Available online at
http://agrospheresmagazine.vitalbiotech.org/

ISSN (E): 2582 – 7022

Agrospheres:e- Newsletter, (2026) *7*(7), 100-106

Article ID: 1026

Seed Treatment Techniques for Better Germination

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Article History
Received: 08.07.2026
Revised: 13.07.2026
Accepted: 18.07.2026

INTRODUCTION

Seeds are the basic input of crop production and determine the success of agricultural systems. The establishment of a healthy crop begins with rapid and uniform seed germination. Poor germination due to low seed quality, seed-borne diseases, unfavorable soil conditions, and environmental stresses results in weak plant stands and reduced productivity. Seed treatment is a pre-sowing technology in which seeds are treated with different physical, chemical, biological, or organic agents before planting. The main objective of seed treatment is to improve seed performance by enhancing germination rate, protecting seeds against pathogens, and increasing early seedling growth. With increasing demand for sustainable agriculture, seed treatment has become an important component of integrated crop management. Advanced techniques such as biological seed coating, hydropriming, nanotechnology-based treatment, and microbial consortia are gaining importance for improving crop establishment under changing climatic conditions.

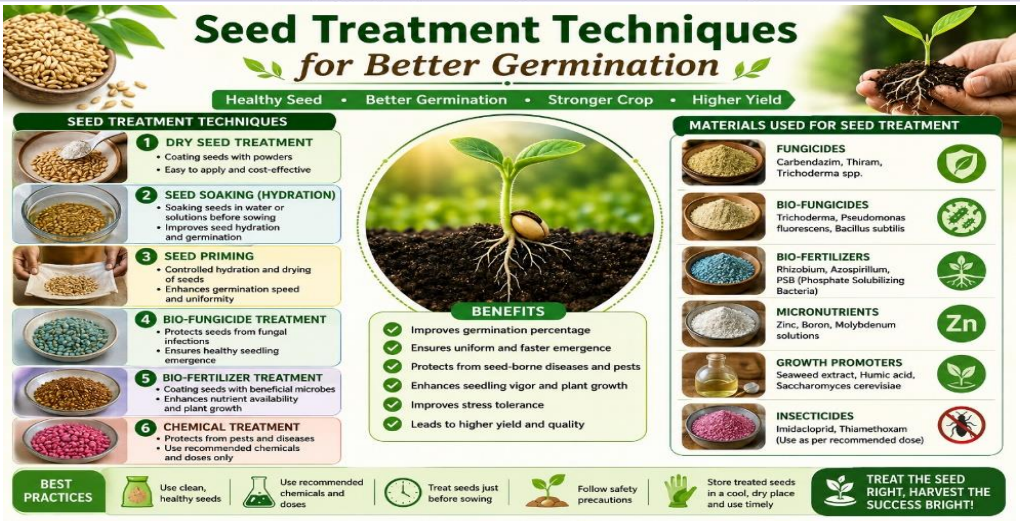
2. Concept of Seed Treatment

Seed treatment refers to the process of applying protective, nutritional, or growth-promoting substances to seeds before sowing to improve germination, seedling vigor, and crop performance.

Seed treatment can be performed through:

- Seed dressing – Application of chemicals or biological agents directly on seed surface.
- Seed coating – Covering seeds with protective materials or nutrients.
- Seed pelleting – Increasing seed size and improving handling ability.
- Seed soaking or priming – Controlled hydration of seeds before sowing.

ISSN (E): 2582 – 7022



3. Importance of Seed Treatment for Better Germination

3.1 Improvement in Germination Percentage

Seed treatment enhances the physiological and biochemical processes within seeds by improving water absorption, activating hydrolytic enzymes, and promoting embryo development. Treated seeds exhibit faster and more uniform germination compared to untreated seeds. This results in early seedling emergence, better crop establishment, and optimum plant population. Improved germination reduces seed mortality and ensures efficient utilization of available resources. As a result, seed treatment contributes to healthy plant growth, higher productivity, and improved crop performance under diverse environmental conditions.

