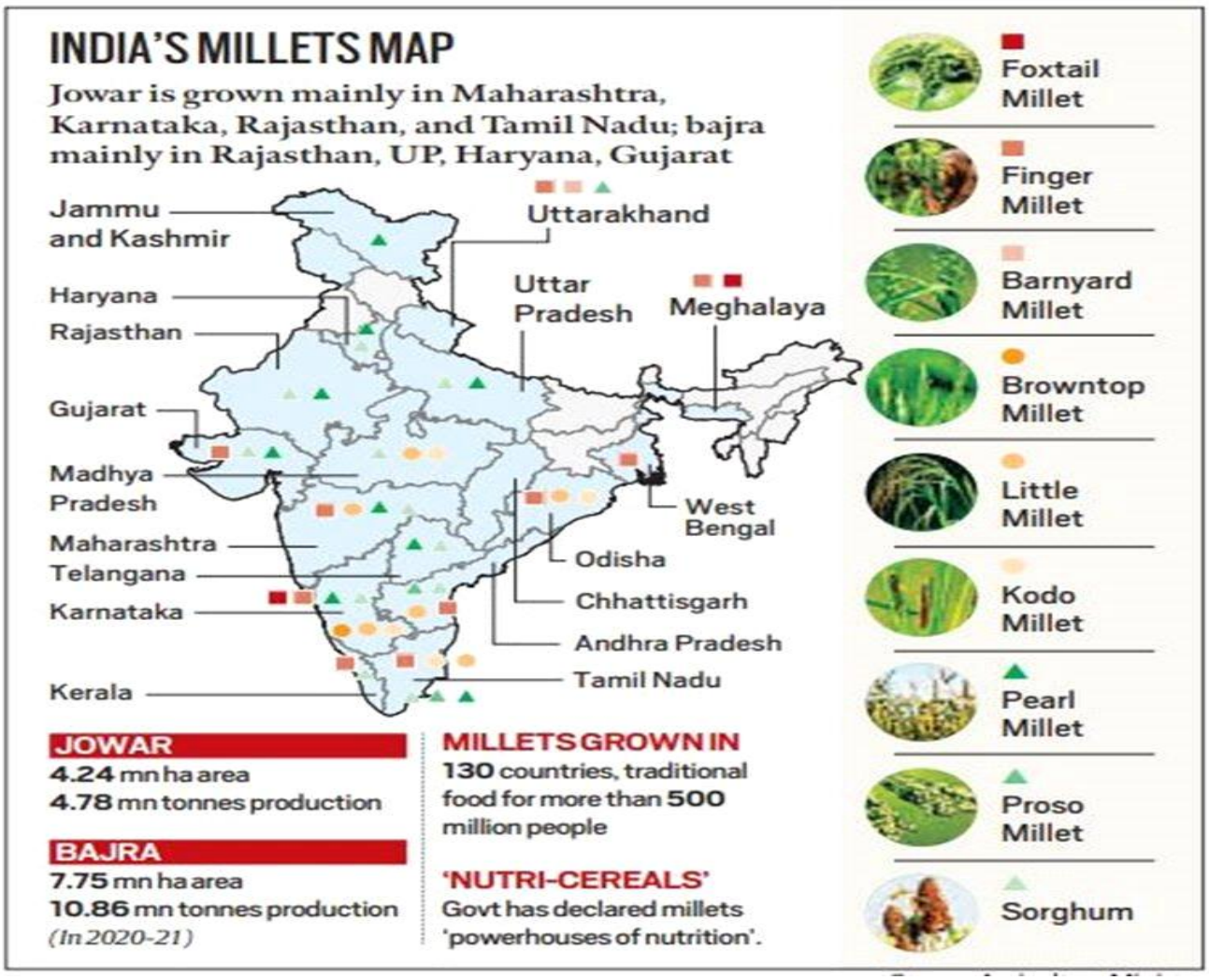

Fig.1. INDIA'S MILLETS MAP[27]

