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6. Potential Millets: A Viable Option

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Abstract:

Sustainable agriculture methods are becoming more and more important for environmental stability and food security as global climate change picks up speed. Millets are an essential crop in the battle against climate change because of their outstanding resilience to harsh environmental conditions, low water requirements and minimal need for chemical inputs. This chapter provides a comprehensive overview of millets, emphasizing their significance, nutritional advantages and potential to mitigate climate change effects. Millets are known for their exceptional nutritional value, offering high levels of proteins, dietary fibers, vitamins, minerals and low glycemic index. These characteristics position millets as a superfood, particularly beneficial in areas where malnutrition is a problem. Furthermore, millets demonstrate remarkable resilience to climate adversities such as drought, poor soil fertility, high temperatures and water logging to some extent making them suitable for cultivation in marginal lands where other crops may fail. The cultivation of millets can contribute significantly to climate change mitigation. Because of their efficient carbon sequestration and minimal demand for synthetic fertilizers, they benefit soil health and reduce emissions of greenhouse gases. Additionally, millets biodiversity contributes to agricultural ecosystems stability, increasing resilience to pests and diseases. Despite millets being considered as smart food, they face challenges in widespread adoption, primarily due to lack of awareness, limited market demand and agricultural policy biases favoring conventional staple crops. The promotion of millets through legislative support, stepping up research and development for better varieties, and raising awareness about their advantages for the environment and human health are some strategies to get beyond these barriers. This chapter emphasizes the importance of millets not merely as an alternative crop but as a strategic component of sustainable agriculture and climate change mitigation. Thus, integrating millets into global agricultural systems is essential for a resilient agricultural future.

Keywords:

climate change, drought, food security, millet, potential

6.1 Introduction:

As the global climate continues to change at an alarming rate, agriculture faces unprecedented challenges. Rising temperatures, erratic rainfall patterns and increased frequency of extreme weather events pose significant threats to food security and livelihoods worldwide (Beer, 2018). In this context, the search for resilient crops capable of thriving in adverse environmental conditions has become imperative.

Amidst this backdrop, millets emerge as a promising solution (Bandyopadhyay *et al.*, 2017). Because millets are climate-tolerant, they can adapt well to a wide range of shifting ecological conditions. They also require less water and nutrient input and are more resilient to environmental stressors (Kole *et al*., 2015). Millets, a group of small-seeded grasses cultivated for their edible grains, have been cultivated for thousands of years and have adapted to a wide range of agro-climatic conditions. The total production of millets in the country during 2022-23 is 17.32 million tonnes (Ministry of Agriculture & Farmers Welfare, 2023). Their resilience to drought, heat, and poor soil fertility makes them a viable option for farmers grappling with the impacts of climate change.

6.2 Overview of Millets:

Millets have a long history of cultivation, dating back thousands of years to ancient civilizations in Asia and Africa. They were among the earliest domesticated crops and played a crucial role in the agricultural systems of ancient societies. They have also been used for brewing alcoholic beverages, fodder for livestock and as traditional medicines in various cultures. The cultural significance of millets is reflected in religious ceremonies, festivals, and culinary traditions across different regions.

Millets represent a diverse group of small-seeded grains belonging to the grass family Poaceae. They play a crucial role in global food security, particularly in regions with challenging agro-climatic conditions. Millets are characterized by their small, round seeds, which are typically enclosed in hard seed coats. They belong to the subfamily Panicoideae within the grass family and their botanical characteristics vary depending on the species. Millets are generally annual or perennial grasses with erect, slender stems ranging from a few centimeters to several meters in height. Their leaves are linear or lanceolate, and they produce inflorescences in the form of panicles or spikes.

Table 6.1. Millets and Their Origin

Sr. No.	Millet	Scientific name	Common name	Origin
1	Sorghum	*Sorghum bicolor*	Great millet, jowar, cholam, jola, jonna, durra, Egyptian millet, feterita, Guinea corn, jwari, juwar, milo, shallu, gaoliang, kaoliang, kafir corn, dura, dari, mtama, solam	African Savannahs
2	Pearl millet	*Pennisetum glaucum*	Bajra, cattail, bulrush, candlestick, sanyo, munga, seno	West African Savannah
3	Finger millet	*Eleusine coracana*	Ragi, African,bird's foot, rapoko, Hunsa, wimbi, bulo, telebun, koracan, kurakkan	East African highlands
4	Foxtail millet	*Setaria italica*	Italian, German, Hungarian, Siberian, kangani, navane, thanaha	China

