REVIEW ARTICLE

Seed Priming: An Old Empirical Technique with New Contemporary Perspectives in Respect to *Pisum sativum* L: A Review

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Abstract

Pea is a small duration pulse crop which gives a different performance in field emergence and seed yield at different soil type and environment. Major factors that deteriorate pea yield are a fungal infection at germination, low nodules formation and slow food stimulation process to seeds. For surpassing such a problem, seed priming is the best solution. Seed priming is of many types depending upon the priming material like chemicals, bio-agents, water, nanoparticles, radiations, growth hormones and many more. Using different priming technique, seed's hormonal and metabolomic process can be altered and managed in a positive way, resulting in better germination and appropriate plant stand with greater biological and seed yield. This review deals with different priming techniques and their effect on pea crop's germination, phenological and yield attributing traits for getting good crop establishment and better yield performance.

Keywords: Calcium chloride and potassium chloride, Germination synchrony, Pisum sativum, Priming, Sodium molybdate.

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Introduction

Legumes are the third largest family of flowering plants, with more than 650 genera and 18.000 species (Lewis *et al.,* 2005). Legumes have a major contribution to diet as good sources of protein, carbohydrates, several water-soluble vitamins and minerals (Rodriguez *et al.,* 2008; Gour *et al.,* 2017). It contains 17 % protein and one of the most vital farming plants of the legumes family. Globally it has the third position among the grains in terms of production rate. India is the largest producer and importer of pulses in the world whereas; productivity is low as compared to China and USSR (Singh *et al.,* 2017).

In semi-arid tropical zones, crop establishment and production is important constraint ensuing to germination (Matarira *et al.,* 2004). Adverse physical conditions in the seedbed viz., mechanical resistance, high temperatures, the high solute concentration at seed-water interface leading to peak osmotic potential and rapid soil drying and crusting often experience in the seeds and seedlings (Parera and Cantliffe, 1994). In low-precipitation areas, often slow, asynchronous, unreliable germination, delayed emergence, and insufficient crop stand establishment are major issues.

Improving the productivity of pea under rainfed environment is possible through seed priming treatment (Koutu *et al.,* 2019). Primed seeds usually reveal an increased germination rate, greater germination, uniformity and at times, greater total germination percent under sub-optimal conditions (Lin and Sung, 2001; Basra *et al.,* 2005). Increased germination and uniformity have assigned to metabolic repair for the period of imbibitions (Bray *et al.,* 1989), accelerate germination-enhancing metabolites (Basra *et al.,* 2005), osmotic adjustment (Bradford, 1986) and for seeds that are not re-dried after treatments, a simple reduction in imbibitions lag time (Bradford, 1986).

Positive and diversified effects of priming on the yield components of forming plants in different places, due to a difference in the environment condition are of special importance. Therefore, this topic is reviewed to collect knowledge on the effect of priming treatments on the germination, phonological and yield components of the pea.

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Brief history of priming

Seed priming is a very old practice, used eons ago by Greek's people. The term was given by Heydecker in 1973 for the soaking drying seed treatments (Sivasubramaniam *et al.,* 2011). Theophrastus (372–287 BC) used cucumber seed and presoaked in milk or water germinate fast and vigorously (Michael Evanari, 1984). Further, Heydecker, (1973) used seed

priming to enhance seed germination and emergence under stressed conditions in many crops.

Harris, (2006) a veteran, promoted a large number of farmers and tested seed priming for themselves and found improved yield in 40% percent with upland rice in Cameroon, 70% in Ghana, 33% in Sierra Leone, 25% in the Gambia, 113% in Nigeria and 10% in Thailand. In wheat, 275 farmers in India, Pakistan, and Nepal have tested seed priming (5–35%). Maize trials by 72 (29%) farmers in Pakistan and Zimbabwe were also very successful. In the case of chickpea, Bangladesh, Nepal, and Pakistan's farmers implemented more than 40% trials. The farmers reported that seed priming was found to be effective in semi-arid and forest agriculture interface production systems. This approach has been extended with some of the changes, to enable farmers to test seed priming in developing countries viz., Bangladesh, Cameroon, Gambia, Ghana, India, Nepal, Nigeria, Pakistan, Sierra Leone, Thailand, and Zimbabwe.

