

Effect of Climate Resilience on Micronutrients in Rice

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Introduction:

In rice, climate resilience is essential for preserving the grains' nutritional content as well as for guaranteeing consistent yield and stress tolerance in the face of shifting environmental conditions. Stresses brought on by the climate, such as drought, high temperatures, and flooding, can have a major effect on the rice plant's capacity to store key micronutrients for human health, such as iron (Fe), zinc (Zn), and selenium (Se). Breeding projects for rice are concentrating more on improving the crop's nutritional value and resistance to environmental stress as a result of the ongoing changes in the world's climate. Addressing food security and malnutrition requires rice varieties to be able to withstand climate stress while preserving or increasing micronutrient levels, especially in areas where rice is a primary diet.

Impact of Climate Change Factors

a) Elevated CO₂ Levels

A major component of climate change, elevated CO₂ levels, might negatively impact rice grains' nutritional value. Higher CO₂ usually causes the plant to produce more carbohydrates, but it does not increase the uptake of vital minerals like zinc (Zn) and iron (Fe). As a result, the concentration of these micronutrients in rice grains falls, causing a dilution effect. Rice's zinc and iron content can drop by as much as 30% due to high CO₂ levels, according to studies like the Free-Air CO₂ Enrichment (FACE) experiments. This raises concerns about how climate change may affect rice yields and nutritional value, especially in areas where rice is a staple food.

b) Heat Stress (High Temperature)

By preventing vital minerals like iron (Fe) and zinc (Zn) from moving from the roots to the grains, heat stress, or high temperatures, can have a substantial effect on the micronutrient content of rice. Additionally, early maturity in rice plants can result from high temperatures. This shortens the grainfilling phase, which in turn decreases the amount of time that the grains have to accumulate micronutrients. Furthermore, heat stress may damage the enzyme systems that

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carry iron and zinc, which would further restrict the uptake and deposition of these elements in rice grains. The nutritional value of the crop and the health of populations that depend on rice as a staple food may be impacted by the decreased amounts of these essential micronutrients in rice cultivated under heat stress.

c) Drought Stress

Because it restricts root growth, particularly in the higher soil layers where vital elements like zinc (Zn) are concentrated, drought stress can significantly impair rice's capacity to absorb micronutrients. Reduced water availability during drought also makes micronutrients less mobile and soluble in the soil, which makes it more difficult for plants to absorb them. In particular, dry soils reduce the



availability of zinc, a mineral that is essential for human health and plant growth, making shortages worse. Drought stress is therefore a significant issue for both food security and nutrition in drought-prone areas since it not only reduces rice yields but also lowers the nutritional value of the grains.

d) Flooding/Submergence

In rice fields, flooding or submersion produces anaerobic conditions that drastically change the availability of nutrients. For instance, flooding can enhance the amount of iron available for plant absorption by reducing iron (Fe) from its oxidized state (Fe3+) to the more soluble and accessible Fe2+ form. However, because nutritional antagonism occurs when the uptake of one mineral interferes with the uptake of another, the same anaerobic environment might decrease the JR availability of zinc (Zn). The nutritional value of rice grains may be impacted by this imbalance, which may result in a rise in iron availability but a fall in zinc. Flooding can therefore increase the availability of iron while also decreasing the vital mineral zinc, which might have an impact on the crop's nutritional value and overall health.

Climate Factor	Micronutrient Impact
Elevated CO ₂	\downarrow Fe and Zn (dilution)
Heat stress	↓ Nutrient translocation
Drought	↓ Root uptake of Zn/Fe
Submergence	\uparrow Fe, \downarrow Zn (in some cases)

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Effect of Climate Resilient on Rice

1. Climate-Resilient & Varieties **Micronutrient Effects**

Not all climate-resilient rice varieties able sustain high levels are to of micronutrients; others are bred exclusively for vield stability, with special attention to features like drought or flood resistance. One advantage of these types is their capacity to maintain stronger root systems, which enhance uptake, especially nutrient in stressful situations. In order to combine resilience and improved nutritional content, new breeding techniques are now being developed. For example, biofortified rice lines that are rich in vital micronutrients and stress-tolerant are But there are some being developed. significant drawbacks to take into account. Stress-resilient characteristics are frequently breeding programs, which lowers concentrations of vital micronutrients including iron (Fe) and zinc (Zn). It can be difficult to balance all of these qualities in a single variety since there may be genetic tradeoffs between maintaining high micronutrient density and optimizing yield or stress tolerance.

2. Biofortification & Climate Resilience Integration

Researchers are creating rice lines that are stress-tolerant and enriched in vital

micronutrients in order to overcome the difficulty of balancing high micronutrient levels with climate resilience. Efforts are being made to produce rice that can withstand climate stress while still offering superior nutritional content, such as the zinc-rich DRR Dhan 45 and BRRI Dhan 62 varieties. To make sure that both qualities are successfully incorporated into the breeding lines. researchers are also using marker-assisted selection (MAS) to target important genes linked to stress-tolerance genes and zinc and iron (Fe) content (QTLs). Furthermore, cutting-edge technologies like CRISPR gene editing are being investigated to simultaneously improve the plant's stress response mechanisms and increase nutrient uptake. This provides a precise method for creating rice varieties that are nutrient-dense given precedence over grain nutrition in many R and resilient, thereby enhancing yield and nutrition in the face of harsh environmental conditions.