Sr. No.	Millet	Scientific name	Common name	Origin
5	Proso millet	Panicum milliaceum	Common, hog, broom, samai, Russian, panivarigu, panic, maha meneri	China
6	Little millet	*Panicum sumatrense*	Blue panic, heen meneri	India
7	Kodo millet	*Paspalum scrobiculatum*	Varagu, bastard, ditch, naraka, water couch, Indian paspalum, creeping paspalum, amu	India
8	Barnyard millet	*Echinochola crusgalli*	Japanese, sanwa, sawan, Korean, kweichou	Japan
9	Tef	Eragrostis tef	Abyssinian lovegrass	Ethiopian highlands
10	Fonio	Digitaria exilis	Fundi, hungry rice, acha	West Africa

(Weber and Fuller, 2008)

6.3 Nutritional Value:

Millets are valued for their high nutritional content, making them an important staple food for millions of people worldwide. They are rich in carbohydrates, protein, dietary fiber, vitamins, and minerals. Millets are particularly notable for their high protein content compared to other cereals, making them an essential source of plant-based protein, especially in vegetarian diets. They also contain essential amino acids, including lysine and methionine, which are often limited in other grains like rice and wheat.

Additionally, millets are rich in micronutrients such as iron, zinc, magnesium, and phosphorus, contributing to overall health and well-being. Their high fiber content aids in digestion and helps regulate blood sugar levels, making them suitable for individuals with diabetes or those seeking to manage weight (Agrawal *et al.*, 2023). Furthermore, millets are gluten-free, making them a valuable alternative for individuals with celiac disease or gluten intolerance (Asrani *et al.*, 2022). Consuming millets offers numerous health benefits, includes lowering cholesterol level and reducing risk of heart, body weight management, healthy digestion preventing constipation, strong and healthy bones, regulate blood sugar levels and contain some antioxidant properties (Rao *et al.*, 2017; Chaurasia and Anichari, 2023).

Table 6.2. Nutritional Composition of Millets

Grain	Carbo-hydrates (g)	Protein (g)	Fat (g)	Energy (Kcal)	Dietary fibre (g)	Ca (mg)	P (mg)	Mg (mg)	Zn (mg)	Fe (mg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)	Folic acid (µg)
Sorghum	67.7	09.9	1.73	334	10.2	27.6	274	133	1.9	3.9	0.35	0.14	2.1	39.4
Pearl Millet	61.8	10.9	5.43	347	11.5	27.4	289	124	2.7	6.4	0.25	0.20	0.9	36.1

Grain	Carbo-hydrates (g)	Protein (g)	Fat (g)	Energy (Kcal)	Dietary fibre (g)	Ca (mg)	P (mg)	Mg (mg)	Zn (mg)	Fe (mg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)	Folic acid (µg)
Finger millet	66.8	07.2	1.92	320	11.2	364.0	210	146	2.5	4.6	0.37	0.17	1.3	34.7
Kodo millet	66.2	08.9	2.55	331	06.4	15.3	101	122	1.6	2.3	0.29	0.20	1.5	39.5
Proso millet*	70.4	12.5	1.10	341	-	14.0	206	153	1.4	0.8	0.41	0.28	4.5	-
Foxtail millet*	60.1	12.3	4.30	331	-	31.0	188	81	2.4	2.8	0.59	0.11	3.2	15.0
Little millet	65.5	10.1	3.89	346	7.7	16.1	130	91	1.8	1.2	0.26	0.05	1.3	36.2
Barnyard millet*	65.5	06.2	2.20	307	-	20.0	280	82	3.0	5.0	0.33	0.10	4.2	-
Wheat flour	64.7	10.6	1.47	321	11.2	39.4	315	125	2.8	3.9	0.46	0.15	2.7	30.1
Rice	78.2	07.9	0.52	356	02.8	07.5	96	19	1.2	0.6	0.05	0.05	1.7	9.32
Amaranth seed	61	13.3	5.6	356	7.5	162.0	412	270	2.8	8.0	0.04	0.04	0.52	24.7
Quinoa	54	13.1	5.5	328	14.7	198.0	212	119	3.3	7.5	0.83	0.22	1.7	173

*Source: Indian Food Composition Tables, NIN – 2017; *Nutritive value of Indian Foods, NIN – 2007*

6.4 Significance of Millets:

Millets hold significant potential as a climate-resilient crop due to several key attributes:

