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Review

Seed priming: a tool for effective crop management in vegetable crops

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ABSTRACT

Seed is one of the important inputs in agriculture. The response of other inputs depends on the availability of quality seed. Majority of the cultivated area under vegetable crops is rainfed; as a result seed after sowing is subjected to the vagaries of weather. Seed invigoration techniques can play a pivotal role in ensuring a good crop stand and yield of quality produce under such conditions. The negative effect of salinity on seed germination can be reduced by seed priming. Imbibition of water is an essential step for the metabolism of stored starch and proteins in the seed. The duration and extent of imbibition for seed germination depends on the cultivar, species and relative availability of moisture.

Keywords: Priming; vegetables; hyrdopriming, osmopriming, seed imbibition

INTRODUCTION

In simple words, priming in agriculture means water imbibition before planting or sowing of the seed. Different methods of priming are available in the literature such as hydropriming, osmotic priming or osmoconditioning, matrix-priming and membrane priming. Hydropriming involves soaking of the seed in plain water and it is the most commonly used method of seed priming. In osmotic priming, the seeds are immersed into osmotic solution to allow controlled imbibition of water and activation of the metabolic processes but without radical protrusion. The osmotica used in osmocoditioing comprise the aqueous solution of mannitol, polyethylene glycol (PEG 4000, PEG 6000 or PEG 8000), glycerol, sorbitol or salts such as the KCl, KNO_3 and NaCl having low water potential thereby restricting the water uptake by seeds and allowing the pre-germinative metabolic events to continue but prevent the seminal root protrusion (Ashraf and Foolad 2005). Further to have aided advantage through priming, plant hormones affecting different stages of seed germination or beneficial microorganisms (which help to control fungal and bacterial diseases) can also be added to the osmotic solutions.

Hydropriming/osmopriming and seed quality

Hydrorpiming is a starter procedure for germination without emergence of the radical that involves soaking of the seed in water followed by drying (Ashraf and Rauf 2001). Hydropriming is a very simple, economical and environment friendly technique. This technique has been found to improve seed germination and seedling growth. Positive impact of hydropriming in rapid seed germination and uniform crop establishment has been reported in various crops (Adebisi et al 2013). Priming temperature has a profound effect on the effectiveness of the methodology employed. Huang et al (2006) noticed enhanced speed of germination in cucumber seed lots (Bingo-I with high and Bingo-II with low germination) after hydropriming the seeds at moisture content of 25-30 per cent for 3 days at 25°C under saturated humidity conditions. However de Paiva et al (2012) found that hydropriming improved germination and vigour in seed lots of melon hybrids (Mandacaru and Vereda) hydroprimed on paper towel at 20°C until they reached water content of 39.1 (Vereda) and 44.1 per cent (Mandacaru). Sowmya et al (2013) investigated the effect of hydropriming temperature and duration on seed quality parameters in cucumber. They observed

higher germination, seedling length and seed vigour index in seeds primed at 25°C for 48 hours. In their study with bitter gourd cv Solan Hara, Mehta et al (2014) found that hydropriming of seeds at 20°C between towel paper for 52 hours significantly improved seed quality parameters viz germination (%), speed of germination, seedling length and dry weight and vigour index-I and II in comparison to the remaining treatments and control. Similarly different methods of seed priming viz osmopriming (aerated PEG 6000 solution), hydropriming and drum priming were tried with onion seed lots. It was observed that these priming treatments could not give the desired results in less vigorous onion seed lots. It was concluded that hydropriming significantly improved speed of germination in all the six lots of onion seed that were evaluated especially under 96 hours of priming (Caseiro et al 2004).

Priming duration is an important factor in harnessing the beneficial effects of hydropriming. Significant effect of basil seed hydropriming on seed germination (%), dry weight and vigour of seedlings was achieved by hydropriming seeds for 12 hours (Farahani et al 2011). Similarly Sikhondze and Ossom (2011) observed that out of the four hydropriming durations (6, 12, 24 and 36 h) studied on okra, the best seedling growth and development in terms of mean length and diameter of the stem were noticed in the seeds primed for 24 h. Ghassemi-Golenzani et al (2008) evaluated the effect of hydropriming durations (0, 7, 14 and 21 hours) on field performance of three pinto bean (*Phaseolus vulgaris* L) cultivars (Talash, COS16 and Khomain) and recorded maximum plant stand, foliage cover, plant biomass and grain yield in priming for 7 hours followed by 14 hours.