Types of Seed Priming

Seed priming deals with a practice that enhances rapid and homogeneous seedling emergence consequently beneficial for better establishment of crops in a field situation. Depending upon the priming material seed priming is classified into various types (Fig. 1).

Conventional Methods of Seed Priming

In conventional priming method, several categories of seed priming substances, i.e., hydro-priming, osmopriming, chemopriming, hormopriming, bio-priming, solid matrix-priming, nutriopriming and thermopriming (Farooq *et al.,* 2007; Chen, 2011) are included.

It is routinely used in horticultural crops, but large scale utilization of priming in cereals or other field crops is limited (Murungu *et al.,* 2004). Same priming practice may often have a diverse effect among species, cultivars, and even seed lots (Pill *et al.,* 1994).

Latest Approaches of Seed Priming

Researchers are continuously engaged in finding out some different but effortless methods for seed priming which can be used as a substitute to conventional protocols, and at the same instance, the latest techniques should be rapid, cost-effective and environmentally safe. Among the latest techniques, the use of physical agents and nanoparticles for seed priming is rapidly rising. The physical agents include the magnetic field, UV radiation, Gamma radiation, X-rays, Microwaves, Electro and Ultrasonic. Whereas, nanoparticles of calcium phosphate, ZnO, SiO_2, silver, and iron are included in nano-priming (Dutta, 2018).

Seed priming with respect to phenology and plant growth parameters

Germination Speed and Rate

Primed seeds can get better germination of many crop species, particularly under unfavorable conditions such as low temperature (Zheng *et al.,* 1994; Hardegree and Van Vactor, 2000; Kaya *et al.,* 2010). Thus, priming of seeds with water or osmotic solution before sowing is extensively

