Hydropriming for Plant Growth and Stress Tolerance

Muhammad Fasih Khalid, Sajjad Hussain, Muhammad Akbar Anjum, Shaghef Ejaz, Maqsood Ahmad, Mehwish Jan, Sumaira Zafar, Iqra Zakir, Muhammad Arif Ali, Niaz Ahmad, Muhammad Junaid Rao, and Shakeel Ahmad

Contents

Abstract The technique of seed priming has potential in increasing seed longevity during the storage, reducing the time of seedling emergence, improving germination as well as increasing the crop yield, which is reported in various crops. Among the different seed priming techniques, hydropriming is one of the mostly used seed

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M. F. Khalid · S. Hussain (✉) · M. A. Anjum · S. Ejaz · M. Jan · S. Zafar
Department of Horticulture, Bahauddin Zakariya University, Multan, Punjab, Pakistan
e-mail: sajjad.hussain@bzu.edu.pk

M. Ahmad
Mirpur University of Science and Technology (MUST), Mirpur, Pakistan

I. Zakir · S. Ahmad (✉)
Department of Agronomy, Bahauddin Zakariya University, Multan, Punjab, Pakistan
e-mail: shakeelahmad@bzu.edu.pk

M. A. Ali · N. Ahmad
Department of Soil Science, Bahauddin Zakariya University, Multan, Punjab, Pakistan

M. J. Rao
Key Laboratory of Horticultural Plant Biology (Ministry of Education), Huazhong Agricultural University, Wuhan, People's Republic of China

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priming techniques to start the germination of seeds without the emergence of radicle. Recent reports suggest that hydropriming of seed has the potential to upregulate plants' tolerance to multiple abiotic stresses by enhancing seed germination, seedling growth and development, modulating physiological activities and antioxidant response, as well as expression of genes and proteins. But the changes occurred during hydropriming need to be further addressed by plant scientists using molecular and genomic approaches to cope with abiotic stresses. Therefore, in this chapter, we reviewed the recent knowledge on seed hydropriming focusing abiotic stress tolerance in various plant developmental stages along with the antioxidant metabolism and molecular responses of crops.

Keywords Abiotic stress · Antioxidant defence system · Germination · Priming · Physiological response

1 Introduction

Delay in seed germination and nonuniformity is a major problem. To establish a healthy crop, unified and rapid germination of seeds is very necessary. Crop yield and quality are directly affected by the growing period from time of sowing to establishment of crop. This growing time of a crop is very important to get better yield. Difference in germination time of seeds is a major factor for low yield of a crop. After uniform and prompt emergence, unified and fast growth of seeds is very essential to get good yield of a crop. The technique of seed priming has potential to cope with the poor seed emergence in crops, which have small seeds. By the technique of seed priming, germination rate of seeds and uniformity in crop establishment is increased. Seed priming only regulates the early process of germination in seeds, but the final phase of radicle emergence is not affected. In the process of seed priming, seeds are soaked in water or either in osmotic solution or in mixture of water and solid medium in a precise ratio. After this process, seeds are dried before the emergence of radical. Previous studies reveal that priming of seed is used to hasten time of seedling emergence, to increase seed longevity during the storage, to improve germination, and to increase the yield. Favorable effects of seed priming are shown in crops such as barley, sugar beet, lentil, chickpea, and grass fox. Beneficial effects of priming are related with various biochemical, molecular, and cellular metabolisms including synthesis of proteins and ribonucleic acid (Bray et al. 1989; Davison and Bray 1991; Dell'Aquila and Bewley 1989).

2 Hydropriming

Among different seed priming techniques, hydropriming is one of the mostly used techniques. Seeds are soaked in a solution called priming agent followed by drying in this technique. This technique is used to start the germination of seeds without the emergence of radical (Afzal et al. 2005). Seeds are quickly reached to a specific level of moisture in hydropriming with continuous supply of oxygen that will increase the number of enzymes associated with the production of energy and metabolites associated with the process of germination. The technique is used to get uniformity in germination and to increase the speed of germination for the improvement of final stand. If seeds are contaminated with the pathogens, then hydropriming should be used with complete care. If seeds are affected with fungus, then the growth of fungus will be increased by hydropriming that will cause stand growth of plants. To control the adverse effects of pathogens, biopriming was developed.

