



Seed Priming: Concepts, Mechanisms, and Agricultural Applications

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Seed priming is a pre-sowing treatment that partially hydrates seeds to initiate early metabolic processes of germination without allowing radicle emergence. This controlled hydration followed by re-drying enhances seed performance by improving germination rate, uniformity, seedling vigour, and stress tolerance. Over the past few decades, seed priming has emerged as a simple, cost-effective, and environmentally friendly technique widely adopted in both conventional and stress-prone agricultural systems. This article discusses the concept of seed priming, its major types, underlying physiological and biochemical mechanisms, and its significance in improving crop establishment and productivity.

Keywords: Seed priming, germination, seed vigour, abiotic stress, crop establishment

Introduction

Rapid and uniform seed germination is a prerequisite for successful crop establishment and yield realization. However, under field conditions, seeds often encounter unfavourable environments such as drought, salinity, temperature extremes, and poor soil fertility, which delay germination and reduce seedling vigour. Seed priming has been developed as a practical pre-sowing strategy to overcome these limitations. By allowing seeds to undergo the initial phases of germination under controlled conditions, priming equips them with enhanced physiological readiness to perform better once sown in the field. Seed priming is particularly relevant in the context of climate variability and resource-limited agriculture, as it improves stand establishment with minimal input costs. The technique has been successfully applied to a wide range of crops including cereals, pulses, oilseeds, vegetables, and millets.

Concept and Principles of Seed Priming

Seed priming involves soaking seeds in water or osmotic/chemical solutions for a specific duration, followed by drying back to their original moisture content. During priming, seeds complete Phase I (imbibition) and partially progress through Phase II (metabolic activation) of germination, but radicle protrusion is prevented. Upon subsequent sowing, primed seeds rapidly resume germination, resulting in faster and more synchronized emergence compared to non-primed seeds. The success of seed priming depends on several factors, including seed quality, priming agent, duration of treatment, temperature, and crop species. Proper optimization is essential to avoid over-priming, which can reduce seed viability.

Types of Seed Priming

1. Hydro-priming

Hydropriming is the simplest form of priming, where seeds are soaked in water for a defined period. It enhances water uptake, enzyme activation, and early metabolic processes. Due to

its low cost and ease of adoption, hydropriming is widely used by farmers, especially in rainfed and smallholder farming systems.

2. Osmo-priming

Osmopriming involves soaking seeds in osmotic solutions such as polyethylene glycol (PEG), mannitol, or salts with controlled water potential. This method allows precise regulation of water uptake and is effective in improving germination under drought and salinity stress conditions.

3. Halo-priming

Halopriming uses inorganic salt solutions (e.g., NaCl, KNO₃, CaCl₂) for seed treatment. It enhances ionic balance, osmotic adjustment, and stress tolerance, particularly under saline environments.

4. Hormonal Priming

In hormonal priming, seeds are treated with plant growth regulators such as gibberellic acid, salicylic acid, abscisic acid, or jasmonic acid. These hormones modulate signaling pathways associated with germination, stress responses, and early seedling growth.

5. Bio-priming

Biopriming combines seed hydration with inoculation of beneficial microorganisms such as plant growth-promoting rhizobacteria or fungi. This approach not only improves germination but also enhances nutrient uptake, disease resistance, and overall plant health.

6. Nutri-priming

Nutri-priming involves soaking seeds in solutions containing essential nutrients like zinc, iron, boron, or phosphorus. It improves early nutrient availability, seedling vigour, and micronutrient use efficiency.

Physiological and Biochemical Mechanisms

- Seed priming triggers a series of physiological and biochemical changes that collectively enhance seed performance. These include:
- Enhanced enzyme activation: Increased activity of enzymes such as α -amylase and proteases accelerates reserve mobilization.
- Improved membrane integrity: Repair of cellular membranes during priming reduces solute leakage and enhances stress tolerance.
- Activation of antioxidant defence: Primed seeds show higher activity of antioxidant enzymes, which protects cells from oxidative damage.
- Hormonal balance: Priming modulates the balance between growth-promoting and inhibitory hormones, favouring rapid germination.
- Gene expression and metabolic readiness: Early transcription and translation of germination-related genes enable faster radicle emergence after sowing.

Role of Seed Priming in Stress Tolerance

Seed priming plays a crucial role in enhancing tolerance to abiotic stresses such as drought, salinity, heat, and chilling. Primed seeds exhibit better osmotic adjustment, higher chlorophyll content, improved root architecture, and efficient water and nutrient uptake. These traits contribute to better seedling survival and growth under adverse conditions.

Agricultural Significance and Applications

The benefits of seed priming extend beyond germination and early growth. Improved crop stand establishment leads to better resource use efficiency, reduced weed competition, and ultimately higher yield stability. Seed priming is particularly valuable in:

- Rain-fed and dryland agriculture
- Marginal and degraded soils
- Organic and low-input farming systems
- Climate-resilient crop production strategies

Due to its simplicity and adaptability, seed priming is increasingly being promoted as a farmer-friendly technology for sustainable agriculture.

Limitations and Future Prospects

Despite its advantages, seed priming has certain limitations, such as reduced storability of primed seeds and the need for precise standardization of protocols. Future research is focusing on molecular-level understanding of priming-induced memory, development of seed-friendly priming formulations, and integration of priming with modern seed technologies.

Conclusion

Seed priming is an effective and economical seed enhancement technique that significantly improves germination, seedling vigour, and stress tolerance. By activating early physiological and biochemical processes, priming prepares seeds for rapid and uniform establishment under diverse environmental conditions. With appropriate optimization and large-scale adoption, seed priming holds great potential for improving crop productivity and ensuring agricultural sustainability in the face of increasing climatic challenges.