Foxtail Millet: A Climate-Resilient Crop with Potential to provides Food and Agriculture Security

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Global warming, anomalous average rainfall, flood, expanding soil salination and atmospheric waves prevailed at different regions of the globe that resulted in gradual climate change. Both, the natural (solar waves, volcanic eruption, ocean water temperature etc) and artificial (mass deforestation, emission of industrial gases, fossil fuel consumption, increase in greenhouses gases etc.) stress factors have contributed equally to climate change. Rise in atmospheric temperature across the globe is at alarming condition as it is estimated to increase by approximately 4-5°C before the end of 21st Century. Increase in the level of sea water is another problem of climate change which hastens the process of soil salination. Gradual salination of fertile landmasses is posing complications to the affected farmers to produce food at their maximum yield. The maximum areas of agricultural lands that are affected by salinity are in Australia, followed by Central and North Africa, Southern part of America and West and South Asia. Another calamitous consequence of climate change is drought which happens due to low rainfall, declination of ground water level, heat stress and salinity. The effect of occurrence of combination of heat and drought or drought and salinity is more devastating for crop yield than the individual stress when occurs separately. Up to 70-80% yield loss may occur if severe heat and drought extends throughout the growing season of a particular crop species in a given area. These abiotic stresses impose detrimental impact on agricultural production and weaken global food security.

Foxtail millet [*Setaria italica* (L.) P. Beauv.], is a genetically diverse C4 photosynthetic panicoid crop with excellent climate change/stress elasticity and nutritional profiles. It is mostly cultivated for food and forage in the arid and semi-arid regions across the globe. Being reared in environments having minimal resources, these crops still retain their potential to withstand high temperature, drought, pathogen and pest infection, and poor soil nutrition. In addition, the crop has excellent water- and nitrogen-use efficiency (WUE and NUE) and is phylogenetically adjacent to major cereals and biofuel grasses including napiergrass (*Pennisetum purpureum*), pearl millet (*Pennisetum glaucum*) and switchgrass (*Panicum virgatum*). The in-depth genetic and physiological analysis of foxtail millet would reveal the molecular adaptations endured in a naturally abiotic stress tolerant plant. The present article discusses the salient features of foxtail millet along with their nutritional and abiotic stress responsive properties and potential in ensuring global food and agricultural security amidst climate change.

Potential of Foxtail Millet in Ensuring Food and Nutrition Security

Foxtail millet is a perfect example of neglected species that have the potential to address both food and nutritional insecurities prevalent among the ever-growing global population. In terms of any nutritional parameter, it is far ahead of other most popular cereals like wheat and rice. Foxtail millet grains are rich in protein content (12-15%), dietary fiber (6-8%), crude fat (7-8%) and minerals, including iron, calcium and zinc. Apart from higher protein content, it also contains higher number of essentials amino acids and sulfur-containing amino acids, including methionine and cysteine. Foxtail millet has approximately forty times more fibre than rice; dietary fibre is essential for stomach and intestine health. The proportion of resistant starch in foxtail millet flourvaries from 13-15%, which is significantly higher than the most commonly consumed cereal grains like rice and wheat. It is an extraordinary beneficial dietary supplement for diabetic patients. In type-II diabetes patients it aids in controlling serum glucose level, reducing serum lipids and glycosylated haemoglobin. It is also used for the treatment of dyspepsia, rheumatism, poor digestion and stomach-ache. The other remarkable feature of foxtail millet as food is their low glycaemic index (GI) polysaccharide, gluten free in nature and higher amounts of polyphenols and antioxidant contents. Considering its nutritional prospects, climate-resilient and other aspects, Food

and Agriculture Organization (FAO) of the United Nations has declared the year 2023 as the 'International Year of Millets'.

