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# Influence of different seed treatments in enhancing seed germination of vegetable and field crops

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## Abstract
Seed is a fundamental and essential input for sustained growth in agricultural productivity and production. A high germination rate is necessary for both fast and consistent seed germination, which when paired with the best agrotechnical events, ensures healthy growth. Rapid and uniform crop emergence is an essential prerequisite to increase yield, quality and ultimately profits. Various physiological and physical seed invigoration techniques are used to lower the emergence time, achieve uniform emergence and a healthy crop stand in many horticultural and field crops. These physical and physiological seed enhancement techniques allow the poor seeds to catch up with good ones during the pre-sprouting germination events. It reduces the stress during germination, which eventually leads to the establishment of seedlings successfully in an abiotic stress environment.

**Keywords:** Seed, germination, quality, enhancement, growth

## Introduction
Seed plays vital role in horticulture since ancient times. It is the first determinant of the future plant development and the most promising factor for successful production.Vigorous and high-quality seeds will secure the advantages after the application of other means of production such as watering or fertilization. Optimum seed germination is a main factor in good crop stand establishment as seed is an essential factor in crop production. At present, due to different environmental and abiotic stress, the rate of seed germination, emergence, and vigour of seedling has been unfavorably affected, which eventually results in poor crop yield. To enhance the seed germination process numerous physiological and non-physiological techniques are accessible for enhancing seed performance as well as to conflict environmental limitations. Seed enhancement concerns with the post-harvest treatments that improves germination and seedling growth which promote the delivery of seeds and other materials required at the time of sowing (Taylor *et al*. 1998) [54]. Direct seed sowing initiates the cultivation cycle for majority of vegetable crops and field crops; as a result, consistent germination and high seedling vigour are critical components of successful crop establishment and, ultimately, crop performance (Damalas *et al*. 2019) [10]. Quick germination and emergence of seedlings are necessary for successful crop establishment, importance of good and high crop establishment is renowned by researchers and as well as by farmers and they are prime challenges in successful crop production (Chivasa *et al*. 1998 and Murungu *et al*. 2004) [8, 29]. The principal reasons for the successful crop stand are high germination percentage and good vigor of seedlings. Current deliberate approaches are although mandatory for sustainable development of crops with the purpose of increasing demand in both domestic and export market (Soubhagya Behera, 2016) [52].

## Seed Enhancement Techniques
### Seed fortification
A pre hydration technique which deals with the soaking of seeds in water or a diluted solution of bioactive substances such as vitamins, growth regulators, micronutrients, and seed protectants. Depending on the crop type, the seeds are left to absorb for 6–24 hours after being combined with a nutrient solution equal to one-third of the seed volume. It is recommended to dry the imbibed seeds in shade. The effectiveness of treatment can be further increased by the use of botanicals in different crops (Vadivelu *et al*. 2001) [58]. E.g., In cow pea, $ZnSO_4+MnSO_4+Na_2MO_4$ is used @ 100 mg/kg for 3 hours. Seed fortification improves seed

germination and vigour due to addition of nutrients. Chemical dormancy could be overcome by the bioactive substances used in fortification. Seed storability is increased by the reduction of lipid peroxidation achieved by fortification with $FeSO_4$. Pre sowing treatment as seed fortification with 1% Mg $SO_4$ increases the plant growth, seed quality and seed yield of cluster bean (Umesha and Channakeshava, 2015) [57]. In maize, paddy and ragi the spent wash and cow urine increased the seed germination, field emergence and seedling vigour (Vishwanath *et al*. 2015) [59].

**Seed infusion**

It is the technique of impregnating seeds with bioactive chemicals using organic solvents rather than water. Seed infusion is a highly suitable approach for seeds that suffer from soaking or seed coat injury since it helps to prevent the damage caused to the seeds by soaking in water. Seeds are immersed in solvent for a duration of 5-24h depending upon species. Bio active like plant growth regulators, macro and micronutrients, fungicide, bactericide, herbicides etc. and organic solvents like dichloromethane, acetone, petroleum ether and ethanol etc. are used.