- Deep root systems enable them to access moisture stored in deeper soil layers, making them drought-tolerant and well-suited to regions with erratic rainfall patterns
- Millets exhibit a remarkable ability to withstand high temperatures, making them suitable for cultivation in areas prone to heat stress.
- They require minimal inputs such as water, fertilizers, and pesticides, thereby reducing the environmental footprint of agricultural production (Tiwari *et al.*, 2022)
- Millets offer nutritional benefits that contribute to food security and public health. They are rich in protein, fiber, vitamins, and minerals, providing essential nutrients particularly in regions where malnutrition is prevalent (Srivastava and Arya, 2021) Incorporating millets into diets can help combat micronutrient deficiencies and mitigate the risk of chronic diseases such as diabetes and cardiovascular ailments (Tripathi *et al.*, 2023)
- Millets have cultural and socio-economic significance. They are deeply ingrained in the culinary traditions and cultural practices of many communities, especially in regions of Asia and Africa (Kheya *et al.*, 2023)
- Promoting millet cultivation can preserve cultural heritage while also generating economic opportunities for smallholder farmers, particularly women and marginalized groups.

6.5 Agricultural Benefits of Millets:

Millets are valuable crops for sustainable agriculture because of their many agronomic benefits, especially in areas where there is a shortage of water, degraded soil and unpredictable weather. Due to their low water requirements, millets are perfect for rainfed farming and regions with constrained access to irrigation (Das and Rakshit, 2016).

They yield satisfactorily with minimal water, which relieves pressure on water supplies and reduces the possibility of crop failures due to drought. Millets maximize land productivity and diversity by allowing for multiple crops in throughout the year, with growth cycles that usually last between 60 to 90 days (Kheya *et al.*, 2023).

Their capacity to grow in marginal areas with little soil fertility, little moisture retention, and high salinity boosts food security by increasing agricultural output. Millets also aid in soil conservation efforts by preventing erosion and restoring degraded ecosystems (Michels and Bielders, 2006).

In addition to improving soil fertility, expanding revenue streams, and fostering biodiversity, millets have potential for intercropping and mixed cropping (Maitra, 2020).

Their vast root systems enhance the structure of the soil and the uptake of nutrients, decreasing the demand for chemical fertilizers and lowering pollution. Farmers can improve soil fertility, carbon sequestration, and agricultural sustainability by incorporating millets into their crop rotations (Wang *et al.*, 2023). Millets agronomic traits, coupled with their adaptability to climate variability, contribute to resilience against extreme weather events, stabilizing incomes and mitigating climate change impacts on agriculture.

6.6 Climate Resilience of Millets:

Millets possess inherent traits that confer them with remarkable resilience to a variety of climatic stresses, including drought, heat, and pests. This resilience makes them invaluable crops in the face of increasingly unpredictable weather patterns and climate change

A. Drought Resistance:

- Deep Root Systems: Millets typically develop extensive root systems that penetrate deep into the soil, enabling them to access moisture stored in lower soil layers during periods of drought. This allows millets to withstand prolonged dry spells and thrive in regions with limited rainfall. Ashok *et al.* (2018) concluded that barnyard millet recorded the highest grain yield (18.94 g plant^{-1}) and straw yield (41.12 g plant^{-1}) during reproductive stage followed by finger millet and little millet under drought situations.
- Efficient Water Use: Millets exhibit a high degree of water use efficiency (WUE), meaning they can produce satisfactory yields even with minimal water availability. Their ability to maintain metabolic processes while conserving water makes them well-suited to arid and semi-arid environments. The WUE of millets ranked in the order of Peral millet > barnyard millet> proso millet> finger millet > foxtail millet > jobs tear under drought conditions (Zegada-Lizarazu and Iijima, 2005).

B. Heat Tolerance:

- C4 Photosynthesis: Many millet species utilize a photosynthetic pathway known as C4 photosynthesis, which is highly efficient in hot and dry conditions. This adaptation allows millets to continue photosynthesizing even at high temperatures, ensuring sustained growth and productivity.
- Rapid Growth and Flowering: Millets often have short growth cycles and rapid rates of growth and flowering, allowing them to complete their life cycle before the onset of extreme heat stress. This trait minimizes exposure to adverse environmental conditions and enhances heat tolerance.