3 Hydropriming-Mediated Stress Tolerance

3.1 Germination

Seed germination is very much sensitive to abiotic stresses. When exposed to uneven environment, it delays germination. When seed germinates in stress condition, it cannot withstand the field environment and has less vigor and decrease in productivity. Seed germination is utmost salt-sensitive plant growth stage (Goumi et al. 2014) and is severely interrupted by increasing salinity (Bouda and Haddioui 2011). Under salinity, seed germination and plant growth are improved by seed priming (Passam and Kakouriotis 1994). The major purpose of seed priming is to maximize emergence rate; however, postemergence growth are also enhanced by these. Primed seeds give earlier, uniform and occasionally maximum germination and seedling emergence (Bradford 1986). Exposure to soaking the seed technology has been tested in various crops to aid the seed germination depending on the situation and even promote plant tolerance in the event of stress (Idris and Aslam 1975). Priming treatments have proven to promote seed vigor that is effective to achieve fast and uniform seed germination of various vegetable species (Taylor et al. 1998) and many field crops including rice (Lee et al. 1998). Hydropriming is a unique, easy, low-priced, and nature-friendly priming technique due to the use of simple water, and the farmers of developing countries adopt this technique (Mabhaudhi and Modi 2011). Earlier study indicated hydropriming (for 24 h) in wheat showed more production (Kahlon et al. 1992). Hydropriming is an effective method, as suggested by Harris (1992) with various valuable impacts on different field crops, i.e., chickpea, soybean, maize, sunflower, and rice (Ashraf and Foolad 2005; Kaya et al. 2006).

Hydropriming has also been used profitably in sunflower, wheat, cotton, and chickpea (Kaur et al. 2002). Furthermore, hydropriming elevated emergence and growth under salinity (Kaur et al. 2002; Kaya et al. 2006). Hydropriming is a starter procedure for germination without emergence of the radicle that involves soaking of seeds in water followed by drying (Ashraf and Rauf 2001). Roy and Srivastava (2000) proposed that the negative effect of salinity on seed germination can be reduced by seed priming. Generally, seed germination and seedling emergence are enhanced by hydropriming. Hydropriming permits the seeds to rapidly attain good moisture with a persistent oxygen supply, thus resulting in increase of germination process/metabolites which associated with energy production. Generally, hydropriming has been established as profitable and is currently being explored. Hydropriming brings about certain physiological modifications in organic compounds, sugar content, and cumulated ions within the seed, root, and lastly in the leaves of plant leading to high germination rate and great resistance to unpleasant conditions (Alvarado et al. 1987). Chojnowski and Come's (1997) work revealed that the increase in ATP production, the respiration activities, protein synthesis, and induced RNA activity in the treated seeds promoted emergence rate of sunflower seed.

