Seed priming techniques in field crops - A review


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ABSTRACT

Germination and seedling emergence are the critical stages in the plant life cycle. Insufficient seedling emergence and inappropriate stand establishment are the main constraints in the production of crops which receiving less rainfall. Farmers do not have sufficient resources to meet the requirement of seedbed preparation for sowing and they are at more risk as compared to progressive farmers. On the other hand good establishment increases competitiveness against weeds, increases tolerance to drought period, increase yield and avoids the time consuming need for re-sowing that is costly too. It is well accepted fact that priming improves germination, reduces seedling emergence time and improves stand establishment. A method to improve the rate and uniformity of germination is the priming or physiological advancement of the seed lot. The general purpose of seed priming is to partially hydrate the seed to a point where germination processes are begun, but they would exhibit rapid germination when re-imbibed under normal or stress conditions. A lot of work has been done on seed priming and results of these studies indicate well the importance of priming to get a good crop stand in many crops of tropical region such as rice, maize, sorghum and pigeon pea.

Key words: Crop establishment, Germination, Seed priming.

Stand establishment is of primary importance for optimizing field production of any crop plant. At suboptimal conditions of environment conditions, poor seed germination and subsequently poor field establishment is a common phenomenon. It has been reported that one of the major obstacles to high yield and production of crop plants is the lack of synchronized crop establishment due to poor weather and soil conditions (Mwale et al., 2003). On the other hand seeds are occasionally sown in seedbeds having unfavorable moisture because of the lack of rainfall at sowing time which results in poor and unsynchronized seedling emergence (Angadi and Entz, 2002).

Strategies for improving the growth and development of crop species have been investigated for many years. Rapid germination and emergence are essential for successful crop establishment, for which seed priming could play an important role. Seed priming is an effective technology to enhance rapid and uniform emergence and to achieve high vigour, leading to better stand establishment and yield. It is a simple and low cost hydration technique in which seeds are partially hydrated to a point where pre-germination metabolic activities start without actual germination, and then re-dried until close to the original dry weight. Seed priming is employed for better crop stand and higher yields in a range of crops. Harris et al., (2007) reported that seed priming led to better establishment and growth, earlier flowering, increase seed tolerance to adverse environment and greater yield in maize.

The beneficial effects of seed priming have been demonstrated for many field crops such as wheat, sweet corn, mung bean, barley, lentil, cucumber etc. (Sadeghian and Yavari, 2004). Rehman et al., (2011) reported that seed priming is a cost effective technology that can enhance early crop growth leading to earlier and more uniform stand with yield associated benefits in many field crops including oilseeds.

Various seed priming techniques have been developed which include hydro-priming, halo-priming, osmo-priming and hormonal priming. Hydro-priming soaking the seeds in water before sowing and may or may not be followed by air drying of the seeds. Hydro-priming may enhance seed germination and seedling emergence under both saline and non-saline conditions. Roy and Srivastava (1999) found that soaking wheat kernels in water improved their germination rate under saline conditions. It also had pronounced effect on field emergence its rate and...
early seedling growth of maize crop and it improved the field stand and plant growth both at vegetative and maturity of maize (Nagar et al., 1998). Hydro-priming plays an important role in the seed germination, radical and plumule emergence in different crop species. Similar to other priming techniques, hydro-priming generally enhance seed germination and seedling emergence under saline and non-saline conditions and also have beneficial effect on enzyme activity required for rapid germination.

Halo-priming refers to soaking of seeds in solution of inorganic salts i.e NaCl, KNO₃, CaCl₂ and CaSO₄ etc. A number of studies have shown a significant improvement in seed germination, seedling emergence and establishment and final crop yield in salt affected soil in response to halo-priming. Khan et al., (2009) evaluated the response of seeds primed with NaCl solution at different salinity levels 0, 3, 6 and 9 dSm⁻¹ in relation to early growth stage and concluded that seed priming with NaCl has found to be better treatment as compared to non-primed seeds. Priming with NaCl and KCl was helpful in removing the deleterious effects of salts (Iqbal et al., 2006). In sorghum seeds soaked in CaCl₂ or KNO₃ solution increased the activity of total amylase and proteases in germinating seeds under salt stress (Kadiri and Hussaini, 1999). In pigeon pea seed treatment with CaCl₂ or KNO₃ generally exhibited improvement in proteins, free amino acid and soluble sugars during germinating under salt stress (Jyotsna and Srivastava, 1998).

Afzal et al., (2006) reported that wheat cultivar Auqab-2000 was treated with different priming agents i.e. Abscisic acid (ABA), Salicylic acid (SA) and ascorbic acid and were sown under normal and saline condition (15 dSm⁻¹), and showed that under saline conditions these treatment reduced the time for 50% germination, increased final germination count, and significantly increased the fresh and dry weight but ascorbic acid did not show such results. Hormonal priming has reduced the severity of the effect of salinity but the amelioration was better due to 50 ppm SA and 50 ppm ascorbic acid treatments as these showed the best results on seedling growth, fresh and dry weights under non-saline and saline conditions whereas hormonal priming with ABA as not effective under present experimental material and conditions (Afzal et al., 2006).

Osmo-priming technique refers to soaking of seeds for a certain period in solution of sugar, PEG etc followed by air drying before sowing. Osmo-priming not only improves seed germination but also enhance crop performance under non-saline or saline conditions. Salehzade et al., (2009) conducted a study to enhance germination and seedling growth of wheat seeds using osmo-priming treatments. Seeds were osmo-primed with PEG-8000 solution for 12 hours. Osmo-priming treatments improved the seedling stand establishment parameters. Shorrocks (1997) reported that priming with boric acid showed stimulatory and inhibitory effect on different crops plants. In papaya species the priming with boron increased the growth of all plants.