Seed osmopriming is a pre-sowing seed treatment allowing controlled imbibition of water through different salts/osmotica to start the pre-germinative processes but insufficient for radical protrusion. This treatment triggers the activity of the majority of the enzymes associated with mobilization of the food reserves (Srinivasan et al 2009). Roveri-Jose et al (2000) observed that the effect of osmotic conditioning (PEG 6000 at -1.1 M Pa) for different periods (4, 8, 12 and 16 days) and temperatures (5, 15, 20 and 25°C) on seeds of pepper (*Capsicum annuum*) cv Yolo Wonder for 8 days at 25°C produced significantly better results by reducing mean number of days to 50 per cent germination and increasing germination rate. Yadav et al (2012) tested 15 genotypes of okra involving hydropriming and halopriming ($CaCl_2$ and KNO_3) wherein all the seed priming treatments enhanced the speed of germination and synchronous germination in genotypes IC411698 and IC89936. Differential response to osmopriming in tomato cv Sioux, chilli cv Garam Jwala, cauliflower cv Pusa Katki and brinjal cv Pusa Kranti was seen by Saxena and Singh (1987). Tomato seeds were primed with PEG 6000 at 20, 25, 29, 32.4, 35 and 40 per cent or equal amount of distilled water at 4°C in darkness and tested at 20°C. For chilli, cauliflower and brinjal, seeds were primed with 29 and 32.4 per cent PEG 6000 and distilled water for 4, 8 and 12 days. Overall, polyethylene glycol treated seeds had better germination percentage as compared to control. Rao et al (2000) compared seedlings of bell pepper cv California Wonder obtained from hydroprimed seed (imbibed for 24 h) and osmoprimed seed (-0.05 M Pa to -1.0 M Pa 0.8 M Pa PEG 6000 for 10 days at 25°C in an incubator) with those of untreated seeds. They observed that root and shoot growth was significantly higher in the primed seed at -0.4 M Pa compared to untreated seeds. Seed priming with polyethylene glycol (PEG) at -1.25 M Pa for 2 days significantly ($P < 0.01$) improved germination rate of locally grown tomato cultivars than untreated control (Soulange and Levantard 2008). Seed priming using PEG 6000 (-1.5 M Pa for 6 days) has been found beneficial in bitter gourd (cv Co-1) sown dry or wet for getting maximum germination and shoot growth (Thirusenduraselvi and Jerlin 2009).

Osmoprimed seeds exhibited good crop stand even under sub-optimal conditions of temperatures and moisture (Bradford 1986). In their seed priming experiment on sweet corn cv Honey 236, Sung and Chang (1993) primed the seeds with PEG 6000 and vermiculite for 24 hours at 25°C and tested for seed quality parameters at temperature 10, 15, 20 and 25°C. It was noticed that osmopriming with PEG 6000 (-1.5 M Pa) for 24 h improved emergence percentage, mean germination time and uniformity of emergence under sub-optimal temperature. In spinach cv Bloomsdale, seeds primed with PEG 8000 (-0.6 M Pa) at 15°C for 8 days in darkness were tested at sub-optimal (5°C) and super-optimal (20°C) temperatures. It was found that seed priming with -0.6 M Pa at 15°C for 8 days produced the best results in terms of germination performance at 5 and 20°C (Chen et al 2010). However Dursun and Ekinci (2010) treated parsley seeds for 2, 4, 6 and 8 days with the PEG 6000 (-0.5 M Pa, -1.0 M Pa and -1.5 M Pa), KNO_3 (0.30 and 0.35 mol/l), mannitol (0.50 and 0.60 mol/l), hydroprimed

(12, 24, 36 and 48 h) and unprimed (control). It was concluded that seed germination percentage was enhanced by priming of seeds at low as well as high temperature. de Lima and Marcos-Filho (2010) studied the effect of seed osmopriming (-0.1 and -0.2 M Pa) on seedling emergence in cucumber varieties Safira and Joia having seed moisture content of 29 to 32 per cent respectively. PEG 6000 (-0.2 M Pa) primed seeds tested at varied temperatures (15, 20, 25, 30 and 35°C) were efficient for affecting the speed of germination under suboptimal temperatures. Similarly Silva et al (2012) evaluated the effect of aerated osmoconditioning with PEG 6000 (-1.0 M Pa) for 7 days on germination of hot pepper cv Mari at different temperatures (15, 20, 25, 30 and 35°C) wherein total seed germination decreased with increasing temperature. However osmotic conditioning was effective in improving seed germination at all temperatures especially at high temperature.

The methodology of priming to be followed differs with the crops. Kuppusamy and Umarani (2014) subjected okra and beet root seeds to four methods and two durations of priming viz hydropriming (12 and 24 h), sand matrix priming (60% WHC; 3 and 6 h), halopriming (3% NaCl; 12 and 24 h) and osmopriming PEG 6000 (-1.0 and -1.5 M Pa) for 24 h. Sand matrix priming (3 hours in 60% WHC of sand) was found to be the best for okra whereas hydropriming (for 12 h in water) in beet root was equally effective. Kaur et al (2015) observed that seedling length of okra seed was influenced by priming (hydropriming, osmopriming with 5% PEG and osmopriming with 10% PEG) treatments consisting of soaking durations at 6 h interval (24, 30, 40 and 48 h) and dry seeds as a control. The maximum seedling length, seed vigour index-I and II were obtained in the treatment osmopriming with 5 per cent PEG for 24 h.