Potential of Foxtail Millet in Ensuring Agricultural Security

Foxtail millet contains excellent genetic diversity among the large number of wild as well as cultivated accessions, which are maintained as core and mini core collections around various gene banks across the globe. China encompasses the largest collection of wild and cultivated germplasms of foxtail millet followed by India, France and Japan. These germplasms are the exceptional source of gene pull required for crop improvement programmes. Numerous of these germplasms could be tolerant to various abiotic stresses, mostly to heat, drought and salinity, and their phenotypic and physiological attributes must be exploited for crop improvement through genomic-assisted breeding (GAB) and biotechnological approach. The availability of whole genome sequence has prompted the development of high throughput genomic resources, detection of molecular markers/quantitative trait loci (QTLs), comparative mapping, and GAB of foxtail millet and related grained crops. Transcriptome and whole genome RNA sequencing (RNA-seq) platforms are being utilized to identify large number of abiotic stress related genes; among which some of them are specific to foxtail millet. The integrative omics approach comprising of genomics, transcriptomics, phenomics, metabolomics, proteomics and bioinformatics would provide extensive insight regarding genetic determinants of such stress tolerance attributes in foxtail millet. Miserably no such integrative approach has been attempted in foxtail millet till date, however independent metabolome and proteome analysis.

The transfer of foxtail millet's genic regions contributing enhanced stress tolerance to the highly cultivated though stress susceptible crops such as rice, wheat or others may resuscitate the agricultural loss due to adverse climatic conditions. For example, the integration of foxtail millet Autophagy-associated gene, *SiATG8a* into the rice genome resulted in the improved tolerance to abiotic stress and nitrogen starvation. Similarly, the overexpression of stress-related transcription factors including *SiMYB3* and *SiWLIM2b* have exhibited nitrogen starvation and drought tolerance in rice, respectively. Targeted genome editing is another widely accepted technology employed to generate improved crop plants. The application of recently emerged Clustered regularly interspaced short palindrome repeats (CRISPR)/ CRISPR-associated protein (Cas) technology has the potential to design climate smart plant species. The DNA sequence of foxtail millet genome may be taken as reference in order to detect polymorphism among the genome of related crops and targeted base editing at stress tolerance providing locus may alter their environmental stress response.

Conclusion

Naturally, foxtail millet is rich in minerals, nutrients and bioactive compounds and less dependent on synthetic fertilizers, systemic irrigation and pest/weed control. They serve as an excellent resource material for abiotic stress related gene function dissection and elite allele mining. Therefore, it could be concluded that the foxtail millet has the potential to fulfill the purpose of food and nutrition security in one hand and resuscitate the agriculture system on the other hand.

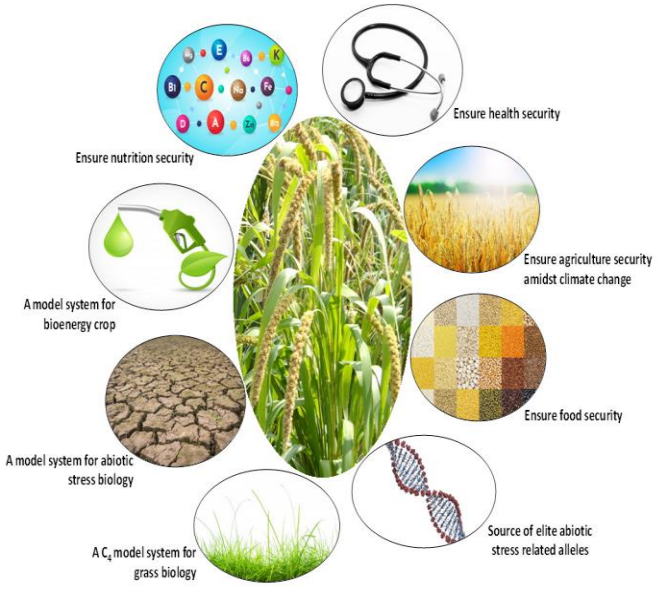

Fig. 1 Foxtail millet serves as an exemplary model system and ensure multiple security including food, nutrition, heath and agriculture

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