Vigyan Varta
www.vigyanvarta.in

Vigyan Varta an International E-Magazine for Science Enthusiasts

Vol. 7, Issue 8

E-ISSN: 2582-9467
Popular Article
Santosh et al. (2026)

Drought Proofing of Finger Millet in India – Why and How?

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OPEN ACCESS

Keywords

Finger millet, Climate resilience, Rainfed agriculture, Water stress, Nutritional security

How to cite this article:

Santosh, H. B., Bhargavi, B., Alam, B. K., Savitha, S., Boraiah, K. M. and Basavaraj, P. S. 2026. Drought Proofing of Finger Millet in India – Why and How? *Vigyan Varta* 7 (08): 52-57.

ABSTRACT

Finger millet (*Eleusine coracana*), popularly known as ragi, is one of the most important climate-resilient cereal crops cultivated in the semi-arid and rainfed regions of India. It serves as a vital source of food, nutrition, fodder, and livelihood for millions of small and marginal farmers. Although finger millet is naturally more drought tolerant than many major cereals, increasing climate variability, delayed monsoons, prolonged dry spells, and rising temperatures are posing serious threats to its productivity. Studies have reported yield losses of up to 61% under severe drought conditions. Therefore, strengthening the drought resilience of finger millet has become essential for ensuring sustainable millet production and nutritional security. This article discusses the importance of drought proofing in finger millet, the major challenges posed by drought, and the scientific and management approaches available to enhance drought tolerance. These include genetic improvement, identification of drought-tolerant varieties, agronomic interventions, soil and water conservation practices, and modern breeding tools. A comprehensive drought-proofing strategy can significantly contribute to climate-resilient agriculture and improve the livelihoods of farming communities in drought-prone regions of India.

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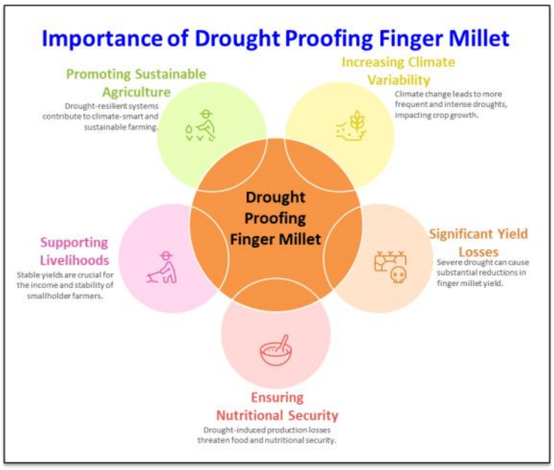
INTRODUCTION:

India is one of the largest producers of millets in the world and has played a pivotal role in promoting millet-based farming systems. Among the various millets, finger millet occupies a unique position because of its remarkable nutritional value and adaptability to adverse environmental conditions. The crop is rich in calcium, dietary fibre, iron, and essential amino acids, making it an important component of healthy diets. Globally, finger millet is cultivated on about 2.31 million hectares with a production of approximately 3.33 million tonnes. India contributes nearly half of the global production, cultivating the crop on around 1.10 million hectares with a production of about 1.58 million tonnes and productivity of 1584 kg/ha. Major finger millet-growing states include Karnataka, Tamil Nadu, Uttarakhand, Maharashtra, Odisha, Andhra Pradesh, Gujarat, Telangana, and Jharkhand. Most finger millet cultivation occurs under rainfed conditions where crop productivity depends heavily on the timely availability of rainfall. With increasing climate change-induced droughts and erratic rainfall patterns, there is an urgent need to strengthen the drought resilience of finger millet production systems (Vetriventhan *et al*. 2020; Numan *et al*. 2021).

Why is Drought Proofing of Finger Millet Important?

The need for drought proofing of finger millet in India has become increasingly important due to rising climate variability and the growing frequency of drought events. Climate change has led to erratic rainfall patterns characterized by delayed monsoon onset, prolonged dry spells during crop growth, and premature withdrawal of rains. These adverse weather conditions negatively affect critical growth stages such as germination, crop establishment, flowering, grain filling, and ultimately reduce crop productivity. Although



finger millet is recognized as one of the most drought-resilient cereal crops, severe moisture stress can still cause substantial yield reductions, with studies reporting losses of up to 61 percent under extreme drought conditions (Krishnamurthy *et al*. 2016; Talwar *et al*. 2020). Furthermore, considerable variation exists among finger millet genotypes in their ability to withstand drought (Bhatt *et al*. 2011), highlighting the need for systematic identification and development of highly resilient varieties.

