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Seed Priming for Enhancing the Cultivation of wheat (*Triticum aestivum* L.) in Response to Abiotic Stress Factors

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Stress induces a diminishment in essential physiological processes that are vital for the growth and reproductive success of plants. Stressors can be categorized into biotic and abiotic factors. Wheat (*Triticum aestivum* L.) constitutes one of the primary crops cultivated as a food source globally (Ashraf *et al.*,2007). Drought stress can be characterized as an inadequate supply of water necessary for optimal growth and reproductive functions in plants. Salt stress can be delineated as an elevation in soluble salts beyond optimal levels, which decreases plant size and overall growth. The deleterious effects induced by salt stress are not attributable to a singular factor; rather, they reflect the cumulative impact of multiple metabolic pathways that are altered in response to elevated salt concentrations (Ashraf et al., 2012). Heat stress is characterized by an increase in temperature that surpasses the optimal range for plant development. This form of stress engenders irreversible alterations, such as stunted growth and a reduction in the plant's lifespan.

Seed priming is a straightforward, secure, economical, and efficient method for boosting seed germination, early seedling growth, and yield in both stressed and non-stressed environments (Sedghi *et al*., 2014). A seed preparation method known as "seed priming" involves pre-soaking seeds in a particular solution before planting, which permits partial hydration but prevents germination and causes them to redry to their initial moisture content. Seed priming constitutes a pre-sowing treatment of seeds that entails a controlled partial hydration process, wherein the emergence of the radical is deliberately prevented through desiccation before sowing. Empirical evidence supports that seed priming represents a cost-effective methodology that significantly enhances the growth attributes of cereal crops (Farooq *et al*., 2009). The pre-sowing soaking of seeds can markedly improve the rate of growth and the establishment of seedlings. This study aims to understand the function of priming in environments characterized by heat stress, dryness, and salt, specifically hydro priming, halo priming, and osmo-priming.

The impact of abiotic stress on crop development and growth

Plant growth, productivity, and yield are negatively impacted by abiotic stressors, which can occur singly or in combination and result in physical, morphological, biochemical, and cellular alterations. Many different types of plants, including crop plants, suffer significant cell damage from the main abiotic stresses of heat, drought, salinity, and cold (Figure 1). Drought or water stress is an important global issue for agricultural productivity. Increased electrolyte leakage may result from excessive wilting, which alters the ratio of membrane lipids.