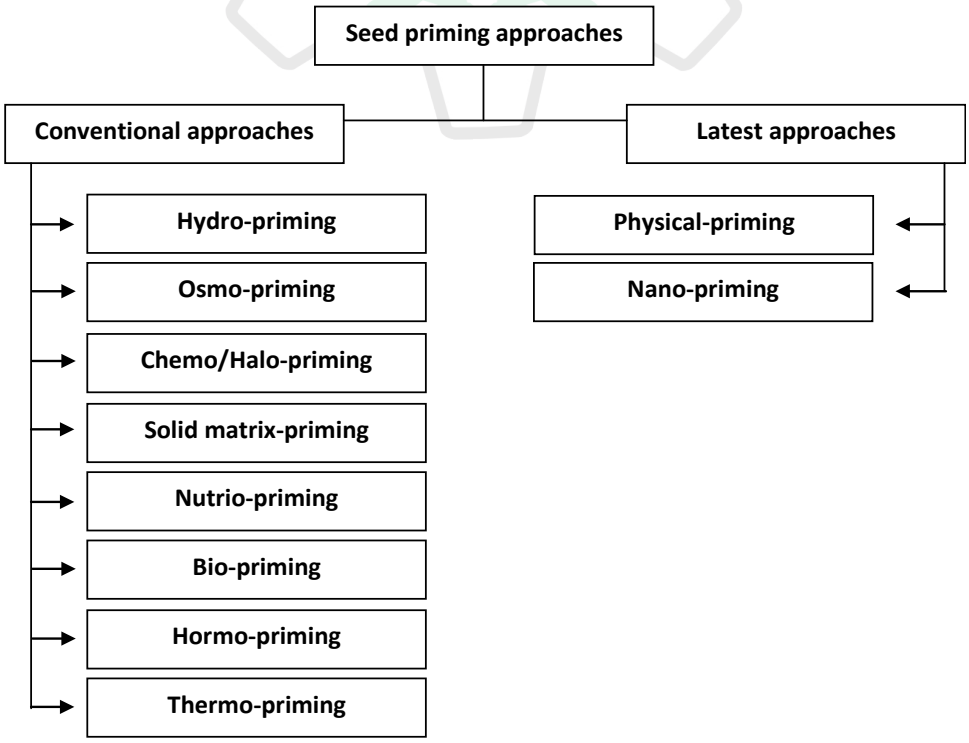

Fig. 1: Types of priming techniques

adopted to overcome unfavorable effects of temperature on germination (Yan *et al.,* 1989; McDonald, 1999). Compared with the unprimed seeds, priming treatments induce faster germination at different germination temperatures. Alike increase in germination speed of chickpea (Elkoca *et al.,* 2007), maize (Harris *et al.,* 1999), soybean (Yan *et al.,* 1989), pea (Sivritepe and Dourado, 1995), grass seeds (Hardegree and Van Vactor, 2000), canola (Zheng *et al.,* 1994), wheat and barley (Al-Karaki, 1998) through seed priming have been reported in previous studies. These valuable effects of priming on seed germination rate are associated with the repair and build-up of nucleic acid, enhanced synthesis of RNA and proteins, repair of membranes and some age-induced damage (Bray *et al.,* 1989; Dell' Aquila and Bewley, 1989; Davison and Bray, 1991; Bray, 1995), and enhanced respiratory activity of seeds (Halpin-Ingham and Sundstrom, 1992; Benamar *et al.,* 2003). However, the pea is particularly sensitive to osmotic stress (Wilson *et al.,* 1985). Some investigators recorded an accumulation of proline (Pyrrolidine-2-carboxylic, anon-essential amino acid) in all plants exposed to osmotic stress (Chauhan *et al.,* 1980). Besides, germination was reduced with increased osmotic stress of the seeds (Akeson *et al.,* 1980). It is also reported that the growth of tropical pasture legume plants was reduced under osmotic stress (Hutton, 1971). Koutu *et al.,* 2019 resulted that pea seed treatment with Sodium Molybdate @ 500 ppm/kg seed showed significantly highest germination %. However, Aroubandi, 2016 resulted in maximum germination percentage using the zinc sulfate treatment.

Germination Synchrony

Elkoca *et al.,* 2014 studied priming treatments with 3% and 1% mannitol solution improve germination synchrony at 17, 23°C and 26°C. But, compared with the priming treatments at the other temperatures, germination synchrony of unprimed seeds were similar or better. It seems that priming treatment, priming duration, and temperature are truly correlated with each other in reference to germination synchrony. Similarly, McDonald, (2000) has also reported that the seed priming treatments sometimes do not stimulate germination synchrony because an equal amount of water cannot be taken by each seed under seed priming conditions and this prevents a uniform physiological activity in seeds.

Thermal Time Requirement

The coefficients generated by thermal germination models that integrate potential response over a wide range of temperature conditions (Garcia-Huidobro *et al.,* 1982; Covell *et al.,* 1986; Hardegree *et al.,* 1999). These coefficients can be compared directly to rank the relative potential performance of seed lots (Covell *et al.,* 1986) and can be validated by confirming the germination response under variable temperature conditions (Hardegree *et al.,* 1999; Hardegree and Van Vactor, 2000). Earlier and faster germination and emergence have been associated with a lower value of thermal time requirement (Mohamed *et al.,* 1988). In cold soils, the low thermal time requirement is of great importance for rapid germination (Bierhuizen and Wagenvoort, 1974) because the germination of seeds will be delayed until the thermal time requirement is met. Elkoca *et al.,* 2014 also quantified the priming effect by calculating the thermal-response parameter from the sub-optimal temperature data, and resulted that compared with the unprimed treatment, priming treatments significantly decreased thermal time requirements and also stated that best thermal time requirement results for germination were obtained from seeds treated with mannitol solution of 1% and 2% for 12 h (Fig. 2). Dahal *et al.,* (1990), Hardegree and Van Vactor (2000), Hardegree *et al.,* (2002) and Elkoca *et al.,* (2007) also investigated priming effects on thermal germination response. They also found that priming significantly decreased thermal time requirements.