3. Agronomic **Practices Support** to **Micronutrient Content**

A number of agronomic techniques can be used to increase the nutritional content of rice. Applying foliar sprays of zinc and iron during the flowering stage is one efficient method that guarantees the plants' availability of these vital minerals during crucial growth stages. Furthermore, using organic matter in conjunction with balanced fertilization can



greatly increase the soil's availability of micronutrients, which will boost the plant's ability to absorb them. A decrease in zinc intake can be avoided by preventing persistent flooding, as prolonged waterlogging can produce conditions that lower the bioavailability of micronutrients like zinc. Proper water management is also essential. When combined, these techniques promote the production of more nutritious rice while preserving environmental sustainability.

Breeding methods for Micronutrient **Retention in Climate-Resilient Rice**

with 1. Combine Climate Resilience Nutrition (Dual-Goal Breeding)

Creating rice cultivars that are stresstolerant—able to tolerate heat, drought, and flooding—and micronutrient-rich, especially in iron (Fe) and zinc (Zn) is a crucial strategy for tackling the issues of climate change and R make early selections in breeding populations Breeders nutrition. can concentrate on improving stress tolerance and micronutrient density at the same time by incorporating multi-trait selection into breeding pipelines. In order to support food security and human health, this dual-goal breeding technique makes sure that rice varieties are both nutritionally enhanced and resistant to climatic challenges.

2. Marker-Assisted Selection (MAS)

In contemporary breeding, markerassisted selection (MAS) is a useful technique

that makes it possible to find and choose molecular markers associated with significant features. MAS targets micronutrient content genes in rice breeding, including qZn8.1 and qFe4.1, which are connected to iron and zinc accumulation, respectively. Additionally, it targets genes involved in stress tolerance, such as DREB for drought resistance and SUB1 for submersion tolerance. MAS speeds up the production of resilient and nutrient-rich rice varieties by accelerating the introgression of both nutritional and stress tolerance characteristics into elite breeding lines.

3. Genomic Selection (GS) & Genomic-**Assisted Breeding**

A sophisticated method for forecasting how breeding lines will perform for intricate features like micronutrient efficiency under stress is genomic selection (GS). Breeders can without requiring extensive field testing by examining genetic data. By enhancing both stress resilience and micronutrient content, GS makes it possible to choose rice cultivars that function well under a variety of stressors. This technique greatly speeds up the creation of superior cultivars when paired with genomicassisted breeding.

4. Use of Biofortified Parents

To guarantee both nutrient density and stress resilience, crosses with stress-tolerant lines can include biofortified parents, such as



high-zinc/iron donors like IR68144, a variety produced by IRRI. Breeders can improve rice varieties' nutritional value and environmental adaptation by preserving nutritious features over backcross generations. This method guarantees that new cultivars maintain high concentrations of vital micronutrients while also surviving in harsh environments.

5. Incorporate Root Traits

Enhancing nutrient uptake requires root characteristics, particularly in areas that are prone to drought or in soils with poor zinc availability. The ability of rice plants to obtain water and micronutrients is improved by choosing for deep and effective root systems. especially in difficult soil conditions. In climate-smart breeding, root phenotyping is becoming more and more crucial since improved root systems can greatly enhance nutrient uptake and overall plant performance, *IR* tolerance, *Z* even particularly in stressful environmental conditions.

6. Avoid Yield-Nutrition Trade-offs

The possible "dilution effect," in which high-yielding lines frequently have lower concentrations of micronutrients, is one of the difficulties in breeding for both yield and nutrition. In order to get around this, breeders emphasize features like the harvest index for micronutrients rather than merely overall biomass or yield in order to balance nutritional content and yield. By avoiding trade-offs

between yield and nutritional value, this strategy guarantees that rice varieties maintain while maintaining high production or improving their micronutrient content.

7. Use of Modern Tools (Gene Editing & **Transgenics**)

Rice's ability to absorb nutrients and withstand stress could be greatly enhanced by using contemporary techniques like CRISPR/Cas9 gene editing. Breeders can create rice varieties that are more tolerant to environmental challenges and more nutrientdense by improving stress response mechanisms and altering genes involved in zinc and iron transport, such as OsNAS and OsZIP, Transgenics and gene editing have enormous potential for the future of rice breeding, offering a precise and effective way to increase both nutrient content and stress though they are still constrained by regulatory restrictions.

8. Collaborate with Agronomy

The success of nutrient-rich and climate-resilient rice cultivars cannot be guaranteed by breeding alone. It is essential to work with agronomists to incorporate nutrient techniques, such the management as application of organic inputs and zinc fertilizers. By optimizing fertilizer application enhancing soil nutrient availability, and precision agriculture techniques can further improve nutrient efficiency. Even in harsh

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environmental circumstances, this comprehensive method guarantees that rice plants get the nutrients they need to flourish.

9. Field Testing Under Climate Stress

To make sure that yield and nutritional characteristics remain constant under a variety of circumstances, it is essential to field test new rice lines under realistic stress situations like heat, drought, and flooding. To evaluate these lines' adaptation and gauge micronutrient retention in various temperatures, multilocation trials are crucial. By supplying useful information on how novel cultivars function in the face of climate change, these trials guarantee that the created variety can reliably provide high yields and nutritional content under a range of growing circumstances.

