

REVIEW ARTICLE

SEED PRIMING: A MULTIFACETED AND COST-EFFECTIVE TECHNIQUE TO IMPROVE CROP PRODUCTION

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ABSTRACT

Seed priming is a cost-effective technique which involves prior seed exposure to an abiotic stress that makes the seed more resistant to future lethal exposure. Seed priming stimulates pre-germination metabolic processes and makes the seed ready for sprouting. It helps to up regulate the antioxidant enzyme activities and repairs membrane damage. These changes promote seed vigour and emergence under abiotic stress. This article aims to review the different priming processes as well as the physiological, biochemical and molecular changes induced by priming that lead to synchronized seed germination. Plants' responses to some priming agents under abiotic stress have been reported based on recent investigations.

Keywords: Seed priming techniques, seed germination, abiotic stress, crop productivity.

1. INTRODUCTION

In spite of encountering multiple biotic and abiotic obstacles, plants being sessile, cannot escape such unfavourable conditions. This results in their retarded growth and productivity. Crop production is highly dependent on the use of high quality seeds. Rapid germination and sprouting of seeds help in determination of potential crop yield. Longevity of crops depends upon seed quality and vigour. Therefore, various seed priming or seed invigoration techniques can be adopted for improving crop productivity worldwide. Seed priming refers to pre-sowing treatments in water or in osmotic solution that allows seed to imbibe water or an osmotic solution to progress towards germination whereas seed invigoration not only helps to hasten germination and synchronize emergence but also enhances seed storability. Seed priming is an effective seed invigoration method adopted during the last twenty years to improve agronomic productivity worldwide. The controlled process of hydration that involves exposure of seeds to low water potentials which permits pre-germinative physiological and biochemical alterations resulting in better stand establishment and yield is called seed priming (1).

Several literatures reveal that seed priming advances germination and improves seed quality characters which lead to better establishment and increase crop yield in diverse environments. Seed priming is also known to alleviate ageing-induced deleterious events by improving seed performance (2). Seed priming has been employed for a wide range of crops expecting their increased crop stand and output. The beneficial effects have also been

demonstrated for many food crops like sweet corn, wheat, mungbean, barley, lentil, cucumber, etc. (3). Priming resulted in better establishment, growth, earlier flowering, increased seed tolerance to adverse environment in maize (4). This review aims to focus on the different priming processes as well as the physiochemical and molecular changes induced by priming that lead to synchronized seed germination promoting better crop stand and yield.

2. PRIMING TECHNIQUES

Various priming techniques have been developed with an intention to boost crop production on a large scale which is necessary for feeding the increasing population worldwide. Windauer *et al.* (5) proposed different seed invigoration and seed priming techniques, viz., hardening, osmohardening, hydropriming, hormonal priming etc.

Hydropriming refers to the soaking of seeds in water prior to seed sowing. Hydropriming of wheat kernels has been reported to improve seed germination rate under saline conditions (6). Using hydropriming technique reported improved seed germination and seedling growth in wheat (*Triticum aestivum*) seeds under both saline and drought stressed conditions (7). Dastanpoor *et al.* (8) also reported that hydropriming improved germination percentage and mean germination time under varying temperature conditions in common sage (*Salvia officinalis*). Thus, this technique not only enhances seed germination and seedling emergence under saline condition but also has beneficial enzyme stimulatory activity that is essential for quick seed sprouting.

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Halopriming refers to the treatment of seeds with salt in order to improve germination and decrease salt intolerance. Numerous studies have shown that halopriming of seeds resulted in improved seedling germination, growth, establishment and productivity. Seed treatment with CaCl_2 or KNO_3 resulted in improved accumulation of amino acids and proteins in pigeon pea (*Cajanus cajan*) (9), improved activity of amylases and proteases in germinating sorghum (*Sorghum bicolor*) seeds under salt stress. Priming of seeds with NaCl and KCl was effective in removal of deleterious effects of salts in wheat (*Triticum aestivum*) seedlings (10). NaCl primed hot pepper (*Capsicum annuum*) seeds showed better performance than non-primed seeds at salinity levels 3, 6 and 9 dSm^{-1} by exhibiting improved seedling vigour and stand establishment under salt-stressed conditions (11). Preconditioning of mungbean (*Vigna radiata*), pigeon pea (*Cajanus cajan*) and blackgram (*Vigna mungo*) seeds with sublethal dose of NaCl (50mM) has also been reported to show improved seedling vigour and growth upon germination under lethal levels of NaCl (50mM, 100mM, 150mM) (12,13). Evidences of reduced DNA damage and improved respiratory cycle in NaCl pretreated mungbean seedlings have also been reported from our laboratory (14,15).

