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Effect of Seed Priming Techniques on Germination and Seedling Vigour of Vegetable Crops

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Seed germination is a crucial phase that determines the final yield of vegetable crops. Poor germination caused by factors such as hard seed coats, dormancy, and abiotic stress is a major challenge. Seed priming is a low-cost technique used before sowing that enhances germination speed, uniformity, and tolerance to stress. This article provides an overview of various priming methods—including Hydropriming, Halopriming, Osmopriming, Hormonal priming, and Biopriming—and their effects on vegetable crops like Tomato, Brinjal, Chilli, Onion, and Carrot.

Introduction

Vegetables crops are important in human nutrition and its importance in daily nutrition is getting increases all around the world. Vegetables are important sources of vitamins, minerals and other nutrients of medicinal and therapeutic value. Rapid germination and emergence of seedlings are essential for successful crop establishment, importance of good and high crop establishment is recognized by researchers and as well as by farmers they are major challenges in successful crop production. Main reasons for the successful crop stand are high germination percent and good vigor of seedlings. Research on techniques for improving the germination, growth and yield of crop species has been done for many years. For successful crop establishment seed priming could play a vital role in crop production. Seed vigour is a cost effective technique to ensure uniform emergence and high vigourity of seeds which is leading to better crop establishment and yield. It is a simple, effective and low cost technique in which seeds are partially hydrated to a point where pre-germination metabolic activities start without actual germination by treating with different chemicals or growth regulators, and then redried until close to the original dry weight. In crop production, stand establishment determines plant density, uniformity, and management options. Vegetables require high-quality seed for uniform crop stand. In dry zones soil moisture stress reduces germination to 50-60%. Seed priming involves controlled hydration of seeds to activate pre-germinative metabolism without radicle emergence. It is farmer-friendly, cheap and organic.

Types of Seed Priming Techniques

Concept and physiological basis of seed priming

During priming, seeds are imbibed under controlled conditions that permit water uptake and metabolic activation but prevent completion of germination. This controlled imbibition triggers DNA repair, synthesis of RNA and proteins, activation of hydrolytic enzymes (amylases, proteases, lipases), accumulation of compatible solutes, and upregulation of antioxidant defense systems. As a result, primed seeds exhibit reduced lag time to germination, improved synchrony of emergence, and enhanced tolerance to abiotic stresses such as drought, salinity, temperature extremes, and heavy metals. Some priming treatments also induce "stress memory" via hormonal signaling and epigenetic modifications, enabling seedlings to respond more effectively to subsequent stress episodes.

Major types of seed priming techniques

Seed priming methods can be grouped based on the nature of the priming medium (water, osmotic solutions, solid matrices, biological agents, chemicals, nanomaterials) and the level of control over hydration. The most widely used techniques are described below.

A) Hydropriming (Water priming): Hydropriming involves soaking seeds in plain water for a defined period, followed by surface drying to near-original moisture content before sowing. It is the simplest, oldest, and most cost-effective priming method, requiring no specialized chemicals or equipment. Water uptake during hydropriming is relatively rapid and less controlled compared with osmotic methods, which can increase the risk of over-imbibition in some species if duration and temperature are not optimized. Despite this, hydropriming has been shown to improve germination percentage, speed of emergence, and early seedling growth in many field and vegetable crops, making it highly suitable for on-farm adoption. Eg: Onion 12 hrs, Tomato 24 hrs. Increases germination by 15-20%.

B) Halopriming (Salt priming): Halopriming is a variant of osmopriming that employs inorganic salt solutions such as $NaCl$, KCl, $CaCl_2$, KNO_3, KH_2PO_4, or $MgSO_4$ as the priming medium. In addition to osmotic control, the ionic components can modulate ion homeostasis, osmolyte accumulation, and stress-related gene expression, thereby improving salinity tolerance and overall seedling Vigor. Halopriming has been reported to enhance germination rate, seedling growth, and stress resilience in several crops under saline and drought conditions. Optimization of salt type, concentration, and exposure time is critical to avoid ion toxicity or excessive osmotic stress. Best for: Chilli and Brinjal under saline soils.

C) Osmopriming: Osmopriming uses solutions with low osmotic potential, typically polyethylene glycol (PEG) or other Osmotica to regulate water entry into seeds. The reduced water potential of the solution allows slow and controlled imbibition, activating pre-germinative metabolism while minimizing the risk of cellular damage from rapid hydration. Osmopriming is particularly effective in enhancing germination under suboptimal temperatures and moisture stress, and is widely applied in vegetable and horticultural crops. However, it requires careful standardization of solution concentration, temperature, aeration, and duration, and the osmoticum must be non-toxic and preferably reusable or disposable in an environmentally safe manner. Eg; Used for high-value crops like Capsicum and Cucumber.

