EFFECT OF SEED PRIMING ON STORABILITY, SEED YIELD AND QUALITY OF SOYBEAN [*Glycine max* (L.) Merill]

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1. INTRODUCTION

Soybean [*Glycine max* (L.) Merill] is one of the most important protein and oil seed crops throughout the world. Its oil is the largest component of the world's edible oils. Soybean seed contains 20 % oil and 40% protein. The world production of edible oils consists of 30% soybean. It is an ingredient of more than 50% of the world's high protein meal. The United States of America has the largest area under soybean cultivation with the highest yield and production (Anon, 1996).

The native of soybean is Eastern Asia. Soybean was introduced to India during 1880. Soybean is globally grown over an area of 91.40 m.ha. with a production of 204.00 mt and productivity of 2233 kg per ha (Anon., 2007). In India soybean is grown over an area of 8.87 m.ha with a production of 9.46 mt and productivity of 1069 kg per ha which is much below the average productivity of the world (2233 kg/ha). The major soybean producing states are Madhya Pradesh, Maharashtra, Rajastan, Karnataka, Uttar Pradesh, Andhra Pradesh and Gujarath.

In Karnataka state also, soybean is becoming popular as an oil seed crop. The increase in area was from 0.16 lakh ha during 1991-92 to 1.78 lakh ha during 2006-07. Karnataka ranks fourth in area and production next to Madhya Pradesh, Maharashtra and Rajasthan. Dharwad, Belgaum, Bidar, Bagalkot and Haveri are the major soybean growing districts of Karnataka (Anon., 2007).

Soybean has many commercial applications and its processing form a large agro-industrial complex because of its high protein content. There has been an increasing demand for soybean seeds to satisfy the demands of an expanding producer and consumer market with very promising future perspectives.

Despite the high yielding potential and various advantages of soybean, the yield per unit area of the crop is low in India. Poor germination and low seed viability are among the serious problems limiting the production of soybean. Soybean absorbs 50 % of its weight in moisture to germinate compared to only 30 % for maize. It must be planted in soils with adequate moisture to ensure maximum germination (Hatam and Abbasi, 1994). The use of high quality seeds is essential to establish a suitable population in soybean fields, giving better financial results (Krzyzanowski *et al*., 1993). Highly vigourous seeds germinate rapidly, uniformly and are able to withstand environmental adversity after sowing (Del Giúdice, 1996). However, the use of soybean seeds of low physiological quality is a common practice under tropical and subtropical production conditions, leading to inadequate plant population in the field.

Rapid germination and emergence is an important factor of successful establishment. It is reported that seed priming is one of the most important developments to help rapid and uniform germination and emergence of seeds and to increase seed tolerance to adverse environmental conditions (Heydecker *et al*., 1973, 1975; Harris *et al*., 1999). Seed priming has presented promising, and even surprising results, for many seeds including the legume seeds (Bradford, 1986). The few studies on soybean are not overemphasized and are encouraging, but more information is required before its use as a routine practice in seed technology (Knypl and Khan,1981).

Priming in its traditional sense, soaking of seeds in water before sowing, has been the experience of farmers in India in an attempt to improve crop stand establishment but the practice was with out the knowledge of the safe limit of soaking duration (Harris, 1996). Moreover, Harris *et al*. (1999), promoted a low cost, low risk technology called 'on-farm seed priming' that would be appropriate for all farmers, irrespective of their socioeconomic status. On-farm seed priming involves soaking the seed in water, surface drying and sowing the same day. The rationale is that sowing soaked seed decrease the time needed for germination and allow the seedling to escape deteriorating soil physical conditions. According to, Khan (1992), osmotic conditioning in its modern sense, aims to reduce the time of seedling emergence, as well as synchronize and improve the germination percentage, by subjecting the seeds to a certain period of imbibition using osmotic solutions. The seeds normally begin water uptake on contact with this solution and stop the process as soon as they become balanced with the water potential of the solution.

The advantage of seed priming in reducing the germination time and improving emergence uniformity is well established under laboratory conditions. However, few detailed studies have been reported on the performance of osmotically treated seeds under field condition. Park *et al*. (1997) reported that priming aged seeds of soybean resulted in good germination and stand establishment in the field trials. Seed pretreatment with PEG-6000 increased seed germination and vigour index (Gong Ping, *et al*., 2000; Finch-Savage *et al*., 2004). The direct benefits of seed priming in all crops included: faster emergence, better, more and uniform stands, less need to re-sow, more vigourous plants, better drought tolerance, earlier flowering, earlier harvest and higher grain 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 (Harris *et al*. (2001a). (Harris *et al*. (2001b) reported that maize genotypes responded positively to priming. Where priming was effective (i.e. in eleven trials) the extra grain produced varied from 0.3 t per ha to about 1.4 t per ha and represented increases ranging from 17 % to 76 %. In three remaining trials priming had no negative effect on yield.

Seed priming is basically a pre-sowing seed treatment. However, osmoprimed seeds may be dried back to their initial moisture content and stored for variable periods of time depending on the species. Primed and dried seeds normally have a more rapid and uniform germination when subsequently re-hydrated, especially under adverse environmental conditions (Bradford, 1986). The mechanism of seed drying after chemical priming is known as the hydration-dehydration process or dry back and is used to reduce the degree of moisture in seeds to levels compatible with storage and maintaining the beneficial effects of the treatment, without quality loss caused by rapid seed deterioration.

The few studies available using the chemical seed priming in soybean seeds are promising, but their use as routine in seed quality enhancement and commercial application depends on getting more detailed information about the safe priming duration, storability and their performance in the field. Keeping these aspects in view, the present investigation entitled “Effect of seed priming on storability, field performance, and seed quality of soybean” was carried out with the following objectives:

i. To standardize the optimum priming duration favourable for soybean seeds

ii. To study the influence of different seed chemical priming on storability of soybean.

iii. To study the influence of different seed chemical priming on field performance, seed yield and quality of soybean.

2. REVIEW OF LITERATURE

The literature pertaining to seed priming duration, storability, seed yield and quality as influenced by seed priming and the use of different seed priming chemicals to improve seed quality with special reference to soybean and other related crops are presented in this chapter.

2.1 Seed invigouration and seed priming

High quality seed is the key to successful agriculture. Modern agriculture with its favoritism for technology and precision demands that each and every seed should readily germinate and produce a vigourous seedling ensuring high yield. Uniformity of growth and synchrony in development are highly desirable characters for mechanized cultural operations. As such, only of high quality i.e., genetically pure and morphologically, pathologically and physiologically sound seed is capable of increasing the productivity, the seeds should also have better storability to produce good crop during the next season. The Vigour of the seed could be activated through extrinsic management techniques, which are termed as invigouration treatments. According to Basu (1990), seed invigouration implies to an improvement in seed performance by any postharvest treatment that focused on improvement in germiablity, storability and better field performance. One method of improving seed germination performance both in the field and in the glass house has been through the use of presowing treatments such as priming (Heydecker *et al*., 1973).

