International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(3): 1588-1594

Received: 18-03-2018
Accepted: 20-04-2018

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Techniques of seed priming in field crops

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Abstract
Priming in botany and agriculture is a form of seed planting preparation in which the seeds are pre-soaked before planting. 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, sorghum and maize.

Keywords: Seed priming, germination

1. Introduction

Various studies have been carried out to reduce the period between sowing to emergence as this play a key role in crop production. One of the important developments in this area has been the seed priming technique. The theory of seed priming was first proposed by Heydecker (1973) [31]. 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) [30] 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) [46]. 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.

Hormonal priming is the pre - seed treatment with different hormones like GA_3, kinetin, ascorbate etc., which promotes the growth and development of the seedlings. Ashraf *et al*., (2001) found that GA_3 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.

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 50ppm SA and 50ppm 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).

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 KNO_3 increases yield, fruit size and improves quality in field and vegetables crops. Assefa *et al*., (2010) [2] reported that seed priming with GA_3 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) [9].

Bensen *et al*., (1990) [10] demonstrated that hypocotyls growth rate of soybean crop is directly associated with the amount of GA_3. The enhanced plant height was due to the improved and faster plant emergence in GA_3, KH_2PO_4 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.

Mishra and Dwibedi (1980) [38] found that seed soaking in 2.5% KCl for 12 hour before sowing increased wheat yield by 15%. KCl and KH_2PO_4 have been introduced as the osmotica which have shown good potential to enhance emergence and germination in wheat. Riedell *et al*., (1985) [41] and Maske *et al*., (1997) [37] reported that GA_3 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) [59] in Okra, Rajandran, (1982) [42] in red gram and Basha, (1982) [11] in green gram. According to Graf *et al*., (1987), KH_2PO_4 showed a relatively positive effect presumably because phosphorous reserves in the seed play very important role in the metabolism of germinating seed.

Sarika *et al*., (2013) [45] conducted a lab experiment to study various physiological and biochemical changes by priming in French bean at Bangalore. They reported that chemo priming with GA_3 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 (6.02cm) and final (11.5cm) root length, initial and final shoot length, seedling vigour index and dry seedling weight with GA_3 is observed in the crop.

Farahbakhsh (2012) [23] reported that the concentration of 0.25 and 0.5mM 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.

Kata *et al*., (2014) [35] 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 50ppm, ascorbic acid 200ppm, citric acid 200ppm, proline 0.2%, calcium chloride 2%, Na_2HPO_4 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 á-amylase which in turn has resulted in better mobilization of stored carbohydrate reserves resulted in improvement of germination and other related parameters.

A study was conducted by Chavan *et al*., (2014) [19] 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 @10ppm, $CaCl_2.2H_2O$ @ 0.5%, KH_2PO_4 @ 50ppm and GA3 @ 20ppm. 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 $CaCl_2.2H_2O$ (0.5%) treatment.

Sedghi *et al*., (2010) [44] results indicated that with increasing salinity, germination traits such as germination percent, rate and plumule length decreased, but seed priming with GA_3 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 $7.5dSm^{-1}$ 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_3 and NaCl can prepare a suitable metabolic reaction in seeds and can improve seed germination performance and seedling

Tanaka *et al.* (1991) [55] reported that two blue grass variety seeds 'Abbey' (non-dorment) and 'Chateau' (relatively dormant) were primed 10 days in a 0.2% KNO_3 solution at 5-15°C with 8 hours. Priming increased germination percentage still after 21 days at 10-15°C for all lots, and might have attained higher levels with additional time.

Caseiro *et al*., (2004) [18] 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) [16, 17]. 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) [3] found that GA_3 treatment enhanced the vegetative growth of two wheat cultivars under but caused a slight reduction in their grain yield. GA_3 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) [28] 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.

Halo-priming refers to soaking of seeds in solution of inorganic salts i.e NaCl, KNO_3, $CaCl_2$ and $CaSO_4$ 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) [36] evaluated the response of seeds primed with NaCl solution at different salinity levels 0, 3, 6 and 9dSm^{-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) [32]. In sorghum seeds soaked in $CaCl_2$ or KNO_3 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 $CaCl_2$ or KNO_3 generally exhibited improvement in proteins, free amino acid and soluble sugars during germinating under salt stress (Jyotsna and Srivastava, 1998) [33].

Bassi *et al*., (2011) [12] reported that priming with GA_3 @ 50ppm 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) [25] to evaluate the effect of priming on seed in vigouration 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 KNO_3. On contrary, seedling emergence percentage and germination time were significantly adversely affected by seed priming (KH_2P0_4 and KNO_3) as compared to non-primed seeds.

Ahmadvand *et al*., (2012) [8] 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 KNO_3 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%.

