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Effect of pre-sowing and pre-storage seed treatments on seed quality, field performance and storage potential in soybean [*Glycine max* (L.) Merill]: A review

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Abstract

High quality seed is the key to successful agriculture. Modern agriculture demands that seed should have high quality and produce a vigorous seedling ensuring high yields. Unfortunately, in tropical and sub-tropical zones of developing countries, the seed used is often very poor in quality, especially from the physiological standpoint. In India, less than 15 per cent of fields are sown with quality seeds. Chowdhury (1999) emphasized that good quality seed can boost the yield to 10-25 per cent. Seed vigour, the vital factor is still not considered with the seriousness it deserves. Seed invigouration improves seed performance by improving germinability, field performance and extends storability than corresponding untreated seed (Basu, 1993). To derive enhanced effects of seed invigouration treatments in laboratory and field, the seed should not be fresh but should not have germination below 50 per cent (Saxena *et al.*, 1974). Therefore, efforts were made to review the research findings related to effect of pre-sowing and pre-storage seed treatments on seed quality, field performance and storage potential in soybean.

Keywords: Invigouration, seed containers, seed treatments, soybean, storage

Introduction

Soybean [(*Glycine max* (L.) Merill] is known as "Golden bean" and "Miracle crop", of the 20th century, because of its multiple uses (Kumar *et al.*, 2013) [45], and often designated as "Wonder crop" and "Gold of soil". Soybean is economically the most important crop in the world, providing vegetable protein to millions of people. It is a leguminous plant closely related to peas, alfalfa and clover. Soybean is an annual, small, erect, semi spread and spread plant. Stems, leaves and pods are soft and hairy. It is basically a crop of temperate region. Most of the varieties needs a temperature range of 30-38 ^{o}C.

As soybean has greater economic and nutritive value, much emphasis is being given for increasing its area, production and productivity, which is possible only through use of quality seeds of high yielding varieties. Non-availability of high quality seeds of soybean in adequate quantity may be attributed to lesser area under seed production on account of drought conditions, lower seed yield, non-availability of high yielding varieties, non-adoption of seed production practices by farmers, *etc*. Hence, there is a need to increase seed yield and quality of soybean varieties.

In recent years, importance of soybean has increased and large number of farmers cultivating it. Seed industry is playing an important role in production and supply of quality seeds to farmers. Despite its great food value, it is known to have poor field emergence compared to seeds of other *kharif* oilseeds/pulse crops due to its inherent seed structure and composition.

In modern agriculture, success of seed industry and seed programmes depends on how carefully seeds are stored for next planting season without loss of seed viability and vigour. "A seed saved is seed produced" an old adage also still holds good even today. The storage losses of seeds in terms of quality and quantity may range from zero to even 100 per cent under unhygienic storage conditions.

Seedling establishment is an important factor and largely depends on the seed germination and vigour. Seed priming is a wonderful technique of seed invigoration which has the potential not only to enhance the seed vigour and germinability of normal seeds but also has the excellent ability to revive the partially aged seeds and improve the germination power over a wide range of environmental conditions (Harris *et al.*, 1999) [29]. Seed priming has presented promising and even surprising results, for many seeds including the legume seeds (Bradford, 1986) [13]. The advantage of seed priming in reducing the germination time and improving emergence uniformity is well established under laboratory conditions. The direct benefits of seed priming in all crops included: faster emergence, better, more and uniform stands, less need to re-sow, more vigorous plants, better drought tolerance, earlier flowering, earlier harvest and higher seed yield. The indirect benefits reported were: earlier sowing of crops, earlier harvesting of crops and increased willingness to use of fertilizer because of reduce risk of crop failure. Park *et al.* (1997) [67] reported that priming aged seeds of soybean resulted in good germination and stand establishment in the field trials.

Pre-sowing seed treatment techniques has been used as an alternate approach to overcome the ailing effects of abiotic stresses in agricultural production because of its low cost and risk (Khan *et al*., 2016) [42]. Pre-sowing seed treatment technology is a control seed hydration in solution containing organic or inorganic solutes followed by re-drying that allows pre-germinative metabolic activities but prevent radical emergence (Khalil *et al*., 2015) [41]. The primed/hardened treatments proved to be better for vigor improvement than traditional soaking (Manjunath and Dhanoji, 2011) [51]. Seed priming/hardening treatments enhances seeds vigor by protecting structure of the plasma membrane against injury during stress environment (JunMin *et al*., 2000) [37]. Pre-soaking seeds with optimal concentration of phyto-hormones enhance their germination, growth and yield under stress condition by increasing nutrient reserves mobilization through increased physiological activities and root proliferation (Khan *et al*., 2016) [43]. Different pre-sowing seed treatments have successfully been integrated for vigour enhancement in soybean resulting good germination and plant stand establishment in field, faster emergence, better, more and uniform plant stand, less need to re-sow, more vigorous plant, earlier flowering, earlier harvest and higher seed yield. Seed coating material were reported to improve seed handling, germination, plant stand and increase the seedling emergence at changing soil moisture. Depending on coating material, seed can be protected from disease, pest, nematode, etc.

Oil seeds are very sensitive to the adverse environmental conditions. The oil inside the seeds will get oxidized easily and deteriorate the seed health during storage (Kausar *et al*., 2009) [39]. The storage conditions of seeds influence the germination characteristics and vigor potential of seeds. Diverse environmental conditions such as temperature, pests and diseases, seed oil and moisture content, mechanical damages, storage time and relative humidity of store may affect the viability of seeds (Marshal and Levis, 2004) [52]. The environment where the seeds are stored greatly influences the length of seed survival. Seed deterioration leads to the reduction in the quality, viability and vigor either due to aging or effect of adverse environmental factors (Siadat *et al*., 2012) [79]. Decrease in seed vigor may be due to decrease in germination indexes and also can increase the susceptibility of seeds to environmental stress. Soybean seed losses its viability in very short period of storage. Soybean seeds treated with boric acid powder, neem kernel powder, wood ash and calcium hypochlorite maintained better seed quality for long time and storing the seeds in vapor proof container like aluminium foil bag and air tight plastic container, is found to be more useful in maintaining the desired quality of seeds for longer period.

Therefore, efforts were made to review the research findings related to effect of pre-sowing and pre-storage seed treatments on seed quality, field performance and storage potential in soybean.

Seed invigouration treatments to improve seed quality

Nalawadi *et al.* (1973) [62] reported that presoaking of soybean cultivars in water for 24 hours had significant effect on germination and seedling fresh weight. The increase in germination percentage was from 21.20 to 54.00 per cent and seedling fresh weight from 1.735 g to 3.445 g. Bharati *et al.* (1983) [12] evaluated the effect of temperature on germination and the effect of hydration-dehydration pre-treatments on germination at suboptimal temperatures for several soybean lines. Optimal temperatures for germination and hypocotyl-radicle elongation were 31 ºC and 27-31 ºC, respectively. Prior hydration at 31 ºC hastened rate of germination and/or synchronized germination within seed lots at 10 ºC, and in less vigorous seed lots, increased germinability. These effects were progressively dissipated by subsequent dehydration-storage treatments, a response more pronounced with dehydration at higher temperature, dehydration to original water content, and longer storage after dehydration. With less vigorous seed lots, germinability and/or rate of germination at 10 ºC after dehydration and storage were actually reduced relative to untreated seed. The effect of pre-treatment appeared due to both an increase in the rate of initial water uptake at suboptimal temperature, and to the more rapid activation of metabolic activity during germination. Although the effect of pre-sowing hydration *per se* on germination at suboptimal temperature was encouraging, the magnitude and unpredictability of the effect following dehydration suggest that the approach may have limited practical application in mechanized soybean production.