3. AREA AND PRODUCTION

"India is the largest producer of Millets in the world. In India, Millets are grown in about 21 States. There is a major impetus in Rajasthan, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Kerala, Telangana, Uttarakhand, Jharkhand, Madhya Pradesh, Haryana, and Gujarat"(Rao et al., 2019). "In India, millets are cultivated in an area of 12.45 million hectares, producing 15.53 million tonnes with a yield of 1247 kg/ha. Sorghum is the fourth most important food grain in India after rice, wheat, and maize in terms of area (3.84 Mn. ha) and production (4.31 Mn. MT). Bajra (7.05 m ha) is contributing more than 50 per cent of the country's area under millets with a nearly equal percentage of production. It is interesting to note that, India is the topmost producer of Barnyard (99.9%), Finger (53.3%), Kodo (100%), Little millet (100%) and pearl millet (44.5%), producing about 12.46 million

metric tonnes from an area of 8.87 million ha" (ACCII,2022). "Rajasthan has the highest area under millet cultivation (29.05%) followed by Maharashtra (20.67%), Karnataka (13.46%), Uttar Pradesh (8.06%), Madhya Pradesh (6.11%), Gujarat (3.94%) and Tamil Nadu (3.74%). The states of Gujarat and Madhya Pradesh have increased their area under millets over the recent years. However, the highest yields were recorded in Andhra Pradesh (2626.58 kg/ha), Tamil Nadu (2153.22kg/ha), Haryana (1906.78 kg/ha), Gujarat (1762.05 kg/ha) and Madhya Pradesh (1729.70 kg/ha). The states like Gujarat and Andhra Pradesh have shown better productivity levels as compared to their counterparts" (Satyavathi, C. Tara, et al.)

CROP	AREA (m ha)	PRODUCTION (m tons)	YIELD (kg per ha)
Sorghum (Kharif)	1.76	1.58	967
Sorghum (Rabi)	3.07	2.73	1002
Sorghum (Total)	4.83	4.31	989
Bajra	7.55	9.22	1374
Ragi	1.01	1.67	1747
Small Millets	0.459	0.33	809
Total Millets	13.83	15.53	1248

