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Seed priming: An emerging technology to impart abiotic stress tolerance in rice

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Abstract

Plants are exposed to any number of potentially adverse environmental conditions such as water deficit, high salinity, extreme temperature, submergence, etc. These abiotic stresses adversely affect the plant growth and productivity. Seed priming is an easy, low cost and low risk method for improving growth and development of plants especially under adverse environmental conditions. Seed priming has been developed as an indispensable method to produce tolerant plants against various stresses in rice. The beneficial effects of seed priming include faster emergence, better stands, and lower incidence of re-sowing, more vigorous plants, better drought tolerance, earlier flowering, earlier harvest and higher grain yield. These beneficial effects of seed priming are due to several reasons such as activation of enzymes associated with endosperm utilization and seed germination, mobilization of storage proteins, changes in hormonal balance and synthesis of proteins that play an important role during seed germination. Seed priming emerges as a promising technology for combating abiotic stress in crops and alleviating the detrimental effects of abiotic stress without much affecting its fitness. Seed priming methods are widely used as an emerging technology to produce tolerant crop varieties against abiotic stresses.

Keywords: Seed priming, rice, abiotic stress, tolerance

Introduction

Rice (*Oryza sativa* L.) is one of the most important cereal crops in the world and it forms the staple food of more than 50% of the world's population. Rice contributes 43% of total food grain production and 46% of total cereal production in India. Thus, rice plays a vital role in the national food supply (Mondal *et al.*, 2011) [43]. Due to its importance, an adequate and stable supply of rice is essential for the financial growth, food security and poverty reduction in Asia, particularly in India. The traditional agricultural practices are not sufficient to produce rice grains according to the needs of an ever-increasing world population. It has been postulated that the world's annual paddy production must have to increase up to 781 million tons by 2020 and over a billion tons by the next century (Sass and Cicerone, 2002) [53]. In India, due to the irregularity of rainfall distribution, the rice-growing areas frequently experience severe drought, which directly influences rice productivity (Dey and Upadhyay, 1996) [11]. In rainfed ecosystems, drought is the leading environmental stress in rice and furthermore, rice is also highly sensitive to salinity and its tolerance varies with growth stages. In rice, seed germination and seedling growth stages are very sensitive to abiotic stresses, especially salinity (Deivanai *et al.*, 2011) [10]. Abiotic stress alone results in 50% of the total yield loss in rice crop, and salinity, drought and extreme temperatures are major obstacles which limit global rice production.

Plants are exposed to any number of potentially adverse environmental conditions such as water deficit, high salinity, extreme temperature, submergence, etc. These abiotic stresses adversely affect the plant growth and productivity. Several ways and means for enhancing the plant tolerance towards abiotic stress have been experimented like breeding of plants and developing transgenics (Jisha *et al.*, 2013) [35]. Seed priming is an easy, low cost and low risk method for improving growth and development of plants especially under adverse environmental conditions. Seed priming has been developed as an indispensable method to produce tolerant plants against various stresses.

Seed priming

Seed priming is a controlled hydration technique that triggers the normal metabolic processes during early phase of germination before radicle protrusion (Hussain *et al.*, 2015)^[26]. Priming allows some of the metabolic processes necessary for germination to occur without germination take place. In priming, seeds are soaked in different solutions with high osmotic potential. This prevents the seeds from absorbing in enough water for radicle protrusion, thus suspending the seeds in the lag phase (Taylor *et al.*, 1998)^[56]. Seed priming has been commonly used to reduce the time between seed sowing and seedling emergence and to synchronize emergence (Parera and Cantliffe, 1994)^[47]. Moreover, plants raised from primed seeds showed sturdy and quick cellular defense response against abiotic stresses. Seed priming is the induction of a particular physiological state in plants by the treatment of natural and synthetic compounds to the seeds before germination. Seed priming is defined as a physiological process by which a plant prepares to respond to imminent abiotic stress more quickly or aggressively. Seed priming is an effective, practical and facile technique to enhance rapid and uniform emergence, high seedling vigor, and better yields in many field crops particularly under unfavorable environmental conditions (Jisha *et al.*, 2013; Paparella *et al.*, 2015)^[35, 46]. Priming for enhanced resistance to abiotic stress obviously is operating via various pathways involved in different metabolic processes. The seedlings emerging from primed seeds showed early and uniform germination. Higher and synchronized germination of primed seeds primarily occurs due to reduction in the lag time of imbibition (Brocklehurst and Dearman, 2008)^[7], enzyme activation (Lee and Kim, 2000)^[39], build-up of germination enhancing metabolites (Hussain *et al.*, 2015)^[26], metabolic repair during imbibition (Farooq *et al.*, 2006)^[15], and osmotic adjustment (Bradford, 1986)^[6].