Seed priming or osmopriming is a water based process that is carried out on seeds to increase uniformity of germination and emergence, and enhance plant establishment. It entails the partial germination of seeds by soaking them in water (or in a solution of salts) for specified period of time, and then re-dry them just before radicle emerges (Copeland and McDonald, 1995; Desai *et al*, 1997). Priming stimulates many of the metabolic processes involved with the early phases of germination. Given that part of the germination processes have been initiated, seedlings from primed seed grow faster, grow more vigorously, and perform better in adverse conditions (Basker and Hatton, 1987; Desai *et al*, 1997). The duration of the emergence period is decreased, leading to more uniform plant stand (Mikkelsen, 1981; Basker and Hatton, 1987).

2.2 Seed priming and its mechanism

According to Matthews (1980) slow, asynchronous and unreliable germination and emergence, within germinable, low vigour seeds, arise due to seed ageing. Seed invigoration treatments have, therefore, been developed to improve seed performance during germination and emergence. Most of these involve a period of controlled hydration of the seed to a point close to, but before, the emergence of the radicle after which the seeds are dried back to their initial moisture content before sowing (Basu, 1994; Khan, 1992; Matthews and Powell, 1988). Such treatments include priming in which hydration is controlled in an osmoticum such as polyethylene glycol (PEG) or a salt solution (Heydecker and Coolbear, 1977), solid matrix priming in which seeds imbibe in an inert medium held at a known matrix potential (Taylor *et al*., 1988), humidification where seeds are hydrated at a high relative humidity (Van Pijlen *et al*., 1996), and aerated hydration in which seeds imbibe in aerated water for a specified time (Thornton and Powell, 1992). These treatments, and others, have improved the rate, uniformity and reliability of germination and emergence in a range of crop species (Basu, 1994; Khan, 1992; Matthews and Powell, 1988).

Many factors can influence the imbibition and germination process, among them integument composition and permeability water availability in the environment, hydrostatic pressure, temperature, and seed physiological condition (Vertucci ,1989). The water uptake in seeds follows a triphasic pattern with an initial rapid uptake phase known as imbibition. (Phase-I) followed by lag period (phase-II) and then a second increase in water uptake associated with seedling growth (phase-III). Seeds are desiccation tolerant during phase-I and phase-II but become intolerant during phase-III. At each phase, water uptake is controlled by the availability of water to the seed. In seed priming regime, seed water potential is at a level sufficient enough to initiate metabolic events in phase-II of germination process but which prevents radicle emergence (Simon, 1984). Germination response to priming are obtained approximately at seed moisture content of 30 % and it increased linearly over the range of 45 to 50%, the upper limit depending up on the species.

2.3 Seed water imbibition curve

The study of the imbibition curve is very important, especially for the development of pre-germination techniques aimed at improving seed physiological quality (Lopes *et al*., 2000) by detecting the reversion point of the imbibition process without damaging the embryo. This is the basic principle of the osmoconditioning technique which consists of allowing pre-germination metabolic activities to occur but without the radicle emerging (Bradford, 1986). The osmoconditioning or "priming" can be used for increasing the germination rate, uniformity of emergence, and the capacity of seeds to withstand adverse environmental effects (Nath *et al*., 1991; Khan, 1992; Braccini *et al*., 1997).

The optimum condition required for osmoconditioning varies among the species as well as in relation to the osmotic condition. Under favorable conditions, the mobilization of reserves; activation and renewed synthesis of some enzymes; DNA and RNA synthesis; production of ATP; and repairs of damage in the membrane system are initiated during osmotic conditioning (Bray, 1995). When the obstacle to germination is removed, rapid embryo growth is observed. Several physiological and biochemical changes occur in seeds during the treatment or as a consequence of osmoconditioning. These changes include macromolecular synthesis, activity of several enzymes, increased germination vigour, and release from seed dormancy (Fu *et al*., 1988; Smith & Coob, 1992; Sung & Chang, 1993; McDonald, 1998).

2.4 Hydration-dehydration on seed quality enhancement

Germination enhancement technologies based on presowing hydration have attracted considerable interest in both seed physiological research and industry circles, where they have been extensively commercialized. Heydecker's work (Heydecker *et al*., 1975) is often taken as the starting point for modern research in this area.

Veera Raj *et al*. (1970) soaked the seeds of six rice varieties in water for 24 hours and dried seed for 48 hours. The germination of water soaked seeds varied from 41 to 100 per cent in different rice varieties in 24 hours, while untreated seed took 48 to 72 hours for germination. Great variation existed among the varieties with respect to emergence, number of roots, root length, shoot length and dry weight of shoot and roots. Water soaking increased all these parameters

Nalawadi *et al*. (1973) 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 and seedling fresh weight from 1.735 g to 3.445 g.

In some studies, priming treatments adversely affected the storage life of tomato (Alvarado & Bradford, 1988; Owen & Pill, 1994), wheat (Nath *et al*., 1991), and muskmelon (Oluoch & Welbaum, 1996a) seeds but did not adversely affect the storage life of tomato (cv. Ierica) (Van Pijlen et al., 1996), carrot, and leek seeds (Dearman *et al*., 1987). The response of primed seeds to storage is species and variety dependant. It is thus important that for the beneficial effects of priming to be retained, new techniques and markers have to be used to monitor the priming progress.

Massawe *et al*. (1999) observed that hydration for different duration in three cultivar of Bambara groundnut significantly increased the germination per cent (49.00 to 74.00), seedling emergence (42.00 to 72.00), and dry weight (160 to 250 mg). Unsoaked seeds started germination six days after sowing while hydrated seeds started germination on the fourth day.

Harris *et al*. (2001a) conducted laboratory and field experiments and reported that germination of maize without priming ranged from less than 40 h to more than 70 h in the laboratory experiment. Priming seeds of maize for 12h reduced the time for germination in all varieties except SC-501. For the maize varieties that responded positively to priming, the treatment reduced the range of germination times to between 20 h and 40 h. final germination of all seed lots was not significantly affected by priming.

Khan *et al*. (2003) soaked the seeds of three sunflower genotypes in water for 24 hours then dry back to its original moisture level and dry dressing with thiram (0.25 %), which significantly enhanced germination percentage, field emergence, root length, shoot length and vigour index, respectively in APSH-11, 7-1 B and &-1 A.

Basu and Choudhary (2005) reported that presowing hydration treatment significantly enhanced field emergence (79.77 per cent), 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 per cent, 29.27, and 3.73 g, respectively) in both seasons, where in the treatment effect was more evident in winter season.

Joodi and Sharif (2006) suggested that that under undesirable condition such as dry land areas, hydropriming of barley seeds could be one possible way of enhancing seed germination performance and seedling establishment.

2.5 Hydration-dehydration on growth and seed yield

Chatterjee *et al*. (1982) reported that the groundnut crop rose from seed kernels treated with water appreciably increased the seed yield (30 to 50 per cent), this is mainly due to increases in number of pods per plant and higher 100 seed weight of kernels. Water soaking treatment of seed had significantly higher pod yield (1476 kg ha^{-1}), number of pods per plant (9.80) and 100 kernels weight (192.30 g) as compared to control (899 kg ha^{-1}, 8.80 and 172.80 g, respectively).

