Health and Nutritional Benefits of Barnyard Millet

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Barnyard millet (*Echinochloa* species) is an ancient millet crop grown in warm and temperate regions of the world and widely cultivated in Asia, particularly India, China, Japan, and Korea. It is the fourth most produced minor millet, providing food security to many poor people across the world. Globally, India is the biggest producer of barnyard millet, both in terms of area (0.146 m ha^{-1}) and production (0.147 mt) with average productivity of 1034 kg/ha during the last 3 years. Barnyard millet is primarily cultivated for human consumption, though it is also used as a livestock feed. Among many cultivated and wild species of barnyard millet, two of the most popular species are *Echinochloa frumentacea* (Indian barnyard millet) and *Echinochloa esculenta* (Japanese barnyard millet). Barnyard millet is a short duration crop that can grow in adverse environmental conditions with almost no input and can withstand various biotic and abiotic stresses. In addition to these agronomic advantages, the grains are valued for their high nutritional value and lower expense as compared to major cereals like rice, wheat, and maize. It contains a rich source of protein, carbohydrates, fiber, and, most notably, micronutrients like iron (Fe) and zinc (Zn) that are related to numerous health benefits. All these features make barnyard millet an ideal supplementary crop for subsistence farmers and also as an alternate crop during the failure of monsoons in rice/major crop cultivating areas.

Despite barnyard millet's excellent nutritional and agronomic value, the lack of awareness has led this crop to be considered as a neglected and underutilized crop. Over the past decades, efforts made to study the features of barnyard millet are limited compared to other minor millets. So far, most of the studies have been aimed at exploring the knowledge of diversity within the germplasm through morphological. Also, several studies disclosed the nutritional profile of barnyard millet, particularly the high Fe and Zn content in the grains. However, comprehensive research is needed to understand the accurate details of germplasm accessions, identify the trait-specific donors, develop mapping population, and discover the quantitative trait locus (QTLs) and gene. Genomic resources are helpful for the progress of any crop species and they assist effective characterization of germplasm resources and their subsequent use in the discovery of QTL/gene(s) for the crop improvement program. However, genome research in barnyard millet is still in the early stage and far behind the other minor millets. This is mainly due to the complex nature of the genome ($2n = 6x = 54$, hexaploid). Recently, second and third-generation sequencing technologies unlocked several genome sequencing issues and facilitated to identify the genome sequence of wild and transcriptome sequences in cultivated *Echinochloa* species. These genome resources facilitated the chance for better genotyping studies such as genetic diversity analysis, development of highly dense linkage maps and accurate physical maps, and detection of QTLs associated with micronutrients and agronomic traits.

Relevance of Barnyard Millet in Climate Change and Nutritional Security

The *Echinochloa* species generally has potential resistance against various biotic and abiotic stresses. However, cultivated species such as *E. esculenta* and *E. frumentacea* are widely threatened by pest and diseases (i.e., shoot fly, stem borer, grain smut, and loose smut) at different growth stages of the crop. Aphid's infection at the vegetative stage causes considerable yield reduction to *E. frumentacea*. So far, DHBM 996 and TNEF-204 were found to be resistant genotypes for shoot fly and stem borer). Meanwhile, some of the authors reported that some *E. frumentacea* accessions have the potential for antifeeding activity against brown plant hopper, which is among the major pests that affect rice production. On the other hand, loose smut (*Ustilago tritici*) and grain smut (*Ustilago panici frumentacea*) are major fungal diseases that affect the grain formation in both the cultivated species of *Echinochloa*). A heavy infestation of smuts during head formation leads to a significant reduction in grain yield and quality.

Abiotic stresses are a major threat to important food crops such as rice, wheat, and maize, and cause serious yield loss across the world. However, *Echinochloa* species have a high degree of tolerance to various abiotic stresses. Among the 89 *Echinochloa* accessions, CO (Kv) 2, MDU 1, PRJ1, TNEf 301, TNEf 204, TNEf 361, TNEf 364, and VL 29 exhibited better germination as compared to the rice variety, White Ponni, at 200 mM NaCl concentration. Similarly, *Echinochloa* species are also the preferable choice of farmers for cultivation in various adverse environments such as those prone to drought or flooding. These features showed that the *Echinochloa* species might have some specialized rhizosphere organizations that can facilitate the uptake and release of oxygen (O_2) from their roots at stressful conditions. Zegada-Lizarazu and Iijima (2005) reported higher water uptake efficiency (deep root) of barnyard millet (*E. utilis*) over other minor millets, including pearl millet, and found that barnyard millet sustained and increased the water use efficiency, leaf area index, and dry matter production in both drought and flooding conditions. Therefore, it is also worth investigating the *Echinochloa* species mechanism behind the tolerance to drought and flooding stress. Further, identification and characterization of genes and pathways associated with resistance to saline, drought, and flooding stress in *Echinochloa* species may not only be useful to develop superior cultivars but also assist in improving the tolerance in a major cereal crop. It is also well known for its excellent nitrogen-use efficiency over cereal crops and has been recommended as a natural phyto-extractor in heavy metal (lead, cadmium, and chromium) contaminated soils and sodic soils due to hyper accumulation nature. Since heavy metals are currently of much environmental concern, phyto-based soil reclamation is an alternative, cost-effective, and eco-friendly approach that needs to be imparted in soil health restoration programs.

Conclusion

Despite its nutritional and agronomic benefits, barnyard millet has remained an underutilized crop and has received very little attention from researchers as well as farmers across the globe. Barnyard millet breeding programs have stagnated due to limited funding from various funding agencies and research organizations. Therefore, considerable efforts are needed to develop varieties or hybrids with farmer/consumer preferred traits.

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