Seed Priming Techniques

Several seed priming methods were successfully used in agriculture for seed conditioning to accelerate the germination rate and improve the seedling uniformity (Nouman *et al.*, 2012; Aghbolaghi and Sedghi, 2014; Bagheri, 2014; Lara *et al.*, 2014)^[44, 2, 5, 38]. Moreover, seed priming is reported in many crops, which helps them to neutralize the adverse effects of abiotic stress (Ashraf and Foolad, 2005; Patade *et al.*, 2009; Jisha *et al.*, 2013)^[4, 48, 35]. Various seed priming techniques including hydropriming, osmopriming, chemical priming, nutrient priming, hormonal-priming, and redox priming are employed in rice under wide range of environmental stresses (Jisha *et al.*, 2013; Paparella *et al.*, 2015)^[35, 46].

A. Hydro-priming

The phenomena in which seeds are hydrated in a column of aerated water to a moisture content close to that required for radicle protrusion is called hydropriming or aerated hydration (Thornton and Powel, 1992)^[59]. Hydro-priming involves soaking the seeds in water before sowing (Pill and Necker, 2001)^[49] and may or may not be followed by air-drying of the seeds. This pre-sowing seed treatment, known as hydro-priming, allows the seed to imbibe water and go through the first phase of germination in which pre-germination metabolic activities are started while the latter two phases of germination are inhibited (Pill and Necker, 2001)^[49]. Before sowing, soaking the seeds in water for some time and surface drying is referred as On-farm priming. It is a simple, low cost,

minimum risk method of promoting rapid seedling establishment and vigorous early growth (Harris *et al.*, 1999, 2000, 2002)^[21, 19, 20]. Although soaking seed in water and drying before sowing is the easiest way to achieve hydration, a major disadvantage is that it may result in uneven hydration and non-uniform germination. Effects of hydro-priming on water potential, the driving force for water uptake during imbibition, and the activity of α -amylase were examined in rice kernels (Andoh and Kobata, 2002)^[3]. In rice seed, hydro-priming did not change either water or osmotic potential. The improvements in seed germination and seedling emergence were due to enhanced supply of soluble carbohydrates to the growing embryo, which was caused by an increase in α -amylase activity (Farooq *et al.*, 2006)^[13]. Re-drying of seed following hydro-priming did maintain activity of other enzymes at the levels required for occurrence of germination.

B. Halo priming

Halo priming refers to soaking of seeds in solution of inorganic salts i.e. NaCl, KNO₃, CaCl₂, CaSO₄, etc. Halopriming have very important role in germination, seedling emergence, and plant growth at all developmental stage of the plants in salt affected soils. Seed germination is promoted by halopriming but also stimulate subsequent growth, thereby enhancing final crop yield (Eleiwa, 1989; Sallam, 1999)^[12, 52].

C. Osmopriming

This is also known as osmo-conditioning or osmotic conditioning. In this technique, seeds are soaked for a certain period in solutions of sugar, polyethylene glycol (PEG), glycerol, sorbitol, or mannitol followed by air drying before sowing. Osmopriming not only improves seed germination but also enhances general crop performance under non-saline or saline conditions. Numerous biochemical changes have been reported in osmo-primed seeds of different plant species.