Hormonal priming is the pre - seed treatment with different hormones like GA₃, kinetin, ascorbate etc., which promotes the growth and development of the seedlings. Ashraf et al., (2001) found that GA₃ treatment enhanced the vegetative growth of two wheat cultivars. It enhanced the deposition of Na⁺ and Cl⁻ in both root and shoots of wheat plant. It also caused a significant increase in photosynthetic at the vegetative stage of the crops.

Improvement in priming is affected by many factors such as plant species, priming media, its concentration, priming duration, temperature and storage conditions etc. With the proper treatment of seeds they are able to germinate and emerge better as the inorganic salts improve germination and growth parameters of the treated seed; KCl increases the protein and starch content in grains and KNO₃ increases yield, fruit size and improves quality in field and vegetables crops. Assefa et al., (2010) reported that seed priming with GA₃ enhance emergence and germination rate of soybean. Cytokinins can also be used as priming agent as they are mainly involved in the breakdown of dormancy of some seeds (Arteca, 1996).

Seed priming is a pre-sowing treatment that offers the possibility to improve post-harvest seed quality and allow the release of dormancy leading to increased final germination as well as germination speed and uniformity. The technique involves the initiation of germination metabolism by controlling the hydration of seeds and activating various metabolic processes without allowing radical protrusion (Heydecker, 1973; Bradford, 1986 and Taylor et al., 1998).

Mishra and Dwibedi (1980) found that seed soaking in 2.5% KCl for 12 hour before sowing increased wheat yield by 15%. KCl and KH₂PO₄ have been introduced as the osmotica which have shown good potential to enhance emergence and germination in wheat. Riedell et al., (1985) and Maske et al., (1997) reported that GA₃ treated soybean seeds recorded better field performance due to its stimulation effect in the formation of enzymes which are important in the early phase of germination which helps for a fast radical protrusion in many field crops. Beneficial effects of KCl have been reported by Vijayakumar et al., (1988) in Okra, Rajandran, (1982) in red gram and Basha, (1982) in green gram. According to Graf et al., (1987), KH₂PO₄ showed a relatively positive effect presumably because phosphorous reserves in the seed play very important role in the metabolism of germinating seed.

Bensen et al., (1990) demonstrated that hypocotyls growth rate of soybean crop is directly associated with the amount of GA₃. The enhanced plant height was due to the improved and faster plant emergence in GA₃, KH₂PO₄ and KCl primed seed plots. Park et al., (1997) reported that the priming aged seeds of soybean resulted in good germination and stand establishment in the field trials.

The direct benefits of seed priming were reported by Harris et al., (2001) in crops like wheat, rice and maize which included faster emergence, better and uniform stands, less need
to re-sow, more vigorous plants, better drought tolerance, earlier flowering, earlier harvest and higher grain yield. The indirect benefit reported were earlier sowing of crops, earlier harvesting of crops and increased willingness to use of fertilizer because of reduce risk of crop failure and also reported that water has been used successfully as a seed priming medium for wheat. Harris et al., (2007) conducted an experiment and reported that seed priming led to better establishment and growth, earlier flowering, increased seed tolerance to adverse environment and higher yield in soybean. Raun et al., (2002) reported that priming the rice seed with KCl improved its germination index. Greater efficiency of seed priming with KCl is possibly related to the osmotic advantage that K⁺ has in improving cell water saturation and that act as co-factor in activities of numerous enzymes (Taiz and Zeiger, 2002).

A field experiment was conducted by Bassi (2005) to monitor the effect of various seed priming treatments on late sown wheat. Result showed that Gibberellic acid treatment enhanced germination and emergence (94 and 82%, respectively) as compared to non-primed seed treatment (85 and 77%, respectively). Yari et al., (2010) conducted experiment in Iran to evaluate the effect of different seed priming techniques on germination and early growth of two wheat cultivars. Seeds were primed for 12, 24 and 36 hours at different temperature range in four priming media (PEG 20%, KCl 2%, KH₄PO₄ 0.5 and KH₂PO₄ 1%). They reported that KH₂PO₄ and KCl showed good potential to enhance germination, emergence, growth and grain yield of wheat. It has also been reported that seed priming improves emergence, stand establishment, tillering, grain and straw yields and harvest index in wheat (Farooq et al., 2008).

Bassi et al., (2011) reported that priming with GA₃ @ 50 ppm for 2 hour enhanced emergence, germination and speed of germination in soybean as compared to non-primed seed lots. A laboratory study and a field experiment was carried out by Golezani et al., (2011) to evaluate the effect of priming on seed vigour and field performance of soybean. Results showed that pods per plant, seeds per plant and seed yield per plant were significantly enhanced by seed priming particularly with KNO₃. On contrary, seedling emergence percentage and germination time were significantly adversely affected by seed priming (KH₂PO₄ and KNO₃) as compared to non-primed seeds.

Assefa and Hunje (2011) reported that the speed of germination in soybean increased as the priming duration increased from 0 to 14 hours. The germination decreased with increased priming duration beyond 14 hours. In the early stage of germination seeds of a wide variety of plants can be dried back to 10 per cent moisture without loss of viability, but if they are dried after radical emergence (as the duration increases) the seeds are not able to germinate. The priming duration affected the speed of germination more than the final percentage of germination. Significantly higher speed of germination (57.1), root length (16.3 cm), shoot length (13.8 cm) and vigour index (293) were consistently in favour of 14 hour seed priming duration as compared to lesser and more duration.

Ahmadvand et al., (2012) conducted two laboratory and green house experiments to evaluate effect of seed priming with potassium nitrate on germination and emergence traits of two soybean cultivars cv. Gorgan -3 and cv. Sahar at Bu-Ali Sina University, Iran. They reported that seed priming with KNO₃ caused a significant increase in germination and emergence percentage, radical and plumule length, seedling dry weight, plant height, plant leaf area and plant dry weight. Seed priming led to significant increase of leaf area per plant and leaf area of non-primed seeds was decreased by 78%.