C. Pest and Disease Resistance:

- Natural Pest Resistance: Millets possess inherent resistance to certain pests and diseases, reducing the need for chemical pesticides and mitigating the risk of pest outbreaks. For example, pearl millet is known for its resistance to certain insect pests such as stem borers and shoot fly (Prasad and Babu, 2016).
- Allelopathic Effects: Some millet species produce allelochemicals that inhibit the growth of competing weeds and pests, providing natural pest control and weed suppression. This allelopathic effect contributes to the resilience of millet crops and promotes sustainable pest management practices. Khan *et al.* (2019) observed that aqueous leaf extracts of pearl millet has showed allelopathic effect on weeds *viz.*, signal grass, common lambs' quarters, field bindweed, broad leaved dock, slender amaranth, wild melon, annual sow thistle and wild jute.

D. Adaptability to Marginal Lands:

- Tolerance to Poor Soil Fertility: Millets exhibit tolerance to a wide range of soil conditions, including poor fertility, acidity, and salinity. They can thrive in marginal lands where other crops struggle to grow, making them valuable for reclaiming degraded ecosystems and enhancing agricultural productivity in resource-constrained environments.

E. Versatility in Agroecosystems:

- A wide range of agroecosystems, such as rainfed agriculture, mixed cropping systems, and intercropping systems, can be utilized with millet. Because of their adaptability, millets can be used by farmers into sustainable farming methods that increase biodiversity and resilience to climatic fluctuations (Yadav and Yadav, 2000).

F. Adaptability to flood:

- Millets exhibit some level of adaptability to flooding and waterlogging, especially when grown in mixed cropping systems. A study conducted by Iijima *et al.* (2016) found that mixed cropping of pearl millet and sorghum (upland-adapted crops) with rice can enhance the flood tolerance of the millet and sorghum crops.

This suggests that millets can adapt to some degree of waterlogging or flooding when grown in mixed cropping systems.

Table 6.3. Climate Resilient Trait of Millets

Millet	Duration	Climate resilient trait
Sorghum	100-125	Drought tolerant, excellent recovery mechanism from stresses, highly adapted to wide range of soils, altitudes and temperatures, responsive to high input management
Pearl millet	80-95	Highly resilient to heat and drought, come up in very poor soils, but responsive to high input management
Finger millet	90-130	Moderately resistant to heat, drought and humidity, adapted to wide altitude range
Foxtail millet	70-120	Adapted to low rainfall, high altitude
Proso millet	60-90	Short duration, low rainfall, high altitude adapted
Little millet	70-110	Adapted to low rainfall and poor soils- famine food; withstand waterlogging to some extent
Kodo millet	100-140	Long duration, but very hardy, needs little rainfall, comes up in very poor soils, good response to improved management
Barnyard millet	45-60	Very short duration, not limited by moisture, high altitude adapted
Tef	60-120	Short duration, drought and flood tolerant, high altitude adapted, fit in diverse cropping systems
Fonio	60-80	Short duration, adapted to poor soils with less rainfall

(Bhat *et al.*, 2018**)**

6.7 Potential to Contribute to Climate Change Mitigation:

Millets have significant potential to contribute to climate change mitigation through various mechanisms, including carbon sequestration, water conservation, and reduced greenhouse gas emissions.

A. Carbon Sequestration:

- **Soil Carbon: Millet** cultivation can enhance soil organic carbon levels through practices such as minimal tillage, cover cropping, and agroforestry. Healthy soils with higher organic carbon content act as sinks for atmospheric carbon dioxide, helping mitigate climate change.
- **Agroforestry Systems:** Introducing millets into agroforestry systems, where trees are integrated with agricultural crops, can further enhance carbon sequestration. Trees sequester carbon in their biomass and contribute to improved soil structure and fertility.

B. Water Conservation:

- Drought Tolerance: Millets are known for their resilience to drought and heat stress, making them suitable crops for water-scarce regions. Their deep root systems enable them to access moisture from deeper soil layers, reducing the need for irrigation.
- Rainfed Agriculture: Millets are primarily rainfed crops, requiring minimal external water inputs compared to water-intensive crops like rice or maize. Cultivating millets in rainfed areas can contribute to water conservation and sustainable water management practices.

C. Reduced Greenhouse Gas Emissions:

- Lower Input Requirements: Millets typically require fewer inputs such as synthetic fertilizers and pesticides compared to other cereal crops. By reducing chemical inputs, millet cultivation can help lower emissions of nitrous oxide, a potent greenhouse gas. (Patel *et al.*, 2020)
- Crop Residue Management: Incorporating millet crop residues into the soil or using them for livestock feed can reduce emissions of methane, another potent greenhouse gas produced during organic matter decomposition.

