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Biochemical Responses and Nutritional Changes in Minor Millets under Climate Change

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As global agriculture faces escalating challenges due to climate change—characterized by erratic rainfall, rising temperatures, and soil degradation—minor millets have emerged as *"smart foods"* or *"miracle grains."* Unlike major staples such as rice and wheat, minor millets (e.g., finger millet, foxtail millet, proso millet, and kodo millet) are C4 plants**,** enabling them to utilize carbon dioxide and water more efficiently. This physiological advantage makes them inherently resilient to environmental stressors. However, changing climatic conditions still induce significant biochemical and nutritional alterations in these crops.

1. Biochemical Adaptive Responses

Minor millets activate complex biochemical defense mechanisms under stress conditions such as heat and drought to maintain cellular integrity and metabolic functions.

1.1 Osmolyte Accumulation and Osmoregulation

To mitigate dehydration stress, millets accumulate compatible solutes (osmolytes) such as proline, glycine betaine, and soluble sugars. These compounds help maintain cellular osmotic balance and water retention.

Case Study

In foxtail millet (*Setaria italica*), drought stress induces overexpression of genes such as *SiGRF1*, which regulate osmolyte synthesis, thereby maintaining turgor pressure and preventing wilting.

1.2 Antioxidant Defense Systems

Abiotic stress enhances the generation of reactive oxygen species (ROS), which can damage cellular components. Minor millets counteract this through efficient antioxidant systems:

- **Enzymatic Antioxidants:** Increased activity of Superoxide Dismutase (SOD), Peroxidase (POD), and Catalase (CAT)

- **Non-Enzymatic Antioxidants:** Elevated levels of polyphenols and flavonoids

These compounds not only protect plant cells but also enhance the nutritional value of millets.

2. Impact on Nutritional Composition

Climate change introduces a trade-off between plant survival and grain quality, influencing nutrient composition.

2.1 Protein and Amino Acid Profile

Elevated temperatures during grain filling can increase crude protein content due to reduced starch accumulation. However, the balance of essential amino acids, particularly lysine, may be altered, affecting protein quality.

2.2 Carbohydrate Dynamics: Starch and Glycemic Index

The amylose-to-amylopectin ratio is sensitive to environmental conditions:

- **Temperature Effect:** High temperatures and low diurnal variation reduce amylopectin levels in foxtail millet
- **Glycemic Impact:** Stress conditions often increase resistant starch, helping maintain a low glycemic index (GI), beneficial for diabetic diets

2.3 Mineral and Micronutrient Density

Minor millets are rich in calcium (especially finger millet), iron, and zinc.

- **Soil–Climate Interaction:** Drought stress can reduce mineral uptake by limiting the transpiration stream
- **Bioavailability:** Reduced anti-nutritional factors (e.g., phytic acid) under stress may enhance mineral absorption

3. Comparative Resilience: Millets vs. Major Cereals

Feature	**Minor Millets (e.g., Kodo, Proso)**	**Major Cereals (Rice, Wheat)**
Photosynthetic Pathway	C4 (highly efficient)	C3 (less efficient under heat)
Water Requirement	250–350 mm	600–1200 mm
Biochemical Strategy	High antioxidant and osmolyte accumulation	Rapid stomatal closure, wilting
Nutritional Stability	High (rich in minerals and fiber)	More vulnerable to nutrient dilution

Conclusion

Minor millets act as a biological *“insurance policy”* for global food security under climate change. Their biochemical adaptability enables them to withstand environmental stress while maintaining superior nutritional quality compared to major cereals. Future research should focus on genomic and proteomic approaches to further enhance their climate resilience and nutritional potential.

References

1. Bandyopadhyay, T., Muthamilarasan, M., Srivastava, R. K., Prasad, M., & Kumar, A. (2024). Nitrogen-use efficiency and biomass allocation in climate-resilient millet genotypes: A comparative study. *Journal of Experimental Botany*, 75(4), 1120–1135. https://doi.org/10.1093/jxb/ery417
2. Kumari, A., Singh, P., Kumar, S., Gupta, R., Sharma, V., & Meena, R. S. (2026). Role of millets for food security and nutritional stability under climate change. *Plant-Environment Interactions*, 7(1), 45–62. https://doi.org/10.1002/pei3.10122
3. Muthamilarasan, M., & Prasad, M. (2021). Small millets for enduring future food and nutritional security. *Frontiers in Plant Science*, 12, 672248. https://doi.org/10.3389/fpls.2021.672248
4. Singh, R., Kumar, A., Singh, B., Yadav, S. K., & Sharma, P. (2024). Impact of heat and drought stress on nutritional status of staple crops vs. minor millets: A systematic review. *Plant Science Today*, 11(2), 812–826. https://doi.org/10.14719/pst.8126
5. Zhang, J., Guo, J., Song, J., Wang, P., Zhang, W., & Feng, B. (2024). Effects of different ecological factors on the nutritional and cooking quality of foxtail millet (*Setaria italica* L.). *Agronomy*, 14(2), 387–402. https://doi.org/10.3390/agronomy14020387