**Seed priming**

It is a pre-sowing procedure where seeds are immersed in an osmotic solution, which permits water absorption and the initial stages of germination but prevents the protrusion of radicles through the seed coat. It was Heydacker (1973) who initially suggested seed priming. By enhancing germination, seed priming breaks dormancy, promotes early flowering and maturity, and increases crop resistance to abiotic stresses. Seed priming may be recognised as a better solution against problems related to germination when seeds are grown under unfavourable conditions. The basic idea behind it is controlled imbibition, which is done to a level that allows pre germination metabolism to proceed, but prevents actual emergence of radicle (Bradford, 1986) [6]. Seed priming controls hydration that starts the metabolic process during the early stages of germination before the protrusion of radical (Lutts *et al*. 2016) [23]. Seed priming is a cost-effective technique to ensure uniform emergence and high vigourity of seeds which is leading to better crop establishment and yield. This technique, which is simple, efficient, and low-cost, uses seeds that have been treated with various chemicals or growth regulators to partially hydrate them to the point where pre-germination metabolic activities begin without actual germination, and then the seeds are dried again until their dry weight is restored.Seed vigor is the main factor for determining seed quality, in the context of effective crop stand establishment. Hence seed enhancement of seed vigor has been a major area of interest for researchers, owing to its high industrial and economic implications. The most promising enhancement technique for improving the rate and uniformity of plant stand is seed priming (Pandey *et al*. 2017) [34]. Seed priming with sodium molybdate @ 500 ppm + seed coating with *Trichoderma harzianum* @ 15 g/kg seed on pea variety KPMR-522 (Jay) significantly improved the seeds with percent germination improvement, shoot length, seedling dry weight and seed vigour index (Singh *et al*. 2017) [49].

**Advantages of seed priming**

- Seed priming enhances seed germination and seedling vigour by increasing biochemical and metabolic processes which occur during controlled hydration and subsequent drying to its original moisture content.
- It is accountable for crop establishment that is rapid and more uniform.
- It reduces the time between seed germination and seed sowing.
- It is found to be reducing or eliminating the seed born as well as soil born plant pathogens.
- Because of priming crops can perform better against weed infestation and under biotic and abiotic stresses.

**Types of seed priming**

Seed priming techniques includes hydropriming, halopriming, osmo-priming, hormonal priming, solid matrix priming and biopriming. Primed seeds are more useful because of various advantages such as uniformity, early and faster appearance (Musa *et al*. 1999) [31], germination in broad range of temperature, crop establishment, efficient use of water and allowing germination in dormant seeds by increasing metabolic events (Soleimanzadeh, 2013) [51].

**Hydropriming**

Hydropriming is the process of soaking seeds in water prior to sowing and air drying of the seeds may or may not be part of this process.Hydro-priming is a very essential technique which results in fast germination, enhancing seed growth and accomplishing uniform stand establishment in numerous crops (Adebisi *et al*. 2013) [1]. Okra seedlings grown from seeds that are primed for 24 hours had the greatest mean stem length and diameter as compared to other durations (6, 12 or 36 hours) and control. The positive effect of hydro-priming may be due to maintenance of tissue water content, rise in antioxidant activities and carbohydrate metabolism (Farooq *et al*. 2008) [12]. Hydro-priming of bean seeds in water for 7-14 hours can promote the plant performance (Ghassemi-Golezani *et al*. 2010) [13]. The mean germination time, seed germination, and seedling vigor are significantly improved by the 12-hour hydro-priming approach and the 24-hour solid matrix priming using calcium aluminum silicate. Seed soaking in hot water (45 ºC) for 5 minutes in bitter gourd effectively enhanced germination percentage, seedling vigour, other growth parameters such as primary branch length, shoot length and total number of fruits per plant (Tania *et al*. 2019) [53].