Rate of Water Uptake

Rate of water uptake, which is necessary to activate the physiological processes in seed, is directly related to the osmotic potential of the priming solution (Hardegree and Emmerich, 1992) and decreasing water potential adversely affects the rate of water uptake in seeds (Al-Karaki, 1998; Kader and Jutzi, 2002). In the study of Elkoca *et al.,* 2014, –0.5 bar solution of PEG, which had the highest water potential among the PEG treatments, also gave the best results in the PEG treatments. But, lower water potentials

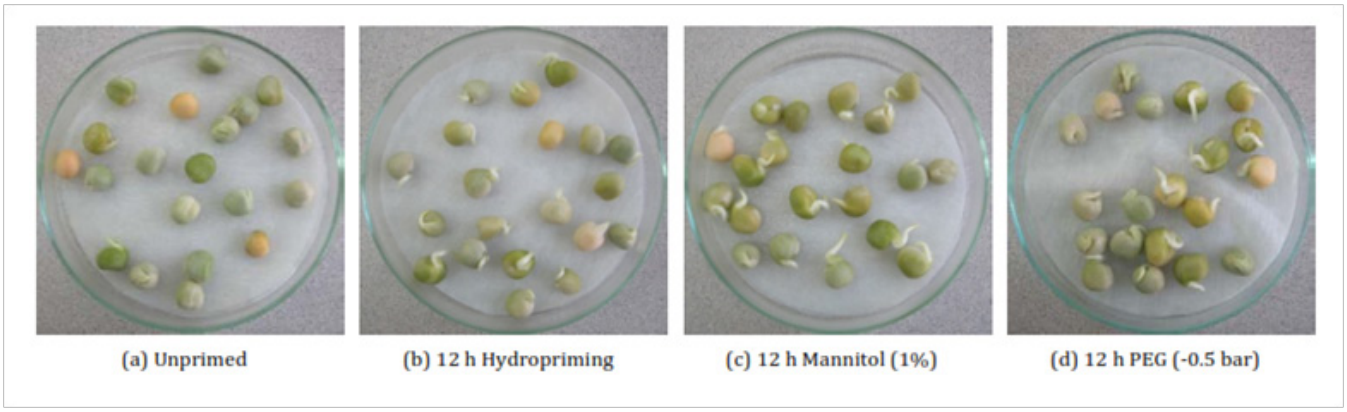

Fig. 2: Germination of pea seeds at 200th hour under the lowest temperature (5°C) conditions (Source:- Elkoca *et al*., 2014)

in PEG treatments, especially –1.5 bar, adversely affected germination speed and thermal time requirement. These adverse effects may be related to the decreased water uptake in the presence of greater levels of PEG. Related results have been reported by Danneberger *et al.,* (1992), Al-Karaki, (1998) and Elkoca *et al.,* (2007). But, this effect was not clear in the presence of greater levels of mannitol.

Priming Duration

The effect of seed priming on seed germination can vary depending on priming duration (Elkoca *et al.,* 2007; Ghassemi-Golezani *et al.,* 2008). The study of Elkoca *et al.,* 2014 resulted that compared with the priming duration of 12 hours, priming duration of 24 h had a generally negative effect on the 50% germination time and thermal time requirements for 10%, 50% and 90% germination. Similar reductions in germination parameters with increasing priming duration were observed for soybean (Khalil *et al.,* 2001), chickpea (Elkoca *et al.,* 2007) and bean (Ghassemi-Golezani *et al.,* 2010). These results show that over priming is detrimental. This is supported by Murray (1989), who concluded that over priming may cause oxygen deficiency and the build-up of inhibitors. The findings of the Elkoca *et al.,* 2014 study suggested that the priming duration of 12 hours was generally safer for pea as compared with 24 h. Similarly, soaking the seeds from overnight to 24 hours has also been recommended for many crops such as chickpea, maize, rice and bean (Harris *et al.,* 1999; Elkoca *et al.,* 2007; Ghassemi-Golezani *et al.,* 2010).

Root Length

Root length is measure trait for best stand of plants in stress condition. Koutu *et al.,* 2019 studied 10 different treatments in pea seeds and reported the highest root length for priming with water. Seed priming with water leads to enhancement in the vigour due to an increase in the seed hydration status required to achieve critical and threshold water potential for germination finally leading to rapid and uniform field crop establishment and increase in seed yield.

In the priming process, the seeds are soaked in different solutions that are having high osmotic potential. This high osmotic potential prevents the seeds from absorbing in enough water for radicle protrusion, thus suspends the seeds in the lag phase (Taylor *et al.,* 1998). In priming, the osmotic pressure and the duration of maintaining the seeds in contact with the membrane are enough to allow pre-germinative metabolic processes to be occurring within the seeds up to a level limited to that instantly preceding radicle emergence.