Beyond its role as a climate-resilient crop, finger millet is also a vital contributor to food and nutritional security. Often referred to as a "nutri-cereal," it is exceptionally rich in calcium, dietary fibre, iron, and other essential micronutrients that support human health. Any decline in finger millet production due to drought can therefore have direct implications for the nutritional well-being of rural and economically vulnerable populations that depend on it as a staple food. In addition, millions of small and marginal farmers in dryland regions cultivate finger millet as a source of income, food, and livestock fodder. Ensuring stable yields under drought conditions is therefore essential for sustaining rural livelihoods, reducing economic risks, and enhancing resilience against climate-related uncertainties. Moreover, finger millet requires relatively fewer external inputs and performs well even on marginal lands, making it an ideal crop for sustainable and climate-smart agriculture. Developing and promoting drought-resilient finger millet production systems can thus play a significant role in strengthening agricultural sustainability, conserving natural resources, and ensuring long-term food and livelihood security in India.

Current Status of Drought Tolerance Research

Finger millet possesses several inherent mechanisms that help it survive under moisture stress. Compared with many major cereals, millets exhibit better adaptation to drought and other abiotic stresses. However, further improvement is necessary to cope with emerging climate challenges. Researchers have evaluated several germplasm accessions and varieties for drought tolerance. However, most studies have been limited to a small number of genotypes or conducted under controlled conditions (Mukami *et al.* 2019; Bhatt *et al.* 2011; Mude *et al.* 2020). Field-based evaluations under natural drought conditions remain relatively limited despite being more realistic and useful for crop improvement programmes. Another challenge is the large variability in crop duration and flowering time among finger millet varieties. This makes it difficult to compare drought responses accurately unless stress is imposed at comparable crop growth stages. India has released more than 140 finger millet varieties, including several developed during the last decade (Hariprasanna, 2023). However, many of these varieties have not been comprehensively evaluated for drought tolerance under diverse field environments.

Several important gaps need to be addressed to strengthen drought resilience in finger millet:

1. Lack of comprehensive information on drought resilience among Indian finger millet varieties.
2. Limited identification of highly drought-tolerant genotypes suitable for cultivation in drought-prone regions.
3. Absence of registered genetic stocks specifically recognized for drought tolerance.
4. Insufficient understanding of the impact of drought on grain and fodder nutritional quality.
5. Limited knowledge regarding the genomics and molecular mechanisms governing drought tolerance.

Addressing these gaps can accelerate the development of climate-resilient finger millet varieties.

How Can Finger Millet be Drought Proofed?

1. **Development of Drought-Tolerant Varieties:** The most sustainable approach is the development and deployment of drought-tolerant cultivars. Screening large germplasm collections under field and controlled conditions helps identify promising donor lines with superior drought resilience. Modern breeding programmes can combine drought tolerance with high yield, disease resistance, and nutritional quality.
2. **Exploitation of Genetic Diversity:** India possesses rich finger millet genetic resources, including released varieties, germplasm accessions, and mutant lines. Comprehensive evaluation of these resources can identify novel sources of drought tolerance. Such genetic resources can serve as valuable donors in breeding programmes.

3. **Molecular and Genomic Approaches:** Recent advances in genomics provide powerful tools for understanding drought response mechanisms. Transcriptomics, molecular markers, and genome-wide studies can identify genes associated with drought tolerance. The identification of drought-responsive genes can facilitate marker-assisted breeding and accelerate the development of resilient varieties.

4. **Efficient Water Management:** Efficient water management is a key component of drought proofing in finger millet cultivation. Several agronomic practices can significantly improve water-use efficiency and help the crop withstand periods of moisture stress. Timely sowing with the onset of the monsoon ensures that the crop effectively utilizes available rainfall throughout its growth period. In rainfed areas, transplanting allows effective use of early monsoon rainfall and helps the crop withstand short dry spells better than direct-seeded crops. In direct sown crop, the use of conservation furrows enhances rainwater infiltration, reduces runoff, and facilitates better soil moisture storage. Construction of farm ponds enables the harvesting and storage of excess rainwater, which can later be used for supplemental irrigation during dry spells. Providing life-saving irrigation during critical growth stages such as flowering and grain filling can prevent severe yield losses caused by drought stress. Collectively, these water-management practices help maintain adequate soil moisture, improve crop resilience, and substantially reduce drought-induced yield losses in finger millet.