Punjabi *et al*. (1982) noticed that presoaking of barley seeds in water for two hours followed by drying back to its original moisture level significantly increased grain yield (2.47 t ha^{-1}) over control (2.11 t ha^{-1}). Similar results were obtained by Karivartharaju and Ramakrishna (1985) who observed that tillering, plant height; dry matter production and grain yield were significantly increased by hydration treatment as compared to control in ragi.

Naphade *et al*. (1996) soaked the seeds of groundnut in water and reported that it significantly increased the yield (18.23 q ha^{-1}) over control (15.61 q ha^{-1}). The oil percent was also significantly higher in soaking of seed in water (43.90 per cent) over control (42.40 per cent).

Rama Rao and Gopel Singh (1991) 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^{-1}), compared to low vigour seed lot (50.00 cm, 2.15, 28.00, 11.85 g and 2.10 t ha^{-1}, respectively)

Dharamlingam and Basu (1993) soaked 12-momth-old seeds of mungbean in water and dilute solution of chemicals. Among various treatments the water soaking showed significantly higher yield (455 kg ha^{-1}) compared to soaking of seeds in urea (441 kg ha^{-1}), P-amino benzoic acid (447 kg ha^{-1}), tannic acid (384 kg ha^{-1}) and control (326 kg ha^{-1})

Harris *et a*l. (1999) used participatory rural appraisal techniques to identify poor crop establishment as a major constraint on rainfed crop production by farmers in India and Zimbabwe. Some farmers in both countries reported experience of soaking seeds in water before before sowing in attempt to improve establishment but the practice was neither widespread nor regularly followed. Almost 1250 on-farm trails, considering the safe limits, were implemented by farmers in India for maize, upland rice and chickpea between 1995 and 1998 and 91 trials for maize and sorghum in Zimbabwe in 1997-98. In each trial, farmers were asked to seed overnight, surface dry it and sow in the normal way in a plot next to a plot with dry seed. The farmers in each village evaluated the trials during farm walks and group discussions. These group methods allowed farmers to assess the effect of seed priming over a wide range of soils and levels of management. Direct benefits in all crops included: faster emergence, better, more uniform stands, less need to re-sow, more vigorous plants, better drought tolerance, earlier flowering, earlier harvest and higher grain yield. in India, where a post rainy season crop is often grown on residual soil moisture or using supplementary irrigation, indirect benefits reported were: earlier sowing of the following crops, earlier harvesting of those crops, which allowed earlier seasonal migration from the area in search of work for cash, increased willingness to use fertilizers because of reduced risk of crop failure and use of time saved to grow a third crop (mungbean) instead of migrating. Subsequent uptake of on farm seed priming by participants in the trails has been almost universal and spread from farmer to farmer exhibits characteristics similar to those of the spread of seed of desirable new varieties. On-farm seed priming is a key technology (that is low cost and with low risk) to produce an immediate benefit, unlocking the farming system and giving the farmer a reasonable access to further benefits.

The phrase ‘on-farm seed priming ’, coined by Harris *et al*. (1999), is used to distinguish the soaking procedure from higher technology seed priming or seed conditioning techniques suitable for temperate agriculture, such as drum priming (Parera and Cantliffe, 1994; Rowse, 1996). Although not a new technique, on-farm seed priming has spread through participatory research. In recent years, priming has been tested in over 1000 trials in India, Pakistan, Nepal, Bangladesh and Zimbabwe on a range of crops, including maize (*Zea mays*), sorghum (*Sorghum bicolor* (L.) Moench), rice (*Oryza sativa*), wheat (*Triticum aestivum*) and chickpea (*Cicer arietinum*) (Harris, 1996; Harris *et al*., 1999; 2001a, b). As well as better establishment, farmers have reported that primed crops grew more vigorously, flowered earlier and yielded higher. In wheat, researchers have recorded mean yield increases in six large series of on-farm trials of 5% (non primed yield 4.2 t ha^{-1}) to 36% (non-primed yield 1.4 t ha^{-1}) (Harris *et al*., 2001b). In two similar series of on-farm trials of priming in maize, mean yield increases of 6% (non-primed yield 4.4 t ha^{-1}; Harris *et al*., 2001a) and 33% (non-primed yield 3.1 t ha−1; Harris *et al*., 2002) were recorded. In chickpea, mean yield increases of 47% and 20% were recorded in a series of trials in two growing seasons (non-primed yields 1.1 and 1.2 t ha^{-1} respectively; Musa *et al*., 2001).

Rashid *et al.* (2004) reported the effect of on-farm seed priming on improving yield of mungbean. Farmers’ yields were proportional to rainfall over consecutive four years study and the mean increase in grain yield due to priming in the 39 trials was 30%. Benefits from priming were the result of a combination of faster germination and emergence and more vigorous growth and development, leading to better crop stands and bigger, more productive plants. They concluded, whatever the mechanism responsible for the beneficial effects of seed priming, the empirical evidence confirmed its effectiveness for mungbean and the practice should be tested by, and promoted with, all farmers who wish to grow mungbean.

2.6 Seed priming chemicals on seed quality enhancement

Christiansen and Foy (1979) and Hecht- Buchholz (1979) reported a higher germination recorded of seeds primed with calcium salts in membrane integrity and reported Seed calcium slats. Concentration and germination percentage were positively related suggesting the role of calcium as an important component in membrane stabilization and as an enzyme cofactor.

Kathiresan *et al*., (1984a) reported that the field emergence and early seedling growth of sunflower were improved by soaking seeds in KH_2PO_4 (2.0%) solution. The increased seedling vigour was associated with associated enhanced oxygen uptake and increased amylase activity and efficiency of metabolizing nutrients from the cotyledons to the embryonic axis.

Vanangamudi and Karivaratharaju (1986) concluded that pre-storage fortification with potassium chloride for four hours was found to be effective in retarding decline in germineablity of redgram, blackgram, and greengram seeds during storage for 48 months.

Kulkarni and Eshanna (1988) reported that one per cent calcium chloride seed treatment of maize seeds increased germination, speed of germination, emergence, vigour index and seedling vigour significantly over untreated seed.

Ghosh and Sen (1988) reported that the ber seeds treated with potassium dihydrogen phosphate (1.0%) showed highest germination of 88.0 percent (in 203 day old seeds) though it recorded lowest germination with 30 days old seeds.