D. Incorporating Millets into Climate-Smart Agriculture:

- Crop Diversification: Integrating millets into crop rotations or intercropping systems can enhance biodiversity, soil health, and resilience to climate variability. Diversified cropping systems are more resilient to extreme weather events and pest outbreaks.
- Conservation Agriculture: Practices such as minimum tillage, mulching, and crop residue management, commonly associated with conservation agriculture, are well-suited for millet cultivation. These practices help conserve soil moisture, improve soil structure, and reduce erosion.

E. Sustainable Food Systems:

- Dietary Diversity: Promoting the consumption of millets diversifies diets and reduces reliance on resource-intensive staple crops. Including millets in food systems can improve nutrition, particularly in regions where micronutrient deficiencies are prevalent. (Srivastava and Arya, 2021)
- Local Food Sovereignty: Encouraging the production and consumption of locally adapted millet varieties strengthens food sovereignty by reducing dependence on imported food commodities. Localized food systems also have lower carbon footprints due to reduced transportation emissions.

By incorporating millets into climate-smart agriculture practices and sustainable food systems, we can harness their potential to mitigate climate change, conserve natural resources, and enhance resilience to environmental challenges while promoting food security and livelihoods for farming communities.

F. Challenges:

Despite their numerous benefits, the widespread adoption of millets faces several challenges and barriers:

a. Limited Awareness: Many consumers and even farmers have limited awareness of the nutritional benefits and culinary versatility of millets.
b. Traditional preferences for other staple crops may overshadow the potential of millets.
c. Limited market infrastructure and distribution networks for millets may restrict farmers' ability to sell their produce at fair prices.
d. Lack of demand from mainstream food markets may result in limited opportunities for farmers to sell millets profitably.
e. Agricultural policies and subsidies often favor high-yielding cereal crops over traditional or minor crops like millets
f. Insufficient policy support for research, development, and promotion of millet cultivation and consumption.

6.8 Strategies to Overcome:

To overcome these challenges and promote the widespread adoption of millets, several strategies can be implemented such as, investing and conducting research and development to improve millet varieties, enhancing their yield, nutritional content, and resilience to climate change, Facilitating the development of value chains for millets, including processing, packaging, and marketing infrastructure, promoting value addition and agri business startups, launching public awareness campaigns to educate consumers about the nutritional benefits and culinary uses of millets, making efficient policies supports millet cultivation, and building the capacity of farmers, extension workers, and agribusinesses through training programs and knowledge-sharing platforms. By implementing targeted strategies, we can unlock the full potential of millets to contribute to sustainable agriculture, improve nutrition, and enhance the livelihoods of farming communities.

6.9 Conclusion:

In conclusion, millets are an economically feasible and environmentally friendly farming approach that has the potential to significantly reduce the effects of climate change. Their adaptability to varying climates is demonstrated by their capacity to flourish in conditions of drought with minimal water and fertilizer needs, rendering them perfect for cultivation in ever-changing climates. We can improve soil health, boost biodiversity, and cut emissions of greenhouse gases by including millets into agricultural systems. This not only helps to mitigate the effects of climate change but also guarantees food security in areas that are susceptible. focusing on the production and consumption of millets may be a crucial tactic in our global response to the climate catastrophe.

6.10 References:

1. Agrawal P, Singh BR, Gajbe U, Kalambe MA and Bankar M. 2023. Managing Diabetes Mellitus with Millets: A New Solution. *Cureus*. 15(9): e44908.