At Varanasi, Srivastava and Bose (2012) conducted an experiment on seed priming of rice varieties with or without nitrate salts (Mg (NO₃)₂ and KNO₃). Results showed the beneficial effect of priming treatments which was clearly exhibited in plant height, leaf area and number of leaf and yield attribute characteristics i.e. fertile tillers, panicle and grain quality with nitrate treated varieties. Seed priming treatment resulted in increased crop growth rate in treated sets which encouraged deposition of more photo-assimilates in key plant parts, greatly affecting the final yield.

Sarika et al., (2013) conducted a lab experiment to study various physiological and biochemical changes by priming in French bean at Bangalore. They reported that chemo priming with GA₃ and Ethrel improved the seed quality and showed improved seedling length, seedling dry weight which in turn improved higher seedling vigour index, germination speed and mean germination time. Significant increase in initial (6.02 cm) and final (11.5 cm) root length, initial and final shoot length, seedling vigour index and dry seedling weight with GA₃ is observed in the crop.

Arif et al., (2008) conducted a field experiment in Peshawar, Pakistan and they reported that priming improved the seed establishment in soybean which might be due to the completion of pre germination metabolic activities earlier which makes the seed ready for radical protrusion. Grain yield decreased with extending seed priming duration. Seed priming duration of 6 hour resulted in faster and improved emergence and higher grain yield of soybean as compared to 12 and 18 hour.

Field experiment was conducted by Mahajan et al., (2011) at Punjab Agricultural University Ludhiana to enhance the performance of dry direct seeded basmati rice with four seed priming treatments (control, osmo hardening, water hardening and hydro-priming). Crop with hydro-priming gave superior performance as compared to other seed priming treatments. Highest grain yield of Pusa Basmati 1121 was obtained with hydro-priming at 60 kg/ha of N application applied in 3 splits. Hydro-primed seeds produced more panicles/m² (291), filled grain per panicle (67), 1000 grain weight and spikelet sterility (25.9 g and 21.9 %).
On-farm seed priming (seed soaking) has been reported to improve crop establishment, growth and yield. Murungu et al., (2004) conducted experiment to study how priming affected emergence and growth of maize in semi-arid Zimbabwe. In both the years 1999-2000 and 2000-2001 growing season, primed and non-primed maize was sown on 8 consecutive days into an initially moist seedbed and soil moisture, crop emergence and growth were monitored. In the 1999-2000 seasons, priming increased final emergence but the overall result was not significant. Priming decrease mean time to 50% emergence by 12 hour in the 1999-2000 season and by 24 hour in the 2000-2001 season. It was concluded that priming benefits result from improved crop stand and from advancement of germination and emergence.

Ayman and Hannachi (2012) carried a study in order to evaluate the effect of NaCl seed priming techniques on germination and early growth of safflower (Carthamus tinctorius L.). Safflower seeds were primed with four concentrations of NaCl as priming media (5, 10, 15 and 20 g/l) for 12, 24 and 36 hours. Results indicated that different priming concentrations and duration have significant effect on total germination percentage, mean germination time, germination index and coefficient of velocity of safflower seeds. It was also observed that 12 hour priming duration had the most significant effect on studied traits as 5 g/l priming concentration treatment. In general, primed seeds showed better performance than control in all studied parameters.

Farahbaksh (2012) reported that the concentration of 0.25 and 0.5 mM of salicylic acid on germination, germination rate, seed stamina index, hypocotyl length, radical length, seedling fresh and dry weight of fennel (Foeniculum vulgare) was more effective as compared to other levels (0 and 0.75 mM). Therefore, seed priming with salicylic acid could be a suitable tool for improving germination characteristics of fennel.

Sharma et al., (2010) conducted an experiment at CSK Himachal Pradesh Agricultural University to study the effect of seed priming on late sowed rainfed wheat. The results showed that emergence count was increased with pre sowing hydration of seed with 3% calcium chloride and 15 ppm gibberellic acid as compared to rest of the treatments.

Elouaer and Hannachi (2012) conducted a germination experiment at Tunisia in which safflower seeds were primed with 5 g/l NaCl and KCl solutions for 12 and 24 hour respectively at 20°C. Results showed that seed priming increased germination by 8.66% and 5.06% using NaCl and KCl solutions as compared to non-primed seeds. In fact NaCl seed priming has the highest germination percentage (82.7%) followed closely by KCl seed priming (78.6%), control having the lowest total germination (73.6%) other parameters like germination index, coefficient of variation, shoot and root length was also recorded higher as compared to control.

Soughir et al., (2012) conducted a study to develop an optimum protocol for fenugreek and determinate the effect of NaCl seed priming on seed germination. Fenugreek seeds were primed with four concentrations of NaCl as priming media (0, 4, 6 and 8 g/l) for different durations. Results indicated that different priming concentration of NaCl and duration has significant effects on total germination percentage, mean germination time, germination index and coefficient of velocity of fenugreek seeds and the best results was obtained with 4 g/l for 36 hour. The result of this experiment showed that under undesirable conditions such as salinity stress, priming with NaCl can prepare a suitable metabolic reaction in seeds and can improved seed germination.

Patane et al., (2009) conducted an experiment to study the effect of reduced water potential in NaCl and pre-osmo-priming in PEG on seed germination and early radical growth at different temperature in the laboratory for sweet sorghum. They suggested that when early sowing of sweet sorghum are requested, the use of primed seeds is better as PEG-osmo-priming is helpful in overcoming the negative effect imposed by reduced water potential upon seed germination under suboptimal thermal conditions.