5. **Nutrient Management:** Balanced nutrition strengthens crop tolerance to stress. Adequate application of nitrogen, phosphorus, potassium, zinc, and micronutrients promotes better root development and physiological resilience under drought conditions. Organic amendments further improve soil health and water-holding capacity. Possible microbial bio-fertilizer options for finger millet include Azospirillum, PSB, Trichoderma, Bacillus, arbuscular mycorrhizal fungi (AMF), and plant growth-promoting rhizobacteria (PGPR). The findings of a study conducted by Prabhakar *et al.*, (2023) revealed that substituting chemical fertilizers either completely or by up to 50% with organic manures supplies adequate amounts of nutrients, improves the yield of finger millet, economic returns, and soil properties. Integrated use of 50% RDF, 2.5 t ha^{-1} Gliricidia, and 2.5 kg ha^{-1} each of Azotobacter and PSB (INM7) is recommended for improving productivity of finger millet in eastern India (Dass *et al.*, 2013)

6. **Climate-Smart Crop Management:** Climate-smart crop management practices play a vital role in enhancing the resilience of finger millet production systems against drought and other climatic uncertainties. Drought contingency planning enables timely adoption of alternative management strategies during periods of moisture stress, thereby minimizing crop losses. Intercropping systems involving finger millet and compatible crops improve resource utilization, reduce production risks, and provide yield stability under variable environmental conditions. Intercropping systems such as finger millet + groundnut (8:2) and finger millet + pigeon pea (8:2) enhanced resource-use efficiency, stabilized yields, and minimized production risk under moisture stress conditions (Niharika *et al.*, 2026). Inclusion of carefully selected legume crops in finger millet-based crop rotations can help to minimize inorganic N fertilizer

requirements, as symbiotically fixed N can be transferred from previous legumes to a subsequent finger millet crop (Thilakarathna & Raizada 2015). Mixed farming approaches that integrate crops, livestock, and other farm enterprises enhance income diversification and strengthen overall farm resilience (Bussa & Behera 2023). Similarly, crop diversification reduces dependence on a single crop and helps farmers better cope with climatic fluctuations and market uncertainties. Weather-based advisories help farmers make informed decisions regarding sowing, irrigation, fertilizer application, and crop protection based on prevailing and forecasted weather conditions. Together, these climate-smart practices contribute to sustainable agricultural production, improved resource-use efficiency, and enhanced resilience of farming communities in drought-prone regions.

Role of Farmers in Drought Proofing

Farmers play a central role in implementing drought-resilient technologies. Adoption of drought-tolerant varieties of finger millet, improved soil management practices, and efficient water conservation techniques can substantially improve productivity under water-limited conditions. Community-based watershed development programmes, rainwater harvesting structures, and collective resource management can further strengthen drought preparedness at village level.

Benefits of Drought-Proofing Finger Millet

Drought-proofing of finger millet offers numerous benefits that are crucial for ensuring the sustainability and resilience of rainfed farming systems. Effective drought-management strategies help maintain stable crop yields even under conditions of moisture stress, thereby reducing the risk of crop failure and production losses. Consistent production of finger millet contributes significantly to food and nutritional security, particularly in rural and drought-prone regions where it serves as an important source of essential nutrients. Improved crop performance also ensures better availability of fodder for livestock, supporting integrated farming systems and livestock productivity. By minimizing yield fluctuations, drought-proofing measures enhance income stability for farmers and reduce their vulnerability to climatic uncertainties. Furthermore, these interventions strengthen the capacity of farming communities to adapt to climate change while promoting the sustainable use of land, water, and other natural resources. Overall, drought-proofing of finger millet contributes directly to the development of climate-resilient, environmentally sustainable, and economically viable agricultural systems.

CONCLUSION

Finger millet is a strategic crop for ensuring food, nutrition, and livelihood security in the drought-prone regions of India. Although the crop possesses inherent drought tolerance, increasing climate variability necessitates additional efforts to strengthen its resilience. Significant opportunities exist through the identification of drought-tolerant germplasm, development of improved varieties, adoption of climate-smart agronomic practices, and application of modern genomic tools. Integrating genetic improvement with effective soil, water, and crop management strategies can substantially reduce drought-induced losses. Drought-proofing finger millet is therefore not only a scientific necessity but also a critical pathway towards sustainable agriculture, climate resilience, and nutritional security for future generations.

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