3.2 Protection Against Seed-Borne Diseases

Seed treatment plays an important role in protecting seeds from various pathogens present on the seed surface or inside seed tissues. These microorganisms can cause infection during germination and early seedling growth, leading to poor crop establishment. Treatment with fungicides, biocontrol agents, or microbial formulations prevents pathogen development and improves seed health. It effectively controls diseases such as seed rot, damping-off, smut diseases, wilt diseases, and root rot, ensuring healthy seedlings and better crop productivity.

3.3 Enhancement of Seedling Vigour

Seed treatment improves seedling vigour by enhancing physiological processes such as enzyme activation, nutrient mobilization, and cell development. Treated seeds produce stronger roots and shoots, resulting in better plant establishment. Improved root growth increases water and nutrient absorption, while enhanced shoot development supports healthy plant growth. Seed treatment also increases tolerance against environmental stresses such as drought, salinity, and temperature variations. Vigorous seedlings establish rapidly in the field, leading to uniform crop growth, higher productivity, and improved yield potential.

4. Different Seed Treatment Techniques

4.1 Chemical Seed Treatment

Chemical seed treatment is a widely adopted technique used to protect seeds from pathogens and improve successful crop establishment. In this method, seeds are treated with chemical agents such as fungicides and insecticides before sowing. Fungicide treatment prevents fungal infection by eliminating pathogens present on seed surfaces or within seed tissues. Common fungicides used for seed treatment include Carbendazim, Thiram, Captan, and Metalaxyl. This method prevents seed decay, controls seed-borne diseases, improves germination percentage, and reduces early crop losses. For example, Carbendazim treatment in

pulse crops effectively controls fungal diseases and promotes healthy seedling establishment.

4.2 Insecticidal Seed Treatment

Insecticidal seed treatment is an effective method of protecting young seedlings from insect pests during the early growth stages. In this technique, seeds are coated or treated with suitable insecticides that provide protection against soil-borne and early-season insect attacks. Common insecticides used for seed treatment include Imidacloprid, Thiamethoxam, and Fipronil. This treatment reduces insect damage, protects seedlings from sucking pests, and improves plant survival. It helps in maintaining a healthy plant population, ensuring better crop establishment and reducing the need for repeated insecticide applications during early crop growth.

4.3 Seed Priming Techniques

Seed priming is a pre-sowing technique in which seeds are partially hydrated under controlled conditions to activate metabolic processes without allowing actual germination. This process prepares seeds for rapid and uniform emergence after sowing. Priming enhances water absorption, activates essential enzymes, improves cellular repair mechanisms, and increases seed vigor. It helps seeds overcome unfavorable environmental conditions and promotes better seedling establishment. Seed priming techniques such as hydropriming, osmopriming, halopriming, and hormonal priming are widely used to improve germination, crop performance, and productivity.

Types of Seed Priming

A. Hydropriming

Hydropriming is a simple and cost-effective seed enhancement technique in which seeds are soaked in water for a specific duration and then dried back to their original moisture level before sowing. This controlled hydration activates metabolic processes, improves enzyme activity, and prepares seeds for rapid germination. Hydroprimed seeds generally show faster and more uniform emergence compared to untreated seeds. It is an economical method requiring no special chemicals or equipment, making it suitable for small and marginal farmers. It improves seedling establishment and contributes to better crop productivity.

B. Osmopriming

Osmopriming is an advanced seed priming technique in which seeds are treated with osmotic solutions such as polyethylene glycol (PEG) and potassium nitrate (KNO_3) under controlled conditions. This process allows seeds to absorb water slowly and activate metabolic activities without initiating germination. Osmopriming improves germination performance, especially under drought and moisture stress conditions. It enhances seed vigor, promotes uniform seedling emergence, and improves early plant growth. This technique is particularly useful for achieving better crop establishment under unfavorable environmental conditions.