Sivritepe et al., (2002) studied the effect of NaCl priming on salt tolerance in melon seedlings grown under saline conditions. They reported that NaCl priming of melon seeds increased salt tolerance of seedling by promoting K and Ca accumulation, besides inducing osmo regulation by the accumulation of organic solutes. NaCl priming diminished inhibiting effect of salinity on seed germination and seedling growth in cucumber and tomato (Wiebe and Muhyaddin, 1987).

Anese et al., (2011) conducted an experiment to study the effect of seed priming in improving endosperm weakening, germination and seedling development of Solanum lycocarpum. Hydro-priming for 15 days at 15°C is a useful a method to improve seed germination and seedling development of Solanum lycocarpum. Hydro-priming is effective as a result of decreased required puncture force of and increased enzyme activity. A field experiment was conducted by Patter et al., (2014) to study the effect of seed priming on grain yield of chickpea. Results showed that 2% SSP recorded higher seed yield of 1705 kg/ha with significantly higher N uptake.

Sharma et al., (2013) conducted an experiment to study the various seed priming methods for seed germination, seedling vigour and fruit yield in okra. Seeds were subjected to four priming methods, namely, hydro-priming, osmo-priming, halo-priming and solid matrix along with control. Hydro-priming for 12 hour and SM priming with calcium aluminium silicate for 24 hour significantly increased the seed germination, seedling vigour, mean germination time and marketable fruit yield.
Singh et al., (2014a) conducted an experiment to study the effect of osmo-priming duration on germination, emergence and early growth of cowpea in Nigeria. Treatment consisted three osmo-priming duration (soaking in 1 % KNO₃ salt for 6, 8 and 10 hrs) and one hydro-primed control (10 hr). The results showed that osmo-priming with KNO₃ for different durations were superior to unprimed treatment in term of seed germination, emergence, plant height and dry matter accumulation in cowpea. Primed seeds (both osmo-priming and hydro-priming) increased performance of cowpea. However, osmo-priming with KNO₃ salt (soaked in 1 % KNO₃ salt solution and dried before sowing) for 6 hours could result in greater seed germination and seedling height than hydro-priming.

A field experiment was conducted by Vazirimeh et al., (2014) at Iran with potassium nitrate solution in five seed priming levels (0, 0.5%, 1%, 1.5%, and 2 %) on corn. They conclude that 1 % potassium nitrate showed significant results as compared to rest of the levels. Highest germination percentage (92.6 %), biological yield (33.2%), harvest index (10.4%) and tassel weight (4.3%) was due to the fact that osmo-priming with 1 % potassium nitrate accelerated germination, shorten the time from seed emergence and prevention of biotic and abiotic factors also improves dry matter partitioning to grain and increased harvest index and seed yield. Various literatures suggested that seed priming with nitrate salts could manipulate the yield determining parameters successfully in many diverse environment and various crops (Bose and Mishra, 2001; Bose and Pandey, 2003; Sharma and Bose, 2006; Bose et al., 2007 and Sharma et al., 2009).

Murungu et al., (2003) carried out a pot experiment with cotton and maize at Zimbabwe. They showed that priming improved emergence and early growth of maize and cotton in drying soils in the laboratory. Priming increase emergence from 75 to 99 % at soil matric potentials. Primed cotton seedling had longer roots than non-primed seedling at all initial matric potentials. This work indicated that there was no direct effect of priming on growth, time to flowering and maturity or yield of plants. Instead, benefits from priming appeared to be indirect effects of improvements in crop stand and the advancement of germination and emergence.

Savage et al., (2003) conducted an experiment to the on farm priming effect on maize crop. The results indicated that the effect of priming in maize can vary and unlike unprimed seeds. The effect of hypoxia during soaking exacerbated by moist conditions and high temperature at sowing. These effects differed variation in response to priming following sowing in the field. Priming decreased the temperature optimum and ceiling temperature for germination.

An experiment was conducted by Rahimi (2013) to study the effect of seed priming improves the germination performance of cumin. Seed priming showed positive effect on germination characteristic of cumin. It could be used as pre-sowing treatment in field conditions. Osmo-priming improves germination performance it produces high seed vigour and radical and plumule length at low temperature. Seed priming has been found a double technology to enhance rapid and uniform emergence and to achieve high vigour and better yields in cumin (Nematollahi et al., 2009).

Two experiments were designed by Safiatou (2012) to study the effect of hydro-priming (water) and osmo-priming (Mannitol and NaCl at -1.5 M Pa) and seed size on germination, seedlings establishment, vigour and biomass at maturity of three varieties of Sorghum bicolor L. Moench and Vigna subterranea L. Verde. The experiments were (1) a laboratory test with seeds germinated in wet sand for 10 days to determine germination traits, shoot and root lengths and (2) a field experiment at the Savanna Agricultural Research Institute. Seeds of three varieties of sorghum, ‘Dorado’, ‘Kapaala’ and ‘Kadaga’ were primed with Mannitol and NaCl (-1.5 M Pa) for 72 hours at 25° C and also in water for 24 h at 28 ± 3°. Large and small seeds of three varieties (‘Cream with black eye’, ‘Cream with brown eye’ and ‘Red’) of Bambara groundnut were separately primed with Mannitol and NaCl (-1.5 M Pa) for 120 h at 25° C and also primed in water separately for 24 h at 28 ± 3°. The laboratory results showed that osmo-priming of sorghum and Bambara significantly improved germination percentage, germination index, and mean germination time and seedling vigour, compared to other seed treatments. Likewise hydro-priming significantly improved seedling dry weight as compared to other seed treatments. The field results of the Bambara groundnut also showed that osmo-primed seeds had the least average delay (lag period) from the start of imbibition to radicle emergence, were the earliest to start to germinate, obtained higher number of pods per plant in comparison with the other seed treatments. Hydro-priming significantly increased the number of plants per plot compared to other seed treatments. Seed biomass had effect on the overall percentage and seedling vigour. In all Bambara groundnut varieties, the smaller seeds had the faster germination, the higher percent germination and seed vigour. On the contrary, plants grown from large seeds produced greater dry matter compared to those grown from small seeds for all varieties.