Table 1:Source: - Final Estimates-2021-22, DES, Government of India

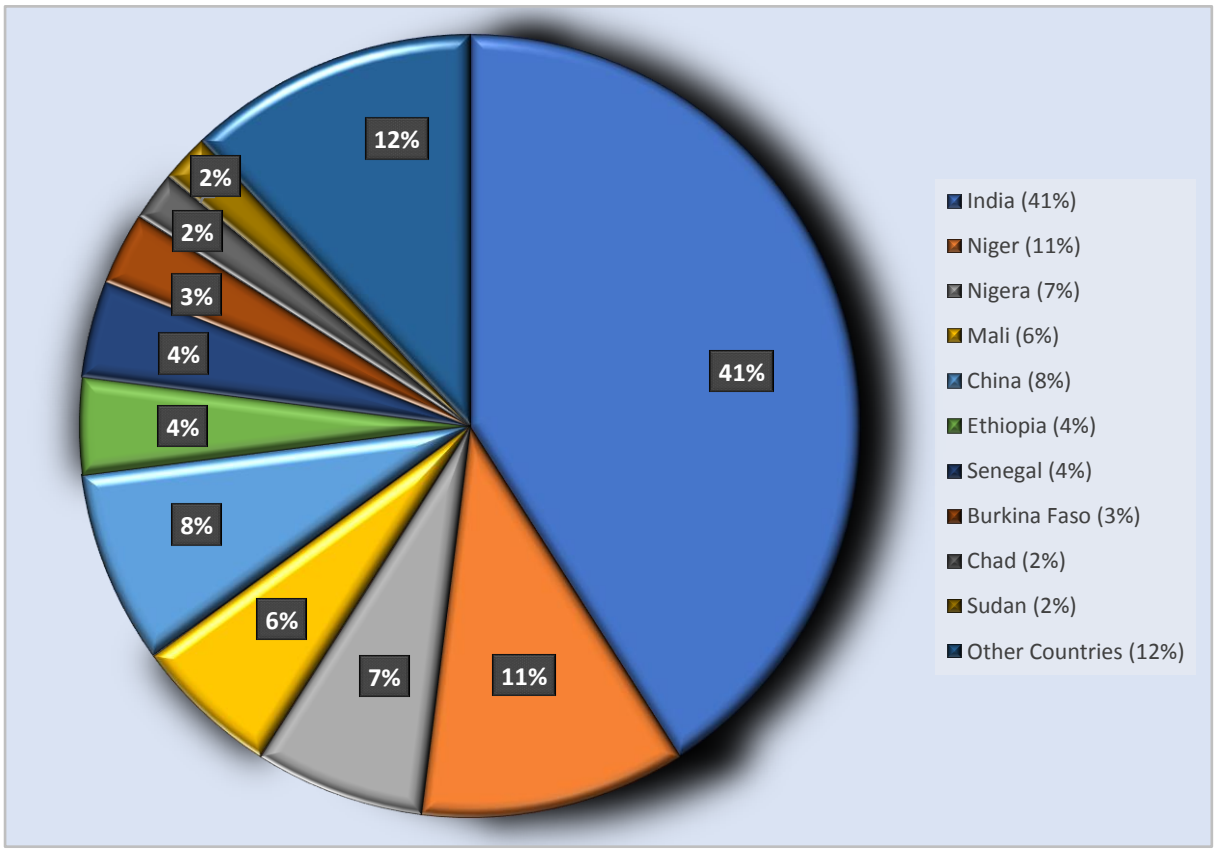

Fig.2. Country wise production of millet

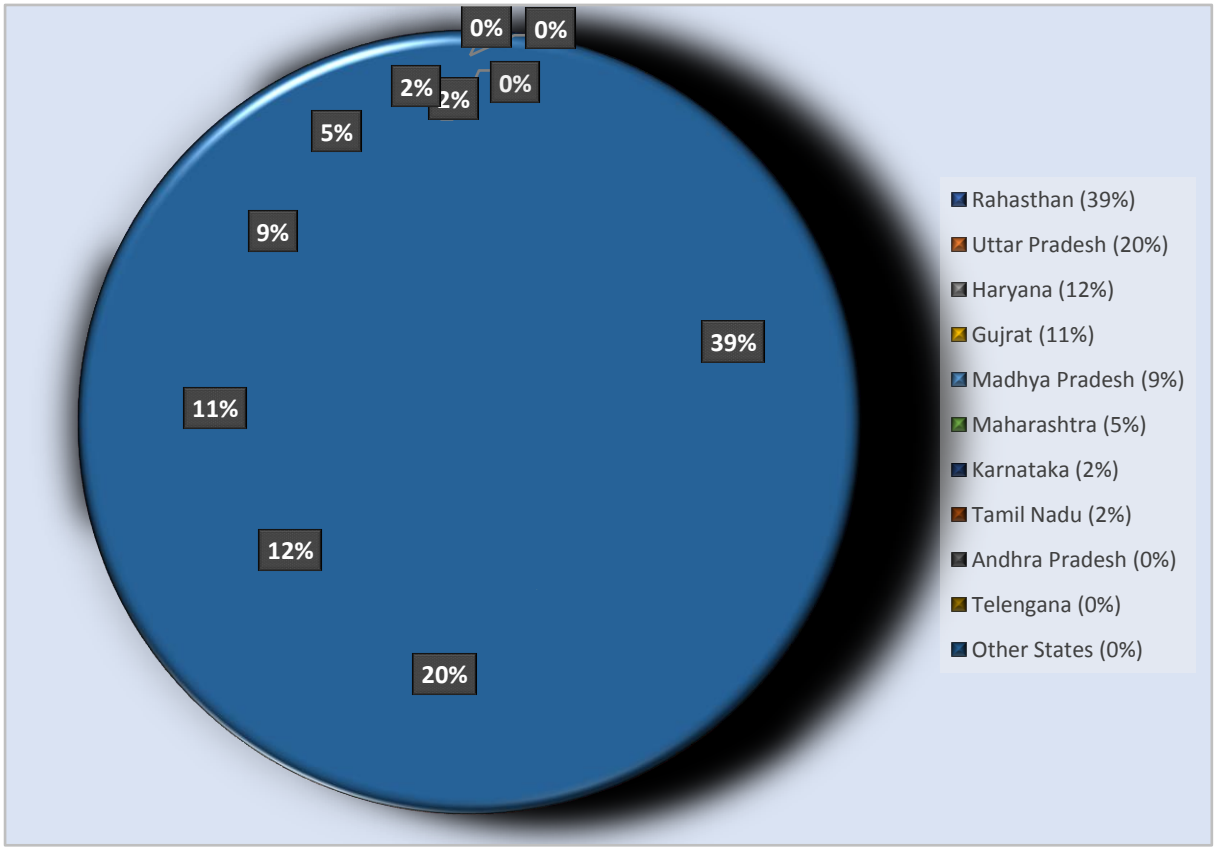

Fig.3. State-wise millet production (2021-22)

4. MILLETS FOR NUTRITIONAL IMPORTANCE

"Millets are a smart food because they are good for your health, and the environment because they require less water to grow and have a low carbon footprint, and for the farmers as well because they are more tolerant of changing weather patterns. Millets are a source of food for more than 90 million people in Asia and Africa"(Saleh et al., 2013). "Wheat, rice, and maize, in contrast, are staple foods for 4 billion people"(Kumar et al., 2022)."The millets contain as high as 13-38 % of total dietary fibre that could be considered in the management of disorders like diabetes mellitus, obesity, hyperlipidaemia, etc. The glycaemicload-lowering effects of barnyard millet arethe highest among all millets"(Kumari and Thayumanavan,1998)."Foxtail millet exhibits antihyperglycemic and antilipidemic activities. An aqueous extract of 300 mg of foxtail millet per kg body weight of rats exhibited a 70% reduction in blood glucose level in streptozotocin in induced diabetic rats"(Sireesha et al., 2011)."Millets are also a good source of carotenoids (78-366mg/100g) and possess higher antioxidant capacity"(Devi et al., 2014).