Root Nodulation

Samaiya *et al*. reported using pea variety "Arkel" that significantly high number of root nodules per plant in seeds primed with sodium molybdate @ 500 ppm + seed coating with T. harzianum @ 15 g per kg of seed. The higher root nodules per plant might be due to the fact that molybdenum is needed primarily on the seed coat in order to enhance nodulation with nitrogen-fixing bacteria, which requires molybdenum for the proper functioning of the nitrogen-fixing enzyme nitrogenase, to uphold high rates of biological nitrogen fixation. This evidence is in conformity with the findings of Johnson *et al.,* (2005) in chickpea and lentil, Beedi *et al.,* 2017 in chickpea and Umair *et al.,* (2011) in mungbean they reported that seed treated with sodium molybdate enhance the nodulation, nitrogen fixation, and nutrient uptake. However, *Trichoderma spp.* are common saprophytic fungi found in almost any soil as rhizosphere mycoflora, and have been investigated as potential inducers of growth and resistance in the plant because of their ability to reduce the incidence of diseases caused by plant pathogenic fungi, particularly many common soil-borne pathogens (Dubey *et al.,* 2007)

Seed priming in respect to yield components

The maximum average number of pod, grain fresh weight, pod number, and pod total weight have been observed in control treatment by Aroubandi, 2016; whereas maximum pod fresh weight and number of grains per plant have been observed in a calcium chloride treatment, the maximum average grains weight per plant has been observed in potassium chloride treatment; and the biggest pod size has been observed in the distilled water treatment. Koutu *et al.,* 2019 reported that the treatment of Sodium molybdate with the combination of *T. harzianum*, leads to enhancement in no. of pods per plant, 100 seed weight, biomass per plant (gm) and seed yield per plant (gm). It is justified that sodium molybdate as a source of molybdenum leads to activation of enzymes involved in nitrogen fixation and nitrogen assimilation *viz.,* nitrogenase and nitrate reductase which directly leads to increase in rubisco per unit area leading to enhancement in photosynthetic rate and molybdenum as a cofactor of enzymes involved in nitrogen assimilation leads to increase in the protein content in pea finally leading to increase in yield and seed quality attributes. Whereas, *T. harzianum* leads to activation of biosynthesis of plant growth promoting hormones and induce biotic stress tolerance finally leading to enhancement in seed yield.

Conclusion

This review shows the effect of priming treatment on the majority of emergence, phonological, and yield components in pea crop. From the various studies given above, it can be concluded that in pea seed priming in water improves emergence and reduces the time taken to various phenological stages. Seed priming along with biofertilizers can give significantly better results in root and nodule formation so nitrogen uptake of plant increases, which leads to enhancement of growth and yield. Priming treatment with sodium molybdate is the best option for mitigating the adverse effect of low moisture and improving the growth of yield attributing traits of a pea crop. Similarly, calcium chloride and potassium chloride also induces food stimulation in pods and seeds, which ultimately increase

yield and provide plants to tolerate adverse conditions like water deficiency, etc.

References

Akeson, W.R., Henson, M.A., Freytag, A.H. and Westfall, D.G. (1980). Sugar beet fruit germination and emergence under moisture and temperature stress. Crop Science, 20:735-739.

Al-Karaki, G.N. (1998). Response of wheat and barley during germination to seed osmopriming at different water potentials. Journal of Agronomy and Crop Science, 181: 229-235.

Aroubandi, H. (2016). The Effect of Priming Treatment on Yield Components of Pea (Greenaro). Hajar Aroubandi et al. International Journal of Institutional & Industrial Research, 1(1)10-14.

Basra, S.M.A., Farooq, M. and Tabassum, R. (2005). Physiological and biochemical aspects of seed vigour enhancement treatments in fine rice (*Oryza sativa* L.). Seed Science and Technology, 33:25–29.

Beedi, S., Macha, S.I., Gowda, B., Kurnallikar, V. and Savitha, A.S. (2017). Effect of seed priming on growth and seed yield of kabuli chickpea cv., MNK – 1 (*Cicer arietinum* L.). International Journal of Chemical Studies, 5(6): 541-544.

