Seed Treatment: An Elixir for Uniform Germination and Early Vigour

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ABSTRACT

Seed treatment is a strategic pre-sowing intervention designed to enhance crop establishment under diverse biotic and abiotic stress conditions by improving germination, seed vigor and early-stage protection. Chemical, biological and physical seed enhancement techniques including priming, coating and dressing are evaluated using standard seed quality parameters such as germination percentage and seedling vigor index. These treatments have been shown to improve germination by 10-25 per cent and contribute to yield gains ranging from 5-15 per cent, depending on crop and environment. By increasing input-use efficiency and strengthening stress tolerance, seed treatment plays a critical role in climate-resilient agriculture and sustainable crop intensification.

INTRODUCTION

Seed is the primary biological determinant of crop establishment, productivity and resilience and its quality has been emphasized across civilizations as a prerequisite for agricultural success. Ancient Indian agronomic thought recognized the seed as the foundational unit of crop productivity, a principle encapsulated in the traditional maxim: “***Yad bījam śuddham suropitam, tat bahuphalaṃ bhavati***” pure and properly treated seed becomes highly productive. Classical literature such as *Manusmriti* underscores the importance of sowing superior seed in fertile soil to ensure abundant yield, thereby highlighting the integrated role of seed quality and growth environment. Similarly, Surapala's *Vrikshayurveda* (circa 800 AD) provides systematic descriptions of pre-sowing seed treatments including steeping in milk, coating with cow dung, drying and repeated application of honey mixed with powdered *Vidanga* (*Embelia ribes*). From a modern scientific perspective, these practices represent early forms of seed sanitation, bio-priming, nutrient fortification and biological protection.

Subsequent scientific advancements have substantiated these traditional insights through experimental validation and technological refinement. Tull (1973) reported that wheat seeds inadvertently soaked in seawater exhibited reduced incidence of bunt disease and improved crop performance compared to untreated seeds, leading to the development of brine-based seed treatment approaches for managing seed-borne pathogens. These historical and experimental evidences collectively demonstrate that the principles underlying seed treatment enhancement of germination, strengthening of seed vigor and suppression of seed and soil-borne pathogens are deeply rooted in agronomic tradition and continue to underpin modern seed technology. Thus, contemporary seed treatment strategies represent an evolution of long-standing knowledge systems aimed at ensuring healthy crop establishment, uniform stand development and sustainable yield realization.

Seed treatment is a critical component in modern agriculture, aimed at enhancing seed performance and ensuring healthy crop establishment. This practice involves applying chemical, biological, or physical agents to seeds before planting to protect them from diseases, pests and unfavorable environmental conditions. By improving germination rates and seedling vigor, seed treatments play a vital role in increasing agricultural productivity and sustainability. Seed treatment is a process of application either by mixing or by coating or by soaking in solutions of chemicals or protectants (with fungicidal, insecticidal, bactericidal, nematicidal or biopesticidal properties), nutrients, hormones or growth regulators or subjected to a process of wetting and drying or subjected to reduce, control or repel disease organisms, insects or other pests which attack seeds or seedlings growing there from. There are various **types of seed treatments**;

Chemical treatments

These involve the use of fungicides and insecticides to protect seeds from pathogens and pests. Chemical treatments are widely used due to their effectiveness and ease of application. Chemical method of seed treatment involves steep treatment, sprinkle treatment, dust treatment, slurry treatment, wet treatment, fumigation and pelleting.

Biological treatments

Biological seed treatments utilize beneficial microorganisms or natural products (Botanicals and biofungicides) to enhance seed health. These treatments can promote plant growth, improve disease resistance and increase nutrient uptake.

Physical treatments

Physical methods include techniques like seed priming, where seeds are soaked in water or solutions to enhance germination and thermal treatments, which use heat to kill pathogens. These methods can also involve mechanical scarification to break seed dormancy. This involves hot water treatment, dry heat treatment, aerated steam treatment and radiation.

Mechanism of action of seed treatments

1. **Metabolic activation:** Seed priming initiates controlled hydration, activating key hydrolytic enzymes (α-amylase, proteases and lipases) that mobilize stored reserves. This accelerates energy release and supports rapid embryo growth and early seedling vigor.

2. **Membrane stabilization:** Treatments restore phospholipid membrane integrity damaged during desiccation. Improved membrane stability reduces electrolyte leakage and enhances uniform cell expansion during germination.