Hydropriming/osmopriming and seed storability

Different workers have suggested that primed seeds should be stored in hermetically sealed packs at low temperatures after treatment. Sampaio and Sampaio (1998) primed the seeds of carrot (cv Brasilia) in aerated solutions of PEG 6000 (200 g/l), KNO_3 (0.3 M), K_2HPO_4 (0.3 M) or distilled water for 24, 48 or 72 h at 25°C. Osmotic priming with PEG 6000 increased the speed and uniformity of germination (both at 15 and 35°C). The viability of primed seeds was decreased by 11-13 per cent after 150 days of storage in paper bags under ambient laboratory conditions whereas the viability of control non-treated seeds remained constant. Similarly Tamanini et al (2002) primed the seeds of tomato cv Santa Clara in aerated solutions of PEG 8000 (300 g/l) and KH_2PO_4 (0.3 M) for 96 h and in distilled water for 24 and 48 h under ambient temperature. Primed seeds were dried for 96 h under ambient temperature to approximately 11 per cent moisture and stored in paper packs involving two treatments viz with temperature and humidity control (15°C and 40% relative humidity) and without temperature and humidity control (ambient conditions). Germination tests were performed immediately after the drying of seeds and after the storage period. It was reported that seeds maintained the beneficial effects of priming for at least 6 months when stored under controlled conditions. Priming with KH_2PO_4 was more efficient than that with PEG.

Storability of the primed seeds also varies with the plant species in question. The effect of priming on relative storage potential of cucurbit seeds viz cucumber, watermelon and muskmelon seed lots tested after storing in relatively adverse storage conditions of 25°C and 12 per cent moisture content for 6, 12 and 18 months in sealed aluminium foil revealed that seed lots were dead after 12 to 18 months of storage in watermelon and cucumber respectively. Further the initial germination before storage was significantly correlated with seed longevity (Demir and Mavi 2008). Seeds of some plant species need to be used immediately for sowing after priming. Dearman et al (1987) in their study primed carrot and leek seeds with PEG 6000 (-1.0 and -1.2 M Pa) for 10, 14 and 17 h followed by accelerated ageing for 0, 24, 48, 72 and 96 h and reported that loss of viability in leek (*Allium porum* L) and carrot (*Daucus carota* L) seeds was dramatically faster in primed seeds as compared to control. The primed and dried leek seeds were stored for 12 months at 10°C. In some of the plant species seed deterioration in the storage can also be prevented through osmopriming as antioxidant enzymes like catalase, peroxidase and superoxidase are activated. van Pijlen et al (1996) reported that tomato seed invigorated in solution of KNO_3 or PEG 8000 would counteract the adverse effect of storage and reduce the mean time for germination by as much as 53 per cent. Pandita and Nagarajan (2000) primed tomato cultivars Pusa Ruby, Pusa Gaurav, Pusa Sheetal and S 120 seeds with PEG 6000 (-1.0 M Pa) or water for 7 days, dried to 6.5 per cent moisture content, stored in sealed aluminium foil bags, subjected to accelerated ageing at 40°C and 100 per cent RH for 6 days and assessed for germination, seedling growth and vigour

index. They found that priming with PEG improved the germination of seeds.

Osmopriming can delay the onset of deterioration caused by accelerated ageing. It was observed that osmoconditioning followed by ageing in four tomato cvs Pusa Ruby, Pusa Sheetal, Pusa Gaurav and S-120 improved speed of germination in seeds osmoprimed with PEG 6000 (-1.0 M Pa) at 40°C for 6 days over the aged seeds (Nagarajan and Pandita 2001). In spinach also seed priming with PEG 8000 (-0.6 M Pa) for 8 days at 15°C improved germination and seedling establishment under extreme conditions of temperatures and drought (Chen et al 2010). Method as well as duration of priming affects the viability of primed seeds. Venkatasubramanian and Umarani (2010) compared four different methods of seed priming viz hydropriming, halopriming, sand matrix priming and osmopriming of tomato, egg plant and chilli seeds stored for two durations. The results indicated that 48 hours of hydropriming in tomato and sand matrix priming (80% WHC, 3 days) in brinjal and chilli seeds were quite effective in enhancing seed vigour as well as viability. In another study Selvarani et al (2011) subjected onion seeds to hydropriming, sand matrix priming (80% WHC-solid) and salt priming (KNO_3 and NaCl at 3%) for 12 and 24 hours and osmopriming (PEG -0.25 M Pa) for 8 and 12 hours. The seeds were then stored for 4 months under ambient conditions (33°C and 57% RH) after dividing into two lots based on moisture content (7 and 8%) and packed in aluminium pouches and cloth bags respectively. In both the containers, seeds primed with sand (80% WHC) for 24 h exhibited the best results over rest of the treatments throughout the period of storage.