D) Hormonal Priming: Hormonal priming involves treating seeds with solutions of plant growth regulators such as gibberellins (GA), auxins, cytokinins, abscisic acid (ABA) modulators, or brassinosteroids. These hormones influence key germination processes, including dormancy release, enzyme activation, reserve mobilization, and stress signaling. Hormonal priming can improve germination under adverse conditions, enhance seedling vigor, and modulate stress-responsive pathways, including antioxidant systems and osmolyte synthesis. However, the effectiveness depends on hormone type, concentration, species sensitivity, and interaction with endogenous hormonal balance, requiring careful optimization to avoid inhibitory effects. Eg: GA3 priming in Tomato increases germination from 72% to 94% in 5 days.

E) Biopriming: Bio-priming combines controlled seed hydration with inoculation of beneficial microorganisms such as Trichoderma spp., Pseudomonas spp., Bacillus spp., mycorrhizal fungi, or nitrogen-fixing bacteria (e.g., Azospirillum). The biological agents colonize the seed and early root system, enhancing nutrient acquisition, producing growth-promoting substances, and inducing systemic resistance against pathogens. Bio-priming has been shown to improve germination, seedling growth, and tolerance to both biotic and abiotic stresses, contributing to reduced dependence on chemical inputs. It is considered a key component of integrated and sustainable crop management strategies. Coating seeds with beneficial microbes - Trichoderma, Pseudomonas, Azospirillum after hydropriming. Provides disease protection + growth promotion. Latest trend in organic farming.

F) Solid Matrix Priming: Solid matrix priming (SMP) is a method where seeds are mixed with a moist, non-reactive solid material like vermiculite, sand, sawdust, peat, or charcoal. The water potential of this matrix helps control how the seeds take in water. Instead of relying on osmotic forces, the matrix holds water through its physical properties, which allows the seeds to absorb moisture gradually and evenly over several days. This method not only increases the number of seeds that successfully germinate and speeds up the germination process but also boosts biochemical activities such as protein and nucleic acid production, enzyme activation, and the use of stored food reserves in the seed. It has proven to be very effective for vegetable crops such as cauliflower and broccoli, especially when growing conditions are not ideal, like during cold weather, high salt levels, or drought. The technique is practical for large-scale use in commercial seed treatments, but it requires choosing the right matrix and managing moisture properly. This method is suitable for small-seeded vegetables such as carrots and lettuce.

G) Drum Priming: Drum priming is a controlled method of hydropriming where seeds are soaked in a rotating drum with controlled temperature, air flow, and moisture. The constant movement of the seeds ensures they all get the same amount of water and oxygen, which reduces differences among seeds and helps prevent anaerobic conditions. Drum priming is commonly used in commercial seed treatments where large quantities of seeds need to be handled consistently. It combines the simple nature of hydropriming with better control over the treatment process, making it suitable for high-value vegetable and horticultural seeds.

H) Nutri-priming (Micronutrient Priming): Nutri-priming involves soaking seeds in solutions containing essential nutrients or micronutrients like zinc, copper, manganese, molybdenum, phosphorus, or potassium. This process adds nutrients to the seeds, which support early growth processes, root development, and enzyme activity, resulting in stronger and more stress-resistant plants.Nutri-priming is especially useful in soils that lack nutrients or in programs designed to improve the nutritional value of crops. Like other chemical priming methods, the type, amount, and duration of nutrient exposure must be carefully controlled to avoid harming the seeds or causing osmotic stress.

Methodology for Farmers / Experiment

Seed priming can be easily implemented by farmers using affordable materials and simple steps. The following methods are appropriate for use on farms and have been shown to enhance germination, uniformity, and early growth of many crops.

General precautions for all priming methods

- Use clean, high-quality seeds and clean water.
- Do not soak seeds for too long; excessive water absorption can lead to premature germination or damage.
- After priming, dry the seeds to their original moisture level before planting or short-term storage.
- Plant primed seeds as soon as possible, preferably within 24–48 hours, for the best results, especially in field conditions.
- Avoid using fungicides or insecticides after priming unless specifically recommended, as this may reduce the effectiveness of the priming.
- Select 100 seeds of each vegetable.

Treatments: T0-Control, T1-Hydropriming for 12 hours, T2-1% KNO_3 for 12 hours, T3-100ppm GA_3 for 12 hours, T4-Biopriming.After priming, air dry in shade for 2 hours. Sowing on germination paper or in pots.

Observations: Germination percentage (after 7 and 14 days), mean germination time, seedling length, and Vigour Index = Germination percentage × Seedling length.

Results & Benefits

Hydropriming reduces the mean germination time by 2–3 days. Halopriming increases germination by 25% under 100mM salt stress. Biopriming decreases the incidence of damping-off disease by 40%.Reports include uniform crop growth, earlier flowering, and a 12–15% increase in yield. Precautions: Do not soak seeds too long (to prevent rotting), dry seeds in shade instead of sun, and plant seeds immediately after priming for best results.

Conclusion

Seed priming is a cost-effective and climate-friendly technology suitable for vegetable growers. Hydropriming and Biopriming are recommended for small and marginal farmers in Andhra Pradesh and Telangana due to their zero cost and organic nature. Adoption of these techniques can boost vegetable productivity by 15–20% without requiring additional fertilizers.

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