**Halopriming**

Halopriming refers to the process of soaking of seeds in inorganic salt solution such as NaCl, $KNO_3$, CaCl, KCl, $KH_2PO_4$, $CaSO_4$. Numerous studies have shown that, in salt-affected soil, halo-priming dramatically increases seed germination, seedling emergence and establishment, and final crop production (Khan *et al*. 2009) [6]. Less vigorous cabbage seeds exhibited improved germination and vigor with priming with 2% $KNO_3$ and 2% $KH_2PO_4$. In mung beans, early seed treatment with a low dose of NaCl reduces the adverse effects of NaCl stress (Saha *et al*. 2010) [43]. Maize seeds halo-primed with 1% $KH_2PO_4$ for 6 hours seeds recorded higher seed yield and resultant seed quality in contrast to other treatments (soaking in water for 6 hours, soaking in $KH_2PO_4$ 1% for 6 h, soaking in $KNO_3$ 3% for 6 h, soaking in $CaCl_2$ for 6 h, soaking in $ZnSO_4$ 1% for 6 h and soaking in KCl 1% for 6 h) and control (Narayan *et al*. 2019) [32].

## Osmopriming

Osmotic priming of seeds also known as osmo-priming or osmo-conditioning expresses incubation of seeds with aerated solutions of low water potential that are rinsed off afterwards. Polyethylene glycol (PEG), glycerol, sorbitol or mannitol are used as osmoticants to generate low water potential solutions.Osmo priming basically exposes seeds to a low water potential to limit the amount and extent of imbibition. Osmo priming is related to an extended early imbibition of seeds that sets in motion a gradual progression of numerous pre-germinative metabolic activities. In wild rye (*Leymus chinensis* L.) seed priming with 30% PEG for 24 hours resulted in cell activity of peroxidase and a rapid increase in the respiratory intensity which were associated with an increase in germination and vigour (Jie *et al*. 2002) [18]. Under salt stress conditions, priming of chickpea seeds with water and 2–4% mannitol lengthens and increases the biomass of roots and shoots of seedlings as compared to the non-primed control (Kaur *et al*. 2005) [20]. Cowpea seeds primed with 1% $KNO_3$ for 6, 8 or 10 hours were superior to unprimed treatments in terms of dry matter accumulation, plant height, and seed emergence (Singh *et al*. 2014) [50]. Osmo priming with a 50 mm NaCl concentration for a duration of 24 hours had a positive effect on seed germination in soybean under salinity conditions of 150 Mm of NaCl (Arini and Wisuda, 2021) [2].

## Hormonal priming

Thisprocess involves the soaking of seeds in a solution of phytochemicals and plant growth regulators, including auxins (IAA, IBA's and NAA) as well as gibberellins, cytokinins, brassinosteroids and abscisic acids to improve plant growth and development. During the preparation of hormones, seeds absorb plant growth controls, eventually having a straight effect on seed metabolism. $KNO_3$ increases yield, fruit size and enhances the traits of garden and vegetable crops. Priming of tomato seeds with $GA_3$ in Utkal Kumari the germination was increased by 30.56%. Soybean seeds primed with gibberellic acid @ 100 ppm and 150 ppm can positively affected the germination rate and shorten the mean germination time (Erol and Arslanoglu, 2022) [11].

## Solid matrix priming

In solid matrix priming or matric conditioning, solid or semi-solid medium is used in place of liquid medium. (Copeland and McDonald, 1995) [9]. When seeds go through this procedure, the soil's natural imbibition mechanism is triggered, causing the seeds to hydrate gradually. The method involves combining seeds with a solid or semisolid substance and a certain volume of water. Examples of matrix carriers are calcinated clay, vermiculite, peat moss, sand, micro-gel, etc. For rapeseed, the most effective treatment to increase overall germination and seedling emergence was solid matrix priming with animal compost for 12 and 24 hours. Solid matrix priming was beneficial in enhancing seeds of soybean through improvement in percent seed germination (Mercado and Fernandez, 2002) [27]. *Trichoderma viride* in combination with solid matrix priming can effectively increase seedling emergence and productivity in okra plants grown at low temperatures (Pandita *et al*. 2010) [35].

## Bio priming

A biological seed treatment method that combines seed hydration (a physiological component of disease management) and seed inoculation (a biological component of disease control) with helpful organisms to protect seed using beneficial bacteria and fungi. Beneficial microorganisms are used like *Trichoderma* spp., *Pseudomonas* spp. and *Bacillus* spp. which are known to enhance biotic/abiotic resistance and improve crop performance. Bio priming with *Trichoderma harzianum*/ *Pseudomonas fluorescens*/ *Trichoderma viride* for 12 hours enhanced germination, seedling length and seedling vigour index in tomato, brinjal, onion and chilli (Jaiman *et al*. 2020) [17]. In wheat, increasing the germination percentage of seed through biopriming with several salinity-tolerant isolates of *Trichoderma* were effective (Rawat *et al*. 2011) [39]. Application of plant growth promoting Rhizobacteria enhances the seed germination percentage in chickpea under saline conditions and also improves the root length, shoot length and dry matter content (Mishra *et al*. 2010) [28]. Different types of seed priming in vegetable and field crops is shown in Table 1.

