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Finger Millet: A Climate-Resilient and Multi-Nutrient Crop for the Uncertain Future

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Finger millet grown in marginal soil in Mississippi's hot and dry environment. Photo by Raju Bheemanahalli, MSU.

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Finger millet (*Eleusine coracana* L.), ragi, is not just a crop; it can be a potential game-changer for the uncertain future. However, its potential is still being explored in many countries, including the United States. This small-seeded, short-day, warm-season, C4 annual coarse cereal of the grass family is commercially cultivated in Africa and South Asia and can adapt to diverse environments. According to the Food and Agriculture Organization (FAO), a 60% increase in food production is necessary to sustain a global population of approximately 9.3 billion by 2050. However, the gradual depletion of soil resources, including essential nutrients, and extreme weather events present a significant challenge in meeting this demand. Addressing these challenges requires the development of varieties or the introduction of alternative crops with climate-resilient traits and high responsiveness to inputs, even at low concentrations.

Considering escalating challenges such as adverse crop growing conditions and the reduction of arable land due to unsustainable agricultural practices, there is a pressing need for climate-resilient crops with inherent health benefits. The prevalence of health conditions such as diabetes, high cholesterol levels, osteoporosis, and malnutrition worldwide further underscores the urgency for such crops. While various strategies have been deployed to enhance the tolerance to stresses and nutritional values of major cereals like rice, wheat, and maize, the underexplored finger millet demonstrates remarkable nutraceutical value and stress resilience. Moreover, its ability to thrive in low-fertility soil and under low-input agricultural conditions positions finger millet as a promising candidate crop to ensure food security in the face of an uncertain future.

Abiotic Stress Tolerance

Finger millet has been grown and recognized as a crop that can withstand tough weather conditions. It has been commonly grown in dry regions of Asia and Africa because of its greater resilience to multiple stressors (Mbinda & Mukami, 2021; Opole et al., 2018; Tadele, 2016). Studies have shown that finger millet can adapt to stress by changing its characteristics from the cell to whole-plant level to survive and maximize production. For example, short life cycles, short stature, small leaves, thick cuticles and cell walls, leaf waxiness, leaf pubescence, staying green, and dense root systems are often reported as stress-adaptive traits in finger millet. Physiologically, finger millet genotypes exhibit saving and spending strategies under drought stress. Genotypes with a saving strategy minimize water loss through transpiration by reducing stomatal conductance and leaf rolling. In contrast, those with a spending strategy maintain adequate tissue–water relations by improving the spatial and functional architecture of roots (Gupta et al., 2017; Tadele, 2016; Tiwari et al., 2022). Additionally, as a C4 crop, finger millet is reported to be a naturally high-water-use efficient type compared with other cereals due to the above-listed resilient traits. Furthermore, finger millet shows quick recovery potential even after severe stress, unlike other crops, which often face complete failure under similar conditions (Opole et al., 2018; Reddy et al., 2021).

While major cereals generally exhibit low nitrogen use efficiency and utilize only half of the applied nitrogenous fertilizers, finger millet stands out as a crop that responds favorably to low soil nutrient status, particularly nitrogen and phosphorus (Gupta et al., 2012; Kumar et al., 2015). Notably, finger millet demonstrates the potential to thrive and produce quality seeds with enriched amino acids even in nitrogen-deficient soil conditions (Kumar et al., 2009). Diverse doses of nutrients are recommended for finger millet production based on site-specific needs. However, as a broad recommendation, a nutrient ratio of 40:20:20 N:P: K (kg/ha) is suitable for this crop, which is less than half of the standard recommendation for other major cereals (Thilakarathna & Raizada, 2015). On the other hand, the finger millet genotypes can also maintain high ratios of K^+/Na^+ and Ca^{2+}/Na^+ using exclusion and compartmentalization mechanisms, similar to other glycophytes (Mbinda & Mukami, 2021). These characteristics suggest that finger millet may possess unique mechanisms for efficiently utilizing available soil nutrients, warranting comprehensive exploration from phenotypic to genomic levels using advanced phenome-to-genome approaches. Overall, these adaptive strategies highlight finger millet’s tolerance and resilience to stresses, which can be attributed to the coordinated operation of morphological and molecular networks.