Benamar, A., Tallon, C. and Macherel, D. (2003). Membrane integrity and oxidative properties of mitochondria isolated from imbibing pea seeds after priming or accelerated ageing. Seed Science Research, 13:3545.

Bierhuizen, F. and Wagenvoort, W.A. (1974). Some aspects of seed germination in vegetables. I. The determination and application of heat sums and minimum temperature for germination. Scientia Horticulturae, 2:213-219.

Bradford, K.J. (1986). Manipulation of seed water relations via osmotic priming to improve germination under stress conditions. Horticulture Science (USA), 21:1105.

Bray, C.M. (1995). "Biochemical Processes During the Osmopriming of Seeds, 767-789". In: Seed development and germination (Eds. J. Kigel & G. Galili). Marcel Dekker, New York.

Bray, C.M., Davison, P.A., Ashraf, M. and Taylor, R.M. (1989). Biochemical changes during osmopriming of leek seeds. Annals of Botany, 63:185-193.

Chauhan, R.P.S., Chauhan, C.P.S. and Kumar, D. (1980). Free proline accumulation in cereals in relation to salt tolerance. Plant and Soil, 57:167-175.

Chen, K. and Arora, R. (2011). Dynamics of the antioxidant system during seed osmopriming, post-priming germination, and seedling establishment in spinach (Spinacia oleracea). Plant Science, 180:212-220.

Covell, S., Ellis, R.H., Roberts, E.H. and Summerfield, R.J. (1986). The influence of temperature on seed germination rate of legumes. I. A comparison of chickpea, lentil, soybean and cowpea at constant temperatures. Journal of Experimental Botany, 37: 705-715.

Dahal, P., Bradford, K.J. and Jones, R.A. (1990). Effects of priming and endosperm integrity on seed germination rates of tomato genotypes. I. Germination at suboptimal temperature. Journal of Experimental Botany, 41:1431-1439.

Danneberger, T.K., McDonald, M.B., Geron, C.A. and Kumari, P. (1992). Rate of germination and seedling growth of perennial ryegrass seed following osmoconditioning. Hortscience, 27: 28-30.

Davison, P.A. and Bray, C.M., (1991). Protein synthesis during osmopriming of leek (Allium porrum L.) seeds. Seed Science Research, 1:29-35.

Dell'Aquila, A. and Bewley, J.D. (1989). Protein synthesis in the axes of polyethylene glycol treated pea seeds and during subsequent germination. Journal of Experimental Botany, 40:1001-1007.

Dubey, S.C., Suresh, M. and Singh, B. (2007). Evaluation of Trichoderma species against Fusarium oxysporum f. sp. ciceris for integrated management of chickpea wilt. Biological Control, 118-127

Dutta, P. (2018). Seed Priming: New Vistas and Contemporary Perspectives. Advances in Seed Priming, https://doi.org/10.1007/978-981-13-0032-5_1.

ELKOCA, E. (2014). Osmo- and hydropriming enhance germination rate and reduce thermal time requirement of pea (Pisum sativum L. cv. Winner) seeds. Akademik Ziraat Dergisi, 3(1):1-12.

Elkoca, E., Haliloglu, K., Esikten, A. and Ercisli, S. (2007). Hydro- and osmopriming improve chickpea germination. Acta Agriculturae Scandinavica Section B-Soil and Plant Science, 57:193-200.

Evanari, M. (1984). Seed Physiology: Its History from antiquity to the beginning of the 20th century. The Botanical Review, 50:119-142.

Farooq, M., Basra, S.M.A. and Khan, M.B. (2007). Seed priming improves growth of nursery seedlings and yield of transplanted rice. Archives of Agronomy and Soil Science, 53:311-322.

Garcia-Huidobro, J., Monteith, J.L. and Squire, G.R. (1982). Time, temperature and germination of pearl millet (Pennisetum typhoides S. and H.). I. Constant temperature. Journal of Experimental Botany, 33:288-296.

Ghassemi-Golezani, K., Chadordooz-Jeddi, A., Nasrollahzadeh, S. and Moghaddam, M. (2010). Effects of hydro-priming duration on seedling vigour and grain yield of pinto bean (*Phaseolus vulgaris* L.) cultivars. Notulae Botanicae Horti Agrobotanici Cluj, 38:109-113.