D. Hormonal priming

Hormonal priming is the pre-seed treatment with different hormones i.e. GA₃, salicylic acid (SA), ascorbate, kinetin, etc. which promote the growth and development of the seedlings. Recently, non-protein amino acids like β -amino butyric acid (BABA) were employed in seed priming of various crops against biotic and abiotic stress (Worrall *et al.*, 2012). GABA (γ -amino butyric acid) is an isomer of naturally occurring nonprotein amino acid and is a xenobiotic compound (Jakab *et al.*, 2005; Mayer *et al.*, 2006)^[33, 42], whose natural occurrence is very rare. BABA is known as a potent inducer of resistance in plants against nematodes (Oka *et al.*, 1999)^[45], microbial pathogens (Cohen, 2002)^[9], insects (Hodge *et al.*, 2005)^[23] and abiotic stress (Jakab *et al.*, 2005; Zimmerli *et al.*, 2008)^[33, 66]. BABA exerts its action by priming plants to respond faster and stronger to future stress. According to Zhong *et al.* (2014)^[65], BABA can bring plants into a sensitization state in which defenses are not expressed, but are able to react more rapidly and/or more strongly to various stress. BABA-induced priming functions were probably by the interaction of several hormones like salicylic acid (SA), abscisic acid (ABA) and ethylene (Jakab *et al.*, 2005; Ton *et al.*, 2005)^[33, 60].

Role of Seed Priming Technique in Combating Abiotic Stresses

Hydro-priming in rice improved germination percentage, enhanced subsequent seedling growth resulting in higher

grain yield in dry direct-seeded rice (Mahajan *et al.*, 2011)^[41]. Osmoprimed rice seed with KCl and CaCl₂ enhances seed vigour evidenced by improved germination, seedling emergence, kernel yield, number of fertile tillers, straw yield and harvest index. Rapid and uniform germination occurs due to elevated α -amylase activity and enhanced starch hydrolysis there by more sugar are available for embryo and seedling growth that leads to improvement in yield and quality (Farooq *et al.*, 2006)^[13]. Seeds of pigmented and non-pigmented rice were soaked in water Hydropriming and osmopriming (with CaCl₂) both were effective in improving stand establishment, growth, polyphenols, flavonoids and antioxidant activity in rice under drought condition (Hussain *et al.*, 2017)^[17]. The primed and non-primed rice seed performed differently under water deficit condition and the amount of proline and soluble protein are found higher in primed seed (Yuan-Yuan *et al.*, 2010)^[63]. Drought stress severely effects on seed germination and seedling establishment as critical stages in crops lifetime. Seed priming in rice dramatically improved early seedling establishment, better emergence, early growth vigour which helped the crop escape from drought (SATrends 2001)^[54]. Seed hydro priming is useful process for improving crops tolerance to drought stress. Hydro priming of Malaysian Indica rice (MR219) seeds is associated with the accumulation of proline and modulating the activity of ascorbate peroxidase and catalase under drought stress. This study suggests the hydro priming as an effective technique on rice seeds to withstand under drought condition which could be a step forward to commercialization (Kalhori *et al.*, 2018)^[36]. Seed priming with polyethylene glycol (PEG) had a better effect on seed germination and seedling growth under drought stress. Higher concentrations of PEG had negative effects on seed germination. Moderate priming intensity improved metabolism of rice seed, germination indices, seedling quality, and drought tolerance of seedlings under drought stress. However, such effects had limited capability, and severe drought stress inhibited germination and caused damages of rice seedlings. Drought resistance in rice seedlings conferred by PEG seed priming (Goswami *et al.*, 2013)^[17]. SA-priming as a more effective strategy to alleviate the PEG induced stress in rice (Li and Zhang, 2012)^[40]. Likewise, PEG-primed seeds of the rice have robust protective mechanisms against the drought (Goswami *et al.*, 2013)^[17]. Thakuria and Sharma (1995)^[57] concluded that priming with 4% KCl solution significantly increased the rice grain yield in drought condition and better N, P, K uptake and water use efficiency (WUE), it may be attributed to more filled grains / panicle as result of priming. Seed-priming with Salicylic acid (SA) of 100 ppm not only increased seedling dry weight but also reduced mean germination time compared to the untreated seeds. Seedling growth of SA-primed seeds had higher root and shoot length than non-primed seeds. It indicated reduction in severity of the effect of water stress on germination and seedling growth parameters of rice by priming with SA of 100 ppm which ultimately could tolerate deficit moisture conditions to some extent (Shatpathy *et al.*, 2018)^[55]. Kata *et al.* (2014)^[37] conducted that ascorbic acid and salicylic acid pre-treatment @ 200ppm and 50ppm respectively results in improvement of germination properties of paddy under heat stress condition because of its antioxidant capacity. Rehman *et al.* (2011)^[51] studied seed priming with CaCl₂ improves the stand establishment, yield and quality attributes in direct seeded rice (*Oryza sativa* L.) and showed that seed priming particularly osmopriming with CaCl₂ with re-drying for improved crop performance in direct seeded rice

