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Seed invigoration techniques: A review

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Abstract
Seedling establishment is an important factor and largely depends on the seed germination and vigour. Seed priming is a wonderful technique of seed invigoration which has the potential not only to enhance the seed vigour and germinability of normal seeds but also has the excellent ability to revive the partially aged seeds and improve the germination power over a wide range of environmental conditions. Since, seed priming is found to be a useful technology there is a need to standardize this technology in every crop species particularly in vegetables and floriculture crops. A proper understanding of seed quality problem requires a thorough review of the existing technology and its effects on growth and yield parameters.

Keywords: Seed priming, seed vigour, crop establishment, GA_3 priming

Introduction
Deterioration of seed is a serious problem in tropical and subtropical countries like India where high temperature and humidity accelerate the seed ageing phenomenon. As seed aged, they came to germinate more slowly than fresh seeds, respire slower and become more susceptible to disease, chromosomal abnormalities and increased proportion of morphologically abnormal seedlings. All the physiological parameters viz., germination percentage, viability percentage, seedling length, seedling dry weight, vigour index, field emergence index, seedling establishment and DHA activity were decreased significantly with progress of ageing period (Kumar, 2004 [24] in onion; Desraj, 2002 [7] in coriander and Kumar, 2010 [25] in coriander).
Use of quality seed is the most important factor as quality seeds ensure better germination as well as better yield. The seedling establishment of crops is influenced by the quality of the seed used (De Figueiredo *et al*., 2003) [6]. Seed priming is an effective technology to enhance rapid and uniform emergence and to achieve high vigour, leading to better stand establishment and yield.
Seed priming is one of the pre-sowing seed management techniques where the seeds are partially soaked and subsequently dried back for invigorative effect that expresses on field emergence and extend up to yield. Priming applications contribute to significant improvement in seed germination and seedling growth in vegetables (Dursun and Ekinci, 2010 [10]; Korkmaz, 2005 [23]; Korkmaz and Pill, 2003) [22]. Improved seed invigoration techniques are well known to reduce emergence time, accomplish uniform emergence and give better crop stand in many horticultural crops and these includes hydro priming, osmo conditioning, hormonal priming and soaking before sowing (Ashraf and Foolad, 2005) [3].
Priming of seeds has been used as pre sowing treatment for seed lots that have lost vigour and viability due to improper storage conditions (Pan and Basu, 1985 [30] in carrot and Singh *et al*., 2001[39] in muskmelon). Harris *et al*., (2007) [14] reported that seed priming led to better establishment and growth, earlier flowering, increase seed tolerance to adverse environment and greater yield in maize. Proper standardization of the pre-sowing seed treatment method and methodology for individual crops and cultivars is the most important determinant of the success of seed priming.
Seed enhancement through priming has led to great improvements in farmer's ability to achieve this goal in the field and under controlled environment/ greenhouse (Amin *et al*., 2016) [2]. Priming responses were attributed mainly to rapid seedling establishment, higher plant stand and earlier crop maturity allowing escape from end-of season stresses (Harris, 1996) [13]. The key basis of all pre sowing is to hydrate the seed under controlled conditions, so that they become physiologically active and thus they are able to initiate repair mechanisms and detoxify the system (Devaraju *et al*., 2011) [8].

Various seed priming techniques have been developed to provide better seed quality which include hydro-priming, halo-priming, osmo-priming, sand matric priming and hormonal priming.

Hydro priming

Involves soaking the seeds in water followed by drying prior to sowing seeds. Hydro-priming increased germination percentage, rate of germination and uniformity of germination, along with other quality parameters in onion (Tajbakhsh *et al*., 2004) [42]. Aged chickpea seeds were hydro primed and found increased rate of germination and dry weight of seedling (Ghassemi-Golezani *et al*., 2012) [12] and the result clearly indicated that hydro-priming repaired deteriorated seeds and enhanced their performance in the field. In millets, it was observed that hydro priming for 15 hrs at 10°C under dark conditions followed by drying increased germination percentage under salinity stress conditions (Aghbolaghi and Sedghi, 2014) [1].