Hydropriming is utilized to enhance the germination and uniformity of seedlings along with improvement in final stand. Hydropriming also deal with attention as seeds can be contaminated with pathogens. In such case, during hydropriming, growth of fungus can be intensified causing plant diseases and restricted development. Hydropriming enhanced the seedling emergence along with growth in *Phaseolus vulgaris* (Kazem et al. 2010). However, in contrast, hydropriming failed to improve germination in common Kentucky blue grass seeds (Pill and Necker 2001), but Basra et al. (2002) found that wheat seeds' treatment with hydropriming (48 h) resulted in the maximum activation followed by 24 h. The favorable priming effect has been related with several biochemical, cellular, and molecular processes containing RNA and protein synthesis (Dell'Aquila and Bewley 1989). By hydropriming, use of chemicals can be reduced or eliminated, and it also avoids disposing of undesirable materials that are hazardous for the atmosphere (McDonald 2000). Hydropriming specifically confirms speedy and uniform emergence along with maximum normal seedling percentage (Singh 1995; Shivankar et al. 2003). Scientists observed that antioxidative enzymes (peroxidase (POD), catalase (CAT), and superoxide dismutase (SOD)) and solute (proline and soluble sugar) contents are significant indicators throughout the process of seed priming and emergence (Wattanakulpakin et al. 2012). Germination metabolites and osmotic adjustment are vital factors to improve seed execution throughout the treatments (Haghpanah et al. 2009). Hydroprimed maize seeds (cv. Zhengdan 958) germinated quicker as compared to non-primed. There was marked change in comparative proteomic analysis between the primed and non-primed seeds, due to identification of eight protein spots (Gong et al. 2013). Hydropriming improved onion seed germination effectively, especially when the seeds were hydrated for 96 h. In cotton, soaking in distilled water (hydropriming) boosted up germination under saline environments as compared to any other seed pretreatment (Shannon and Francois 1977). Moreover, according to Ahmadian et al. (2009), hydropriming under salt stress conditions significantly improved both emergence rate and mean emergence time with maximum normal germination. Results are confirming the investigations in mustard, cauliflower, and brassica. Under osmotic stress, hydropriming promoted fresh weight of seedling. In addition, it resulted in enhanced root growth along with the highest root length. Cayuela et al. (1996) reported that plants from primed seeds have maximum salinity tolerance due to high osmotic adjustment ability. Roots produced from seeds (primed) show high level of sodium and chloride ions, while leaves of primed seeds have more contents of sugars and organic acids as compared with non-primed (Li et al. 2011). Studies showed that hydropriming increases emergence and hasty germination of seedling of pyrethrum in saline and nonsaline conditions, which agreed with results, e.g., in potato seeds, triticale, and sunflower (Demir and Ermis 2003, Yagmur and Kaydan 2008). In hydropriming, the positive effect showed that mobilization of enzymes in tissues of embryo occurred which results in early germination of seeds and production of compounds (i.e., proteins, sugars, and amino acids) in storage organs (Ashraf and Foolad 2005). Practically, due to less expenditure, hydroprimed seeds can be suggested for both salt-affected and non-affected soils to increase probability and rapidity of germination. According to Demir and Mavi (2008), reduced water loss and variances in movement of storage reserves and proteins can cause undesirable effects on germination. In conclusion, the study suggested that pyrethrum seed can be germinated best in the dark by hydropriming treatment. By several seed priming techniques, the negative effect of salt stress on emergence can be relieved (Roy and Srivastava 2000). Akter et al. (2018) proposed that 48 h of hydropriming is the best technique for maize which decreases the salinity stress and had highly significant impact on better germination and superior performance of various seedling attributes. Shukla et al. (2018) investigate that priming is a mechanism that controls germination capacity of seeds by altering the penetrability properties of membranes and enzyme. Rouhi et al. (2011) suggested that hydropriming maximized germination ratios, emergence index, and seed vigor while minimized mean emergence time, the time to get 50% emergence, and energy of emergence. Under salinity and drought, hydropriming resulted in alleviation of harmful effects of both stresses on emergence and growth of the seedling (Kaya et al. 2006). Sung and Chiu (1995) observed that hydropriming hastened mean germination time (MGT) without changing uptake water amount in watermelon. Amini (2011) suggested that hydropriming of alfalfa was an effective method to increase the salt tolerance ability by improving seed emergence and seedling growth under highly saline state. Priming treatment, under saline condition, considerably improved the CAT, POD, SOD activities, and proline content however reduced in malondialdehyde (MDA) accumulation and electrolyte leakage. Hydropriming has proven to be an effective method as compared to halopriming as expressed by the final germination percentage (FGP), root shoot length ratio, and their dry weight (Basra et al. 2006). By priming technique, radicle emergence speeds up through higher enzymatic activities, ATP production, and protein synthesis that cause increase in root length (Parera and Cantliffe 1992). Primed seed results in significantly higher shoot length than that of not primed seeds.

3.1.1 Plant Growth and Development

Khazaei et al. (2016) suggested that, by seed priming, positive remarkable effect can be observed on the length of plumule, green area, fresh and dry weight of plumule, fresh and dry weight of radicle, radicle length, and volume along with seedling vigor at various levels of salinity stress in barley, while time to get 50%