3. **ROS homeostasis and antioxidant defense:** Seed treatments regulate Reactive Oxygen Species (ROS), where moderate ROS levels act as signaling molecules for germination. Enhanced antioxidant enzymes (SOD, catalase, peroxidase) prevent oxidative damage and improve germination uniformity.

4. **DNA repair and cellular recovery:** Hydration activates DNA repair systems that correct storage-induced damage, ensuring genomic stability, efficient transcription and synchronized cell division during seedling emergence.

5. **Induced systemic resistance and microbial enhancement:** Bio-agents such as *Trichoderma* and *Pseudomonas* activate JA–ET mediated defense pathways, strengthen plant immunity and suppress pathogens. They also improve rhizosphere microbial balance, nutrient solubilization and phytohormone production, enhancing stress tolerance and crop establishment.

Methods of seed treatment

Seed treatment comprises a diverse set of techniques designed to meet specific agronomic objectives and production challenges. These treatments aim to confer protective barriers against biotic and abiotic stresses, enhance physiological performance and promote uniform and vigorous germination, thereby playing a critical role in contemporary agricultural systems.

Seed coating: Seed coating refers to the application of a thin, uniform layer of materials such as polymers, micronutrients, bio-stimulants or plant growth regulators onto the seed surface. This treatment enhances seed handling, flowability and visibility during sowing operations. Additionally, coatings may serve as carriers for active ingredients, improving seed performance and early crop establishment.

Seed dressing: Seed dressing involves the application of protective chemical or biological agents primarily fungicides and insecticides to the seed surface. The process typically ensures uniform coverage through mechanical mixing or slurry treatment. This method provides protection against seed and soil-borne pathogens and insect pests during the critical early stages of germination and seedling development.

Seed pelleting: Seed pelleting is a process in which seeds are encapsulated within a thicker, uniform inert material to produce pellets of standardized size and shape. This modification facilitates precision planting, particularly in small or irregularly shaped seeds, resulting in uniform plant spacing, improved crop stand establishment and more efficient weed management.

Seed priming: Seed priming is a controlled pre-sowing hydration technique that initiates metabolic processes required for germination without permitting radicle protrusion. Upon sowing, primed seeds demonstrate accelerated and synchronized germination, leading to rapid emergence, enhanced seedling vigor and improved field establishment.

Seed disinfection: Seed disinfection involves treating seeds with chemical (e.g., fungicides, disinfectants) or non-chemical (e.g., thermal or biological) agents to eliminate or suppress seed-borne pathogens present either externally or internally. This practice is essential for disease management, ensuring pathogen-free planting material and reducing the risk of early-season crop losses.

Seed quality enhancement techniques involves seed hydration technology, seed coating and integrated seed enhancement.

Integrated seed treatment protocol (FIR approach)

Integrated seed treatment with fungicides, insecticides and bio-agents should be carried out in a proper sequence to ensure effective protection and microbial safety. Clean and healthy seeds are first treated with a recommended fungicide at the prescribed dose per kilogram of seed to control seed and soil-borne fungal pathogens, ensuring uniform coating and shade drying afterward. Once dried, a suitable insecticide is applied to protect against early-stage insect pests, followed again by shade drying to remove excess moisture. After completing chemical treatments, bio-agents such as *Trichoderma* or *Pseudomonas* are applied separately as the final step, using a mild adhesive if required, since direct mixing with chemicals may reduce microbial viability. The treated seeds are dried under shade without exposure to direct sunlight and should preferably be sown shortly after treatment. This sequential approach ensures early disease and pest protection while supporting beneficial microbial activity for improved crop establishment.

Benefits of seed treatment

1. Enhanced germination and seed vigor

Breaks physiological dormancy through hydration and metabolic activation (priming). Stimulates enzyme activation (α-amylase, proteases) promoting rapid mobilization of stored reserves. Improves uniform emergence and field stand under diverse soil conditions. Increases germination percentage and speed of germination index (SGI) and reduces imbibitional injury in sensitive seeds (Robinson, 2024).

2. Protection against seed and soil-borne pathogens

Fungicidal seed coatings prevent infection by pathogens such as *Fusarium*, *Rhizoctonia*, *Pythium* and smut fungi. Suppresses pre and post-emergence damping-off. Reduces pathogen inoculum load at the rhizosphere level. Ensures healthier early root–shoot axis development and minimizes secondary disease spread within fields.