Ghassemi-Golezani, K., Sheikhzadeh-Mosaddegh, P., Valizadeh, M. (2008). Effects of hydro-priming duration and limited irrigation on field performance of chickpea. Research Journal of Seed Science, 1:34-40.

Halpin-Ingham, B. and Sundstrom, F.J., 1992. Pepper seed water content, germination response and respiration following priming treatments. Seed Science and Technology, 20:589-596.

Hardegree, S.P. and Emmerich, W. (1992). Effect of matric priming duration and priming water potential on germination of four grasses. Journal of Experimental Botany, 43:233-238.

Hardegree, S.P. and Van Vactor, S.S. (2000). Germination and emergence of primed grass seeds under field and simulated-field temperature regimes. Annals of Botany, 85:379-390.

Hardegree, S.P., Jones, T.A. and Van Vactor, S.S. (2002). Variability in thermal response of primed and nonprime seeds of squirrel tail [Elymus elymoides (Raf.) Swezey and Elymus multisetus (J.G. Smith) M.E. Jones]. Annals of Botany, 89:311-319.

Hardegree, S.P., Van Vactor, S.S., Pierson, F.B. and Palmquist, D.E. (1999). Predicting variable-temperature response of non-dormant seeds from constant temperature germination data. Journal of Range Management, 52:83-91.

Harris, D. (2006). 'On-Farm' Seed Priming. A key technology to improve the livelihoods of resource-poor farmers in marginal environments (extended version). DFID/PSP information booklet, English language version. CAZS Natural Resources, University of Wales, Bangor, UK.

Harris, D., Joshi, A., Khan, P.A., Gothkar, P. and Sodhi, P.S. (1999). On-farm seed priming in semi-arid agriculture development and evaluation in maize, rice and chickpea in India using participatory methods. Experimental Agriculture, 35:15-29.

Harris, D., Joshi, A., Khan, P.A., Gothkar, P. and Sodhi, P.S. (1999). On-farm seed priming in semi-arid agriculture: development and evaluation in maize, rice and chickpea in India using participatory methods. Experimental Agriculture, 35:15-29.

Heydecker, W.J., Heydecker, J., Higgins and Gulliver, K. (1973). Accelerated germination by osmotic seed treatment, Nature, 246:42-46.

Hutton, E.M. (1971). Variation in salt response between tropical pasture legumes. Sabrao Newsletter, 3:75-81.

Johnson, S.E., Lauren, J.G., Welch, R.M. and Duxbury, J.M. (2005). A comparison of the effects of micronutrient seed priming and soil fertilization on the mineral nutrition of chickpea (Cicer arietinum), lentil (Lens culinaris), rice (Oryza sativa) and wheat (Triticum aestivum) in Nepal. Experimental Agriculture, 41:427-448.

Kader, M.A. and Jutzi, S.C. (2002). Temperature, osmotic pressure and seed treatments influence imbibition rates in sorghum seeds. Journal of Agronomy and Crop Science, 188:286-290.

Kaya, G., Demir, I., Tekin, A., Yasar, F. and Demir, K. (2010). Priming uygulamasinin biber tohumlarinin stress icakliklarinda çimlenme, yag asitleri, seker kapsami ve enzim aktivitesi üzerine etkisi. Tarim Bilimleri Dergisi, 16:9-16

Khalil, S.K., Mexal, J.G. and Murray, L.W. (2001). Germination of soybean seed primed in aerated solution of polyethylene glycol (8000). Online Journal of Biological Science, 1:105-107.

Koutu, G.K., Rama Krishnan, R.S., Gour, L., Pathak, N. and Shivwanshi, R. (2019). Enhancement in seed yield and quality attributes due to different seed priming treatment in field Pea. Journal of Pharmacognosy and Phytochemistry SP, 2:866-868

Lewis, G., Schrirer, B., Mackinder, B. and Lock, M. (2005). "Legumes of the World"; Royal Botanical Gardens: Kew, United Kingdom.

Lin, J.M. and Sung, J.M. (2001). Pre-sowing treatment for improving emergence of bitter gourd seedling under optimal temperatures. Seed Science and Technology, 29: 39-50.