Saha and Basu (1984) [74] discussed the physiology of alleviation of soaking injury and ageing damage and the interaction of treatments with the vigour status of seed. Soaking of 12 month old soybean seeds in water for two hours at 28 ºC caused severe injury to the seeds. Moisture equilibration for 24 hours with a water saturated atmosphere (100% relative humidity at 28 ºC) largely overcame the soaking injury. Drying back of moisture equilibrated and soaked (two hours) seed retained the beneficial effect and the moisture equilibration-soak-dry treatment proved very effective in counteracting soaking injury and physiological deterioration of the seeds. Germinability of seeds following the different hydration-dehydration treatments was significantly influenced by the initial vigour status of the seed. In six month old seed, soaking-drying alone was effective but the alleviation of soaking and ageing damage was much more pronounced in the moisture equilibrated-soaked-dried seed. In one month old seed, no soaking injury was evident when seeds were kept fully immersed in water for two hours; the soaked-dried seeds also did not show any harmful effect on immediate germinability but following accelerated ageing or prolonged storage under ambient conditions, the latent deleterious effect of presoaking was clearly discernible. Saha *et al.* (1990) [75] applied five hydration-dehydration treatments involving slow and/or rapid hydration to 6-month-old seeds of soybean cv. Soyamax. Moisture equilibration-soaking-drying (ME-S-D) and moist sand conditioning-soaking-drying (MSC-S-D) treatments greatly reduced the loss of vigour and viability under accelerated as well as natural aging conditions. Post-aging physiological and biochemical studies showed increased amylase and dehydrogenase activities and greater membrane integrity coupled with lower lipid peroxidation in the treated seeds than in the control. It is suggested that the ME-S-D and MSC-S-D treatments improved seed vigour and viability of soyabean seeds, at least in part, by counteracting lipid peroxidation reactions.

Khalil *et al.* (2001) [40] studied the effect of polyethylene glycol (PEG) 8000 concentrations and seed treatment durations on soybean seed germination. Three experiments were conducted: In experiment 1, the seeds were treated for 1, 2 and 7 days. The osmotic potentials of the PEG solutions were 0, -0.1, -0.2, -0.4, -0.5, -0.7 and -1.1 MPa including control. In control the seeds were treated with water for the above duration. In experiment 2, the seeds were treated for 24, 48 and 72 hours the osmotic potentials of the PEG solutions was 0, -0.3, -0.5, -0.9 and -1.5 MPa including control. The control was not treated with water or PEG. In experiment 3, the seeds were separated into small and large seed and were treated with PEG solution having osmotic potentials of -0.5, -1.1 and -1.8 MPa for 0 (control), 24 and 48 hours. The control was not treated with water or PEG. PEG solution having osmotic potentials (-1.1 and -1.8 MPa) improved germination compared to control (no PEG treatment). Seed treatment durations longer than 48 hours were deleterious and reduced the germination. Seed size has no effect on germination.

Arif (2005) [7] studied the effect of seed priming on storability of soybean cv. William 82. Three seed priming durations (6, 12 and 18 h) and five PEG 8000 concentrations (0, 100, 200, 300 and 400 g/l of water) along with dry seed (non primed) as control treatment. Primed seed produced higher germination, greater seedling dry weight and less electrical conductivity for seed stored at room temperature. PEG concentration of 300 g/l of water resulted in higher germination and seedling dry weight. However, water primed seed recorded maximum leachate conductance. Germination and seedling dry weight decreased with increase in seed priming duration. Basu and Choudhary (2005) [10] reported that pre-sowing hydration treatment significantly enhanced field emergence (79.77%), rate of germination (32.59) and seedling dry weight (3.92 g) of parental lines in soybean hybrid seed production compared to control (61.90%, 29.27 and 3.73 g, respectively) in both seasons, wherein the treatment effect was more evident in winter season.

Mahesh and Ravi (2008) [49] studied the effect of seed treatment with botanicals on storability of soybean andfound that seed treatment with sweet flag rhizome powder @ 10 g/kg of seed recorded higher germination (81.44%), root length (16.78 cm), shoot length (15.65 cm), seedling dry weight (94.34 mg), seedling vigour index (2641) and field emergence (73.33%), and lowest electrical conductivity of seed leachates (1.198 dS/m) and moisture content of seed (9.10%) in comparison to control (73.22%, 14.73 cm, 14.10 cm, 87.20 mg, 2146, 67.44%, 1.353 dS/m and 9.69%, respectively). Assefa *et al.* (2010) [8] studied the enhancement of seed quality in soybean following priming treatments and reported that soybean seeds primed with GA_3 (20 ppm) recorded significantly higher speed of germination and shoot length followed by $CaCl_2.2H_2O$ (0.5%) and KH_2PO_4 (50 ppm) primed seeds. The lowest speed of germination exhibited by KCl (100 ppm) primed seeds. Thawale *et al.* (2010) [84] studied the effect of seed soaking treatments on quality parameters of soybean. Main treatments were fresh seed lot and revalidated seed lot and sub treatments consisted of six invigoration treatments including control. Seed soaking treatments with vitavax 200 and hydration (2hrs) followed by dry dressing with thirum recorded the maximum germination, seedling length, seeding dry weight, vigour index, and lower electrical conductivity. The effect of seed soaking treatment seems to be beneficial for enhancing the seed quality parameter in soybean.

Hossein *et al.* (2011) [31] studied the effect of seed osmopriming by using PEG 6000 priming media on germination behaviour and seed vigour of soybean (cultivar 033). Seeds were primed with six levels of poly ethylene glycol (PEG 6000) as priming media (distilled water as control, -0.4, -0.8, -1.2, -1.6 and -2 MPa) for 6, 12, 24 and 48 hours at 25 °C. Dry soybean seeds considered as a control treatment (non-primed). The results revealed that different osmotic potential and priming duration had significant effect on germination percentage, mean germination time, germination index, and the time to get 50 per cent germination, seed vigour and electrical conductivity of seeds. Also -1.2 MPa osmotic potential increased germination percentages, germination index and seed vigour, meanwhile decreased mean germination time, the time to get 50 per cent germination and electrical conductivity of seeds. Also it was observed that 12 h priming duration had most effect on studied traits at -1.2 MPa osmotic potential treatments. Generally primed seeds showed better condition than control treatment in aspect of studied criteria. Usha and Dadlani (2015) [85] gave mid storage corrective hydration and dehydration treatments *viz*., common bleach, *Catharanthus* leaf powder, *Trigonella* powder, chilli powder, sand moist conditioning and sand moist conditioning soaking and drying to high, medium and low vigour seed lots of soybean. The performance of soybean seed was measured in terms of germination per cent and field emergence. Sand moist conditioning soaking and drying was most effective in enhancing germination and field emergence per cent irrespective of different vigour lots of soybean seed. The effect is more prominent in medium and low vigour lots.