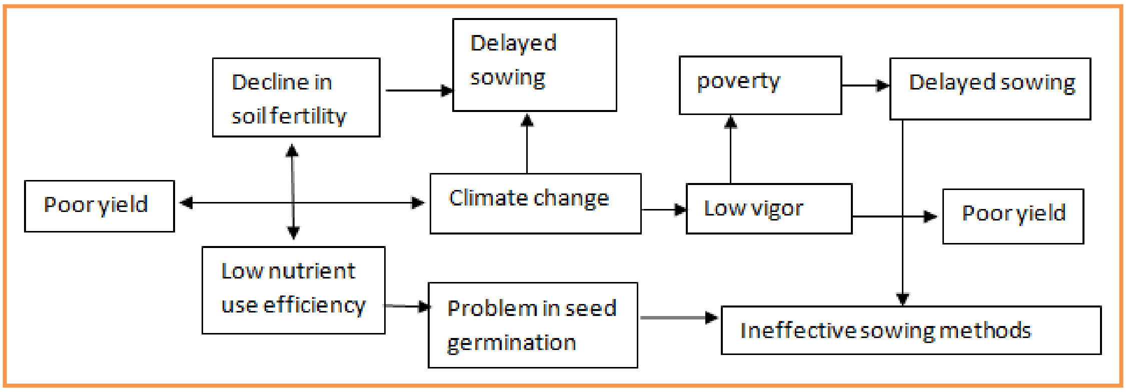

Figure 1: Direct and indirect causes of low productivity of field crops

Abiotic stress during seed germination causes physiological problems, such as a decrease in the seed's ability to absorb water because of the germination medium's low water potential. Fewer and smaller plants are produced by slow or aberrant growth and emergence, making them more vulnerable to different abiotic stressors. Slow imbibition rates can result in several metabolic changes in addition to structural changes at different levels of seed organization. These changes include up- or down-regulation of enzyme activities, disruption of inorganic nutrient mobility to developing tissues, disruption of N metabolism, imbalances in plant growth regulator levels, decreased hydrolysis and utilization of food reserves, and accumulation of compatible osmotic substances like soluble sugars, free proline, and soluble proteins. Due to the ionic toxicity of Na^+ and Cl^-, the salinity of the soil decreases the germination dynamics of plant seeds and decreases the water availability of plant roots through negative (low) osmotic potential (Arun M N. *et al.*, 2022). Heat stress is one of the more severe types of abiotic stress that affects plant cell physiology and metabolism separately. High temperatures have been linked to several physiological ailments, including fruit damage, root and shoot growth suppression, leaf abscission and senescence, and scorching of leaves and stems, all of which reduce plant output. The most vulnerable phases of crop species to salinity stress are seed germination and the early stages of seedling development. Plant growth and final crop output are decreased by salinity, which also slows down, slows down and increases the dispersion of germination phenology. Therefore, the likelihood of producing a good crop under stress will increase if the effects of abiotic stress can be lessened early on (Ibrahim, E. A., 2016).

Importance of seed priming in the alleviation of salt stress

By suppressing pre-germination metabolic activities, seed priming suppresses seed-borne pathogens and increases germination rate and nutrient uptake. In field crops, seed priming offers the advantages of improved and consistent germination, higher yield, and high vigour. The primed seeds show much better germination, increased uniformity of germination, and improved plant performance. For a variety of environmental stressors, rice is subjected to seed priming methods, including halopriming, chemical priming, osmo-priming, hormone priming, hydro-priming, and nutrition priming. Primed seed exhibits significantly improved germination and greater germination uniformity, and plant performance. Seed priming techniques such as halopriming, chemical priming, osmo-priming, hormone priming, hydropriming, and nutrient priming are being used in rice for many environmental stresses. The seed priming technique could be adopted to enhance germination in soils that are contaminated with heavy metals. The imbibition of pepper seeds in water or other solutions containing NaCl resulted in an increased germination percentage (Lal S K. *et al.,2018).*
Storage and viability are the main barriers to the practical use of primed seeds. This restriction might be overcome by understanding the genes and markers involved in seed germination. Then, using these markers, one could evaluate how priming affects seed vigour and germination efficiency (Lal S K. *et al.*, 2018). Polyethylene glycol-6000 (PEG-6000) primed rapeseeds were found to have improved germination, leading to differential expression of 75 proteins and 952 genes upon germination. Osmo-priming is a commercial

technique for enhancing seed strength and germination, regulating seed imbibition, and using hormonal and chemo priming for plant growth and flowering (Harris *et al.*, 2001). Priming has demonstrated a significant impact in inducing the synthesis of nuclear DNA in radial tip cells and activating many cell cycle-related activities. The benefit of quick seedling emergence was demonstrated by the fact that seed priming had the greatest positive impact on leaf area (Arun M N. *et al.*, 2022).

The seed priming procedure used for the field crops

A pre-sowing procedure known as "seed priming" exposes seeds to a particular solution for a predetermined amount of time, allowing for partial hydration but preventing radicle emergence. Imbibition, the lag phase, and the radicle's protrusion through the testa are the three stages of non-dormant seed germination that take place when a dry seed is placed in water (Fig. 2) (Ibrahim E. A., 2015).