Hydro-priming plays an important role in the seed germination, radical and plumule emergence in different crop species. Sharma *et al*. (2014) [38] reported that hydro priming improved the vigour index of okra (*Abelmoschus esculentus*) seeds. Seed invigoration treatment in maize with distilled water for 24 hrs gave higher germination, decreased days to 50% germination, increased shoot length, root length, seedling fresh and dry weight (Khan *et al*., 2017) [21]. Rouhi *et al*. (2018) [33] reported that hydro priming for 5, 10 and 15 h improved final germination percentage to 24.4, 40 and 95.5%, germination rate by 8.6, 29.3 and 41.4% and vigour index by 25.7, 70.7 and 166.8% as compared to non-primed seed, respectively. These results suggest that increased antioxidant enzyme activities affect germination performance of aged coriander seeds due to hydro priming for 15 h.

Halo priming

Is a technique in which seeds are treated with inorganic salts i.e., KNO_3, NaCl, $CaSO_4$, $CaCl_2$ etc. in order to improve germination and decrease salinity intolerance. Devaraju *et al*. (2011)(8) conducted experiment to study the effect of chemo-priming on plant growth and bulb yield of onion taking KNO_3 2% as priming material for 24 hours and recorded increased rate of bulb diameter (10.22 cm), ten bulbs weight (652.5 g), bulb yield per plant (65.25 g), bulb yield per ha (35.65 t/ha), which were 0.033%, 0.063%, 0.0.62% and 0.194% higher than control, respectively.

KNO_3 priming can help in improving the initial quality of onion seeds. Priming enhanced the germination rate of seeds by up to 26.3% after 12 month of storage and the loss of vigour is lower in primed seeds than control (Dong *et al*., 2014) [9]. Piri *et al*. (2009) [31] suggested that the priming material KNO_3 at 15^0C gave higher seedling fresh weight, dry weight, and root volume over control. It was recommended that KNO_3 could be used as suitable priming material to enhance cucumber seed germination at low temperature. Elouaer and Hannachi (2013) [11] showed increased germination as well as growth parameters in Tunisian coriander seeds primed with NaCl and $CaCl_2$ compared with unprimed seeds. Onion seeds treated with KNO_3 at the relatively lower concentration of 1% for a relatively shorter duration of 12 hrs remarkably increased standard germination, germination rate, vigour index, seedling dry weight and both marketable and total onion bulb yields (Nego *et al*., 2015) [28].

Osmo priming

Refers to soaking of seeds in solution of sugar, PEG, sorbital etc. followed by air drying before sowing. Seed priming with PEG has been shown as an effective method to improve seed germination, seedling emergence and stress tolerance of several crop plants under unfavourable conditions such as salt, water, chilling and nano-ZnO stresses (Chen and Arora, 2011 [5]; Zhang *et al*., 2015) [45]. Jagadish *et al*. (1994) [16] reported that hydration-dehydration treatment improved germination capacity of slightly deteriorated seeds in tomato, chilli and onion. Significant enhancement in germination and seedling growth was observed when these seeds were treated with PEG @ 1.20 MPa.

Capsicum seedlings obtained from PEG primed seeds tolerated both the cold and salt stresses whereas control seedlings did not survive exposure to either stress (Yadav *et al*., 2011) [43]. Sadeghi *et al*. (2011) [34] observed that soybean seeds treated with PEG 6000 (-1.2 MPa) increased germination percentages, germination index and seed vigour meanwhile decreased mean germination time, the time to get 50% germination and electrical conductivity of seeds. Osmo priming not only improves seed germination but also enhances general crop performance under non saline or saline conditions. In okra, osmo-priming with 5% PEG for 24 h duration lead to better yield and biochemical quality parameter by tolerating adverse environmental effects (Kaur *et al*. 2015) [19]. Sweet pepper seeds osmo primed with PEG 6000 (-1.5 MPa) for 14 days recorded the highest germination percentage, plant height, number of roots and root length (Kaewduangta *et al*., 2016) [18].

