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Seed priming as a method of preservation and restoration of rice seeds

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Introduction

Rice (Oryza sativa L.) is one of the most important staple crops, feeding nearly half of the world's population. Ensuring its sustainable production is crucial for global food security. However, challenges such as seed aging, poor germination rates, and environmental stressors often impact rice cultivation. Seed priming has emerged as an effective technique for preserving and restoring rice seeds by enhancing germination, improving seedling vigor, and increasing stress tolerance. This chapter explores the various methods of seed priming, their benefits, and their role in the preservation and restoration of rice seeds.

Seed priming is a pre-sowing treatment that partially hydrates seeds to a point where germination processes are initiated but not completed, followed by drying. This technique enhances seed performance by improving germination rates, seedling vigor, and stress tolerance, making it a valuable method for both preservation and restoration of rice seeds.

In rice cultivation, seed priming has been shown to bolster germination and seedling establishment under various stress conditions. For instance, priming rice seeds with water or potassium chloride solutions improved emergence from flooded soils, reduced membrane damage from reactive oxygen species, and accelerated carbohydrate mobilization during germination. These benefits were particularly notable in rice lines with inherent tolerance to flooding during germination.

However, the advantages of seed priming can diminish with improper storage conditions. Studies have indicated that prolonged storage of primed rice seeds at 25°C significantly reduced germination rates and growth attributes compared to unprimed seeds. This suggests that while priming offers immediate benefits, careful consideration of storage conditions is crucial to maintain seed viability over time.

Recent research has also explored the role of seed priming in enhancing rice seedling growth under chilling stress. Various priming agents, including plant growth regulators like gibberellic acid (GA_3) and osmotic agents such as polyethylene glycol (PEG), have been found to improve germination rates, root and shoot growth, and antioxidant enzyme activities in rice seedlings exposed to low temperatures. These treatments help mitigate oxidative stress and maintain cellular integrity, thereby enhancing seedling resilience under adverse environmental conditions.

Beyond rice, seed priming has been recognized as a potential supplement in integrated resource management for sustainable agriculture. Primed seeds exhibit higher vigor and germination rates, contributing to successful crop establishment under stress conditions. This approach aligns with sustainable food production systems by improving resource use efficiency and crop productivity while minimizing environmental impacts. Solid particulate systems and a spectrum of controlled moisture contents (**Taylor *et al.*,1998**). Recently, it has been suggested that priming can be achieved with micronutrients (**Muhammad *et al.*, 2015; Muhammad *et al.*, 2013; Zanan *et al.* 2012**). According to **Farooq *et al*.** (2012), application of micronutrients by seed treatment may be considered a better alternative in many cases, compared to other methods.

In summary, seed priming serves as an effective strategy for preserving and restoring rice seeds, enhancing germination, and promoting robust seedling development. To maximize its benefits, it is essential to select appropriate priming agents and maintain optimal storage conditions post-priming. Working with barley seeds, **Ajouri *et al.* (2004)** found that Zn seed conditioning caused increases in germination and seedling development. Also, **Johnson *et al.* (2005)** reported improved germination in rice seeds primed with a zinc sulfate solution.

Seed Priming: An Overview

Seed priming is a pre-sowing technique that involves controlled hydration of seeds to trigger metabolic processes necessary for germination without actual radical emergence. This method enhances seed performance, improves germination rates, and promotes uniform seedling emergence. Various priming techniques are employed in rice cultivation, each having specific benefits.

Types of Seed Priming

Several methods of seed priming are used in rice seed preservation and restoration. These include:

1. **Hydropriming** – Soaking seeds in water for a specific duration and then drying them before sowing.
2. **Osmopriming** – Soaking seeds in osmotic solutions such as polyethylene glycol (PEG) to regulate water uptake.
3. **Halopriming** – Using salt solutions such as potassium nitrate (KNO3) or sodium chloride (NaCl) to improve seed germination.
4. **Hormonal Priming** – Treating seeds with plant growth regulators like gibberellic acid (GA3) or indole acetic acid (IAA) to enhance physiological processes.
5. **Nutrient Priming** – Soaking seeds in nutrient-rich solutions to enhance seed vigor and early seedling growth.
6. **Biopriming** – Coating seeds with beneficial microorganisms such as Trichoderma spp. or Pseudomonas spp. to improve resistance against pathogens and enhance plant growth.

Each of these priming methods plays a crucial role in seed restoration and preservation by improving germination, seedling vigor, and stress resilience.

Preservation of Rice Seeds through Priming

Seed deterioration is a natural process influenced by factors such as temperature, humidity, oxygen availability, and seed moisture content. Over time, seeds lose viability and germination potential. Seed priming helps mitigate these effects by restoring metabolic activity and improving storage longevity.