germination reduces by the seed treatment. Especially, effective and considerable influence of seed priming on barley was detected under the 200 mM salt stress. Priming causes increment in cell division level within the apical meristem of seedling roots that ultimately results in an increase in plant growth and development (Sakhabutdinova et al. 2003). Hydropriming can be a beneficial tool for production of carrot to increase quality of seed and seedling. Eisvand et al. (2011) work on carrot cultivars (Nantes and Forto) suggested that in both, vigor index, rate of emergence, and length of root and shoot of hydropriming were higher than hormonal priming. Sanchez et al. (2001) found an increase in the root length of pepper and cucumber by hydropriming influence. Salinity stress has adverse effects on growth, chlorophyll content (chlorophyll b reduction was more than chlorophyll a), and mineral composition (K^+ and Ca^{2+}) in all coriander genotypes. By seed priming, the negative effect of salinity diminished in all genotypes and treated plants exhibited satisfactory reaction to salt stress when compared with untreated or non-primed plants (Meriem et al. 2014). These results are in line with the outcome of many researches on various plant species, e.g., wheat (Mehta et al. 1979), canola (Mohammadi 2009), maize (Bakht et al. 2011), *Sorghum bicolor* (Kadiri and Hussaini 1999), *Vicia faba* (Salam et al. 1999), tomato (Mirabi and Hasanabadi 2012), watermelon (Armin et al. 2010), melon (Sivritepe et al. 2003), *Ziziphus spina-christi* (Takhti and Shekafandeh 2012), and safflower (Elouaer et al. 2012). By primed seed, soluble sugar content and chlorophyll content also amended in leaves of all the coriander cultivars under normal and saline conditions (Meriem et al. 2014).

Seed priming upsurges the action of membrane-bounded enzyme and the free radical scavenging enzymes, i.e., POD, SOD and CAT, to enhance the viability and vitality of plant to survive better under salt-affected soils (Shafi et al. 2009; Chang and Sung 1998). Work on muskmelon, cucumber, and amaranth (Nascimento and West 1999) revealed that seed priming technique amended growth of seedling by reducing viscosity of seed coat particularly in drastic conditions. This betterment is brought by improving synthesis of DNA and protein that has great effect in maximizing the stability of cell membrane in embryo. Phospholipids also have a role in embryo cell membrane as these can enhance the cell membrane permeability and resistance (Bradford 1995). Harris et al. (1999) showed that seed priming (overnight seeds soaking in water) distinctly enhanced quick vigor, and establishment of upland chickpea, maize, and rice results in quicker growth and development with earlier flowering followed by maturity and advanced yields. These priming effects are affiliated with the nucleic acids restoring and building up, repairing of membranes as well as improved proteins synthesis (McDonald 2000). Priming technique has also vital role in enhancement of the antioxidative enzyme's activities in primed seeds (Hsu et al. 2003). Due to availability of ready food throughout emergence (Farooq et al. 2006), primed seeds perform better to accomplish the germination process in a short duration while coping with external stresses (Farooq et al. 2007; Kant et al. 2006). Seedlings (7-day-old) taken from hydroprimed seeds indicated three- to fourfold extra growth in respect of shoot and root length than seedlings acquired from non-treated seeds.

The activities of invertases (alkaline and acid), amylase, sucrose phosphate synthase, and sucrose synthase (SS) were greater in primed seedling shoots. In primed seedling roots, growth in the activities of acid and alkaline invertases and SS was also detected. Cotyledons of primed seedlings also indicated twofold increment in sucrose phosphate synthase-specific activity. The higher activity of amylase was observed in shoots of hydroprimed seedlings that enhanced the speedy hydrolysis of transitory starch of the shoot. This hydrolysis leads to more glucose availability for growth of shoot, and this was confirmed by the presence of low level of starch in primed seedling shoots (Kaur et al. 2002). Pradhan et al. (2015) find that hydropriming considerably amended germination, growth of seedling, and seedling vigor under stress and nonstress environments. Similarly, the work of Janmohammadi et al. (2008) indicates hydropriming offers suitability to seed vigor under both saline and drought conditions.

3.1.2 Physiological Responses

Seed priming treatments had significant effects on germination and stress tolerance during which the physiological mechanisms inside the seeds are altered and these changes are characterized by the changes in the level of important indicator solutes such as proline, MDA, CAT, soluble sugars, SOD, and POD. Various studies indicated the effect of unfavorable environment on the seed emergence and stress resistance in different crops as in legumes, wheat (*Triticum aestivum* L.), onion (*Allium cepa* L.), and rice. Yuan-Yuan et al. (2010) reported the influence of drought on primed (hydropriming) and non-primed seeds of rice cultivars. Results concluded that for levels of soluble sugars, MDA were reduced in primed seeds, whereas hydropriming elevated the activities of CAT, SOD, and POD and also enhanced glucose metabolism in stress seeds among all cultivars than control treatment.