Subbaraman and Slevaraj (1989) reported that soaking of groundnut (JL-24) seeds in 0.50 per cent $CaCa_2$ solution for 32 hours followed by 10 h drying resulted in higher germination (98 per cent), field emergence (92.00 per cent), vigour index (3372), and oil content (50.72 percent), compared to water soaking (77.00 per cent, 91060, 3007, and 47.19 per cent)

Hofmann *et al.* (1992) made an investigation on the influence of an aerobic presowing treatment on spring wheat (*Triticum aestivum* L.) and oat (*Avena sativa* L.) of higher and low quality. They reported field emergence slightly accelerated in seeds of higher quality and markedly in seeds of lower quality. Field emergence percentage was considerably improved in seeds of both species and both qualities. Furthermore, Ghana and William (2003) conducted a two-year study involving laboratory, greenhouse, and field components to determine seed priming effects on winter wheat (*Triticum aestivum* L.) germination, emergence, and grain yield. Two cultivars were used because of their strong (Edwin) and moderate (Madsen) emergence capabilities. The most promising laboratory treatments were advanced to greenhouse and field experiments. In the greenhouse, seed primed in potassium chloride (KCl), polyethylene glycol (PEG), and water led to enhanced emergence of Madsen, but not of Edwin. Rate and extent of seedling emergence was greater for Edwin compared with Madsen irrespective of priming media in three of four field plantings. None of the seed priming media benefited field emergence or subsequent grain yield in either cultivar compared with checks. Overall, results suggested that seed priming had limited practical worth for enhancing emergence and yield of winter wheat planted deep into summer fallow.

Ramalal *et al.,* (1993) reported that soaking of maize in KH_2PO_4 solution significantly increased the germination, speed of emergence, mean daily germination, shoot length, root length, seedling vigour index and seedling dry weight over untreated control. Kurdikeri, *et al*., (1993b) reported that 12 month old maize seeds germination was more when soaked in KH_2PO_4 (1.0%) solution. Average vigour index and seedling growth rate were also high.Similarly Paul and Choundhary (1991) reported that soaking wheat seeds in of cultivar sonalika in KH_2PO_4 (1.0%) solution for 12 hours increased the seed germination (60.62 %) and seedling vigour (2158). Similarly, Rangaswamy *et al.,* (1993) conducted laboratory experiment with ground nut seeds and reported that soaking the seeds in 10 per cent KH_2PO_4 solution slightly increased the germination per cent, vigour index and root-shoot ratio.

In a study when Gibberellic acid, (0–0·30 mg/litre) was sprinkled at steep-out on and during germination and growth at 28°C (Agu *et al.,* 1993) reported optimum enzyme levels when 0·20 mg/litre of the GA_3 was applied on millet *(Pennisetum maiwa* and sorghum *(Sorghum bicolor)*. For millet, the highest diastase and cellulase activities were observed on the fifth day of germination (0·20 mg/litre of the GA_3 applied at steep-out), while sorghum showed highest activities of these enzymes on the fourth day of germination for the same concentration of GA_3.

Qingxiang *et al.* (1996) showed GA_3 and kinetin stimulated corn and soybean seedling emergence and improved corn and soybean seedling development; GA_3 was more effective than kinetin at promoting seedling emergence and development of corn and soybean; of the concentrations tested, 0.1 mM was the most effective. Similarly in a study designed to determine whether the application of GA_3 to soybean seed could accelerate germination (Feng *et al*, 1997) indicate that GA_3 application accelerated seedling emergence. Exogenous application of GA_3 to record higher speed of germination may be due to its stimulation effect in the formation of enzymes which are important in the early phases of germination which helps for a fast radicle protrusion and hence and hypocotyl elongation (Maske *et al*., 1997).

Salinas (1996) harvested seeds of soybean cultivars Bragg and Asgrow-7372 manually or mechanically and soaked the seeds in water or treated with polyethylene glycol (PEG) before storage. Some seeds were subject to accelerated aging. Maintenance of viability and vigour during storage were dependent on initial physiological quality, with no response to pretreatment when these parameters were less than 60%. Germination percentage was highest in seeds soaked in water. Emergence in the field was significantly affected by mechanical damage to seeds.

Kursanov *et al.* (1997) reported that the nutrient potassium has a positive effect on the keeping quality of seeds since it activates respiratory enzymes involved in the biosynthesis of seed. It has been reported that potash deficiency of mother plants accelerates deterioration of seeds.

Chojnowski *et al* . (1997) showed more germination at high temperatures (25-30^{o}C) than at temperatures below 20^{o}C in sunflower (*Helianthus annuus* L.) seeds. Osmopriming cultivar Mirasol seeds with polyethylene glycol-6000 for 3-5 days at 15oC strongly increased germination at suboptimal temperatures. This simulatory effect of priming persisted after seed re-drying and during subsequent storage at 20oC (55% RH) for at least 14 weeks. However, primed seeds deteriorated faster than untreated seeds during accelerated aging (45oC, 100% RH). The longer the priming treatement, the higher was the amount of germination but at the same time the higher was the sensitivity of seeds to accelerated aging. Priming enhanced the respiratory activity of seeds transferred onto water and their ability to convert l-aminocyclopropane-l-carboxylic acid (ACC) to ethylene. These effects remained after drying the seeds and were maintained in part during dry storage, whereas they disappeared during accelerated aging. These results suggested that ACC-dependent ethylene production might be a good indicator of seed vigor; it increases with duration of priming and decreases very early during aging, well before significant loss of seed viability. Decrease in ACC conversion to ethylene indicates that aging is probably associated with the membrane deterioration since in vivo ACC oxidase activity depends on membrane properties. However, no increase in electrolyte leakage was observed during aging.

Braccini and Magurie (1998) soaked seeds of four soybean cultivars in solution with osmotic potential of, -0.05, -0.01,-0.2, -0.4, -0.6 0r –0.8 Mpa. Physiological quality was assessed by standard germination tests, seedling length and dry weight. Seedling vigour was more affected by water stress than germination percentage. Performance of cultivar Savanna, which had low seed quality, was satisfactory only at osmotic potential of less than -0.05 Mpa, while UFV 10, Doko RC and IAc 8 gave satisfactory performance up to -0.1 Mpa. At -0.6 Mpa seed germination and vigour were not significant in all cultivars.

Aldesuquy and Ibrahim (2000) reported that seed treatment with shikimic acid improved yield and yield components of cowpea plants by increasing the number of pods plant $^{-1}$ and number of seeds pod^{-1}. Similar results were reported by Basara *et al*. (2003) and Rashid *et al*. (2004) that primed seed plants produced more grains pod^{-1}.

Sanjeevakumar (2000) invigourated seeds of soybean cultivar Js-335 having initial germination of 72 per cent with 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.

In canola *(Brassica napus)* CV. Zafar-2000 seeds the osmopriming and matriconditioning (jute mat) proved to be the best in reducing the time to 50% germination and mean germination time among all priming treatments. During emergence test, both i.e; osmopriming and matriconditioning (jute mat for 24 hours reduced the time to 50% emergence and mean emergence time. Maximum root and shoot lengths were recorded in hydroprimed seeds (Irfan *et al*, 2004).

