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Seed Priming: A Technology for Sustainable Agriculture

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Abstract
Priming is the act of moistening and drying seeds which accelerate the pre-germinative metabolism, resulting in a quicker germination, faster seedling growth, and a greater yield under both optimum and stressful conditions. Compared to un-primed seeds, primed seeds germinate more quickly and uniformly because numerous enzyme activities, anti-oxidant defence mechanism, cellular repair processes, and synthesis of protein are activated. There are many methods for priming seeds, which can be generally categorized into conventional and advanced techniques. Priming of seeds is significantly influenced by a number of factors, including seed qualities, temperature, light, aeration, and the length of priming.

Keywords: Seed priming, Crop growth, germination

Introduction
Seed priming is a process wherein seeds are slightly moistened to the extent where metabolic changes leading to pre-germination begin without true germination. Then seeds are subjected to return to their original weight by re-drying for handling. It is a simple, inexpensive, and efficient technique that can enhance crop performance. Due to a shorter interval between sowing of seed and the synchronizing emergence of seedling, priming improved stand establishment, leading to better crop production. A decrease in lag duration of imbibition, activation of enzymes, and accumulation of metabolites that promote germination, metabolic segments repair, and improved osmotic adjustment are all factors that contribute to synchronized and uniform germination as aftermath of priming. Priming agents used for seeds include water, beneficial microorganisms, inorganic salts, micro- and macro-nutrients, low osmotic potential solutions, solid medium containing water and nutrients, hormones, and plant leaf extracts. X-rays, gamma rays, have shown to be effective physical techniques for priming of seeds because they are rapid, efficient, ecologically friendly, and guaranteed to boost yield in comparison to water and chemical based approaches (Farooq et al. 2019; Wang et al. 2022).

Techniques for priming seeds
There are a number of seed priming strategies, which in general can be divided into advanced and conventional methods. The conventional methods for seed priming include hydro-, on farm-, halo-, osmo-, solid matrix, nutri-, hormonal, chemical, plant extract, and bio-priming. The advanced methods for priming include use of nanoparticles and physical agents. Each of the approach used has been discussed in detail below.

Conventional Techniques: Hydro-priming: It entails the imbibition of seed with water over a specified time stretch depending upon the duration of protrusion of radical from seed coat. In this process, aeration is optional. Later on, surface drying of seeds is done till their original weight is attained. As sole water is utilized in this priming procedure, this priming method is a highly basic, economical, and sustainable approach. Field crop productivity is improved by this priming by promoting germination of seed and seedling emergence. The biggest drawback of hydro-priming is the potential for inconsistent seed hydration, which might result in uneven crop stand or seed germination.

On-farm seed priming: In this approach, seeds are saturated with water for entire night with no aeration and then surface-dried before being sown. It is a safe, affordable, efficient, and straightforward method that enhances germination of seeds, growth and productivity in a variety of crops.

Halo-priming: It is saturating the seeds in solutions made of inorganic salt. It is a simple and affordable agricultural technique that guarantees uniform germination, superior emergence and crop stand synchronization and higher crop production under a variety of environmental situations.

Osmo-priming: Osmo-priming involves regulation of water absorption by soaking seeds in aerated solution of sugar or polyethylene glycol with low osmotic potential. Later, the seeds are surface dried till they regain their original weight. Other names for osmo-priming are osmotic priming or osmo-conditioning. Under a number of environmental scenarios, osmo-priming enhances the germination metabolism in various crops.

Solid Matrix priming: Because osmotic agents are expensive and there are technical issues with aeration, solid matrix priming (matriconditioning), which regulates seed water intake, has been developed as an alternative to osmo-priming. Solid matrix priming involves combining and incubating seeds with a moist solid carrier for an appropriate time period. After which, seeds are extracted from carrier, and dried again. Solid media is used to replicate the natural imbibition process that occurs in the soil and helps seeds to hydrate gradually. Materials used as matrices should have precise physico-chemical properties, such as minimal water solubility and matrix potential, high surface area and water holding capacity and non-toxicity towards seeds, and potential of adherence to seed's surface, in order to successfully complete seed matrix priming.

Nutripriming: This process involves treating the seeds with macro- or micro-nutrient solutions. By nutritional seed priming, field crops' stand, yield, and bio-fortification of grains were all improved. To prevent toxicity of nutrients and seed loss that could hinder the germination of seed, the quantities of these nutrients must be optimized.

Hormonal priming: Seeds are treated with aerated solutions of phytohormones including abscisic acid, ascorbate, kinetin, and salicylic acid are used to saturate seeds during hormonal priming.