2. Ashok S, Senthil A, Sritharan N, Punitha S, Divya K and Ravikesavan R. 2018. Yield potential of small millets under drought condition. *Madras Agricultural Journal*, 105(7-9): 370-372.
3. Asrani P, Ansheef A and Tiwari K. 2022. Millets as an alternative diet for gluten-sensitive individuals: A critical review on nutritional components, sensitivities and popularity of wheat and millets among consumers. *Food Reviews International*. 39(6): 3370-3399.
4. Bandyopadhyay T, Muthamilarasan M and Prasad M. 2017. Millets for Next Generation Climate-Smart Agriculture. *Front. Plant Sci*. 8(1266):1-6.
5. Beer T. 2018. The Impact of Extreme Weather Events on Food Security. In: Mal, S., Singh, R., Huggel, C. (eds) *Climate Change, Extreme Events and Disaster Risk Reduction. Sustainable Development Goals Series.* Springer, Cham. 121-133p.
6. Bhat VB, Rao BD and Tonapi VA. 2018. Millets are Least demanding and Most Sustainable Crops *In: The story of millets.* Karnataka State Department of Agriculture, Bengaluru, India with ICAR-Indian Institute of Millets Research, Hyderabad, India. 124 pp.
7. Chaurasia RK and Anichari N. 2023. Nutritional and health benefits of Millets: A review. *The Pharma Innovation Journal*, 12(6): 3360-3363.
8. Das IK and Rakshit S. 2016. Millets, their importance, and production constraints. In *Biotic stress resistance in millets* Academic Press. pp. 3-19.
9. Iijima M, Awala SK, Watanabe Y, Kawato Y, Fujioka Y, Yamane K and Wada KC. 2016. Mixed cropping has the potential to enhance flood tolerance of drought-adapted grain crops. *Journal of Plant Physiology*, 192: 21-25.
10. Khan A, Malik MWI, Hussain I, Malik MH, Nadim MA and Baloch MS. 2019. Allelopathic potential of aqueous leaf extracts of pearl millet (Pennisetum typhoides S. and H.) on germination and growth of some selected weeds. *Pakistan Journal of Weed Science Research*, 25(3): 223-233.
11. Kheya SA, Talukder SK, Datta P, Yeasmin S, Rashid MH, Hasan AK, Anwar MP, Islam AA and Islam AM. 2023. Millets: The future crops for the tropics-Status, challenges and future prospects. *Heliyon*. 9(11): e22123
12. Kole C, Muthamilarasan M, Henry R, Edwards D, Sharma R, Abberton M. 2015. Application of genomics- assisted breeding for generation of climate resilient crops: progress and prospects. *Front. Plant Sci*. 6(563): 1-16.
13. Maitra S. 2020. Intercropping of small millets for agricultural sustainability in drylands: A review. *Crop Research, 55*(3and4): 162-171.
14. Michels K and Bielders CL. 2006. Pearl millet growth on an erosion-affected soil in the Sahel. *Experimental Agriculture*, 42(1): 1-17.
15. Ministry of Agriculture & Farmers Welfare, 2023. Promoting the Production of Millets Posted On: 05 DEC 2023 6:01PM by PIB Delhi https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1982798#:~:text=The%20total%20production%20of%20Millets%20%28Shree%20Anna%29%20in,%28Shree%20Anna%29%20during%202022-23%20is%20given%20at%20Annexure-I.
16. Patel B, Patel A, Gami B and Patel P. 2020. Energy balance, GHG emission and economy for cultivation of high biomass verities of bamboo, sorghum and pearl millet as energy crops at marginal ecologies of Gujarat state in India. *Renewable Energy*, 148: 816-823.
17. Prasad GS and Babu KS. 2016. Insect pest resistance in pearl millet and small millets. In *Biotic stress resistance in millets.* Academic Press. pp. 147-169.

18. Rao DB, Bhaskarachary K, Christina AGD, Devi SG, Vilas AT, and Tonapi A. 2017. Nutritional and health benefits of millets. *ICAR_Indian Institute of Millets Research (IIMR) Rajendranagar, Hyderabad*, pp 112.
19. Srivastava S and Arya C. 2021. Millets: malnutrition and nutrition security. *Millets and Millet Technology*, Springer. pp.81-100.
20. Tiwari H, Naresh RK, Kumar L, Kataria SK, Tewari S, Saini A, Yadav RK and Asati R. 2022. Millets for food and nutritional security for small and marginal farmers of Northwest India in the Context of Climate Change: A Review. *International Journal of Plant & Soil Science*, 34(23): 1694-1705.
21. Tripathi G, Jitendrakumar PH, Borah A, Nath D, Das H, Bansal S, Singh N and Singh BV. 2023. A review on nutritional and health benefits of millets. *International Journal of Plant & Soil Science*, 35(19): 1736-1743.
22. Wang S, Xiong J, Yang B, Yang X, Du T, Steenhuis TS, Siddique KH and Kang S. 2023. Diversified crop rotations reduce groundwater use and enhance system resilience. *Agricultural Water Management*, 276: 108067.
23. Weber SA and Fuller DQ. 2008. Millets and their role in early agriculture. *Pragdhara*, 18(69): p.e90.
24. Yadav RS and Yadav OP. 2000. Differential competitive ability and growth habit of pearl millet and cluster-bean cultivars in a mixed cropping system in the arid zone of India. *Journal of Agronomy and Crop Science*, 185(1): 67-71.
25. Zegada-Lizarazu W and Iijima M. 2005. Deep root water uptake ability and water use efficiency of pearl millet in comparison to other millet species. *Plant Production Science*, 8(4): 454-460.