Patil *et al*. (2017) [69] carried out a storage experiment to extend the longevity of soybean seeds through mid-storage seed invigoration technique by following moist sand conditioning-soaking-drying method in five months old seeds. The experiment consisted of nine treatments using different salts and botanicals *viz*., T_1: Control; T_2: Water, T_3: NaCl (10^{-3}M), T_4: KI (10^{-3}M), T_5: Na_2HPO_4 (10^{-3}M), T_6: Iodine (0.1%), T_7: $CaCl_2.2H_20$ (1%), T_8: *Pongamia* leaf extract (1%) and T_9: Custard apple leaf extract (1%). It was found that various salts and botanicals effectively reduced the physiological deterioration during subsequent storage period under ambient environmental conditions compared to control. Among the treatments, iodine (0.1%), water and $CaCl_2.2H_20$ (1%) shown great promise in extending the storage potential of soybean seeds by an extra one month by registering higher germination values (74.63, 73.13 and 72.88%, respectively) compared to control (67.38%), possibly by acting as a free radical scavenger that prevent propagation of radical during peroxidation of lipids. Since the availability of water to the farmers is more economical, it can also be used in extending the storage potential for another one month instead of iodine and $CaCl_2.2H_20$. Ansodariya *et al.* (2018) [6] studied the effect of seed priming on physiological changes associated with seed deterioration during storage periods in soybean. The results revealed that seeds of the genotype JS335 primed with $CaCl_2$ (2%) was better in germination percentage, viability test and electrical conductivity throughout the storage period followed by KH_2PO_4 (2%). Miladinov *et al.* (2018) [56] examined the effect of primers on seed quality parameters using different starting values of germination in ten different lines of soybean. The starting values of germination ranged between 48 per cent and 89 per cent. Seeds were surface sterilized with 3 per cent sodium hypochlorite and immersed in different primers: 1 per cent potassium nitrate, 1 per cent potassium chloride and 1 per cent hydrogen peroxide. Untreated seeds were used as the control. The results revealed that the effects of priming depended on soybean line and treatment, whereas the efficiency of this pre-sowing treatment was not affected by the starting value of seed germination. Some lines responded favorably to immersion, while in others priming had an inhibitory effect, causing a significant decrease in germination. There was an increase in germination up to 12 per cent or a decrease up to 11 per cent, depending on line and treatment. Lines that were positively affected by this method also exhibited increased values for other germination parameters: mean germination time (MGT) and time to 50 per cent germination (T_{50}). Lower values of MGT and T_{50} were observed in lines which showed a negative response to priming and a decrease in germination, but also a more rapid radicle protrusion, as compared to the control.

Hemasruthi *et al.* (2020) [30] studied the influence of hydration treatments on seedling characters of soybeanto assess the potential of botanicals for germination, seedling vigour and germination index. Inorganic and organic priming methods were adopted and treatments used were T_0 (Control), T_1 - Zinc sulphate ($ZnSO_4$) (2%), T_2 - Magnesium sulphate ($MgSO_4$) (2%), T_3 - Potassium chloride (KCl) (2%), T_4 - Potassium nitrate (KNO_3) (2%), T_5 - Polyethylene Glycol (PEG) 6000 nm (20%), T_6 - Salicylic acid (2%), T_7 - Moringa leaf extract (5%), T_8 - Curry leaf extract (5%), T_9 - Mint leaf extract (5%) and T_{10} - Neem leaf extract (5%). Among all the treatments, PEG 6000 nm recorded high germination percentage, germination energy, root length, shoot length, seedling length, fresh and dry weight of seedling, seed vigor index (length) and seed vigor index (mass). However, there is no much significant difference in the protein content of seeds hydrated with botanicals and chemicals compared to control. The result indicates that the use of PEG 6000 enhances the seed performance regarding germination and vigor. The process is simple and in economy as no costly equipment is required to overcome the poor germination and poor seedling establishment. Meseret (2020) [55] studied the effect of priming on seed quality of soybean varieties. The experiment consists of three varieties (Belessa 95, Wello and Gishama), three priming types [GA_3 (100 ppm), KH_2PO_4 (50 ppm) and water] and three priming durations (0, 6 and 12 hours). The highest shoot length was observed for Belessa 95 variety primed with GA_3 and the highest root length for Belessa 95 variety primed with water. The highest seedling dry weight was recorded when Belessa 95 variety primed with water for 12 hr. The highest seedling vigor index I was recorded when Gishema variety primed with KH_2PO_4 for 6 hr, the highest seedling vigor index II was recorded when Belessa 95 variety primed with water for 12 hr and the highest speed of germination was recorded when Wello variety primed with water for 6 hr. Soybean varieties primed with water and GA_3 priming medias exhibited the better results in improving seed quality followed by KH_2PO_4. Hence, water priming was recommended to user to overcome the problems of poor crop emergence and establishments under adverse environmental condition. Wello variety which is primed with GA_3 took significantly lower days to 50 per cent flowering followed by primed with KH_2PO_4.

Effect of pre-sowing seed treatments on crop growth, seed yield and quality

Presoaking/Wetting-drying/Hydration- dehydration is soaking of seeds in limited or unlimited amount of water at low to moderate temperature. Seed hydration at low water potential prevents radical from protruding but allows seed to achieve biochemical and physiological changes which result in rapid and synchronous seedling emergence (Khan, 1992) [42]. The main purpose of hydration is to raise seed moisture to 25-30 per cent (wet weight basis) before drying back to safe limits for extending viability during dry storage. Another and most popular approach is to hydrate seeds in low water potential solution of organic and inorganic solutes for extended periods (Osmo-conditioning).

Wolkowski *et al.* (1985) [87] applied three different cytozyme materials (Soil+, Seed+, and Crop+) to corn and soybean at label recommendations as various combinations of each product with and without recommended fertilizers. No consistent significant yield increase or improvement in plant nutrient content was observed where the various cytozyme materials were used alone or in combination with fertilizers. Rao and Singh (1997) [72] noticed that presoaking of high vigour seed lot of soybean in water for 12 to 14 hours followed by drying ensured significantly higher plant height (54.00 cm), leaf area index (2.19), number of pods per plant (32.00), hundred seed weight (12.40 g) and seed yield (2.40 t/ha), compared to low vigour seed lot (50.00 cm, 2.15, 28.00, 11.85 g and 2.10 t/ha, respectively).