5. NUTRITIONAL COMPOSITION OF DIFFERENT MILLETS

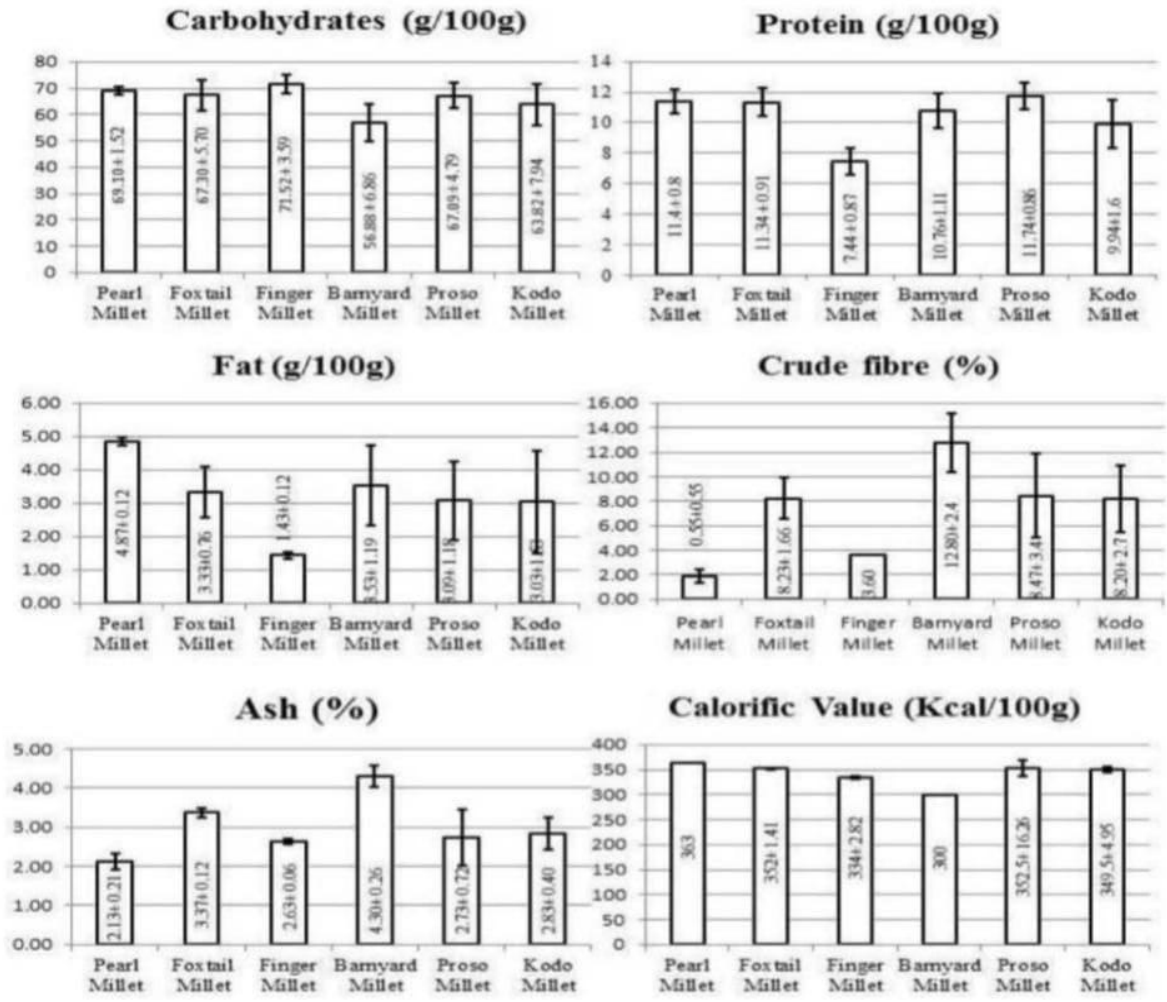

Fig 4: - Charts describing the nutritional composition of different millets (Kumar et al., 2018)

FOODGRAIN	CARBOHYDRATES (gm)	PROTEIN (gm)	FAT (gm)	ENERGY (Kcal)	CALCIUM (mg)	IRON (mg)
Sorghum	72.6	10.4	1.9	349	25	4.1
Bajra	67.5	11.6	5	361	42	8
Finger Millet	72.0	7.3	1.3	328	344	3.9
Foxtail Millet	60.9	12.3	4.3	331	31	2.8
Kodo Millet	65.9	8.3	1.4	309	27	0.5
Porso Millet	70.4	12.5	1.1	341	14	0.8
Barnyard Millet	65.5	6.2	2.2	307	20	5
Little Millet	67.0	7.7	4.7	341	17	9.3
Wheat (whole)	71.2	11.8	1.5	346	41	5.3
Rice	78.2	6.8	0.5	345	10	0.7

(raw, milled)						

Table 2: - Table describing the Nutritional component of different Millets

Source: - National Institute of Nutrition, Hyderabad

6. BENEFITS OF MILLET CONSUMPTION: -

FOOD SECURITY	NUTRITIONAL SECURITY	SAFETY FROM DISEASES	ECONOMIC SECURITY
• Sustainable food source for combating hunger in changing world climate	• Rich in micronutrients like Ca, Zn, Fe and Iodine etc. • Rich in bioactive compounds	• Millets have low water requirements and are drought-resistant. They have a short growing season and require less water during growth. Millets can grow in regions with <50 cm annual rainfall	• Millets offer farmers a stable source of income as they are drought-resistant and less susceptible to failure due to weather-related events
• Resistance to climate stress, pest and diseases	• Better amino acid profile	• They can be grown in dry land areas using farmyard manures, thus reducing the dependence on synthetic fertilisers.	• Millet production requires a low initial capital investment.