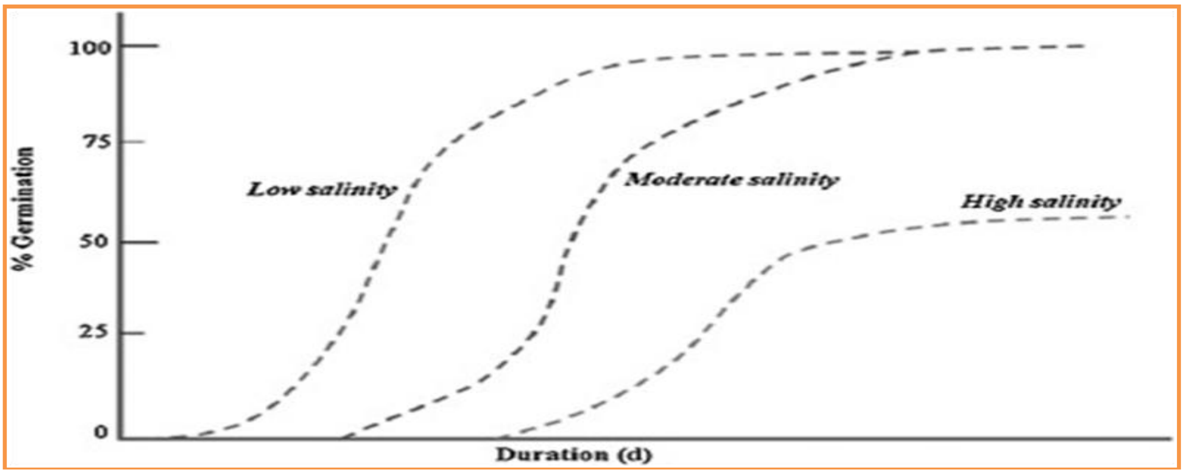

Figure 2: Correlation between germination rate and post-sowing time at varying salt levels (Source: SCIENCE DIRECT)

During seed priming, the seed's water supply is regulated. It lowers the moisture content of the seeds below what is required for actual germination. The seed cannot move toward full germination at this level, but it is sufficient to initiate many of the physiological processes linked to the early phase of germination (pre-germination metabolism). By keeping seeds in the lag phase (activation), they keep them from moving into phase III of hydration (growth) (Fig. 2). Seeds are re-dried to their original moisture level after being taken out of the priming solution. Without sacrificing the quality brought on by quick seed degeneration, this preserves the positive effects of the priming treatment (Arun M N. *et al.*, 2022)

Seed priming methods QTL Mapping in crop improvement wheat (*Triticum aestivum* L.) to mitigate abiotic stress

Drought, heat, salt, and metals are examples of abiotic stresses that significantly decrease wheat growth and yield. By developing resistant wheat cultivars, molecular breeding with the use of genomic tools may be able to overcome these obstacles. Molecular breeding efforts are being supported by speed breeding techniques and wheat SNP-array technologies, which may be combined to produce wheat genotypes that are resistant to stress (Gahlaut *et al.*,2022). Environmental factors and stress tolerance influence plant responses, with seed priming techniques like hydro-priming, halo-priming, osmo-priming, hormone-priming, and bio-priming invigorating seeds, speeding germination, and reducing environmental stress (Rahman *et al.*, 2020).

Table 1: Seed priming methods used in wheat to hasten abiotic stress

S. No.	Priming method and priming agent	Attributed improved	References
1	Hydropriming (12 hr)	Germination, WUE*, Field emergence, Growth and yield, Enzyme activity	Bhusal *et al.*, 2020

2	Osmo-priming (PEG-1.0 MPa)	Germination and grain yield	Arun N.*et al*., 2023
3	Osmo-priming (Sorbitol 1%)	Seed vigor, upregulation of plant growth regulators	Sheler *et al*., 2021
4	Hormonal priming (auxin 50 ppm)	Grain filling, yield photosynthesis	Khanmdi *et al*., 2019
5	Halo-priming [$ZnSO_4$(2%) + $Mg(NO_3)_2$]	Plant height, number of leaves, LAE**, Chlorophyll content, and yield under drought stress	Sathiyanarayanan *et al*., 2019
6	Bio-priming (*Trichoderma asperellum* (24 hr)	Growth-promoting activities for plants, consistent seed emergence, healthy seedling vigor, and establishment under stress	Arun N. 2023

* water use efficiency, ** leaf area index.

Conclusion

Climate change and environmental imbalances have led to a 0.7° to 1.7°c annual increase in global temperature, affecting crop production, photosynthesis, and physiological activities. Seed priming technique could help seeds function better in salinity-stressed environments by establishing defence mechanisms against salinity stress, such as osmotic adjustment and antioxidant defence. However, more research is needed to determine the right material concentration for successful seed germination and early crop growth in salt-affected soil conditions.

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