Gupta and Aneja (2000) [28] obtained soybean seeds of four varieties (JS 80-21, JS 71-05, MACS 58 and Pusa 16) from different regions in India and planted in the field in Haryana during *kharif* season, after dressing with fungicides (captan, thirum, mancozeb and carbendazim). All four fungicides gave significant improvement in field emergence and seed yield. Negalur (2000) [64] soaked seven months old JS335 soybean seeds in 2% KH_2PO_4 for 3 hours and dried to original moisture (9%) and recorded 87 per cent field emergence in treated seeds compared to control (69%). Sanjeevakumar (2000) [76] invigourated seeds of soybean cultivar JS 335 having initial germination of 72 per cent in different chemical solutions for three hours. KH_2PO_4 (2%) could enhance germination up to 88 per cent and was found superior in maintaining seed viability and vigour and increased yield. Oad *et al.* (2002) [65] evaluated the effect of *Rhizobium japonicum* inoculum doses (10, 15, 20, 25, 30 ml and untreated control) of liquid culture on the growth and seed yield of soybean. One liter liquid culture medium was prepared by standard procedure by adding 0.5 g KH_2PO_4, 0.2 g $MgSO_4$, 0.1 g NaCl, 0.05 g yeast extract, 10.0 g Minitol and 1000 ml distilled water. The adequate level of 25 ml with 300 g sand maize as seed treatment inoculant was found more effective for maximum growth and seed yield as compared to higher and lower doses of *Rhizobium japonicum*. Thus, it was concluded that *Rhizobium japonicum* exhibited the positive change in terms of enhanced growth and seed yield. The satisfactory results would be achieved, if the soybean seed treated with 25 ml of *Rhizobium japonicum* inoculums. Muhammad *et al.* (2008) [60] studied the effect of seed priming on emergence and yield of soybean cv. William 82. Seed primed with polyethylene glycol (PEG) solutions for 6, 12 and 18 h using dry seed (non-primed) as a control. Seed priming duration of 6 h resulted in faster and improved emergence and higher seed yield of soybean.

Bellur (2009) [11] conducted field experiment in soybean with six calcium salts *viz*., calcium carbonate, calcium chloride, calcium hypochlorite, calcium oxychloride, calcium sulphate, calcium hydroxide and control (water soaking) and two concentrations *viz*., 0.5 and 1.0 per cent concentrations. Significantly higher seed yield per ha (8.94 q), germination (88.58%) and vigour index (4140) was recorded by calcium chloride followed by calcium carbonate and calcium oxychloride by registering better crop growth, seed yield and quality parameters as against control. Likewise, 1.0 per cent concentration recorded significantly higher seed yield per ha (7.47 q), germination (86.89%) and vigour index (3666) as against to 0.5 per cent concentration. Assefa *et al.* (2010) [8] studied the enhancement of seed quality in soybean following priming treatments and reported that soybean seeds primedwith $CaCl_2.2H_2O$ (0.5%) recorded the highest germination and field emergence followed by GA_3 (20 ppm) and KH_2PO_4 (50 ppm) primed seeds and the lowest in KCl (100 ppm) primed seeds. Thawale *et al.* (2010) [84] studied the effect of seed soaking treatments on yield parameters of soybean. Main treatments were fresh seed lot and revalidated seed lot and sub treatments consisted of six invigoration treatments including control. All invigoration treatments with fresh seed lot recorded more number of pods per plant, 100 seed weight, harvest index, seed yield per plant and yield kg/m^2 over control. Seed treatment of fresh seed lot with vitavax 200 recorded significantly the highest seed yield per plant amongst all the treatments.

A field experiment was carried out to evaluate the effects of priming methods on field performance of soybean (cv. 'Zan'). Irrigation treatments (I_1, I_2 and I_3: irrigation after 70, 110 and 150 mm evaporation from class A pan) and priming methods (water, 3% KH_2PO_4 and 3% KNO_3 for 8 h at 15±1 °C) were allocated to main and sub-plots, respectively. Germination percentage, seedling dry weight and field emergence percentage decreased, but mean emergence time increased, due to seed priming. Seed yield under severe water deficit was 29.32 per cent less than that under normal irrigation. Pods per plant, grains per plant and grain yield per plant were significantly enhanced as a result of low stand establishment caused by seed priming. Consequently, biological and grain yields per unit area and also harvest index were statistically similar for plants from primed and unprimed seeds. In general, priming methods had no any beneficial effect on field performance of soybean seeds (Ghassemi-Golezani *et al*., 2011) [25]. Anitha *et al.* (2013) [5] investigated the efficiency of different biopriming agents *i.e.* biocontrol agents (*Trichoderma harzianum* @ 0.6%, *Pseudomonas fluorescens* @ 0.6%, *Bacillus subtilis* @ 0.6%) and fungicides (Tebuconazole 5% EC @ 0.2%, Captan 70% WP + Hexaconazole 5% EC @ 0.2%, Carboxin 37.5% + Thiram 37.5% @ 0.2%, Captan @ 0.2%, Carbendazium @ 0.2%, Mancozeb 50% + Carbendazim 25% WS @ 0.2%) in enhancing seed germination, seedling growth and yield in soybean seeds of JS-335 variety. Primed seeds were subjected for lab and field experiments. *Bacillus subtilis* @ 0.6% recorded the highest seed yield followed by captan 70% WP + hexaconazole 5% EC @ 0.2% and carbendazim 25% + mancozeb 50% WS @ 0.2%. In all other seed priming treatments there was an increase in number of pods per plant, pod weight per plant, seed weight per plant, 100 seed weight and seed yield compared to untreated control.

Chavan *et al.* (2014) [14] determined the importance of seed priming on field performance and seed yield of soybean. There were two varieties *viz*., Phule Kalyani and JS 335 and six priming treatments *viz*., Control(unprimed seeds), Hydropriming, KCl @10 ppm, $CaCl_2.2H_2O$ @ 0.5%, KH_2PO_4 @ 50 ppm and GA_3 @ 20 ppm. The variety Phule Kalyani primed with $CaCl_2.2H_2O$ (0.5%) were superior in plant height, number of branches, number of pods per plant, number of seeds per pod, seed yield per hectare over those raised from the variety JS335. Moosavi *et al.* (2014) [58] studied the seed water pre-treatment effects on soybeans vegetative and reproductive traits. One of the seed water pre-treatment factors was 8, 12, 16 and 20 hours which were soaked in tap water and dried to 30 percent moisture. A seed sample was also considered as an observation sample (without pre-treatment). The second cultivar factor was Williams and LV (17). Results indicated that there is a significant difference between hydro-priming durations on germination percentage, seedling weight, main stems weight, lateral stems weight, number of pods per plant, dry weight of seeds per plant and yield. In most traits, 8 hours seed water pre-treatment provided the best yield. Moreover, cultivar interaction effects on main stems weight trait in seed water pre-treatment were significant. The results indicated that cultivar Williams had the most height with 8 hours seed water pre-treatment. Also, there was a significant difference among cultivars on main stems weight, lateral stems weight, number of pods per plant, dry weight of seeds per plant and yield and in most traits LV (17) had a better yields comparing to the Williams cultivar. Syaiful *et al.* (2014) [82] evaluated the effects of seed priming with osmoticum poly ethylene glycol (PEG) 8000 in improving tolerance of soybean to drought stress. Green house factorial experiment in a completely randomized design with three replications was conducted. Treatments consisted of five levels of seed priming (dry seeds – untreated, PEG concentration: 0, 100, 200 and 300 g/l water) and three levels of drought stress treatments (100% field capacity, 75% field capacity and 50% field capacity). Results showed that seedling growing from primed seeds differed significantly with respect to plant height increment, shoot/root ratio, chlorophyll content and protein content. However, seed priming with PEG had no effect on relative growth rate (RGR), number of stomata, 100 seed weight and seed yield. Among the various concentration of PEG used, priming with 300 g PEG/l water significantly increased chlorophyll content and protein content. Seed priming and drought stress treatments proved to be significant with respect to shoot-root ratio, 100 seed weight, protein and chlorophyll content. Seeds treated with 300 g PEG/l water demonstrated to be superior to the non-primed and all other primed seeds when water stress increased (50% field capacity). The results indicated that seed priming with PEG can improve plant growth in soybean by conferring more resistant seedlings to drought stress.