Table 3: - Table describing the benefits of millet consumption

(Kumar et al., 2018)

7. HEALTH BENEFITS OF MILLETS

Consuming millets can contribute significantly to overall health and well-being. Millets, such as sorghum, pearl millet, and finger millet, offer a range of health benefits:

- **Lower Bad Cholesterol Level: -** Millets have been shown to help reduce levels of LDL (low-density lipoprotein) cholesterol, commonly known as "bad cholesterol." This is crucial in maintaining cardiovascular health and reducing the risk of heart-related issues.

- **Weight Loss Support: -** Millets are a great addition to a weight loss diet. They are rich in fibre, which promotes a feeling of fullness, helping to control appetite and reduce overall calorie intake. The complex carbohydrates in millets also contribute to sustained energy levels.

- **Decreases High Blood Pressure: -** Millets contain essential minerals, such as magnesium and potassium, which play a key role in regulating blood pressure. Regular consumption of millets can contribute to the maintenance of healthy blood pressure levels, reducing the risk of hypertension.

- **Optimizes Immune System: -** Millets are a good source of various nutrients, including vitamins and minerals, that are essential for a well-functioning immune system. The optimization of the immune system can enhance the body's ability to combat infections and illnesses (Kaveeshwar et al., 2014).

- **Anti-Cancer Properties: -** Millets are a treasure trove of antioxidants that combat oxidative stress, mitigating cellular damage and diminishing the risk of cancer development.Embracing the classification of whole grains, millets confer protective advantages linked to a lowered cancer risk. The array of bioactive compounds within millets exhibits potential anti-cancer effects, further fortifying the body's resilience against malignancies.

- **Gluten-Free Alternative:** Millets are naturally gluten-free, making them an excellent dietary choice for individuals with gluten sensitivity or celiac disease. They offer a versatile and nutritious alternative to wheat and other gluten-containing grains.

- **Rich in Dietary Fiber:** Millets are a good source of dietary fibre, promoting digestive health and helping in the prevention of constipation. The high fibre content also contributes to a feeling of fullness, aiding in weight management.

- **Blood Sugar Regulation:** Certain millets, such as finger millet (ragi), have a low glycaemic index, which means they help regulate blood sugar levels. This can be beneficial for individuals managing diabetes or those looking to maintain stable energy levels.

- **Fixing Sleep Schedule: -**Pearl millet contains tryptophan, a precursor to serotonin and melatonin, pivotal neurotransmitters regulating sleep patterns and promoting restful nights. Also, the complex carbohydrates in millets ensure a gradual energy release, promoting consistent blood sugar levels. This stability prevents sleep disruptions caused by fluctuations in blood sugar, fostering a more stable and restorative sleep cycle.

- **Cardiometabolic Health:** Regular consumption of millet has been associated with improved cardiovascular health, including the reduction of bad cholesterol levels. The inclusion of millets in the diet contributes to a lower risk of heart-related issues.

Incorporating millets into a balanced diet can be a nutritious choice. They aid in combating a plethora of health abnormalities and provide avast array of health benefits that extend beyond the points mentioned here.

Fig 5: - Health Benefits of Millets

8. ADAPTABILITY OF MILLETS IN DIFFERENT CLIMATIC ZONES:

"Future agriculture will face some common environmental changes, such as increased temperature, uncertainty about rainfall, increased levels of CO2 and greenhouse gases, and greater frequency of natural disasters. Under these conditions, climate-resilient agriculture should be adopted, in which the cultivation of climate-friendly crops will play a key role. There is no doubt that millets are climate-smart crops that can simultaneously mitigate the adverse effects of climate change and adapt to changed and broader agro-climatic conditions" (Bandyopadhyay et al., 2017). "Various millets have a unique quality to combat extreme climatic conditions, which is more relevant as an adaptation option in the current scenario of global warming and climate change issues" (Reynolds et al., 2020). "As C4 plants, millet can utilize more atmospheric CO2 and produce more assimilates through the process of photosynthesis, even with increased atmospheric CO2 levels" (Aubry et al., 2011). "In addition, "the water use efficiency (WUE) of millet is higher than that of major cereals, and in the future, under critical water scarcity situations in much of the world, millet will automatically be selected to combat water scarcity" (Saxena et al.., 2018). "In semi-arid and arid regions, the major yield-limiting stressors are abiotic stress such as drought, temperature extremes (cold, frost, and heat), flooding, salinity, etc. Millet possesses numerous morphophysiological, molecular, and biochemical traits that confer better