**Table 1:** Seed priming in vegetables and field crops

| Sr. No. | Crops | Types of priming | Crop response | References |
|---|---|---|---|---|
| 1. | Kale, Carrot and Onion | Biopriming (*Bacillus subtilis* and *Serratia nematodiphila*) | Enhanced seed germination, seed emergence and plant growth | Murunde *et al*. 2018 [30] |
| 2. | Wheat | Biopriming (*Trichodermaharzianum*) | Increased plant height, chlorophyll content and the root length | Meena *et al*. 2016 [25] |
| 3. | Chilli pepper | Halo priming ($KNO_3$)25ppm | Enhanced germination and seedling emergence | Robledo, 2020 [40] |
| 4. | Cucumber | Hydro priming ($CaCl_2$) | Changes in physiological total seedling, dry weight and seedling vigour index | Pandey *et al*. 2017 [34] |
| 5. | Bitter gourd | Hydro priming | Enhanced plant performance and helps to maintain tissue water content | Saini *et al*. 2017 [44] |
| 6. | Soybean | Biopriming (*Pseudomonas fluorescens* and *Trichoderma harzianum*) | Improvement in plant growth, seed yield and quality of crop | Sharma *et al*. 2018 [46] |
| 7. | French bean | Biopriming (PGPR-1, *Rhizobium* strain B1 and *Trichodermaviride*) | Enhanced plant growth, pod yield, seed yield, seed vigour, quality of seed and reduces disease incidence | Negi *et al*. 2019 [33] |
| 8. | Pepper | Hormonal priming (NAA and Gibberellic acid) | Caused significant improving effect on seed germination and plant growth | Tombegavani *et al*. 2020 [56] |
| 9. | Spinach | Halo priming with $ZnSO_4$.7H2O | Early seedling growth and improves function against the biotic and abiotic stress factors. | Chen *et al*. 2011 [7] |
| 10. | Asparagus | NaCl, $KNO_3$, $MgSO_4$ | Increased the speed of seedling growth and germination rate | Bittencourt *et al*. 2004 [5] |
| 11. | Chilli | Osmo priming | Consistent germination of seed | Lanteri *et al*. 2009 [22] |

**Seed coating**

The process of applying a coating material to seeds to improve their performance and placement without changing their shape is known as seed coating. Seed coating in broad sense includes seed film coating, seed coloring and seed pelleting. It is a mechanism of providing plant growth promoting substances with seeds to improve seed quality (Rocha *et al*. 2019) [41]. The goal of seed coating is to improve the handling, placement, storage and planting characteristics of seeds that can be largely enhanced by altering the shape of seeds or placing the chemicals on seed coat that regulate and improves the germination. Seed coatings are applied to the seed that does not obscure its shape. It may be fungicidal, micronutrients and microbiological treatments. In cowpea, seed coating with *Pseudomonas libanensis* significantly enhanced plant biomass and seed yield (Ma *et al*. 2019) [24]. Seed coating with co application of vermicompost and plant based protein showed an increase in seedling dry weight (40-60%) and seedling vigour indexes were higher than control for red clover and ryegrass (Qui *et al*. 2020) [38].

**Advantages of seed coating**

- Improves the efficiency of production products, allowing on excellent covering and adhesion of the active ingredients on the seed.
- Enhances the sowing process
- Protection of the seeds against mechanical damages.
- It helps to protect the seeds stored under high moisture conditions.