Agawane and Parhe (2015) [2] studied the effect of seed priming on crop growth and seed yield of soybean. The results showed that seeds primed with GA_3 @ 100 ppm, 0.5% KNO_3 recorded significantly higher germination percentage *i.e*. 87.33 and 87.00 per cent, respectively over the untreated control (83.00%). The treatments GA_3 100 ppm for 12 hr (77.19), hydration with IAA @ 80 ppm for 12 hr (76.55) and hydration with $CaCl_2$ (2.0%) for 12 hr (76.22) maintained the optimum plant stand at harvest over untreated control. This may likely contributed for boosting up economic yield in soybean cultivar JS 9305. The seed priming significantly influenced the seed yield and yield contributing characters of soybean. The seed priming treatments GA_3 100 ppm for 12 hr and hydration with water + Bavistin 3.0 g/kg found effective for improvement in dry matter content of seedling in soybean variety JS 9305. The treatments 100 ppm GA_3 for 12 hr, hydration with IAA 80 ppm for 12 hr and hydration with 0.5 per cent KNO_3 for 12 hr recorded seed yield per plot of 2078.00, 2008.67 and 1991.00 g/plot, respectively over the untreated control (1647.67 g/plot). Kujur and Lal (2015) primed the seeds of soybean cv. DS 2706 with distilled water, KNO_3 (1%), NaCl (0.5%) and PEG 6000 (5%) for 8, 12, 24 and 48 hrs. at 25 °C. Results clearly showed that osmopriming and hydropriming had significant effect on seed germination and emergence. Mean comparison showed that the highest germination percentage, germination index and vigour index was achieved by priming with PEG 6000 (5%) for 12 hours. Maximum seedling length and dry seedling weight was obtained by hydropriming for 24 hours and least mean germination time and the highest energy of emergence was achieved by osmopriming by NaCl for 12 hours. Mehri (2015) [54] studied the effect of seed priming on seed yield and yield components of soybean. The first factor was priming methods (control, $ZnSO_4$, KH_2PO_4, KNO_3 and H_2O) and the second factor was priming duration (control, 6, 12, 18 and 24 hours). Results showed that priming methods and duration increased germination percentage, germination rate, number of pods per plant, seed numbers per pod, 1000 seed weight, biological yield and seed yield. Seed priming by H_2O with 18 hours had an appropriate performance and could increase seed germination, seed yield and yield components to an acceptable level. Therefore, hydro-priming is a simple, low cost and environmentally friendly technique for improving seed yield in soybean.

Jadhav *et al.* (2017) [36] studied the effect of seed priming on yield and yield components of soybean. The results revealed that seeds primed with $CaCl_2$ @ 1% and GA_3 @ 500 ppm recorded significantly higher germination percentage *i.e.* 84.67 per cent and 83.33 per cent, respectively over the untreated control (76.00%). Seed priming with $CaCl_2$ @ 1% for 2 hrs recorded higher number of initial plant stand (117) followed by seed priming with GA_3 @ 100 ppm for 2 hrs (111) and seed priming with KNO_3 @ 1% for 2 hrs (111). This may likely contributed for boosting up economic yield in soybean cultivar JS-335. The seed priming significantly influenced the seed yield and yield contributing characters of soybean. The highest value for seed yield per hectare was recorded by seeds primed with $CaCl_2$ @ 1% (20.12 q/ha) followed by seed priming with GA_3 @ 100 ppm for 2 hrs (19.02 q/ha) and seed priming with KNO_3 @ 1% for 2 hrs (18.35 q/ ha). All other treatments recorded higher yield than untreated control (14.05 q/ha) showing to the corresponding favourable improvement in number of pods per plant, number of seeds per pod, test weight, seed yield per plot and seed yield per hectare (q). Paudel *et al.* (2017) [70] carried out the experiment to see the effects of seed priming with boron and *rhizobium* inoculation on yield and yield components of soybean under the hot and moist subtropical agro-ecological condition of Birgunj during July-November 2015. Two varieties of soybean *i.e.* Puja and Ransom, and one pipeline genotype PK-7394 were tested under Control, Boron (235 mg borax/kg), Inoculum (*Rhizobium japonicum*), and Boron (235 mg borax/kg) and *Rhizobium*. The seed priming with boron followed by *Rhizobium* inoculation significantly increased yield (2.28 t/ha), fruiting branches per plant (13.33) and harvest index (31.23%), whereas maximum pods per branch (51.06) and test weight (85.02 g) were obtained from those seeds that were primed with boron, but not inoculated with *Rhizobium* strain. Among the three varieties, the highest yield (2.46 t/ha) along with superior yield components *i.e.* fruiting branches per plant (13.42) and pods per branch (50.88) was recorded in pipeline genotype PK-7394, whereas the maximum test weight (83.88 g) and harvest index (31.06%) was obtained in Puja variety. The maximum Benefit: Cost Ratio (*i.e.*2.14) was observed in pipeline genotype (PK 7394) and under combine application of boron and *rhizobium* (1.98), whereas least performance was observed in case of Ransom variety. Saeed *et al.* (2017) [73] conducted a field study composed of two soybean varieties (Faisal Soybean and 95-1) and five priming techniques (control, on-farm priming, hydro priming, hydration inoculation and osmo-priming with 0.5 per cent urea solution). Results revealed that hydro priming, on-farm priming and hydration inoculation significantly reduced the time to 50 per cent emergence (E_{50}), mean emergence time (MET) and emergence index (EI) of both soybean varieties. Moreover, osmo-priming had no significant effect on E_{50}, MET and EI that was at par with control. On an average, days to maturity (96.42), plant height (25.84 cm), plant population at harvest (25.22), 1000-seed weight (94.97 g), seed yield (1.71 t/ha) and biological yield (4.37 t/ha) of both soybean varieties was significantly improved by hydration inoculation and hydro priming techniques.