Hormonal priming is the pretreatment of seeds with different plant growth regulators i.e. salicylic acid, kinetin etc., which promotes growth and development of seedlings (16). Ashraf *et al.* (3) stated that gibberellic acid pretreated seeds showed better vegetative growth in wheat (*Triticum aestivum*), increased photosynthetic activity under salinity. Hussein *et al.* (17) speculated that salicylic acid pretreated maize (*Zea mays*) plants showed better growth performance under saline conditions.

Osmopriming technique involves seeds soaking of seeds in sugar solution, polyethylene glycol, glycerol, sorbitol or mannitol followed by air drying before sowing. Rehman *et al.* (18) reported that priming of seeds with low concentration boric acid that significantly increased seedling growth and parameters. Seedling growth in wheat was also found to improve by osmopriming (19).

3. PHYSIOCHEMICAL AND MOLECULAR ALTERATIONS INDUCED BY SEED PRIMING

Seed priming triggers pre-germination metabolic processes and prepares seeds for radicle protrusion (20). It lowers resistance provided by the endosperm during water uptake, repairs membrane damage and eliminates germination inhibitors leading to the development of immature embryos (21,22,23). The imbibition phase and lag phase of

water absorption are decreased when the primed seeds are allowed to germinate (11). Consequently, the seedlings develop faster, grow more vigorously, and perform better under adverse conditions (24) which is exhibited from their synchronized germination with certain physiological, biochemical, cellular and molecular changes (25,26,27). In addition, priming may generate moderate abiotic stress during procedural steps (28) which becomes beneficial for the seeds to withstand future abiotic stresses during seedling establishment (29). Improved stress tolerance of germinating seeds is achieved via two strategies. Firstly, seed priming triggers enhanced energy metabolism, early reserve mobilization, embryo expansion, and endosperm weakening (30,31,32) which hasten the transition of quiescent dry seeds into a germinating state. Secondly, priming generates an abiotic stress that represses radicle emergence, but stimulates cross-tolerance. These generate a 'memory response' in seeds, which can be recalled upon by the primed seeds later during stress exposure mediating greater stress tolerance in germinating primed seeds (33,34). Priming increases the activity of enzymes involved in metabolism of carbohydrates (α and β amylases), proteins (proteases) and lipids mobilization (isocitrate lyase) that are crucial for mobilization of stored reserves (25). Plants overcome salinity-induced osmotic effects through accumulation of inorganic ions or by synthesis of compatible solutes. Accumulation of these organic solutes is an essential mechanism of salt tolerance in plants that causes reduction of cell osmotic potential and allows an osmotic adjustment to stress (35). Seed priming ameliorates the adverse effects of salinity stress by promoting K^+ and Ca^{2+} accumulation and decreasing Na^+ and Cl^- accumulation in plants (10,36,37). This decreases the osmotic potential of plant and increases water uptake (38).

The antioxidant system is one of the major defense systems in seeds. Cells contain many enzymatic and non-enzymatic antioxidants that help in the scavenging of ROS and the protection of the seed (39,40). Priming treatments increase the activities of antioxidant enzymes, viz., catalase, peroxidase and superoxide dismutase (41,42) and antioxidant compounds, viz., ascorbic acid and reduced glutathione (43,44). These changes can optimize defense mechanisms during seed germination through a decrease in H_2O_2 production (41). In addition, multiple antioxidant enzymes are involved in the scavenging of ROS (45). Seed priming strategies decrease malondialdehyde accumulation under salt stress condition in *Allium fistulosum* seedlings (25,46).

Priming of seeds promote changes in cell division patterns, plasma membrane fluidity, induces stress-related proteins viz. heat-shock proteins and late embryogenesis abundant proteins which brings about changes in transcriptome as well as proteome, proton pump activity (47-49) and changes antioxidant enzyme activities (39). Enhanced progress towards germination in primed seeds is associated with an increased protein synthesis capacity, post-translational processing ability and targeted proteolysis (49). Earlier reports reveal that priming permits early DNA repair and replication, *de novo* synthesis of RNA and protein and reduces the leakage of metabolites. Many germination related genes are up-regulated during priming (42). Seed priming reprograms gene expression for antioxidant synthesis and defends the cells against oxidative damage and lipid peroxidation (49,50).

4. CONCLUSION

Seed priming is a commercially used technique developed mainly to hasten germination and minimize adverse environmental effects. It is a cost-effective technique that helps to solve germination related problems effectively especially under unfavourable conditions. Many priming techniques have been evolved now-a-days which are being utilized in many crops. Thus, seed priming is a process that improves seed performance under abiotically stressed conditions. Seed priming prior to germination helps to strengthen the defense mechanisms in seeds on exposure to lethal levels of salinity stress. Seeds develop a kind of 'memory response' that provokes greater stress tolerance of germinating primed seeds. Little work has been done adopting priming techniques in a limited variety of plants; further research needs to be carried out to standardize the concentration of priming agents that can successfully enhance seed germination and seedling growth of crops under abiotic stress. Future research should focus on understanding the basis of salt tolerance in primed seeds in relation to physiological, molecular, and metabolic pathway alterations.

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