Sand matric priming

Involves use of moist sand as a priming solid matrix. The use of solid medium allows seeds to hydrate slowly and simulates natural imbibition process occurring in the soil (Mc Donald, 2000) [27]. In onion, matric conditioning greatly improved the germination and emergence percentage, seedling fresh and dry weight and reduced electrolyte leakage compared to that of untreated seeds; this beneficial effect was especially evident at suboptimal temperatures (Kerpozynski *et al*., 2003) [20]. Sand priming was an effective method to enhance the ability of salt tolerance and to improve seed germination and seedling growth of alfalfa under high-salt concentration stress condition (Hu *et al*., 2006)(15). Selvarani and Umarani (2011)(37) conducted an experiment to standardize the best methodology and method of priming, specific to each crop seed viz., onion and carrot. It is envisaged that for onion, sand matric priming (24 h in 80% WHC of sand) is the best treatment whereas, for carrot seeds, hydro priming (36 h) in double the volume of seed is optimum.

Srivastava *et al*. (2011) [41] reported that infection by *Pythium aphanidermatum*, *Fusarium solani*, *Rhizoctonia solani* and *Phomopsis vexans* in tomato, brinjal and chilli reduced by sand matrix priming of seed (80% WHC). Pooja (2013) [32] reported best performance of brinjal seed with regard to physiological and biochemical parameters observed by sand matrix priming of seed (80% WHC) and followed by hydro priming. Seeds of okra and beet root subjected with four methods of priming (Nirmala and Umarani, 2014) [29]. Better improvement in seed quality with good storability can be obtained in okra by subjecting the seeds, sand matric priming (60% WHC) for 3 h while for beet root seeds, hydro priming for 12 h in water can be adopted.

GA_3 priming

Is the pre - seed treatment with a hormone like GA_3 which promotes the growth and development of the seedlings. Seed priming with hormones has been an efficient method for increasing seed vigour as well as seedling growth under stressful conditions. Yarnia and Tabrizi (2012) [44] reported that pre-treatment onion seed by hormones especially GA3 and IAA caused germination power and relative growth rate. Sathishkumar (2005) [36] reported that brinjal seeds soaked for 6 hours in GA_3 @ 200 ppm recorded higher germination compared to control. Bassi *et al*., (2011) [4] reported that priming with GA_3 @ 50 ppm for 2 h enhanced emergence, germination and speed of germination in soybean as compared to non-primed seed lots.

Gibberellins are known to regulate developmental and physiological processes such as germination, stem, leaf growth, stimulating transcription of hydrolytic enzymes' mRNA in various plants. Kumar and Singh (2013) [27] reported that bitter gourd seeds primed with 100 ppm GA_3 for 24 h gave better germination, field emergence, speed of emergence, seedling length and vigour index-I over the control. Jendrzejczak and Smigerska (2014) [18] reported that Amaranthus seeds treated with GA_3 showed more abundant growth than control which contributed to maximum yield. Soubhagya Behera (2016) [41] studied the effect of different priming agents in improving the seed quality parameters of solanaceous vegetable crops like tomato, brinjal and chilli. It was observed that priming of tomato, brinjal and chilli seeds with GA_3 had significantly increased germination as well as field emergence percentage as compared to unprimed seeds.

Conclusion Improved seed invigoration techniques are well known to reduce emergence time, accomplish uniform emergence and give better crop stand in many horticultural crops and these includes hydro priming, osmo conditioning, hormonal priming and soaking before sowing. The accurate choice of priming duration and method are important to attain maximum benefits from seed priming techniques.

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