Shete *et al.* (2018) [78] studies the effect of seed priming on yield of soybean with different seven priming treatments given before one day of sowing such as hydropriming, osmopriming, halopriming and control. Results indicated that, relatively higher mean performance of hydropriming for one hour was noted in yield and yield contributing traits such as days to field emergence, number of pods per plant, seed yield per plant, seed yield per ha, test weight and harvest index. Lewandowska *et al.* (2020) [48] studied the influence of priming on germination, development, and yield of soybean varieties. There had been seven soybean varieties (Aldana, Aligator, Annushka, Augusta, Lissabon, Mavka, and Merlin) and each of them had control (unprimed) and seed primed groups. On the basis of statistical analysis, significant differences were found between the applied hydropriming method and the control group in regard to morphological traits. Seed treatment resulted in a slight increase in harvested seed yield, which is within error margin. The seed yield of Aligator increased significantly by 0.5 t/ha, indicating a genotype-specific different reaction to seed priming in terms of yield. Muhammad *et al.* (2021) [59] conducted the study to check the impact of four seed primers (hydro-priming, KNO_3, $MgSO_4$ and $CaCl_2$) on growth and yield of three soybean cultivars (Ajmeri, RAWAL1 and NARC2) under agro-climatic condition of Sargodha, Pakistan. Results confirmed that priming of cultivar NARC2 with 0.5% KNO_3 solution showed highest germination count (34.22 per m^2), maximum leaf area index (0.85), number of branches (8.53), number of pods per plant (25.65), number of seeds per plant (51.53), 1000-seed weight (121.49 g), seed yield (793.82 kg/ha), biological yield (8041.3 kg/ha) and seed oil contents (13.49%) as compared to all other treatments. Cultivar RAWAL1 showed the maximum plant height (46.82 cm) when its seeds were primed with 0.5% KNO_3 solution as compared to other cultivars and priming treatments. Results suggested that NARC2 with the application of 0.5% KNO_3 as priming agent is suitable under the agro-climatic conditions of Sargodha.

Effect of pre-storage seed treatments on seed viability
Varietal variation with storage potential

Kumar (2000) [46] recorded the higher germination (84.8%), field emergence (79.5%), lower EC and seed infection in KHSb 2 compared to Hardee (81.3% germination and 79.1% field emergence) throughout storage in soybean. Both the varieties maintained 70 per cent germination up to 8 months of storage. Singh and Dadlani (2003) [80] reported higher germination (94%) in JS 71-05 followed by PK 327 upto14 months for the seeds packed in polythene bags, but it fell down up to 3 and 1 per cent, respectively, when kept in cloth bags after 8 months of storage in soybean.

Kandil *et al.* (2013) [38] studied the response of some soybean varieties Giza 21, Giza 22, Giza 35, Giza 111 and Crawford to storage periods (3, 6, 9 and 12 months), storage conditions (ambient conditions and refrigerator conditions at 10 ± 1ºC) as well as storage materials on germination characters. Seed germination characters were decreased with increasing period of ageing. Giza 111 exceeded other cultivars in energy of germination and emergence rate. Giza 21 cultivar exceeded other cultivars in germination index. Giza 35 cultivar exceeded other cultivars in final germination percentage. Donga (2014) studied the effect of seed storage containers and seed treatments on seed quality in soybean. The results showed that soybean variety JS 335 was found superior over the GS 1 and GS2 in respect of maintenance of seed quality during storage period. Variety JS 335 recorded significantly higher values of first count, speed of germination, germination percentage, root length, shoot length, seedling length, seedling fresh weight, seedling dry weight, strong seedling, seedling vigour index (length) and seedling vigour index (mass) during storage periods. Devidas (2015) [21] studied the effect of different botanicals and chemicals on storability of soybean. The results showed that variety KDS 344 showed better storability than JS 93-05 and JS 335. Variety JS 335 lost its viability rapidly during storage as compared to other varieties. Variety KDS 344 maintained storability above IMSCS for germination up to 240 days irrespective of seed treatments.

Goswami (2016) [26] evaluated soybean varieties PS 1347, PS 1042, PK 472 and PK 262 for their storage potential using accelerated ageing. The electrical conductivity increases while germination percent, seedling length and seedling vigour index-I decreases with an increase in accelerated aging periods in all varieties. Increase in electrical conductivity was minimum in PS 1042 followed by PS 1347. Decrease in germination percent, seedling length and seedling vigour index-I was less in PK 262 followed by PS 1042. Varieties PK 472 and PK 262 were found same in all studied parameters. This indicates that PS 1042 showed better membrane integrity followed by PS 1347, thus had better storability than rest of the varieties. Issac *et al.* (2016) [35] evaluated three soybean varieties *viz*., Nangbaar, Anidaso and Jenguma, for germination percentage, seed vigour, moisture content, 1000 seed weight, protein and oil contents before storage (control), three months (90 days) and six months (180 days) after storage. The results indicated that soybean seeds of the control recorded a high germination percentage and vigour than those stored for three and six months. On an average, germinability reduced by 17 per cent and 38 per cent at three and six months of storage, respectively than seeds of the control. Seed vigour also reduced by 23 per cent and 71 per cent at 3and 6months of storage than those of the control. Temperature and relative humidity readings were high and fluctuating under ambient storage conditions, and these conditions contributed to increase in moisture and 1000 seed weight. The percentage oil content of the seeds reduced in storage by 0.37 per cent and 0.44 per cent at three and six months of storage. However, protein content of the seeds increased at three and six months in storage by 0.23 per cent and 1.77 per cent.

Gadewar *et al.* (2020) [24] studied the effect of three different storage containers on the moisture content in four different varieties of soybean seeds under tropical storage conditions. In the study, three different bags, polythene bag, cloth bag and jute bag of dimensions 20 cm x 30 cm were used for the storage of soybean seed of four different varieties JS 335, AMS 99-33, TAMS 38 and TAMS 98-21under ambient temperature and relative humidity for a period of 18 months. The corresponding moisture content values of soybean varieties JS 335, AMS 99-33, TAMS 38 and TAMS 98-21 when stored in polythene, cloth and jute bags were different. Variety JS 335 seeds recorded lower moisture content (9.1%) as compared to AMS 99-33, TAMS 38 and TAMS 98-21.

Effect of storage containers on seed quality and longevity

Tatipata (2009) [83] studied the effect of initial moisture content, packaging material and storage period on mitochondria inner membrane. The experimental material consists of 3 factors: moisture content, *i.e.* 8. 10 and 12 per cent; packaging materials, *i.e.* polyethylene, wheat and aluminium foil bags; and storage period *i.e.* 0, 1, 2, 3, 4, 5, and 6 months. The results showed that soybean seed stored in aluminum foil bags recorded high germination and kept moisture content at low level than polyethylene and wheat bags. Monira *et al.* (2012) [57] studied the effect of containers on seed quality of soybean seed during storage. The results showed that initial germination percentage of seeds in tin container, polythene bag and cloth bag was 91.32, 89.15 and 88.40 per cent, respectively, but after storage it was declined. When seed moisture per cent is increasing, the rate of germination percentage is decreases and the deterioration rate was also the highest in seeds of cloth bag. The shoot and root length of seedling as well as seedling vigour was the lowest at the end of storage in cloth bags. So, cloth bag is not safe for soybean seed storage for long time than tin container and polythene bags.