**Polymer seed coating**

Application of chemical and physical substances to the seed to improve its physical, physiological, biochemical and health properties. The primary benefit of coating is that the ingredient for seed enhancement is applied directly to the seed.Material used as polymer are natural dyes and synthetic dyes which includes beetroot, opuntia, turmeric marigold, copper sulphate, congo red, rhodomine–B and potassium permanganate. In tomato seed treated with Vitavax Powder @ 2 g + polymer coating @ 20 ml/kg of seed enhanced seed quality attributes and storability (Harish *et al*. 2014) [15]. Polymer seed coating with Polyvinyl pyrrolidine @ 4ml/kg seeds played an important role in maintaining seed quality during storage which was manifested in improving plant growth, seed yield attributing parameters and seed yield and this was followed by seed coating with Methyl cellulose @ 4 ml/kg seeds of cowpea (Samal *et al*. 2021) [6]. In wheat, seed coating with polycot @ 3 ml/kg + carbaryl @ 3 g/kg seed + neem oil @ 10 ml/kg seeds significantly increased the seed quality parameters, growth, total dry matter production, yield attributes and yield over control (Tiwari *et al*. 2015) [55].

**Film coating**

Film coating is the process of applying a thin layer of a polymeric material on a seed without appreciably changing its size, weight, or form or impairing its functionality. When a thin layer of coating material is applied to a seed, it not only enhances its ballistic qualities but also serves as a vehicle for the application of plant growth stimulants and seed protectants (fungicides, insecticides, hormones, micronutrients, etc.) directly to the seed surface, where they are most effective for germination. Additionally, the coating's slow release of active ingredients prolongs the time that the active ingredients are available to developing seedlings. The colouring agent, which is typically utilized in a film coating, also increases a seed brand's market value and gives it a unique identity. Numerous branded polymers, such as Seedworx and Ezi-cote are available in the market for coating seeds. These polymers are used to coat vegetable seeds that have undergone testing for various valuable attributes, including appearance, dust reduction, flowability and plantability. In addition to making handling seeds easier, coatings are frequently put to commercial seed lots to include active ingredients for seed protection through targeted delivery and to improve germination by the application of stimulators (Pedrini *et al*. 2018) [37].

**Seed pelleting**

Applying essential materials in a way that impacts the seed or soil at the seed-soil interference stage is known as seed pelleting. Pelleting is the process of applying a layer of inert material that may obscure the seed's original shape and size, resulting in a significant weight increase and better palatability. These treatments are used to improve handling, precision placement and assimilation of beneficial microorganisms. Seed pelleting is typically used in seeds that are light in weight and irregular in shape. Pelleting is most commonly used commercially for sugar beet, carrot, onion, lettuce and tomato. Clay, limestone, calcium carbonate, vermiculate, turmeric leaf powder, gum Arabic, gelatin and methyl cellulose are some of the materials used in pellet production. In onion, seeds pelleted with *Azadirechtaindica* leaf powder + clay and *Melia azedarach* leaf powder + clay showed significant effects for enhancing bulb quality, growth, quality and yield of bulb crop raised through direct seeding in last week of October (Panwar *et al*. 2021) [36]. Seed pelleting of fennel seeds with Captan @ 3 g/kg + Imidachloprid followed by neem leaf powder (100 g/kg seeds) showed significant increase in standard germination, speed of emergence, seedling length, seedling dry weight and vigour indices (Singh *et al*. 2020) [47]. Pelleting of fresh seeds of Cowpea with *Rhizobium* liquid culture improves seed quality parameters considerably (Singh *et al*. 2018) [48]. Seed pelleting with 0.3 w/v of hydroxyethyl methylcellulose (MHEC) as a binder with 40 g calcium sulphate / 110 g of seeds showed higher germination and better seed quality in hybrid cucumber variety YokKaow (Kangsopa *et al*. 2023) [19].

**Conclusion**

Seed enhancement techniques improves the germination rate of seeds, quality and vigour of seeds and also enhances crop yield accompanied by efficient use of resources. Seed enhancement techniques evolves different defence mechanism in seeds against biotic and abiotic stresses. A lot of seed enhancement techniques comprises of priming, seed coating and seed pelleting etc. that are used to increase the germination and performance of seed. These enhancement techniques are used to improve and upgrade the quality of seed. These different seed enhancement techniques either directly or indirectly influences seed germination, rapid growth, tolerance against biotic and abiotic stresses, yield and other growth parameters.

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