Nutrient seed priming is a technique in which seeds are soaked in nutrient solution instead of pure water as an approach to increase seed nutrient content along with the priming effect to improve seed quality for better germination and seedling establishment. Maize seed priming with 1 % ZnSO₄ not only enhanced plant growth but also increased the final grain yield and seed Zn content in plants grown on soil with limited Zn availability (Harris et al., 2007).

Guan et al., (2009) reported that maize seed priming with ‘chitosan’ improved germination and seedling growth under low temperature stress conditions. Chitosan is an
abundant and comparatively cheap organic compound in China. It is a large cationic polysaccharide mainly obtained from waste materials from seafood processing. Chitosan treatment of wheat seeds induced resistance to certain disease and improved seed quality (Reddy et al., 1999). Seed soaked with chitosan increased the energy of germination, germination percentage, lipase activity, and gibberellic acid (GA$_3$) and indole acetic acid (IAA) levels in peanut (Zhou et al., 2002). The results showed that the chitosan priming increased the chilling tolerance of maize seedlings demonstrated by improving germination speed and shoot and root growth and maintaining membrane integrity and higher activities of anti-oxidative enzymes. The 0.50% chitosan seems to be a suitable concentration for seed priming it significantly increased seedling growth, root dry weight and root length as compared to control.

An experiment was conducted by Imran et al., (2013) in Germany to study the effect of nutrient seed priming improves seedling development of maize under low root zone temperature during early growth. Results revealed that seed priming shown significant increase in seed contents of the respective nutrients i.e. Fe (25%), Zn (500%) and Mn(800%).

Rehman et al., (2014) conducted an experiment to study the seed priming influence on early crop growth, phonological development and yield performance of Linola in Pakistan. Seeds were treated with 50 mmol/L salicylic acid, 2.2 % CaCl$_2$ and 3.3 % Moringa Leaf Extract (MLE) including untreated dry and hydro-priming control. Results showed that osmo-priming with CaCl$_2$ reduced emergence time and produce the highest seedling fresh and dry weights including chl. A content. It also reduced crop branching and flowering and maturity time and had the maximum plant height, number of branches, tillers, pods and seeds per pod followed by MLE. They too exported an increase in seed weight, biological and seed yields was 9.30, 34.16 and 39.49 %, harvest index (4.12%) and oil content (13.39%) with CaCl$_2$osmopriming. It concludes that seed osmo-priming with CaCl$_2$ and MLE can play significant role to improve early crop growth and seed yield of linola.

Shehzad et al., (2012) conducted an experiment to study the influence of priming techniques on emergence and seedling growth of forage sorghum. Therefore, this study was designed with different seed priming techniques, un-soaked seed (control), Hydro-priming (soaked with distill water), Halo-priming with KNO$_3$ and CaCl$_2$ (1% solution). Experiment was conducted in wire house under natural climatic conditions during 2008. All the priming treatments significantly affected the fresh weight, shoot length, number of roots, root length, vigour index, and time to start emergence, time to 50% emergence and energy of emergence of forage sorghum. Seed priming increase cell division and seedling roots which cause an increase in plant height. It is concluded that seed priming may serve as an appropriate treatment for accelerating the emergence of sorghum genotypes studied.

Meena et al., (2013) conducted an experiment for two consecutive years 2010-11 and 2011-12 to evaluate the influence of hydro-priming grain yield of wheat. The experiment was conducted with seed priming treatments (dry seed, hydro-priming, and pre-germinated seeds) in subplots. Pre germinated seed produced significantly higher grain yield (5.49 t/ha), which was statistically similar to hydro-priming (5.30 t/ha). The hydro-primed and pre-germinated seeds established earlier than dry seeds leading to better crop establishment leading to higher tillering and grain yield. The results of experiment showed that priming with plain water and pre-germinated seeds improved germination indices, seedling growth and crop establishment. Pre-germinated seeds and seed priming in this study resulted significantly higher germination of 153 & 167 per square meter which were significantly higher over dry seeds (136). Yield attributes viz. number of effective /m$^2$ (500), ear head length (10.8) and 1000 grain weight (39.08 g) were the highest in pre-germinated seeds followed by hydro-primed seeds and found significantly higher than unprimed seeds. The highest yield attributes in pre-germinated seeds may be ascribed to higher number of effective tillers which lead to higher dry matter accumulation (biomass), translocation and conversion of photosynthesis in to reproductive parts. Seeds can be soaked before sowing to meet the initial seed imbibition requirement. Similar beneficial effects of seed priming were reported by Rajpar et al., (2006) and revealed that seedlings were significantly faster in emergence, took fewer days to mature and gave significantly higher grain yield. Pre-germinated seeds and hydro-primed seeds registered 9.2 and 5.2 % higher grain yield compared to unprimed seeds, respectively. Increase in grain yield of wheat under pre-germinated seeds and seed priming treatments could be attributed to higher yield attributes whereas, the increase in biological yield was due to higher plant density and plant height. Higher grain and biomass yield in pre-germinated seeds could also be attribute to early germination and vigorous growth, consequently good crop establishment. Higher grain yield with seed priming of wheat has been also reported by Harris et al., (2001) and Rashid et al.,(2002). Harris et al., (1999) reported that early emergence and maturity in seed priming treatment could be due to advancement in metabolic state. Musa et al., (1999) also concluded that priming improve plant stand and provide benefits in term of maturity. Seed priming resulted in earlier emergence of seedlings by 1-3 days and significantly increased plant stand and initial growth vigour. Priming of seeds resulted in an overall 47% grain yield advantage with all yield contributing factors measured showing positive effects of priming.
A laboratory study was conducted by Dezfuli (2008) to evaluate the influence of seed priming techniques on germination and early growth of two maize inbred lines which were include of B73 and MO17. Seeds were hydro-primed for 12, 24, 36 and 48 h, osmo-primed in urea solution and in solution of polyethylene glycol-6000(PEG-6000) for 96 h (water potential -1.2MPa). Priming techniques effected seed germination and early growth of both inbred lines. Hydro-priming resulted in lower time taken to 50% germination and higher germination index, vigour index and final germination percentage in both genotypes. Maximum invigouration was observed in seeds hydro-primed for 36 h as induced by higher germination rate, radical length. The superiority of hydro-priming on germination might indicate that hydro-priming treatments did not damage seed structure or metabolic activity on the flip side it is possible that applied osmotic potential for osmo-priming treatments was lower than critical potential which is required in order to finish the first and second stages of germination without protrusion of radicle. It may be concluded that priming with water for 36 h was better than other priming media tested for high vigour and rapid seed germination.