Kandil *et al.* (2013) [38] studied the response of some soybean varieties Giza 21, Giza 22, Giza 35, Giza 111 and Crawford to storage periods (3, 6, 9 and 12 months), storage conditions (ambient conditions and refrigerator conditions at 10±1 ºC) as well as storage materials on germination characters. Storage under refrigerator conditions at 10±1 ºC surpassed ambient conditions in final germination percentage, germination index, energy of germination and emergence rate. Giza 111 cultivar under refrigerator conditions (10±1 ºC) of soybean seed with cloth bags for 3 months enhanced germination properties. Akter *et al*. (2014) [3] studied seed quality of stored soybean seeds as influenced by storage containers and storage periods. The results revealed that soybean seeds stored in tin container showed maximum germination capacity with high germination index, highest seedling growth, seedling dry weight per plant and vigour index. The seeds stored in cloth bag had the lowest seed quality during the testing period. In addition, germination index, seedling growth, dry weight per plant of soybean seedling and vigor index were decreased with the increase in storage period. Among the three containers, tin container was the best and the cloth bag was the worst storage container for soybean seed storage for long period. Ali *et al.* (2014) [4] studied the effect of storage containers on soybean seed quality. The seeds with 96-98 per cent initial germination were stored at 8 per cent and 12 per cent initial moisture levels in two types of storage containers *viz*., cloth bag and polythene bag (0.06 mm thickness). The final seed moisture content, germination percentage, germination index and seedling dry matter of the seed under different treatments were measured at 60,120 and 180 days after storage (DAS). In both the years, the highest germination percentage (89.33% and 92.67%) of soybean seed was retained at 180 days after storage (DAS) for those seeds stored at 8 per cent initial seed moisture content (SMC) in polythene bag at 50 per cent relative humidity. The seeds stored in cloth bag at 12 per cent SMC showed rapid germination loss and the value went down to 0.00 in both the years. Vigour index and seedling dry matter decreased with increased initial seed moisture content irrespective of storage containers used. Verma and Verma (2014) [86] studied the effect of seed storage containers on germination and seedling vigour of soybean. It was observed that upto sixth months of storage, germination per cent was above MSCS level in both the containers, but with the increase in storage period it was decreased. At the end of 8 months of storage, germination per cent in polythene bag was 74.3 per cent, which was significantly higher than the seed stored in cloth bag (68.7%). The reduction in germination was higher in cloth bag in comparison to polythene bag. The seeds of cloth bag absorbed moisture from the surrounding atmosphere. Due to increase in moisture content of seeds, respiratory activity and other physiological activities of the stored seeds increased and the rate of deterioration in terms of formation of abnormal seedling and dead seeds increased. The shoot length, root length of seedling and seedling vigour was lowest at the end of storage in cloth bag. Goswami *et al.* (2017) [27] studied the effect of storage containers on soybean seed quality under ambient conditions by using seeds of variety PS 1347. The results showed that seeds stored in cloth bags exhibited higher seed infection than in seed stored in polythene bags, irrespective of seed treatment and period of storage. With an increase in storage periods, seedling root, shoot length, seedling fresh and dry weight decreases, this decrease was maximum in cloth bag stored seeds as compared to polythene bag stored seeds.

Lambat *et al.* (2017) [47] studied the effect of storage containers on mycoflora and germinability of soybean during storage. The soybean seeds stored for 6, 12 and 18 months in three types of containers *viz*., jute, cloth and polyethylene bags. Storage of soybean seeds in polyethylene bag showed greater germinability and lesser seed invasion by the fungal flora than jute and cloth bags during storage. Seed quality behavior of soybean as influenced by different packaging materials and storage conditions was studied by Meena *et al.* (2017) [53]. Soybean seeds were stored in different packaging materials *viz*., gunny bags, high density polythene bags and vacuum packed bags stored at room temperature (25 ± 2 ºC) and cold storage (4 ± 1 ºC) for a period of 18 months. The results of the study revealed that the seeds stored in vacuum packed bags maintained the seed quality with least deterioration with respect to all the seed quality parameters compared to seeds stored in gunny bags and high density polythene bags. Nataraj and Jayaramegowda (2017) [63] studied the effect of storage packages (tin, polythene bag 700 gauge and cloth bag) on seed quality of vegetable soybean var. Karune. Seeds were stored in room temperature for nine months. The observations were recorded at tri-monthly interval on seed quality parameters and the results indicated that higher seed germination (73.11%) were noticed in seeds stored in tin fallowed by seeds stored in polythene bag (71.78%), while lower seed germination was noticed in cloth bag (68.30%) at the end of the storage period. Hence, the study indicated that, vegetable soybean variety Karune seed could be treated with bavisitin @ 3g per kg of seed and stored in tin container without affecting seed germination up to nine months. Sonkamble *et al.* (2017) [81] studied the effect of storage techniques on soybean seed during storage. The soybean seed (var. JS 335) stored in cloth bag, polythene bag, airtight container along with silica gel and desiccant beads under ambient condition up to next sowing season. There was a decrease in viability with advancement of storage period in all the storage containers. Among all the treatments, the seed stored in airtight container along with silica gel showed significantly the maximum seed germination, vigour index and the minimum seed infection at the end of 8 month of storage. Airtight container found significantly superior over other packaging materials during storage.

The comparative analysis of the effect of hermetic storage models on some quality parameters of soybean seeds was studied by Orhevba and Atteh (2018) [66]. Freshly harvested soybean pods were de-podded and the seeds were sundried at 33 °C with an average relative humidity of 62 per cent for three days. The seeds were then divided into three portions of 400 g and each portion was put into different storage models which were PVC bags of 400 g, jars of 1 liter capacity and another jar (perforated) of 1 liter capacity which served as the control. The initial quality parameters of the soybean seeds were determined, while the storage models and control were kept for eight weeks. Samples in each storage model and control were analyzed for proximate composition and other quality parameters at the end of every two weeks. Results for the nutritional properties showed that the raw soybean seeds consisted of 8.36 per cent moisture, 15.23 per cent fat, 6.12 per cent ash, 5.18 per cent fibre, 44.18 per cent protein and 20.94 per cent carbohydrate. The values for dry matter and hectolitre weight were 91.63 per cent and 72.30 hl/kg, respectively. The moisture content, carbohydrate and hectolitre weight of the soybean seeds increased significantly in the control, while crude fat, crude fibre, ash content, crude protein and dry matter decreased. For that of the bag and jar, the carbohydrate, hectolitre weight and the dry matter of the soybean seeds increased significantly, while the crude fiber, fat, ash, crude protein and moisture content decreased. Coradi *et al.* (2020) [19] evaluated the quality of seeds of RR and RR2 PRO soybean cultivars stored in ambient air with raffia packaging (ANER), ambient air with laminated packaging (ANEL), modified atmosphere with polyethylene packaging (AMEP), refrigerated atmosphere (1 to 3 °C) with raffia packaging (ARER), refrigerated atmosphere (1 to 3 °C) with laminated packaging (AREL), and modified (-14 PSI) and refrigerated (1 to 3 °C) atmosphere with polyethylene packaging (AMREP), over 6 months of storage. Results showed that the seeds of cultivar RR2 were preserved with better physiological quality. Raffia and polyethylene packaging under natural storage conditions, in a refrigerated and modified atmosphere, did not preserve the seed quality over the storage period. The conditions of storage in ambient air with laminated packaging (ANEL) and in a refrigerated atmosphere with laminated packaging (AREL) reduced the environmental effects of temperature and relative humidity, leading to better results of physiological quality of the seeds. Storage time negatively influenced the physiological quality of seeds, except for AREL and ANEL, which maintained the quality close to that of the initial conditions, over the 6 months of storage. The best alternatives for soybean seeds storage over 6 months are the laminated packaging in a natural environment, matching the refrigerated conditions. Gadewar *et al.* (2020) [24] studied the effect of three different storage containers on the moisture content in four different varieties of soybean seeds under tropical storage conditions. In the study, three different bags, polythene bag, cloth bag and jute bag of dimensions 20 cm x 30 cm were used for the storage of soybean seed of four different varieties JS 335, AMS 99-33, TAMS 38 and TAMS 98-21 under ambient temperature and relative humidity for a period of 18 months. The observations of moisture content of seeds from each container were recorded after 3 months (90 days). The least amount of moisture increase (9.1%) was found in seeds stored in polythene bag as compared to cloth bag and jute bag at the end of 540 days of storage.