Sub-optimal soybean crop establishment is a common occurrence on farmers' fields due to poor germination and emergence. Murungu *et al.* (2005) conducted two experiments to determine the possibility of increasing germination of soybean varieties through seed priming. The first experiment aimed at determining the effects of water potentials (0, -10, -100, -200, -500, -1500 kPa), seed treatments (non-primed, primed, primed and 12-hour drying, primed and 24-hour drying) on germination of four soybean varieties (PAN 872, Safari, Buffalo and A711). The second experiment examined factors such as seed treatments (soaking for 0, 1, 2, 4, 8, 12, 16, 20 and 24 hours, 12-hour soaking and 12-hour drying, 24-hour soaking and 12-hour drying) and varieties (PAN 872 and Safari). In the first experiment, a significant ($p < 0.01$) interaction between seed treatments and water potentials was detected. Un-primed seeds had the largest decrease in percent germination as water potential was lowered. In the second experiment, priming resulted in a decrease in final percent emergence compared with non-soaked seed. The study concluded that priming soybean seed could be recommended where soil water potential is low enough to limit emergence.

Arif (2005) conducted a laboratory storage experiment and studied the effect of seed priming on storability of soybean (Glycine max) 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-1 water) along with dry seed (non primed) as control treatment were included in the experiments. Seeds were primed, air dried and sown. In the storage experiments, 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^{-1} 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.

2.7 Seed priming chemicals on growth and seed yield

Sashidhar *et al*. (1977) reported increased yield in groundnut when seeds were treated with one per cent calcium chloride for eight hours with high free proline accumulation which is an adaptive mechanism of drought tolerance.

Padole (1978) reported that the seed soaking treatments with IAA (40 ppm), NAA (20 ppm and 40 ppm), ascorbic acid (40 ppm), urea (2.00 per cent) and KH_2PO_4 (2.00 per cent) significantly increased grain yield per plot (1.083, 1.200, 0.833, and 1.216 kg per plot, respectively).

Beneficial effects of calcium chloride seed treatments were reported in ragi (Karivaratharaju and Ramakrishna, 1985). Bhati and Rathore (1988) conducted a field trial, in which wheat seed soaked with $CaCl_2$ (2.00 per cent) and KH_2PO_4 (5.00 per cent) for 14 hours, significantly enhanced the number of seedlings per meter row length (13.42 and 14.37), dry matter accumulation (0.409 and 0.482 g) and seedling height (17.20 and 22.00 cm) as compared to water soaking (12.96, 0.402, and 16.90 cm). KH_2PO_4 treatment increased N, P, and K uptake and increased the dry matter accumulation in the plant.

Vijaya Kumar *et al*. (1988) reported that the plants raised from the bhendi seeds given pre-sowing soaking treatment with KH_2PO_4 (0.50 percent) for 16 hours recorded higher number of fruits (14.00), fruit weight (47.90 g) and seed yield per plant (25.57 g). They opined that K element being more permeable through seed coat might have promote quicker germination, early growth and strong vigour.

Rao and Sing (1997) soaked soybean seeds with germination capacity of 90, 70 and 50 % in water or different solutions or conditioned in moist sand before drying back to their original moisture content of 8%. Seeds were then sown in Kharif (monsoon) 1991 and 1992. Growth and yield were better from seeds with high vigor. Hydration-dehydration treatments in 1x 10^{-5}M P-hydroxybenzoic acid and 2x 10^{-5} M tannic acid increased yield. Feng *et al.* (1997) reported that Gibberellic acid applied to soybean seed at the time of planting did not influence final seed and protein yield.

Narayanswamy and Shambulingappa (1998) soaked seeds in 0.5 per cent KCl, KH_2PO_4 (0.50 percent), $MnSO_4$ (0.50 percent), $CaCl_2$ (0.50 percent), Boron (0.50 percent), and a 1:1 mixture of bavistin and thiram in field trial with groundnuts cv. Jl-24 and TMV-2 at Shimoga, Karnataka. $CaCl_2$ (0.50 percent) and KH_2PO_4 (0.50 percent) showed significantly higher 100 seed weight (41.18 and 37.58 g) and graded pod yield (16.14 g and 1349 kg ha^{-1}), compared to the control (32.35 g and 1260 kg ha^{-1}), respectively).

Basara *et al.* (2003) studied the effect of priming on yield and yield components of canola. Number of branches plant $^{-1}$ was significantly affected by different priming treatments. Maximum branches plant $^{-1}$ was recorded by freshly osmoprimed seed for 8 h and was statistically on par with previously osmoprimed for 4 h. Number of seed pod $^{-1}$ was maximum by previously osmoprimed seed for 4 h followed by freshly osmoprimed seeds for 4 h or 8 h. Similarly maximum thousand grain weight, biological yield and seed yield were recorded for previously osmoprimed for 4h or freshly osmoprimed seed for 8 h.

Jayaraj and Sasikala (2004) reported that rice seeds treated with KCl (1 per cent) recorded significantly higher plant height (107.10 cm), seed yield (3864 kg ha^{-1}) and hundred seed weight (2.56 g) over control (104.70 cm, 3242, and 2.30 g).

Arif (2005), analysis of two years average data, indicated that plants of primed seed plots took fewer days to emergence, flowering and maturity as compared with plants of non primed seed plots. Primed seed plots produced more plants m^{-2}, taller plants and higher grain yield as compared with non primed seed plots. Days to emergence and maturity increased with increase in seed priming duration. Emergence m^{-2}, branches $plant^{-1}$ and grain yield decreased with extending seed priming duration. Days to emergence, flowering and maturity decreased with increase in PEG concentration from 0 to 300 g L-1 water. Emergence m^{-2}, number of branches $plan^{-1}$, grains pod^{-1} and grain yield enhanced with increase in PEG concentration from 0 to 300 g L^{-1} water.

2.6 Seed priming on storability

Seed is a living entity and is bound to loose its life due to extrinsic and intrinsic factors (Roberts, 1972). Storage potential of seed is mainly a genetic factor but is influenced by environment (Roberts, 1972; Kneebone, 1976; Wittington, 1978), cultivar differences (Chauhan et al., 1984; Singh and Gill, 1994), period of storage (Reddy, 1985) and seed born fungi (Dash and Narain, 1996).

Seed deterioration is an inexorable, inevitable irreversible process and is mainly dependent on physical, physiological and chemical composition of seed (Delouche, 1973).

Under ambient storage conditions seeds loose their viability and vigour very fast due to changes in environmental conditions such as temperature and relative humidity (Roberts, 1961).

Chemical composition of seed is reported to influence storage potential of seeds. Generally oilseeds loose viability and vigour as faster rate than protein and starchy seeds. Soybean has been classified as poor storer by Delouche (1973), due to its structural and physiological delicacy and high oil content and also due to lipid autoxidation (Koostra and Harrington, 1969).

The exact cause of seed deterioration is not fully elucidated yet, however it is related to several physical, physiological and biochemical changes occurring in seed during storage (Chauhan *et al*., 1984, Abduk-Baki and Anderson, 1973 and Roberts, 1972).