Kata et al., (2014) conducted a field experiment to study the effect of different seed priming techniques on germination of paddy under different temperatures a factorial experiment was conducted with six varieties. Seeds were primed for 12 h in seven priming media (salicylic acid 50 ppm, ascorbic acid 200 ppm, citric acid 200 ppm, proline 0.2%, calcium chloride 2%, NaHPO4, 100ppm and distilled water) to observe the germination and related parameters. Results indicated 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. The other treatments also enhanced the germination properties. Priming treatments including hydro-priming resulted in the increased activity of α-amylase which in turn has resulted in better mobilization of stored carbohydrate reserves resulted in improvement of germination and other related parameters.

Priming has been used to improve the performance of germination at the field, and potassium nitrate (KNO3) is a promising compound for this purpose. The nitrate (NO3-) could be absorbed, being used in the metabolism of the embryo, through the enzyme nitrate reductase (NR). Besides, the priming could also activate the response of the antioxidant system, becoming the primed seeds more prepared for possible stresses. Lara, (2014) conducted a study to evaluate the metabolic effect of nitrate priming in tomato seed germination by the quantification of NR activity, and also evaluate the activity of some antioxidant enzymes as superoxide dismutase (SOD), catalase (CAT) and ascorbate peroxidase (APX). Tomato seeds were primed using solutions of polyethylene glycol (PEG 6000), 50 mM KNO3 and PEG and KNO3. The variables analyzed were germination (germinability, mean germination time, mean germination rate, coefficient of variation of the germination time, uncertainty and synchrony) nitrogen, total proteins and enzymes. The results showed KNO3 increased the NR activity, as well as in the antioxidant enzymes. The germination time (t) and germination rate (v) primed in KNO3 had a better performance compared to the other treatments. The observed benefits in tomato seeds primed with KNO3 were related to the activity of enzyme nitrate reductase in the production of nitrite/nitric oxide, which acted removing dormancy and promoting a faster germination.

Mukundam et al., (2009) opined that priming has significant effect on rate and uniformity of germination and enhanced rate of synchrony and percentage of seedling emergence in many crops under field conditions. Misra and Dwivedi (1980) reported positive effect of seed priming with potassium and distilled water on growth, dry matter accumulation, grain and straw yield in 12 wheat varieties under rainfed conditions. Musa et al., (1999) also stated that seed priming helped chickpea plants to escape from terminal drought.

Harris and Jones (1997) have demonstrated variation in response to priming amongst rice varieties and have postulated that priming of upland rice seed could be beneficial in West Africa and other environments where weed growth is an important constraint to achieve higher yields. Kumar et al., (2002) reported that 8 hours priming of finger millet seeds in water resulted in an increased mean plant height by 9 cm, reduced mean time to 50 per cent flowering and maturity by about 6 days and significantly increased grain yield. Narayanareddy and Biradarpalit (2012) conducted experiment to study the influence of seed priming on sunflower. The seeds treated with polyethylene glycol (PEG) recorded significantly higher germination (71.30%), speed of germination (31.56), root length (12.12 cm), shoot length (12.24 cm), seedling dry weight (165.85 mg), seedling vigour index (1738) and lower electrical conductivity (0.470 dS/m) followed by CaCl2 and water hydration treatments.

A field experiment was conducted by Singh et al., (2014b) during the Rabi seasons in 2009-10 and 2010-11 at Punjab Agricultural University Regional Research Station for Kandi Area, Ballowal Saunkhri to study the effect of seed priming with molybdenum (Mo) on chickpea (Cicer arietinum L.) variety PBG 1. Four treatments comprising seed priming with 250, 500 and 750 ppm solution of molybdenum and untreated control were laid out in randomized complete block design with four replications. Plant height, number of pods/plant, test weight, seed yield, straw yield and rain water use efficiency increased with increasing levels of Mo seed priming up to 500 ppm. Dry weight of root nodules increased up to 750 ppm of Mo. All the levels of Mo were significantly superior to untreated
control for most of the characters. Seed priming with 500 ppm of Mo resulted into 18.9% higher seed yield over control. Higher net returns and Benefit Cost ratios were also observed in case of 500 ppm Mo treatment.