Influence of dry dressing seed treatments on seed quality

Hussaini and Babu (1989) [34] observed that soybean seeds treated with neem leaf powder reported excellent control of seed borne *Colletotrichum dematium* and maintained better seed health during the storage period. Mukhopadhyay *et al.* (1997) [61] studied the seed invigoration treatments for French bean and soybean for improved vigor and viability after storage. They dry dressed freshly harvested soybean seeds with common bleaching powder (active ingredient, calcium hypochlorite) at 3 g/kg and stored in glass bottles and recorded good vigour and viability up to 24 months. Gupta and Aneja (2000) [28] treated the harvested seeds of varieties JS 80-21 and Pusa 16 with mancozeb, thiram, nimbecidine (a neem-based product) and bleaching powder, and stored in cloth bags or polythene bags. These seeds were sown in the field during the next *kharif* season. Only seeds treated with thiram and stored in polythene bags showed significant improvement in seedling emergence and seed yield; the other treatments were not effective. Mandal *et al.* (2000) [50] dry dressed freshly harvested soybean seeds at 9.6 per cent moisture with finely powdered aspro (active ingredient, ortho acetyl salicylic acid) at 100 mg per kg, ibucon (active ingredient, paracetamol) at 100 mg per kg and common bleaching powder (calcium hypochlorite) @ 2 g/kg. The results showed that increased germination (>70%) even after 90 days and also significantly increased field performance and seed yield in all the treatments (22.2 g/plant) as compared to control (18.3 g/plant).

Results by Adebisi *et al.* (2004) [1] in Nigeria showed that soybean seed dressed with fungicides and/or insecticides (Apron Plus, Almithio and Aldrex T) showed significantly longer storage life than untreated seeds even though soybean seed deterioration was not totally arrested. Bellur (2009) [11] conducted laboratory experiment under ambient conditions in soybean with two (1.0 and 0.5%) concentrations of calcium carbonate, calcium chloride, calcium hydroxide, calcium oxychlorode, calcium sulphate, calcium hypochlorite and control (water soaking). The seeds treated with calcium chloride exhibited higher germination (74.42%) and seedling vigour index (2184) with less seed infestation (18.42%), moisture content (8.44%) and electrical conductivity (8.94 dS/m) over control throughout 12 month storage period. It was followed by calcium corbonate and calcium oxycholoride. Similar significant higher germination (67.76%) and seedling vigour index (2295) were recorded in 1.0 per cent concentration compared to 0.5 per cent concentration irrespective of calcium salts throughout storage period. Daniel *et al.* (2012) [20] examined the potential of dried charcoal as a low input and cost effective storage method under humid storage conditions. Soybean seeds placed in sealed polythene bags of 700 gauges with various levels of charcoal desiccant to seed ratio and stored under ambient tropical conditions were evaluated for seed viability and seedling vigour attributes. The results showed that seed preservation was optimal under desiccant to seed ratio of 1:2 with a half life (P_{50}) of 101 days. This can be effectively used as an alternative sealed-dry storage method for soybean seed under ambient conditions in humid tropical regions.

The effect of seed treatment with botanicals was evaluated by Hridya *et al.* (2016) [32] on storability of soybean. Seeds treated with fenugreek seed powder, leaf powders of ashwagandha, tea and noni (ball milled for 1 h) @ 2 g/kg with 60 min shaking and stored in cloth bag for 6 months under ambient conditions. Seeds were evaluated for physiological parameters such as speed of germination, germination per cent, root length, shoot length, vigour index and dry matter production and for biochemical parameter the electrical conductivity at monthly interval. Results revealed that seed dressing with fenugreek seed powder manifested the physiological parameters at higher order with lesser electrical conductivity. Hence seed dry dressing with fenugreek seed powder obtained on ball milling for 1 h @ 2g/kg of seed maintained the germination and vigour in storage. El-Mowafy (2017) [23] studied the effect of treating soybean seed with some plant extracts (Moringa, Basil and Neem) as well as fungicide Vitavax-Thiram-200 (Carboxin 37.5% + Thiram 37.5%) on soybean seed germination, seedling vigor traits and field emergence after the different storage period (0, 6 and 18 months). The main results summarized as-follows; Vitavax treatment recorded the highest germination percentage (85%) and field emergence (75%) compared to other treatments. Treating soybean seed with neem and moringa extracts improved germination parameters and field emergence compared to untreated seed. Increasing storage periods decreased gradually germination parameters and seedling growth traits. Interaction between seed treatments and storage periods had significant effects on germination percentage and field emergence. From this study, soybean seed (cv Giza 111) could be treated before storage by neam, moringa extract instead of vitavax fungicide for maintenance seed germination and field emergence above 75 per cent after 6 months from storage. Patel *et al.* (2017) [68] studied the effect of different storage conditions and seed treatments on seed viability in soybean. The treatment consisted of two storage conditions *viz*., ambient temperature and cold storage at (7 °C + 2 °C), and five seed treatments *viz*., S_1 = Control, S_2 = Carbendazim @ 2 g/kg seed, S_3 = Mancozeb @ 2 g/ kg seed, S_4 = Neem leaf powder @ 10 g/kg seed, and S_5 = Neem oil @ 5 ml/kg seed. The results revealed that among the seed treatments, on an average, after 2 years of seed storage, significantly higher values were recorded by all the seed treatments over the control. However, seed treated with Mancozeb @ 2 g/kg of seed recorded significantly the highest germination percentage (71.50%) and it was at par with neem leaf powder @ 10 g/kg seed (70.67%) and carbendazim @ 2 g/kg seed (69.67%) after 2 years of storage. The germination percentage noted in control treatment was 33.17 per cent after 2 years of storage.

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