Nutraceutical Value

Finger millet is a nutritionally dense cereal with numerous health benefits. It is a nutrient-rich cereal with antioxidative, antiproliferative, and antimicrobial properties. It is rich in carbohydrates, containing 72 g/100 g grain, which is higher than maize (66.2 g/100 g grain) and wheat (69.4 g/100 g grain). Moreover, it has a high protein content of 7.3 g/100 g grain, surpassing rice (6.4 g/100 g grain). Finger millet also offers a higher fiber content of 3.6 g/100 g grain than other major cereals (Ghimire & Mainali, 2024; Jacob et al., 2024). The high dietary fiber prevents constipation, high cholesterol formation, diabetes, and intestinal cancer. Furthermore, finger millet is a good source of essential amino acids such as lysine and methionine, lacking in other cereals like rice and wheat. Its seed fat comprises beneficial unsaturated fatty acids like linoleic acid and oleic acid, offering nutritional and health benefits (Gupta et al., 2017).

This millet is also known for being abundant in micronutrients such as calcium, iron, zinc, phosphorus, and vitamins such as thiamine, niacin, and riboflavin (Jacob et al., 2024). In developing countries, it is often used to make calcium supplements against osteoporosis and is recommended for pregnant women and young children prone to calcium deficiency (Gupta et al., 2017). Like calcium, pregnant women are often deficient in iron. The low phytic acid of finger millet is reported to increase iron bioavailability (Reddy et al., 2022). On the other hand, finger millet is a gluten-free cereal, which is a good source for individuals with celiac disease. Its low glycemic index, high fiber content, and slow digestibility make it a popular antidiabetic cereal grain (Devi et al., 2014; Pradhan et al., 2010). The presence of phytosterols, policosanols, and phytochemicals like phenolics and proanthocyanidins further contribute to its antioxidant, antiproliferative, and antiobesity effects. As a bonus, finger millet straw can serve as excellent animal fodder due to its high (60%) digestible nutrient content (Gupta et al., 2017).

Photo courtesy of Bioversity International\Y. Wachira.

Potential of Finger Millet as a New Crop in the U.S.

Despite being a relatively new crop to the U.S., it has the potential to thrive in hot and dry conditions, making it an alternative option for farmers, especially in crop-growing regions with marginal soils coupled with hot and dry environments. Some recent research studies have shed light on the potential of finger millet production in the United States (Baath et al., 2018; Gowda et al., 2015; Opole et al., 2018). Millet cultivation is limited to a few states, including Colorado, North Dakota, South Dakota, and Nebraska. Researchers have started to recognize the importance of finger millet, and initial studies have shown promising results. Our lab (Plant Stress Physiology, Mississippi State University) recently phenotyped 498 finger millet germplasm accessions from the USDA Germplasm Resources Information Network (GRIN) in marginal soil under rainfed conditions. Finger millet accessions revealed significant diversity in seed characteristics, leaf pigments, plant morphology, and agronomic traits. The study found 71% of the tested accessions flowered and set seed with varying flowering, maturity times, and grain yield. These initial results signify the potential for further crop improvement and expansion of finger millet research in the U.S. Under unfavorable weather patterns, finger millet could offer sustainable solutions for agricultural challenges, benefitting both growers and consumers. Keep an eye out for more developments in this exciting area from our group.

Women in India preparing pappad from the flour of locally produced finger millet. Photo courtesy of Wikimedia Commons/Crops for the Future.

Summary

With its remarkable resilience to stresses, low input requirements, and nutraceutical value, finger millet can become a climate‐resilient crop worldwide. This crop has the potential to thrive in harsh environmental conditions, making it a viable alternative option for hot and dry climates. Exploring the genetic diversity, identifying alleles or genes associated with the stress resilience of this crop, and developing climate-smart varieties could offer multiple benefits. Additionally, incorporating finger millet products into regular diets holds great potential for promoting a healthy lifestyle. Focused research support for this crop could significantly contribute to global food security in the face of an uncertain future. With technological advancement and research, finger millet could help sustain and boost nutrition security, especially in areas where traditional cereals struggle to thrive.

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