3.1.3 Antioxidative Response

Hydropriming significantly affects the antioxidative machinery of the plant under stress condition. When plant goes under stress condition, it produced different active oxygen species (AOS) and reactive oxygen species (ROS), which decline in plant health and its yield. To cope with this effect, different techniques used to overcome this issue among, which priming is key part for annual and some of perennial crops, fruit crops are not much affected by this technique in antioxidative manner. Hydropriming plays a vital part in activation of antioxidative enzymes, which cope with the effect of AOS and ROS in plant cell.

Hydropriming mediates stress tolerance by increasing antioxidant enzymatic activities. Superoxide dismutase, catalase, peroxidase, and ascorbate peroxidase are enzymes that can cope with the negative effect of ROS like lipid peroxidation

Table 1 List of biochemical responses of different plant species affected by hydropriming under stress

Biochemical	Activity level	Crop	References
Superoxide dismutase	Increase	Alfalfa	Amooaghaie (2011)
		Cucumber	Huang et al. (2006)
		Mung bean	Umair et al. (2012)
Peroxidase	Increase	Alfalfa	Amooaghaie (2011)
		Mung bean	Umair et al. (2012)
		Tomato	Araby and Hegazi (2004)
Catalase	Increase	Alfalfa	Amooaghaie (2011)
		Cucumber	Huang et al. (2006)
		Mung bean	Umair et al. (2012)
		Tomato	Araby and Hegazi (2004)
MDA	Decrease	Cucumber	Huang et al. (2006)
		Alfalfa	Amooaghaie (2011)
		Tomato	Araby and Hegazi (2004)
Polyphenol oxidase	Increase	Mung bean	Umair et al. (2012)
Ascorbate peroxidase	Increase	Cucumber	Huang et al. (2006)

mainly measured by malonyldialdehyde. Amooaghaie (2011) observed that the activity of superoxide dismutase increased in alfalfa under salt stress condition when treated with hydropriming. The seed, which are treated with hydropriming, showed more activity of superoxide dismutase and tolerates more under stress condition as compared with non-treated plants. Similar findings were also noted by Huang et al. (2006) and Umair et al. (2012) in cucumber and mung bean.

Peroxidase was also observed higher in the plants grown after the treatment of hydropriming. Alfalfa (Amooaghaie 2011) and mung bean (Umair et al. 2012) and tomato (Araby and Hegazi 2004) observed the increase in the peroxidase contents, which cause in the reduction of ROS. Catalase activity was also observed more in the plant of alfalfa, cucumber, mung bean, and tomato when treated with hydropriming. Polyphenol oxidase and ascorbate peroxidase were also observed more in the plants of mung bean (Umair et al. 2012) and cucumber (Huang et al. 2006) when treated with hydropriming, which means, hydropriming effects increase the stress tolerance by increasing antioxidant enzymes. Cucumber, alfalfa, and tomato when exposed to hydropriming showed decrease or less amount of lipid peroxidation measured by malonyldialdehyde (Table 1).

3.1.4 Molecular Responses

Hydropriming approximately for 12 h enhances the seed germination, growth and development and uncertainly enhances alterations in protein profiles of maize embryo. Eight proteins are greatly different in richness between treated and untreated seeds expressly embryonic protein DC-8 as well as globulin-1. Two proteins such as DC-8 and globulin-1 may possibly be the candidates for the molecular markers for priming effect as well as seed vigor. However, more research work is needed to explore the occupation of these well-known embryo proteins in hydropriming in numerous other maize lines all over the world.

4 Conclusion

Abiotic factors are one of the major problem in crop production. This phenomenon is also led by climate change. Many studies are taken in this aspect to overcome the effect of abiotic stresses. Priming is used to overcome dormancy and also enhances seed vigor. Priming also acts as mediator in stress tolerance. Among the different seed priming techniques, hydropriming is one of the mostly used. In hydropriming, seeds are soaked in a solution called priming agent followed by drying. Hydropriming helps in stress tolerance during germination, plant growth and development, physiological response, and activation of antioxidative enzymes, which cope with the ROS produced under stress. Further, genetic analysis and molecular marker studies are required to assess the role of hydropriming during stress tolerance. Moreover, there is an urgent need to develop and identify functional genetic approaches to evaluate the changes that occurred during hydropriming.

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