Some physiological and biochemical changes leading to seed deterioration have been related to increased activity of enzymes (catalase, peroxidase, etc), lipid autoxidation (Koostra and Harrington, 1969) and accumulation of toxic metabolites, free radical damage, decreased protein synthesis, break down in mechanism triggering germination, reduced respiration, changes in polar lipids, decreased content of glyco and phospholipids, ultrastructural damage to cell and its organells, accumulation of cytotoxic and mutagenic compounds etc. (Roberts, 1972).

Seed storage of oil seeds has attracted attention at many levels and is one of the basic factors for low productivity as the whole subject is controversial in view of conflicting reports by various workers (Heydecker, 1973, Basu and Pal, 1980, Saxena and Pakeeraiah, 1986). Anil et al. (1998), made an attempt to investigate the storage potential of aqueous solution of GA_3, and ABA presoaked seeds of cotton, mustard and cowpea. Plant growth regulators (PGRs) had promotory effect for few months initially, followed by rapid decline in seed deterioration was both in mustard and cotton but in case of cowpea, deterioration was not so drastic. ABA pretreated seeds reduced the loss of viability quite considerably. Pretreatments with GA_3 stimulated the rate of germination provided they were not stored for longer period.

Seed priming which aims to promote faster, more uniform seedling emergence (Heydecker 1977) and may also increase longevity in certain species (Probert *et al*., 1991), can also reduce desiccation tolerance when seeds are dried to low moisture content. For example, Carpenter and Boucher (1991) reported that reducing the moisture content of unprimed seed of the orthodox pansy (*Viola* x *wittrockiana*) from 10.5 to 5.8% caused no damage to germination, but the germination of primed seed was decreased when dried to levels of moisture content below 10%, and even more so when dried to 5.8% moisture content.

Dasgupta *et al.* (1980), McKersie and Stinson (1980) and McKersie and Tomes (1980) reported that in the early stages of germination, seeds of a wide variety of plants can be dried to 10 % moisture without loss of viability, but if they are dried after radicle emergence, the seeds are not able to germinate.

Chiu *et al*. (2002) reported priming offers a means to raise seed performance in many crop species, but the longevity of primed seed is generally decreased. The exact causes of the more rapid deterioration of primed seed are still not established. They evaluated the effects of priming and storage temperatures on germination and antioxidative activities of sweet corn seed (*Zea mays* L.) carrying the *shrunken-2* (*sh-2*) gene. After drying the solid-matrix primed seeds moistened in vermiculite at 10, 15 or 20°C for 36 h, seed were stored at 25, 10, or -80°C for up to 12 months. Solid-matrix priming improved germination, reduced lipid peroxidation, enhanced antioxidative activities, and increased seedling growth. Seed longevity was decreased when 20°C-primed seeds were stored at 25°C for 12 months. Seed primed at 10 and 15°C had superior viability and vigor responses compared with nonprimed control seeds when they were stored at 25°C for 12 months. Reduced storability of the 20°C-primed seeds was attributable to enhanced peroxidation and decreased antioxidative activities. Storage at 10 or -80°C extended the storability of matrix primed *sh-2* seed for at least 12 mo. Enhanced antioxidative activity played a role in maintaining the viability and vigor responses of solid matrix primed seed stored at cool (10°C) or subzero (-80°C) temperatures. Moreover, 10 or 15°C-primed *sh-2* seed could retain viability for 12 months, provided that the primed seed was stored at 10°C.

3. MATERIAL AND METHODS

The field and laboratory experiments were conducted to standardize the optimum duration favourable for soybean seed priming and to study the effect of seed priming on storability, seed yield and quality of soybean Cv. JS – 335 at Seed Research Laboratory of National Seed Project (Crops), University of Agricultural Sciences, Dharwad and at Water and Land Use Management Institute (WALMI) Farm, Dharwad. The details of the material used and techniques adopted during the course of the investigation are presented in this chapter.

3.1 General Description

3.1.1 Location of Experimental Site

The storage experiment was carried out at the Seed Research Laboratory of National Seed Project (Crops), University of Agricultural Sciences, Dharwad. The field experiment was conducted at Water and Land Use Management Institute (WALMI) Farm, Dharwad. Dharwad is situated in northern transitional zone of Karnataka and located at 15^0 26' North latitude, 75^0 7' East longitudes with an altitude of 678 m above mean sea level.

3.1.2 Climatic Conditions

The monthly meteorological data pertaining to rainfall, temperature and relative humidity prevailed during the experimentation (during late *rabi*) at Water and Land Use Management Institute (WALMI) Farm, Dharwad and University of Agricultural Sciences, Dharwad, are presented in Table 1. The total rainfall received during crop growth period , in both stations, was trace. In WALMI Farm, the average monthly maximum temperature of 29.77 ^{0}C was recorded in April and minimum of 20.51 ^{0}C in January month whereas, the highest relative humidity recorded was 69 per cent was recorded during June and the lowest relative humidity of 47 percent during January. In University of Agricultural Sciences, Dharwad, the average monthly maximum temperature of 35.16 ^{0}C was recorded in May and minimum of 12.91 ^{0}C in January month whereas, the highest relative humidity recorded was 71 per cent was recorded during June and the lowest relative humidity of 46 percent during January.

3.1.3 Soil type of the experimental site

The soil of the experimental site was black clay loam. The composite soil sample from experimental site was collected from 0 – 30 cm depth before the start of the experiment and was analysed for physical and chemical characteristics by following the standard procedure. The results are presented in Table 2.

3.1.4 Seed source

The breeder seeds of soybean Cv. JS-335 were obtained from The National Seed Project (Crops), University of Agricultural Sciences, Dharwad.

3.1.5 Isolation Distance

The experimental plot was isolated by three meter to avoid contamination.

3.1.6 Previous crop

Sunflower was the crop grown on the experimental site during *kharif* 2007 and was left fallow to until late *rabi* season.

3.1.7 Description of variety

Soybean Cv. JSS-335 has been released and recommended for zone 1, 2,3, and 8 of Karnataka for general cultivation. It is a short duration (85 – 90 days) variety with yielding ability of 25 – 35 q per hectare. The leaves are dark green and purple flower, pubesescence sparse or almost assent on stem, yellow seed coat, semi determinate, tolerate to pod shattering up to 8 – 10 days after maturity, resistant to bacterial pustule.