Malnassy, P.G. (1971). Physiological and biochemical studies on a treatment hastening the germination of seeds at low temperature, Ph.D. thesis, Rutgers University, New Brunswick.

Matarira, C.H., Makadho, J.C. and Mukahanana-Sangarwe, M. (2004). Vulnerability and adaptation of maize production to climate change in Zimbabwe, Ministry of Environment and Tourism, Zimbabwe.

Mc Donald, M.D. (1999). Seed deterioration: physiology, repair and assessment, Seed Science and Technology 27: 177-183.

McDonald, M.B. (2000). "Seed Priming, 287-325". In: Seed Technology and Its Biological Basis (Eds. M. Black & J.D. Bewley). Sheffield Academic Press, Sheffield, UK.

Mohamed, H.A., Clark, J.A. and Ong, C.K. (1988). Genotypic differences in the temperature responses of tropical crops. II. Seedling emergence and leaf growth of groundnut (Arachis hypogaea L.) and pearl millet (Pennisetum typhoides S & H.). Journal of Experimental Botany, 39:1129-1135.

Murray, G.A. (1989). Osmoconditioning carrot seed for improved emergence. Hortscience, 24:701.

Murungu, F.S., Chiduza, C., Nyamuga, P., Clark, L.J., Whalley, W.R. and Finch, W.E. (2004). Effects of on-farm seed priming on consecutive daily sowing occasion on the emergence and growth of maize in semi-arid Zimbabwe. Field Crop Research, 89:49-57.

Parera, C.A. and Cantiliffe, D.J. (1994). Pre-sowing seed priming. Horticulture Review, 16:109-141.

Pill, W.G., Crossan, C.K., Frett, J.J. and Smith, W.G. (1994). Matric and osmotic priming of Echinacea purpurea (L.) Moench seeds. Scientia Horticulturae, 59:37-44

Rodriguez, C., Frias, J., Vidal-Valverde, C. and Hernandez, A. (2008). Correlations between some nitrogen fractions, lysine, histidine, tyrosine and ornithine contents during the germination of peas, beans, and lentils. Food Chemstry, 108: 245-252.

Singh, A., Jatav, A.L., Singh, P., Singh, B.A., Singh, P. and Sharma, S.K. (2017). Effect of seed priming treatments on seed quality parameters and storability of field pea (Pisum sativum L.). Journal of Pharmacognosy and Phytochemistry, 6(5):161-163.

Sivasubramaniam, K., Geetha, R., Sujatha, K., Raja, K., Sripunitha A. and Selvarani, R. (2011). Seed Priming: Triumphs and Tribulations. Madras Agricultural Journal, 98 (7-9):197-209.

Sivritepe, H.O. and Dourado, A.M. (1995). The effect of priming treatments on the viability and accumulation of chromosomal damage in aged pea seeds. Annals of Botany, 75:165-171.

Taylor, A.G., Allen, P.S., Bennett, M.A., Bradford, K.J., Burris, J.S. and Misra, M.K. (1998). Seed enhancements. Seed Science Research, 8:245-256.

Umair, A., Safdar, A., Rifat Muhammad, H.A., Muhammad, J. (2011). Evaluation of seed priming in mungbean (Vigna radiata) for yield, nodulation and biological nitrogen fixation under rainfed conditions. African Journal of Biotechnology, 10(79):18122-18129.

Wilson, D.R., Jamieson, P.D., Jermyn, W.A. Hanson, R. (1985). Models of growth and water use of field peas (Pisum sativum L.). in: The pea crop: a basis for improvement. Hebblethwaite, P. D.; Heath, M. C.; Dawkins, T. C. K. ed. London, Butterworths, 139-151.

Yan, Y.T., Liang, W.T., Zheng, G.H. and Tang, P.S. (1989). Effect of low temperature imbibition on mitochondrion respiration and phosphorylation of PEG primed soybean seed. Acta Botanica Sinica, 31:441-448.

Zheng, G.H., Wilen, R.W., Slinkard, A.E. and Gusta, L.V. (1994). Enhancement of canola seed germination and seedling emergence at low temperature by priming. Crop Science, 34:1589-1593.

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