Mechanisms of Preservation

1. **Reduction in Aging Effects** – Seed priming rejuvenates aged seeds by reversing oxidative damage and reactivating metabolic pathways necessary for germination.
2. **Enhancing Seed Longevity** – Priming treatments such as osmopriming and biopriming improve the retention of seed vigor and viability during storage.

3. **Protection Against Storage Pathogens** – Biopriming using beneficial microbes suppresses seed-borne pathogens, preventing seed decay during storage.
4. **Strengthening Antioxidant Defense Systems** – Priming treatments enhance antioxidant enzyme activities, reducing the impact of oxidative stress on stored seeds.

Application in Seed Storage

Seed priming is integrated into seed storage protocols to maintain the quality of rice seeds over extended periods. Pre-storage priming treatments, followed by proper drying and packaging, ensure higher germination rates when seeds are later used for sowing.

Restoration of Aged and Low-Vigor Rice Seeds

Seeds that have undergone deterioration due to poor storage conditions or extended aging exhibit reduced germination potential and seedling vigor. Priming techniques offer an effective strategy to restore these seeds, making them viable for cultivation once again.

Mechanisms of Restoration

1. **Reactivation of Metabolic Pathways** – Priming initiates key enzymatic activities necessary for breaking dormancy and initiating germination.
2. **Enhancing Water Uptake Efficiency** – Primed seeds absorb water more efficiently, reducing the time required for germination.
3. **Repairing Cellular Damage** – Priming aids in repairing DNA and membrane integrity, which are often compromised in aged seeds.
4. **Boosting Energy Reserves** – Hormonal and nutrient priming enhance the mobilization of stored carbohydrates and proteins, providing energy for early seedling growth.

Studies on Seed Restoration

Several studies have demonstrated the efficacy of seed priming in restoring aged rice seeds. Research has shown that osmopriming with PEG improves germination rates in seeds stored for prolonged durations. Similarly, hormonal priming with GA3 has been reported to enhance seedling vigor in low-quality rice seeds. These findings highlight the significance of priming in mitigating the effects of seed deterioration.

Priming and Stress Tolerance in Rice Seeds

Rice cultivation is frequently subjected to abiotic and biotic stresses, including drought, salinity, heat, and pathogen attacks. Seed priming enhances stress tolerance by inducing physiological and biochemical changes in seeds and seedlings.

Abiotic Stress Management

1. **Drought Tolerance** – Osmopriming with PEG enhances drought tolerance by improving water-use efficiency and root development.
2. **Salinity Resistance** – Halopriming with NaCl or KNO3 strengthens seedling tolerance to saline environments by regulating ion balance.
3. **Heat and Cold Stress Mitigation** – Hydropriming and hormonal priming improve seed germination and seedling survival under extreme temperature conditions.

Biotic Stress Management

1. **Disease Resistance** – Biopriming with beneficial microorganisms suppresses fungal and bacterial pathogens, reducing disease incidence in rice seedlings.
2. **Pest Resistance** – Seed priming with specific bioagents enhances systemic resistance against insect pests by activating plant defense mechanisms.

Practical Considerations and Challenges

While seed priming offers numerous advantages, its implementation in large-scale rice farming presents some challenges.

Benefits of Seed Priming

- **Enhanced Seed Performance** – Improved germination rates and uniform seedling emergence.
- **Reduced Seedling Mortality** – Higher seedling vigor reduces mortality rates in adverse conditions.
- **Cost-Effective Technology** – Priming methods require minimal investment compared to other seed enhancement techniques.
- **Eco-Friendly Approach** – Biopriming and nutrient priming

reduce the dependency on chemical seed treatments.

Challenges and Limitations

- **Shelf-Life Concerns** – Primed seeds must be properly dried and stored to prevent premature deterioration.
- **Species-Specific Optimization** – Different rice varieties respond variably to priming techniques, requiring specific optimization.
- **Scaling Up for Commercial Use** – Large-scale application of priming techniques requires appropriate infrastructure and expertise.

Future Prospects of Seed Priming in Rice Cultivation

Advancements in seed priming technology are expected to further enhance rice seed preservation and restoration. Future research should focus on:

1. **Development of Standardized Priming Protocols** – Establishing uniform guidelines for priming different rice varieties.
2. **Integration with Modern Agricultural Practices** – Combining priming with precision agriculture and smart seed treatment technologies.
3. **Use of Nanotechnology in Seed Priming** – Exploring the potential of nano-priming to enhance seed vigor and stress resilience.
4. **Climate-Resilient Seed Priming Strategies** – Developing priming techniques tailored to mitigate the effects of climate change on rice production.

Conclusion

Seed priming is a valuable technique for preserving and restoring rice seeds, ensuring high germination rates, seedling vigor, and stress tolerance. By integrating priming methods into seed storage and restoration programs, rice farmers can enhance productivity and sustainability. With continued research and technological advancements, seed priming will play a pivotal role in securing the future of rice cultivation in the face of environmental and agricultural challenges.

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