Table 1. Meteorological data during the crop growth and storage period at WALMI Farm and UAS Dharwad, from January, 2008 to June, 2008

Month	Rainfall (mm)	Temperature (^oC)		Relative Humidity (%)
		Mean Max.	Mean Min.	
	WALMI Farm			
January	0.0	25.13	20.51	47
February	0.0	27.07	21.37	49
March	Trace	27.84	22.39	55
April	Trace	29.77	23.29	56
May	Trace	29.24	24.18	61
June	Trace	29.21	24.10	69
	University of agricultural Sciences (UAS)			
January	0.0	29.71	12.91	46
February	0.0	31.15	16.37	49
March	Trace	32.42	18.96	53
April	Trace	34.72	20.45	57
May	Trace	35.16	20.66	63
June	Trace	28.66	20.90	71
Total	Trace	-	-	-

Table 2. Physical and chemical properties of soil from experimental site

Particulars	WALMI, Dharwad (0-30 cm depth)	Methods adopted	References
A. Physical properties			
1. Coarse sand (%)	6.0	Hydrometer method	Piper (1966)
2. Fine sand (%)	13.00		
3. Silt (%)	28.00		
4. Clay (%)	53.00		
B. Chemical properties			
1. pH	7.80	Bulkmans pH meter	Piper (1966)
2. EC(dSm^{-1})	0.42	Conducto metric method	Jackson (1967)
3. Organic carbon (%)	0.60	Walkely and Black's wet oxidation method	Jackson (1967)
4. Available N (Kg ha^{-1})	182.3	Alkaline permanganate method	Subbaiah and Asija (1956)
5. Available P_2O_5 (Kg ha^{-1})	25.12	Olsen's method	Jackson (1967)
6.Available K_2O (Kg ha^{-1})	373.24	Flame photometer method	Jackson (1967)

Emergence over view

Over view at later stage

Plate 1. General view of the experimental plot

Plate 1. General view of the experimental plot

3.2 Experimental details

3.2.1 Experiment I: Standardization of seed priming duration in soybean Cv. JS – 335

3.2.1.1 Treatment details

T_1 :0 h (Control)	T_8:14 h
T_2:2 h	T_9:16 h
T_3:4 h	T_{10}:18 h
T_4:6 h	T_{11}:20 h
T_5:8 h	T_{12}:22 h
T_6:10 h	T_{13}:24 h
T_7:12 h	

3.2.1.2 Design of the experiment

The design of the experiment adopted was Completely Randomized Design and replicated three times.

3.2.1.3 Method of seed priming and calculating seed water imbibitions

Samples of 100 grams of soybean seeds (Cv. JSS-335) were placed between germination towels wetted with tap water of pH 6.5 at 2-hour intervals for 24 hours. Afterwards the seeds were dried superficially with absorbent paper and weighed with an analytical balance. Later, the difference between initial and final wet weight was calculated to determine the percent of water imbibed. Afterwards, primed seeds were allowed to dry back to their original moisture content under the shad for one day and in the sun for two days to asses for the seed quality parameters.

Seed imbibition regime was determined based on the results of the imbibition curve prior to radicle emergence, according to Bewely and Black (1978). To determine the specific duration of priming the dried-back seeds were tested for the following quality parameters.

3.2.1.4 Germination (%) and speed of germination

Germination test was conducted in four replications of 100 seeds each by adopting between paper towel method as described by ISTA procedures (Anon, 1999). Seeds were incubated at slanting position in Walk-in germinator room in growth cabinets. The temperature of 25 ± 1^0C and RH of 95 per cent was maintained during the germination test. Daily germination count were performed until no further germination occurred for eight consecutive days, then final and speed of germination were calculated.

$$\text{Germination (\%)} = \frac{\text{Number of seeds germinated}}{\text{Number of seeds put for germination}} \times 100$$

Speed of germination= $\sum [n_1/d_1 + n_2\text{-}n_1/d_2 + \ldots\ldots n_n\text{-}n_{n-1}/d_n]$

Where, n= no of seeds germinated on day (d)

d= serial number of days

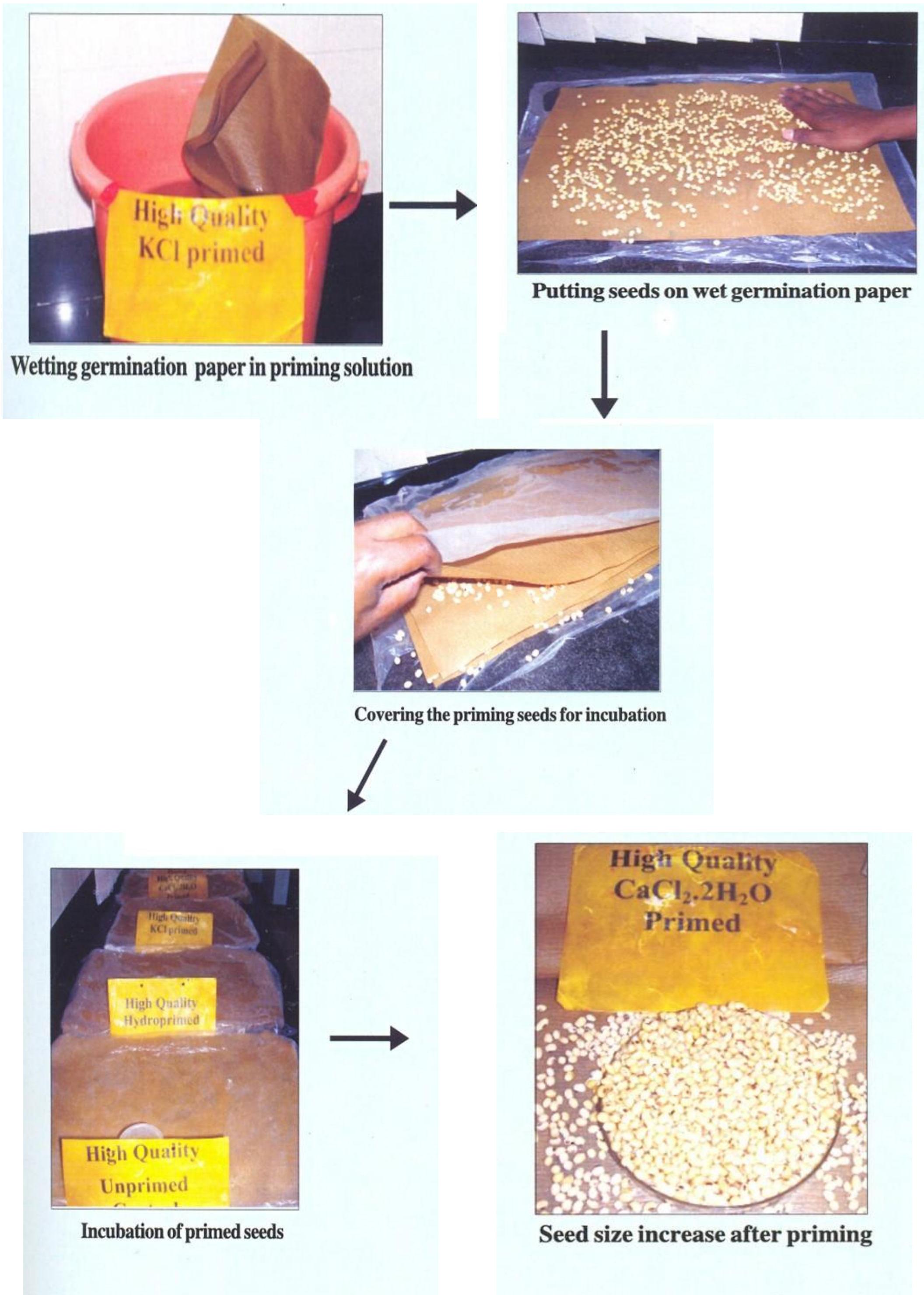

Plate 2. Sequence of seed priming

3.2.1.5 Root length (cm)

Ten normal seedlings were selected randomly in each treatment from all the replications on eighth day from germination test. The root length was measured from the tip of the primary root to base of hypocotyle with the help of a scale and mean root length was expressed in centimeters.