Farhoudi and Sharifzadeh (2006) conducted an experiment to study the effect of NaCl priming on salt tolerance in canola. Seeds of canola (Brassica napus) cultivars “Hayola401” and “Zarfam” were primed with 14 dS m⁻¹ NaCl solution for 24 hours at 20°C. After priming, non-primed (NP) and primed (P) seeds were sown in germination boxes containing perlite. The germination boxes were placed in greenhouse and treated with five different NaCl solutions (0.4 (control), 4, 8, 12 and 16 dS m⁻¹), for a period of 3 weeks. Total emergence and dry weight were higher in canola seedlings derived from P seeds and they emerged earlier than NP seeds. Moreover, seeds from NP groups could tolerate up to 8 dS m⁻¹ NaCl salinity, while the total emergence values of P groups in “Hayola401” and “Zarfam” did not decrease below 50% at 12 and 16 dS m⁻¹, respectively. NaCl priming enhanced proline accumulation and prevented toxic and nutrient deficiency effects of salinity because less Na⁺ but more K⁺ and especially Ca²⁺ was accumulated in canola seedlings. As a matter of fact, Na⁺:Ca²⁺ balances of seedlings derived from P seeds were significantly lower than those of NP seeds under similar salinity levels.

A field experiment was conducted by Afzal et al., (2006) to evaluate the role of seed priming with Zn in improving the performance of maize hybrids in Faisalabad. The two maize hybrids namely SIPRA 4444 and SP13 were tested with hydro-priming, priming with 0.5% ZnSO₄, priming with 1.5% ZnSO₄, priming with 0.5% Zn EDTA and priming with 1.5% Zn EDTA. Observations on seed emergence, physiological parameters, grain yield and yield components were recorded in maize. The results of the study revealed that priming techniques of zinc gave higher values in almost all the physiological and yield parameters. The maximum grain yield (5.35 t/ha), biological yield (16.69 t/ha) were found in priming with ZnSO₄ @ 1.5% in 4 maize hybrid.

Alam et al., (2013) conducted an experiment to study the effect of priming on spinach with various sources and soaking durations in Peshawar. Four priming sources (Distilled water, DAP, SSP, SSP+Na₂CO₃) and soaking durations of 4 hour interval (4 hour to 24 hour) along with control were studied. Number of days to emergence, germination percentage, survival percentage, leaf area (cm²), leaf yield (tons/ha) and 100 number seeds weight (g) were significantly affected by priming sources and durations. Mean values showed that early emergence (5.952 days), maximum germination percentage (88.14), survival percentage (89.96), plant height (31.24 cm), leaf area (63.12 cm²), leaf yield (14.667 tons/ha) and 100 seed weight (1.00 g) were observed in plots in which seeds were soaked in SSP+Na₂CO₃ solution. In case of soaking durations, early emergence (5.917 days), maximum germination percentage (89.42), survival percentage (90.40), plant height (31.16 cm), leaf area (60.72 cm²), leaf yield (14.340 tons/ha) and 100 seed weight (0.966 g) were recorded in the plots in which seeds were soaked for 24h. Mean values of interactions results showed that early emergence (5.0 days), maximum germination percentage (95.33), survival percentage (95.38), plant height (33.70 cm), leaf area (70.78 cm²), leaf yield (16.257 tons ha⁻¹) were observed in plots where seed were soaked in SSP+Na₂CO₃ solution for 24h. Overall SSP+Na₂CO₃ solution proved the best in most of the parameters while distilled water (control) showed comparatively poor performance.

An experiment was conducted by Sarkar (2012) to study the effect of seed priming under Flooded and Non-flooded Conditions in Rice. Seed priming was done with water and 2% Jamun (Syzygium cumini) leaf extract. Seed priming improved seedling establishment under flooding. Acceleration of growth occurred due to seed pretreatment, which resulted longer seedling and greater accumulation of biomass. Seed priming greatly hastened the activities of total amylase and alcohol dehydrogenase in variety Swarna-Sub1 than Swarna. Swarna-Sub1 outperformed Swarna when the plants were cultivated under flooding. Weed biomass decreased significantly under flooding compared to non-flooding condition. Priming had positive effects on yield and yield attributing parameters both under non-flooding and early flooding conditions.

A study was conducted by Chavan et al., (2014) to determine the importance seed priming on field performance and seed yield of Soybean. There were two varieties viz., Phule Kalyani and JS-335 while six priming treatments viz., Control (unprimed seeds), Hydro-priming, KCl @ 10 ppm, CaCl₂.2H₂O @ 0.5 %, KH₂PO₄ @ 50 ppm and GA₃ @ 20 ppm. It may be concluded that soybean seeds positively responded to treatments of priming. Nevertheless, priming generally improves the most parameters of soybean varieties through improving plant height, number of branches, number of pods per plant, number of seeds per pod, seed yield. The highest benefit of priming can be obtained from seeds primed with CaCl₂.2H₂O (0.5%) treatment.

A field experiment was conducted by Gupta and Singh (2012) in SKUAST-Jammu in Inceptisols to find out the effects of seed priming on chickpea. The treatments consisted of seed priming (seed soaking in water for 8 h). The observations on plant height, nodule dry weight, seed index, dry matter accumulation, yield and yield attributes of chickpea were recorded. The results revealed that the growth parameters of chickpea were significantly affected by seed priming. Soaking chickpea seeds in water for about 8 h significantly influenced plant height and nodule dry weight in comparison to unsoaked seeds. Seed priming significantly
affected dry matter accumulation at various time intervals and at harvest. Seed priming, on an average, yielded 22.1% higher dry matter accumulation at different time intervals after sowing. At harvest, seed priming registered statistically higher pods/plant, seeds/pod, grain and biological yield which were 27.0, 11.9, 23.1 and 22.0% higher over no seed priming. Harris (2006) has reported improvement in seed yield in various crops at farmer’s field by seed priming with water. The higher values obtained for growth parameters, periodic dry matter accumulation, yield and yield attributes with seed priming may be due to the fact that primed seeds usually exhibit an increased germination rate and greater germination uniformity (Basra et al., 2005). The results are in conformity with Bray et al., (1989) and Lin and Sung (2001).