C. Halopriming

Halopriming is a seed enhancement technique in which seeds are soaked in low-concentration salt solutions before sowing. Common salts used for halopriming include potassium nitrate (KNO_3), sodium chloride (NaCl), and calcium chloride ($CaCl_2$). This treatment improves seed metabolic activity, activates enzymes, and enhances physiological processes required for germination. Haloprimed seeds show better tolerance against environmental stresses such as drought and salinity. It promotes rapid and uniform seed emergence, improves seedling growth, and helps in better crop establishment under stressful growing conditions.

D. Hormonal Priming

Hormonal priming is a seed treatment technique in which plant growth regulators are applied to seeds to enhance germination and early seedling growth. Common hormones used for hormonal priming include gibberellic acid (GA_3), auxins, and cytokinins. These growth regulators stimulate metabolic activities,

promote embryo development, and improve cell division and elongation. Hormonal priming results in faster germination, better seedling establishment, and improved plant growth. It is particularly useful for seeds with slow or poor germination capacity under unfavorable environmental conditions.

5. Biological Seed Treatment

Biological seed treatment uses beneficial microorganisms to improve plant growth and protect seeds from pathogens.

5.1 Biofertilizer Seed Treatment

Biofertilizer seed treatment is a biological approach in which seeds are coated or inoculated with beneficial microorganisms to improve nutrient availability, plant growth, and crop establishment. These microorganisms enhance soil fertility through biological nitrogen fixation, phosphorus solubilization, and production of plant growth-promoting substances.

Important microorganisms include:

Rhizobium: Forms root nodules in leguminous crops and enhances biological nitrogen fixation, improving nitrogen availability to plants.

Azotobacter: Fixes atmospheric nitrogen and produces growth-promoting substances that stimulate plant development.

Phosphate Solubilizing Bacteria (PSB): Converts unavailable phosphorus into plant-available forms, improving phosphorus nutrition.

Plant Growth-Promoting Rhizobacteria (PGPR): Enhances root growth, nutrient uptake, and plant resistance against environmental stresses.

6. Organic Seed Treatment Techniques

Organic seed treatment techniques are eco-friendly approaches that use natural inputs to improve seed quality, germination, and seedling growth. These methods are widely used in natural farming and sustainable agricultural systems because they enhance biological activity without causing harmful effects on the environment. Organic treatments improve seed vigor, support beneficial microorganisms, and promote healthy crop establishment. They include the use of traditional formulations such as Panchagavya, Jeevamrit, and vermiwash for improving seed performance.

6.1 Panchagavya Treatment

Panchagavya is a traditional organic formulation prepared from cow-based products, including cow dung, cow urine, milk, curd, and ghee. Seed treatment with Panchagavya enhances physiological activity, improves germination, and increases seedling vigor. It provides beneficial microorganisms, nutrients, and growth-promoting substances that support early plant development. Panchagavya treatment also promotes microbial activity around seeds and improves soil biological health, making it an important practice in organic and sustainable farming systems.

6.2 Jeevamrit Seed Treatment

Jeevamrit is a natural microbial formulation prepared from organic ingredients that contains beneficial microorganisms. Seed treatment with Jeevamrit improves microbial activity, enhances nutrient availability, and promotes better seed health. It supports rapid germination, stronger seedling growth, and improved root development. Jeevamrit helps in maintaining soil biological balance and increases the efficiency of nutrient cycling. It is widely used in organic and natural farming systems as an eco-friendly approach for improving crop establishment and sustainable productivity.

6.3 Vermiwash Treatment

Vermiwash is a nutrient-rich organic liquid obtained from vermicomposting systems containing beneficial microbes, enzymes, and growth-promoting substances. Seed treatment with vermiwash enhances seed germination, improves seedling vigor, and promotes early plant growth. It supports better root development and increases nutrient absorption

capacity of young plants. Vermiwash also improves microbial activity around seeds and contributes to sustainable crop production. It is an eco-friendly seed treatment method suitable for organic farming and improving overall crop establishment.