tolerance to environmental stresses than major cereals" (Simmons et al., 2020). "The rainfall requirement of pearl millet and proso millet is 20 cm which is many times less than that of rice as they require more than 120-140 cm" (Kumar et al., 2018). "The short life cycle of millets (~10-12 weeks) compared to other major crops (20-24 weeks) also supports them in alleviating stress. Millet has a higher photosynthetic rate under warm conditions and provides an immediate water and nitrogen use efficiency that is ~1.5 to 4 times higher than that of C3 photosynthesis" Wang et al., 2012). "Compared to maize, pearl millet can better modulate its membrane dynamics for water permeability to achieve better water status during osmotic stress" (Bandyopadhyay et al., 2017). "Increases in leaf tensile strength and root length have been reported in teff and small millet under drought conditions" (Balsamo et al., 2006).

9. CONCLUSION AND FUTURE PROSPECTS: -

In India, diversifying crop production to include more coarse cereals, such as millets and sorghum, can make the food supply more nutritious, reduce resource demand and greenhouse gas emissions, and improve climate resilience without reducing calorie production or requiring more land. Nations can support sustainable food systems in the face of climate change. Thehardy nature of millets and their excellent ability to survive in low water and stress conditions make them an excellent alternative to the main cereal crops. Mono cropping system (rice-rice-rice) is often used in India and especially in West Bengal. By reducing dependence on synthetic fertilizers and pesticides and increasing soil fertility, grain cultivation can help transition to sustainable agriculture, diversifying crop rotation and not promoting monocropping systems.

The UN-FAO recognized the potential of this plant and declared 2023 as the "International Year of the Millets". By that time, the intervention of government and non-governmental bodies in initiating or reviving millet farming may be expected to incentivize increased millet production. This could achieve success in combating hunger and malnutrition among the vulnerable population in any future aberrant conditions.

10. REFERENCES: -

1. Aubry, S., Brown, N.J. and Hibberd, J.M., 2011. The role of proteins in C3 plants prior to their recruitment into the C4 pathway. Journal of experimental botany, 62(9), pp.3049-3059.
2. Balsamo, R.A., Willigen, C.V., Bauer, A.M. and Farrant, J., 2006. Drought tolerance of selected Eragrostis species correlates with leaf tensile properties. Annals of botany, 97(6), pp.985-991
3. Bandyopadhyay, T., Muthamilarasan, M. and Prasad, M., 2017. Millets for next generation climate-smart agriculture. Frontiers in plant science, 8, p.1266.
4. Banerjee, P., Maitra, S. and Banerjee, P., 2020. The role of small millets as functional food to combat malnutrition in developing countries. Indian Journal of Natural Sciences, 10(60), pp.20412-20417.