Mabhudhi and Modi (2011) evaluated whether hydro-priming could improve vigour characteristics and seedling emergence of local maize (Zea mays L.) landraces compared to two commercial hybrids under water stress at the University of KwaZulu-Natal, Pietermaritzburg. Seeds from local landraces were produced and characterized according to kernel colour, white (Land A) and purple (Land B), and compared to two hybrids, SC701 and SR52, which are popular amongst local farmers. Seeds from each variety were soaked in water for 0 hours (unprimed or control), 12 hours and 24 hours, and germinated in a germination chamber at 25°C for 8 days. Parameters measured included final germination, mean germination time (MGT) and germination velocity index (GVI). Priming landraces for 12 and 24 hours reduced MGT by 9% and 7%, respectively, compared to 5% in hybrids for both 12 and 24 hours priming. GVI of landraces was improved by 40% following 12 hours of priming. GVI of hybrids was 11% and 7% slower than landraces after priming seeds for 12 and 24 hours, respectively. Priming seeds for 24 hours improved emergence at 25% FC. Priming seeds for 24 hours reduced MET for all varieties. Priming of hybrids was 11% and 7% slower than landraces after priming with KNO₃ for 24 h. When seeds imbibe, the water content of onion, especially when the seeds were hydrated for 96 h, had a slightly higher seedling rate, when planting early and late in the season. Hydro-priming maize landraces for various periods of time may be used a low-cost technology to enhance emergence and vigour characteristics of landraces under both optimum and water stress conditions.

A laboratory experiment was conducted by Ramesh and Singh (2006) on seed priming in rice with K₂SO₄. The experiment was conducted with four genotype (Pusa Basmati-1, Basmati-385, Saket-4 and IR-36) and six concentrations of K₂SO₄ salt (0.5%, 1.0%, 2.0%, 4.0%, 8.0% and 16.0%) for 5 min, 30 min and 24 h durations. Data on the following quality parameters viz., root length, no. of roots/seedling, shoot length, fresh and dry weights of seedling and germination were recorded. Seed priming with K₂SO₄ for 24 h was effective in enhancing germination and seedling growth. Significant differences were observed between genotypes due to K₂SO₄ priming. Among the four cultivars of rice tested, IR-36 was highly responsive to K₂SO₄ salt particularly at 1.0% concentration.

In wild rye (Leymus chinensis L.) seed priming with 30% PEG for 24 h resulted in increase in the cell activity of superoxide dismutase and peroxidase and a rapid increase in the respiratory intensity which were associated with an increase in germination vigour (Jie et al., 2002). Ghassemi-Golezani et al., (2010) evaluate the effect of different osmo-priming treatments (KNO₃ and NaCl) on seed in vigouration and field performance of winter rape-seed cultivars and concluded that Salt priming, particularly KNO₃ priming, decreased mean germination time and increased seedling size, compared with non-primed seeds. They also reported that the highest improvement in grain yield per unit area was observed for seeds primed with KNO₃ (31.5%) followed by those primed with NaCl (22.5%). Different seed priming methods may have different effects on seed and seedling performance. Ghassemi-Golezani et al., (2008) compared seed germination properties of lentil under two seed priming techniques (osmo- and hydro-priming). They observed that seed priming improved germination and field performance of lentil compared with unprimed treatment, but the effect of different priming was also significant, where in vigouration of lentil seeds by hydro-priming resulted in higher seedling emergence in the field, compared to control and seed priming with PEG. Seedling emergence rate was also enhanced by priming seed with water. Thus, they suggested hydro-priming as a simple and effective method for improving seed germination and seedling emergence of lentil in the field.

Caseiro et al., (2004) found that hydro-priming was the most effective method for improving seed germination of onion, especially when the seeds were hydrated for 96 h compared to 48 h. When seeds imbibe, the water content reaches a plateau and changes little until radicle emergence (Bradford, 1986). Priming up to this point can have a positive effect, while extended priming duration may negatively affect germination. In other words, duration of seed priming, especially hydro-priming, affects seed germination properties. Longer hydro-priming duration has not always more positive effect on seeds germination properties. Ashraf et al., (2002) found that GA₄ treatment enhanced the vegetative growth of two wheat cultivars under but caused a slight reduction in their grain yield. GA₄ treatment enhanced the deposition of Na and Cl in both root and shoots of wheat plants under prevailing field conditions. It also caused a significant increase in photosynthetic activity in both lines.
at the vegetative stage of the crop. Hussein et al., (2007) evaluated the effect of salinity and salicylic acid on growth of maize plants. The beneficial aspects of SA are that it could be used for the improvement of salt bearing capacity of many crops.

Sedghi et al., (2010) results indicated that with increasing salinity, germination traits such as germination percent, rate and plumule length decreased, but seed priming with GA3 and NaCl showed lower decrease. In all of the salinity levels, primed seeds possessed more germination rate and plumule length than control. The highest radicle fresh and dry weight in pot marigold was seen at 7.5 dSm⁻¹ salinity stress level. It seems that higher germination rate in pot marigold shows higher tolerance to salinity than sweet fennel. The results of the experiment under undesirable conditions such as salinity stress, priming with GA, and NaCl can prepare a suitable metabolic reaction in seeds and can improve seed germination performance and seedling establishment. Bajehbaj (2010) evaluated the effects of NaCl priming with KNO₃ on the germination traits and seedling growth off our *Helianthus annuus* L. cultivars under salinity conditions and reported that germination percentage of primed seeds was greater than that of un-primed seeds.

**CONCLUSION**

Seed priming has been used to improve germination, reduce seedling emergence time, improve stand establishment and yield. The beneficial effects of priming have been demonstrated for many field crops. It is the best solution of germination related problems especially when crops are grown under unfavorable conditions. Many priming techniques have been evolved which are being utilized in many crops now days. It can enhance rates and percentage of germination and seedling emergence which ensure proper stand establishment under a wide range of environmental conditions.

**REFERENCE**