A field experiment was conducted by Bassi (2005) [13] 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) [62] 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%, KH_2PO_4 0.5 and KH_2PO_4 1%). They reported that KH_2PO_4 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) [21].

Muhammad (2005) [40] conducted experiment that three seed priming duration (6, 12 and 18hrs) and five PEG 8000 concentrations (0, 200, 300 and 400 g/L water) along with dry seed (non primed as control treatment were included in the experiment). Data indicated that plants of primed seed plots took fewer days for emergence as compared with plants of non-primed seed plots.

Soughir *et al*., (2012) [49] 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 tine, 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.

Sivritepe *et al*., (2002) [50] 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) [61].

Seed priming in rice dramatically improved early seedling establishment, better emergence, early growth vigour which helped the crop escape from drought (SATrends issue 7, 2001) [53].

Aymen and Hannachi (2012) [7, 20] 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.

Elouaer and Hannachi (2012) [7, 20] 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 20Úc. 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.

Singh *et al*., (2014a) [51] 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% KNO_3 salt for 6, 8 and 10 hrs) and one hydro-primed control (10 hr). The results showed that osmo-priming with KNO_3 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 KNO_3 salt (soaked in 1% KNO_3 salt solution and dried before sowing) for 6 hours could result in greater seed germination and seedling height than hydro-priming.

Two experiments were designed by Safiatou (2012) [52] 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 *Vignasubterrenea* L. Verdc. 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.

Umapathy and Shekhrgaund (2003) [58] studied the pre-soaking seed treatments on upland rice like mud coating, water GA_3 (50, 100 and 150ppm), Cytokinin (10 and 25ppm) ethrel (50ppm), KNO_3 (1%), $CaCl_2$ (2%) and foliar application of GA_3 (100ppm)at panicle initiation and salicylic acid (25ppm) at tillering stage. Cytokinin 25ppm, GA_3 150ppm and mud coating resulted in higher field emergence and number of productive tillers. However, higher numbers of seed were obtained with the treatment involving GA_3 50ppm or cytokinin 25ppm foliar application of salicylic acid 25ppm at tillering stage. The pre sowing seed with cytokinin 25 and GA_3 150ppm produced significantly higher seed yield compared to all other treatments.

Farhoudi and Sharifzadeh (2006) [24] 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 14dSm^{-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 16dSm^{-1}, respectively. NaCl priming enhanced proline accumulation and prevented toxic and nutrient deficiency effects of salinity because less Na^+ but more K^+ and especially $Ca^{2+}$was accumulated in canola seedlings. As a matter of fact, Na: Ca^{2+} balances of seedlings derived from P seeds were significantly lower than those of NP seeds under similar salinity levels.

More recently after a series of experiments, it was concluded that pre-sowing seed treatments can't only improve the nursery seedlings and performance but may also enhance the performance of direct seeded rice in both coarse and fine rice. Growth and quality of the transplanted rice and direct seeded rice were also improved owing to seed priming (Farooq, *et al.*, 2005) [22].

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) [34]. Ghassemi-Golezani *et al.*, (2010) [26] evaluate the effect of different osmo-priming treatments (KNO_3 and NaCl) on seed in vigouration and field performance of winter rapeseed cultivars and concluded that Salt priming, particularly KNO_3 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 KNO_3 (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) [27] 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.

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) [31, 16, 17, 56].

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) [43] 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) [47] 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.

Thakuria and Sharma (1995) [57] concluded that priming with 4% KCl solution significantly increased the rice grain yield in drought condition and better N,P,K uptake and water use efficiency (WUE), it may be attributed to more filled grains / panicle as result of priming.

At Varanasi, Srivastava and Bose (2012) [48] conducted an experiment on seed priming of rice varieties with or without nitrate salts (Mg $(NO_3)_2$ and KNO_3). 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.

Arif *et al*., (2008) [4] 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.

Assefa and Hunje (2011) [1, 5] 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 (16.3cm), shoot length (13.8 cm) and vigour index (2933) were consistently in favour of 14 hour seed priming duration as compared to lesser and more duration.

On-farm seed priming (seed soaking) has been reported to improve crop establishment, growth and yield. Murungu *et al*., (2004) [39] 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 shown 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.

Anese *et al*., (2011) [6] 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.

Seed priming can be used to increase yield further by about another 30% by overcoming soil micro and macronutrient deficiencies and improving disease resistance for many crop e.g. upland rice, maize, wheat, barley, sorghum, pearlmillet, fingermillet, chickpea, mungbean etc. (Harris, 1996) [29].

A field experiment was conducted by Vazirimehr *et al*., (2014) [60] 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) [14, 15, 54].

Conclusion

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

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