5. Davis, K.F., Chhatre, A., Rao, N.D., Singh, D. and DeFries, R., 2019. Sensitivity of grain yields to historical climate variability in India. Environmental research letters, 14(6), p.064013.
6. Devi, P.B., Vijayabharathi, R., Sathyabama, S., Malleshi, N.G. and Priyadarisini, V.B., 2014. Health benefits of finger millet (Eleusine coracana L.) polyphenols and dietary fibre: a review. Journal of food science and technology, 51, pp.1021-1040.
7. FAO. The state of food insecurity in the world 2015. Food Agric Organ UN. 2015.
8. Food and Agriculture Organization of the United Nations [technical note]. FAO methodology to estimate the prevalence of undernourishment. Rome, Italy: Food and Agriculture Organization; 2012.
9. Government of India, Ministry of Finance, Department of Economic Affairs, E.D. Economic Survey 2016-17; Delhi; 2016.
10. Hassan, Z.M., Sebola, N.A. and Mabelebele, M., 2021. The nutritional use of millet grain for food and feed: a review. Agriculture & food security, 10, pp.1-14.
11. Kaveeshwar, S.A. and Cornwall, J., 2014. The current state of diabetes mellitus in India. The Australasian medical journal, 7(1), p.45.
12. Krishna Kumari, S. and Thayumanavan, B., 1998. Characterization of starches of proso, foxtail, barnyard, kodo, and little millets. Plant Foods for Human Nutrition, 53, pp.47-56.
13. Kumar, A., Tomer, V., Kaur, A., Kumar, V. and Gupta, K., 2018. Millets: a solution to agrarian and nutritional challenges. Agriculture & food security, 7(1), pp.1-15.
14. Michaelraj, P.S.J. and Shanmugam, A., 2013. A study on millets-based cultivation and consumption in India. International Journal of Marketing, Financial Services & Management Research, 2(4), pp.49-58.
15. Rao, N.D., Poblete-Cazenave, M., Bhalerao, R., Davis, K.F. and Parkinson, S., 2019. Spatial analysis of energy use and GHG emissions from cereal production in India. Science of The Total Environment, 654, pp.841-849.
16. Reynolds, T.W., Waddington, S.R., Anderson, C.L., Chew, A., True, Z. and Cullen, A., 2015. Environmental impacts and constraints associated with the production of major food crops in Sub-Saharan Africa and South Asia. Food Security, 7, pp.795-822.
17. Saleh, A.S., Zhang, Q., Chen, J. and Shen, Q., 2013. Millet grains: nutritional quality, processing, and potential health benefits. Comprehensive reviews in food science and food safety, 12(3), pp.281-295.
18. Saxena, R., Vanga, S.K., Wang, J., Orsat, V. and Raghavan, V., 2018. Millets for food security in the context of climate change: A review. Sustainability, 10(7), p.2228.
19. Simmons, T., Styer, A.B., Pierroz, G., Gonçalves, A.P., Pasricha, R., Hazra, A.B., Bubner, P. and Coleman-Derr, D., 2020. Drought drives spatial variation in the millet root microbiome. Frontiers in plant science, p.599.
20. Sireesha, Y., Kasetti, R.B., Nabi, S.A., Swapna, S. and Apparao, C., 2011. Antihyperglycemic and hypolipidemic activities of Setariaitalica seeds in STZ diabetic rats. Pathophysiology, 18(2), pp.159-164.

21. Sood, S., Khulbe, R.K., Gupta, A.K., Agrawal, P.K., Upadhyaya, H.D. and Bhatt, J.C., 2015. Barnyard millet–a potential food and feed crop of thefuture. Plant Breeding, 134(2), pp.135-147.
22. Van Hung, P., 2016. Phenolic compounds of cereals and their antioxidant capacity. Critical reviews in food science and nutrition, 56(1), pp.25-35.
23. Varshney, R.K., Hoisington, D.A. and Tyagi, A.K., 2006. Advances in cereal genomics and applications in crop breeding. Trends in biotechnology, 24(11), pp.490-499.
24. Von Grebmer, K., Bernstein, J., Hossain, N., Brown, T., Prasai, N., Yohannes, Y., Patterson, F., Sonntag, A., Zimmerman, S.M., Towey, O. and Foley, C., 2017. 2017 Global Hunger Index: the inequalities of hunger. Intl Food Policy Res Inst.
25. Wang, C., Guo, L., Li, Y. and Wang, Z., 2012, December. Systematic comparison of C3 and C4 plants based on metabolic network analysis. In BMC Systems Biology (Vol. 6, pp. 1-14). BioMed Central.
26. Wheeler, T. and Von Braun, J., 2013. Climate change impacts on global food security. Science, 341(6145), pp.508-513.
27. https://indianexpress.com/article/explained/explained-health/indias-big-millets-push-why-it-makes-sense-to-have-these-grains-8430264/lite/
28. Satyavathi, C. Tara, et al. "Pearl Millet Breeding." *Fundamentals of Field Crop Breeding*. Singapore: Springer Nature Singapore, 2022. 309-366.
29. https://eands.dacnet.nic.in/Advance_Estimates.htm