3. Protection against insect pests and storage insects

Insecticidal coatings (e.g., neonicotinoids, diamides) protect against early-season soil insects (cutworms, termites, aphids). Prevents seed damage during storage by controlling bruchids and weevils. Reduces early vector-borne viral infections by limiting insect feeding.

4. Improved seedling health and early growth

Promotes enhanced root elongation and lateral root formation. Biological agents (*Trichoderma*, *Pseudomonas fluorescens*, *Rhizobium*) improve nutrient acquisition. Boosts nitrogen fixation (legumes) and phosphate solubilization. Induces systemic resistance (ISR) against pathogens.

5. Increased tolerance to abiotic stress (Seed Priming)

Enhances tolerance to drought, salinity, temperature stress and osmotic stress.

Stabilizes membrane integrity under stress conditions. Improves osmotic adjustment via accumulation of proline and antioxidants. Promotes faster germination under suboptimal moisture regimes.

Types of priming: 1. Hydropriming: Controlled hydration, 2. Osmopriming: Using osmotic solutions (PEG, salts), 3. Halopriming: Salt-based conditioning and 4. Biopriming: Combined microbial inoculation + hydration

6. Reduced chemical load and sustainable crop protection

Requires lower pesticide quantity per hectare compared to foliar sprays. Targeted delivery reduces environmental contamination. Supports Integrated Pest Management (IPM) approaches and enhances cost–benefit ratio for farmers.

7. Yield stability and productivity enhancement

Ensures optimum plant population per unit area. Reduces crop loss during critical establishment phase. Improves harvest index due to uniform crop growth and contributes to higher and stable yields under variable climatic conditions.

Beejamrutha: Nature's shield for healthy seeds

Beejamrutha is an organic formulation used in agriculture, particularly for enhancing seed germination and seedling growth. Beejamrutha is a solution made from cow urine and cow dung, particularly renowned for its efficacy in safeguarding seeds during germination and establishment against bacterial and fungal diseases.

For the preparation of beejamrutha, 5 kg of desi cow dung was tied in a muslin cloth and hung in a bucket containing 20 liter of water and soaked overnight. 50 g of lime was added to 1 liter of water and then left overnight. Then the next morning, bundle of cow dung was squeezed in that water continuously so that all the essence of cow dung would be accumulated in that water. Handful of soil, 5 liter desi cow urine and lime solution was added to that water (Palekar, 2006). Later, fresh beejamrutha used for seed treatment before sowing.

Equipments for seed treatment

1. **Slurry treater:** Slurry is prepared by mixing the chemical with water. The treatment material to be applied as slurry is accurately measured through a simple mechanism composed of a slurry cup and seed dump pan. The cup introduces a given amount of slurry with each dump of seed into a mixing chamber where the seeds are mixed thoroughly.

2. **Direct treater:** These are the recent ones and include panogen and Mist-O-Matic treater. The Misto-O-Matic treater applies the chemical in the form of a mist directly on to the seeds.

3. **Drum mixer:** A simple mixer can be made by running a pipe through a drum at an angle. The drum is then mounted onto a stand. The seed and treatment are placed in the drum and it is rotated slowly until all the seeds are covered with the chemical.

4. **Grain auger:** Liquid materials can be dripped on the seed as they enter a grain auger or straw conveyer. By the time seeds have left the auger the chemical is spread on the seeds.

5. **Shovel:** Seeds are spread on a clean dry surface 10-15 cm in depth. The proper amount of chemical is diluted with water and sprinkled over the seed. Mixing is done with shovel or sloop turning the seed at least 20 times.

CONCLUSION

Seed treatment stands as a precision-based, climate-smart intervention that enhances germination, accelerates emergence, strengthens seedling vigor and protects against early biotic and abiotic stresses, collectively contributing to 5-20 per cent yield improvement depending on crop and environment. By delivering protective and bioactive agents directly onto the seed surface, it ensures targeted disease and pest suppression while reducing overall chemical load per hectare, thereby supporting sustainable agriculture and integrated pest management frameworks. Physiological priming enhances enzymatic activation, membrane stability and stress tolerance enabling better crop establishment under drought, salinity and temperature fluctuations. As agriculture faces increasing climatic variability and the need for input-use efficiency, seed treatment is evolving from a protective practice to a strategic technological platform. Future innovations should emphasize nano-enabled coatings, smart polymer-based controlled release systems, microbial consortia and seed microbiome engineering to achieve resilient crop establishment, improved resource-use efficiency and sustainable crop intensification.

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