7. Seed Coating and Pelleting Technology

7.1 Seed Coating

Seed coating is an advanced seed treatment technique in which seeds are covered with a thin layer of protective materials containing nutrients, pesticides, or beneficial microorganisms. Common coating materials include polymers, minerals, bioagents, and micronutrients. This technique ensures uniform application of inputs and improves seed quality and performance. Seed coating enhances seed handling, protects seeds from environmental stresses, and supports better germination and seedling growth. It is widely used in modern agriculture for improving crop establishment, precision sowing, and sustainable crop production.

7.2 Seed Pelleting

Seed pelleting is a specialized seed treatment technique in which small and irregularly shaped seeds are coated with inert materials to increase their size, shape, and weight. This improves seed handling, sowing accuracy, and uniform seed placement during planting. Seed pelleting is especially beneficial for small-seeded crops where precise sowing is difficult. It enhances seedling establishment by ensuring better seed-soil contact and uniform emergence. This technique is commonly used in vegetable crops and forage crops for precision planting and improved crop performance.

8. Nutrient Seed Treatment

Nutrient seed treatment is a technique in which seeds are treated with essential plant nutrients to improve germination, early growth, and seedling development. Important nutrients used in seed treatment include zinc, iron, boron, and molybdenum. Zinc seed treatment enhances enzyme activity, promotes root growth, and improves germination percentage by supporting essential metabolic processes. Molybdenum treatment is particularly important for leguminous crops as it plays a key role in biological nitrogen fixation through improved nodule formation and nitrogen metabolism. Nutrient seed treatment improves crop establishment and productivity.

9. Nanotechnology-Based Seed Treatment

Nanotechnology-based seed treatment is an emerging approach that uses nanoscale materials to enhance seed performance, germination, and early plant growth. Nanomaterials such as nano zinc oxide, nano iron, carbon nanoparticles, and nano fertilizers are applied to seeds to improve nutrient availability and physiological activity. These materials enhance nutrient absorption, stimulate metabolic processes, and improve seedling development. Nano-based treatments also increase plant tolerance against environmental stresses such as drought and nutrient deficiency. This advanced technique has great potential for improving crop productivity and supporting sustainable agriculture.

Nano-based seed treatments have potential for climate-smart agriculture.

10. Seed Treatment for Abiotic Stress Management

Climate change has increased the occurrence of abiotic stresses such as drought, salinity, and extreme temperatures, which negatively affect seed germination and crop establishment. Seed treatment techniques help plants develop tolerance against these unfavorable conditions by improving physiological and biochemical processes. Treated seeds show better water absorption, enhanced root growth, and improved antioxidant activity, resulting in increased stress resistance. Hydropriming improves drought tolerance, microbial treatments promote root development, and biochar coating enhances moisture availability. These approaches support better crop survival and productivity under stressful environments.

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11. Methods of Seed Treatment Application

11.1 Dry Treatment

Dry treatment is a simple seed treatment method in which seeds are mixed with powdered chemicals, nutrients, or biological agents before sowing. The treatment material adheres to the seed surface and provides protection against pathogens while improving seed performance. This method is easy to perform, requires less equipment, and is suitable for small-scale farming. Dry treatment helps reduce seed-borne diseases, enhances germination, and supports better crop establishment. It is an economical and convenient technique widely used in agricultural practices.

11.2 Wet Treatment

Wet treatment is a seed treatment method in which seeds are soaked or coated with liquid solutions containing beneficial microorganisms, nutrients, or growth-promoting substances. This technique allows better absorption and uniform distribution of treatment materials on seeds. Common examples include biofertilizer slurry treatment and different priming solutions. Wet treatment enhances seed metabolic activity, improves germination, and promotes healthy seedling growth. It is widely used to increase seed vigor, improve nutrient availability, and support better crop establishment under field conditions.