at farmer's field. Salicylic acid priming also enhance the chilling tolerance of rice seedling. Seed priming with Selenium or Salicylic Acid, was found to be more effective among all treatments to thrive under chilling stress (Hussain *et al.*, 2016)^[25]. Zhang *et al.* (2002)^[64] reported that significantly higher and more rapid germination of osmo-primed rice seeds at low temperature (5°C). Priming with CaCl₂ followed by KCl were more effective in inducing salt tolerance of both rice cultivars owing to enhanced germination capacity, speed of germination, seedling length and dry weight in saline medium. (Afzal *et al.*, 2012)^[1]. Under salt stress, enhanced growth of seedlings raised from seeds primed with Mannitol, KNO₃ and wood vinegar was attributable to greater membrane stability, higher chlorophyll content and lower Na⁺/K⁺ ratio (Theerakulpisut *et al.*, 2017)^[58]. Rafiq *et al.* (2006)^[50] reported that seed priming reduces the effect of salinity on the morphological parameter of the plants. Hydro-priming may enhance seed germination and seedling emergence under both saline and non-saline conditions. Rice seed treated with a mixed salt solution germinated more speedily than unprimed seed under salt-stress conditions due to increase in activity of α -amylase, p-amylase, and root dehydrogenase, and moderate increase in the activity of shoot catalase (Chang-Zhenget *et al.*, 2002)^[8]. Seed priming with H₂O₂ having the capacity to enhance the multi-resistance to heat, drought, chilling and salt stress in rice (Uchida *et al.*, 2002)^[61]. Likewise, seed priming with Hydrogen Peroxide @ 0.25% reduced the effect of salt stress in rice even under higher salt concentrations (Hemlatha *et al.*, 2017)^[22]. BABA priming of rice seeds improved the drought and salinity stress tolerance. It caused increased in the photosynthetic pigment content of the leaves, modified the chlorophyll a fluorescence related parameter and also enhanced the photosystem activities of seedlings. BABA priming also caused increased mitochondrial activities, activity of nitrate reductase enzyme and activities of antioxidant enzymes like guaiacol peroxidase and superoxide dismutase (Jisha and Puthur, 2016)^[34].

Conclusion

The beneficial effects of seed priming include faster emergence, better stands, and lower incidence of re-sowing, more vigorous plants, better drought tolerance, earlier flowering, earlier harvest, and higher grain yield (Harris *et al.*, 1999)^[21]. These beneficial effects of seed priming are due to several reasons such as activation of enzymes associated with endosperm utilization and seed germination (Habib *et al.*, 2010)^[18], mobilization of storage proteins, changes in hormonal balance (Iqbal and Ashraf 2005, 2007, 2010, 2013)^[29, 30, 31, 32], and synthesis of proteins that play an important role during seed germination (Gallardo *et al.*, 2001)^[16]. Seed priming emerges as a promising technology for combating abiotic stress in crops and alleviating the detrimental effects of abiotic stress without much affecting its fitness. Drought, salinity, submergence, and extreme temperature (heat, cold) are major challenges in agriculture. These abiotic stresses have similar effects at biochemical, cellular, and molecular levels, and somehow, they are interconnected and activate similar signaling cascades. It is established that seed priming affects signaling pathway at an early stage of growth and development in a crop that results in better tolerance against abiotic and biotic stress. Priming for enhanced resistance to abiotic stress is obviously operating via various pathways involved in different metabolic processes including the mobilization of reserve food and activation of genes

responsible for the synthesis of vital enzymes. Priming is also capable of repairing damage which occurs inside the seed. Seed priming has an effect on early stage of germination, and it modulates the DNA replication, transcription, and translation. There is a need to standardize suitable priming methods in different crops to combat abiotic stress in a sustainable manner.

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