Chemical priming: The pre-sowing treatment of seeds with a variety of chemicals is known as chemical priming. Synthetic or natural compounds like putrescine, chitosan, ethanol, choline, paclobutrazol can be utilized to prime seeds for improvement of development, and endurance in plants. By pre-treating seeds with these compounds, plants become more resilient to diverse abiotic stresses and grow more as a result.

Plants extract priming: Plant growth can be successfully improved by treating seed with leaf extracts of plants, which improves germination and stand establishment. But, these are costly and occasionally hard to get.

Bio-priming: Seed biopriming integrates seed imbibition with bacterial inoculum. Biopriming with beneficial microbes may be advantageous to fight soil- and seed-borne diseases and increase the micronutrients' bioavailability to the crops, rate of germination,

uniformity of germination, plant development, yield characteristics, and resilience to various stresses (Marthandan et al. 2020; Raj & Raj 2019).

Physical techniques: Given the current problems of agricultural pollution brought on by the improper use of chemical compounds, physical methods of seed priming have a lot of promise and benefits compared with conventional approaches based on chemicals. These physical techniques are also accessible, safe, and eco-friendly. There is an increased likelihood that they will be used to enhance germination and vigor on large-scale.

Magneto-priming: Seed treatment using magnetic field can boost rate of germination, seedling biomass, and seed vigor as well as resilience to abiotic and biotic stresses. This improvement may be related to decreased superoxide radicle generation as well as increased antioxidant enzyme activities.

Ultraviolet irradiation priming: Exposure of seeds to ultraviolet radiation can stimulate germination, growth and promote certain favourable reactions, such as increasing the amount of soluble phenols as well as the potential to reduce environmental stressors by increasing free radical scavenging capabilities.

Gamma-rays priming: An early dormancy break, improved germination, and the ability to withstand daily stress factors like changes in temperature and intensity of light in growth conditions are all results of seed interaction with gamma-rays at doses of less than 100 Gy. This is brought on by advantageous modifications in the hormonal signalling network and activation of the anti-oxidative potential.

Ultrasound priming: Priming with ultrasound waves with frequency ranging between 20 to 100 kHz is a revolutionary physical technique. Ultrasonic waves have seen a lot of use recently as a highly effective method for breaking dormancy of seeds and enhancing germination properties. This method stands out from other seed pre-treatment techniques since it is quick, energy-efficient, and sustainable (Goussous et al. 2010).

Microwave priming: Microwaves in seed technology can be used as a promising approach for seed priming. This method is beneficial for growth of seedling and accumulation of biomass (Dutta 2018).

Nano-priming: It is a novel approach for priming of seeds which uses nanoparticles for priming. It aids in enhancing germination of seeds, growth of seedling, and productivity by boosting the field crops' defence response and improving tolerance mechanism against abiotic and biotic stresses. In comparison to all previous seed priming techniques, nano-priming is a much more effective strategy. Additionally, this might be among the greatest ways to address dormancy issues and boost seed germination in forest species, suggesting that nano-priming could be helpful for forest restoration efforts (Nile et al. 2022).

Factors influencing seed priming

Numerous abiotic and biotic factors have a significant impact on seed priming.

- Aeration
- Light
- Temperature
- Time
- Type, dose and frequency of radiation and magnetic field
- Genotype of plant
- Seed quality

Benefits of priming

- Hastened and synchronized germination
- Facilitates improved stand establishment
- Maintain plant growth

- Tolerance to stress conditions
- Increase crop competitiveness against weeds
- Improve yield related parameters and yield
- Influence nutrient uptake
- Better root system
- Enhanced photo-assimilation
- Increase nutrient content in seed

Limitations of seed priming

Utilizing physical techniques or nanoparticles for priming of seeds yet necessitates comprehensive studies to determine the precise impacts of these approaches on plants and figure out the most effective dose, dosing rate, and exposure duration, which undoubtedly varies with crop, and environment conditions.

Another issue is from the inherent diversity of priming, which makes it difficult to predict which priming protocols would boost seed germination performance. Inappropriate priming conditions can also make seedlings more susceptible to stress by causing the breakdown of protective proteins.

Conclusion

Priming is an efficacious and environmentally secure approach which can be readily employed by farmers with few resources and has numerous advantages for the farmers. In fact, it may be regarded as a useful tactic for enhancing stand establishment in regions with unfavorable agro-climatic conditions with increased yield, tolerance to stressful situations, resistance to diseases, , and efficiency of water use. So seed priming might be considered as a sustainable farming method.

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