11.3 Slurry Treatment

Slurry treatment is a seed treatment method in which chemicals, nutrients, or biological agents are mixed with water to prepare a uniform slurry that is applied to seeds. This technique ensures better coating and improves the attachment of treatment materials to the seed surface. Slurry treatment provides effective protection against pathogens and enhances the survival of beneficial microorganisms on seeds. It improves seed performance, supports better germination, and promotes healthy seedling establishment. This method is commonly used for biofertilizer and microbial seed treatments in sustainable agriculture.

12. Factors Affecting Seed Treatment Efficiency

The effectiveness of seed treatment depends on several factors that influence seed response, germination, and seedling growth. Proper selection of seed quality, treatment materials, and application methods is essential for achieving maximum benefits.

12.1 Seed Quality

High-quality seeds with good viability, genetic purity, and higher vigor respond more effectively to seed treatment. Healthy seeds show better germination, rapid emergence, and improved seedling growth after treatment.

12.2 Treatment Dose

The quantity of treatment material plays an important role in seed performance. An appropriate dose improves seed protection and growth, whereas excessive or insufficient doses may reduce germination, damage seeds, or decrease treatment effectiveness.

12.3 Moisture Content

Adequate moisture content is necessary for proper absorption and activation of seed treatment materials. Excess moisture may affect seed storage quality, while insufficient moisture can reduce the effectiveness of priming and microbial treatments.

12.4 Storage Conditions

Proper storage conditions such as suitable temperature, moisture level, and protection from pests are essential for maintaining the viability and effectiveness of treated seeds. Poor storage may reduce seed vigor and microbial activity.

12.5 Compatibility of Treatments

Chemical and biological seed treatments should be compatible to prevent harmful effects on beneficial microorganisms. Proper combination of treatments ensures effective disease protection while maintaining microbial activity and improving plant growth.

13. Advantages of Seed Treatment

Seed treatment is an important agricultural practice that improves seed performance, crop establishment, and productivity. It provides multiple benefits by protecting seeds from pathogens, enhancing physiological activity, and improving nutrient availability during early growth stages. Treated seeds show better germination, stronger seedlings, and improved resistance against environmental stresses.

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Major advantages include:

- Improves germination percentage**:** Enhances rapid and uniform seed emergence.
- Provides early disease protection: Protects seeds from seed-borne and soil-borne pathogens.
- Enhances seedling vigor: Promotes better root and shoot growth.
- Reduces seed requirement: Improves seed utilization through better establishment.
- Improves nutrient use efficiency: Enhances nutrient uptake and availability.
- Supports sustainable agriculture: Encourages the use of biological and eco-friendly inputs.
- Reduces pesticide requirement: Minimizes early crop losses and chemical applications.
- Increases crop productivity: Ensures healthy crop growth and higher yield potential.

14. Future Prospects of Seed Treatment Technology

The future of seed treatment technology will focus on sustainable, efficient, and precision-based approaches to improve seed performance and crop productivity. Advanced technologies will integrate biotechnology, nanotechnology, and digital tools to develop safer and more effective seed enhancement methods. Nano-enabled seed treatments will improve nutrient delivery and stress tolerance, while microbial consortia will provide multiple plant growth benefits through beneficial microorganisms. Smart seed coatings and biopolymer-based materials will enable controlled release of nutrients and bioagents. AI-based seed quality assessment and climate-resilient seed technologies will further support precision agriculture and sustainable crop production.

CONCLUSION

Seed treatment is a vital technology for achieving better germination, healthy crop establishment, and higher productivity. Different approaches such as chemical treatment, biological inoculation, seed priming, nutrient enrichment, organic treatment, and advanced coating technologies provide protection and enhance seed performance. Sustainable seed treatment methods using biofertilizers, beneficial microorganisms, and nanotechnology offer promising solutions for modern agriculture. Adoption of effective seed treatment practices can reduce crop failure, improve resource-use efficiency, and support climate-smart agricultural production.

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