Zhang et al (2012) studied the effect of osmopriming in PEG solution (10%) kept in dark for 2 days at a temperature of 20 ± 1°C on tomato hybrid ZZ1seed vigour under ageing stress, stored for 4 years under natural (aged) or -20°C (unaged) conditions and observed significantly higher germination percentage, germination index and mean germination rate of primed aged seeds compared with unprimed aged seeds, with a significant increase in root length, shoot length and seedling fresh weight. Rahman et al (2013) studied the effect of pre-storage seed priming treatments with water, PEG 8000 (polyethylene glycol 8000) and mannitol solution on okra seed, dried to initial moisture content (11%) and then evaluated at zero storage, 3 months and 6 months storage for their unsaturated fatty acids, hexanal and proteins. They observed a reduction in unsaturated fatty acids and protein content and increase in hexanal during storage for each treatment but it was significantly controlled by priming with PEG 8000 (-1.2 M Pa) for 18 h duration followed by priming with mannitol at the same water potential and duration as used for PEG priming compared to water treatment and dry seeds.

Hydropriming/osmopriming and field performance

Just like the differential response of crops for effectiveness of duration, methods and temperatures to priming, different workers have reported varying results with regard to the transmission of positive effects of priming on crop growth parameters. Wolfe and Sims (1982) noticed a significantly higher emergence rate than the control in tomato cv UC-82 seeds primed with PEG 6000 (-5 bar) for 7 days prior to planting. In a similar fashion Alvarado et al (1987) observed that the early growth advantage from osmoprimed seeds in tomato (cv UC-204 and UC-6203) did not improve earliness in maturity and total yield wherein seeds were primed in aerated solution of KNO_3 (3%) and PEG 8000 (-1.25 M Pa) at 20°C for 7 days, rinsed and dried in forced air at 30°C. In a study with broccoli cv Earlidawn, seeds were primed either osmotically with PEG 8000 (-1.1 M Pa) or metrically in vermiculite at 68°F for 7 days and it was concluded that the benefit of priming was faster seed emergence, which increased stand by reducing exposure to stress that lead to a decrease in emergence but did not increase yields or accelerated the maturity (Jett et al 1996).

Pandita et al (2009) carried out an experiment on different priming treatments viz osmopriming with PEG 6000 (-0.5 M Pa for 3 days at 25°C), solid matrix priming (in moist vermiculite for 48 h at 25°C) and hydropriming (for 24 h at 25°C) to improve emergence of *Capsicum annuum* (cv California Wonder) seeds under optimal and suboptimal temperatures and noticed a significant reduction in mean number of days to germination both in osmo and solid matrix priming over control.

Benefits of seed priming have been attributed to priming-induced quantitative changes in soluble protein and phosphorus content of the seeds and improved membrane integrity. Priming effect on seedling emergence of two tomato cultivars (Cherry and Falcato) under four different constant temperatures (10, 15, 20 and 25°C) by soaking seeds in polyethylene

glycol 6000 solution (osmopriming) or in moist vermiculite (hydration) for 24 h at 25°C revealed that both the priming treatments were capable of improving mean emergence, mean emergence time (MET) and emergence coefficient (EC) especially under sub-optimal temperatures (Amooaghaie et al 2010). To harness the maximum potential of seed priming, the most suitable method and the methodology should be adopted specific to each crop species. For onion sand matrix priming (24 h in 80% WHC of sand) recorded the highest improvement for days to 50 per cent germination, days to maximum germination and speed of germination however the highest values for the said parameters in carrot were obtained following hydropriming for 24 h (in water at double the volume of seed) than control (Selvarani and Umarani 2011). Raza et al (2013) tried six priming treatments (control, hydropriming, ascorbic acid 50,100 and 150 mg/l and salicylic acid 50 mg/l) along with two stress levels (control and 1.25 ml/l NaCl) under saline soil field conditions. They noticed that hydropriming effectively improved growth, pigments and yield of okra as compared to control under both stress levels. In another experiment, Sharma et al (2014) compared hydropriming (12 hours) and solid matrix priming (calcium aluminium silicate for 24 hours) for seed germination, seedling vigour and fruit yield in okra and advocated hydropriming because of its simplicity, economic feasibility and safety as well as effectiveness to increase the fruit yield (55%) as compared to control. Treatment of okra seed with PEG 6000 (-0.5 M Pa) for 24 h was recorded as the best treatment for characters like days to 50 per cent emergence, total emergence, fruit weight, fruit length, fruit diameter, number of fruits per plant and fruit yield (Sharma et al 2018).

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