3.2.1.6 Shoot length (cm)

The ten normal seedlings used for root length measurement, were also used for the measurement of shoot length. The shoot length was measured form the tip of the primary leaf to the base of the hypocotyle and mean shoot length was expressed in centimeter.

3.2.1.7 Seedling dry weight (mg)

The ten normal seedlings used for root and shoot length measurements were put in butter paper pocket and kept in hot air oven at 70 ± 1^{0}C for 24 hours. The dry weight of the seedlings was recorded and expressed in milligrams.

3.2.1.8 Seedling vigour Index

The seeding vigour index was calculated by adopting the method suggested by Abdul Baki and Anderson (1973) and expressed in number by using below formula.

Seedling vigour Index = Germination (%) x Seedling length (cm)

3.2.1.9 Electrical conductivity of seed leachates (d Sm^{-1})

Five grams of seeds from each treatment in four replications were weighed and soaked in 25 ml distilled water in a beaker and kept at 25 ± 1^{0}C temperature. After 24 hours of soaking the solution was decanted and the volume was made up to 25 ml by adding distilled water. The electrical conductivity of the leachate was measured d Sm^{-1} (Presley, 1958).

3.2.1.10 Field emergence (%)

One hundred seeds selected at randomly from each treatment in four replications were used for the field emergence studies. The seeds were sown in well prepared soil at 2.50 to 3.00 cm deep and covered with soil. Field emergence count was taken on the 15th day after sowing and the emergence percentage was calculated taking into account the number of seedlings emerged three centimeter above the soil surface.

$$\text{Field emergence (\%)} = \frac{\text{Number of seedling emerged on } 15^{th} \text{ day}}{\text{Total number of seeds sown}} \times 100$$

3.2.1.11 Statistical analysis

The data were statistically analyzed using analysis of variance appropriate for a single factor completely randomized design and treatment means were compared using LSD test at 0.05 level of probability, when the F-values were significant (Steel and Torrie, 1984).

3.2.2 Experiment II: Effect of seed priming on storability of soybean seeds Cv. JS-335

As per the result of safe priming duration determined in experiment-I, the seeds were primed between germination papers wetted with the priming chemicals for 14 h. Two seed lots of different physiological vigour were subjected to priming treatments. The same seeds used for storage and field experiment.

3.2.2.1 Treatment details

Factor I. Seed Quality (Q)

Q_1: Seeds with germination above MSCS (= 93 %)

Q_2: Seeds with germination marginally below MSCS (= 69 %)

Factor II. Priming treatments (T)

T_1: Control (unprimed seeds)

T_2: Hydro-priming

T_3: KCl @100 ppm

T_4:CaCl2.2H2O @0.5 %

T_5: K H_2PO_4 @50 ppm

T_6. GA_3 @ 20 ppm

Treatmnet combinations

1. Q_1T_1	5. Q_1T_5	9. Q_2T_3
2. Q_1T_2	6. Q_1T_6	10. Q_2T_4
3. Q_1T_3	7. Q_2T_1	11. Q_2T_5
4. Q_1T_4	8. Q_2T_2	12. Q_2T_6

3.2.2.2 Methods of storage

Primed seeds were stored in HDPE bag in the Seed Research Laboratory of National Seed Project (Crops), University of Agricultural Sciences, Dharwad.

3.2.2.3 Design of the Experiment

The design of the experiment adopted was two factors Completely Randomized Design replicated four times.

3.2.2.4 Collection of data

Monthly observations on seed quality parameters were recorded for a period of five months.

3.2.2.5 Germination (%) and speed of germination

The germination percentage and speed of germination were determined by following the procedure as explained under section 3.2.1.4.

3.2.2.6 Root length (cm)

The root length of the seedlings was determined by adopting the same procedure as mentioned under section 3.2.1.5.

3.2.2.7 Shoot length (cm)

The root length of the seedling was determined by following the procedure as explained under section 3.2.1.6

3.2.2.7 Seeding dry weight (mg)

The dry weight of the seedling was determined by following the procedure as described under section 3.2.1.7.

3.2.2.8 Seeding vigour Index

The vigour index of the seedling was determined by following the procedure as described under section 3.2.1.8.

3.2.2.9 Electrical conductivity (d Sm^{-1})

Electrical conductivity of the seeds was determined by following the procedure as described under section 3.2.1.9.

3.2.2.10 Moisture content (%)

The moisture content of the seed was determined by the hot air oven method as per ISTA rules (Anon, 1999). Five grams of coarsely ground seed material from each treatment in three replications were dried in a hot air oven maintained at a temperature of 103 ± 1^0C for a period of 17 ± hours. Then samples were cooled in desiccators and moisture content was determined by using the formula given below and expressed in percentage.

$$\text{Moisture content (\%)} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

W_1 = Weight of empty aluminum cup (g)

W_2 = Weight of empty aluminum cup with seed before drying (g)

W_3 = Weight of empty aluminum cup with seed after drying (g)

3.2.2.11 Field emergence (%)

Field emergence of stored soybean seeds was determined by following the procedure as described under the section 3.2.1.10

3.2.2.12 Statistical analysis

The data were statistically analyzed using analysis of variance appropriate completely randomized design. Main and interaction effects were compared using LSD test at 0.05 level of probability, when the F-values were significant (Steel and Torrie, 1984). Correlation and regression analysis were also employed.

3.2.3 Experiment III : Effect of seed quality and priming treatments on seed yield and quality of soybean Cv. JS – 335

3.2.3.1 Treatment details

The details of treatments are as mentioned under Experiment II and as indicated in 3.2.2.1.

3.2.3.2 Experimental design and plan of layout

The field experiment was laid out in factorial Randomized Complete Block Design having three replications. The size of the gross plot was 3.00 m x 5.00 m and net plot 2.4 x 4.00 m. The plan of layout is depicted in Fig. 1.

3.2.3.3 Cultural practices

3.2.3.3.1 Land preparation

The land was brought to the fine tilth with one deep ploughing and three harrowings. The residues of the previous crop and weeds were removed from the experimental area. The land was leveled with plank.

3.2.3.3.2 Manures and Fertilizer application

The manures and fertilizers were applied as per the treatment combinations. Farmyard manure was incorporated in soil 15 days before sowing. The recommended fertilizer dose of 40 kg N, 80 kg P_2O_5 and 25 kg K_2O per hectare was applied in the form of urea, diammonium phosphate and muriate of potash respectively at the time of sowing.

3.2.3.3.3 Seeds and sowing

The primed seeds of soybean Cv. JS – 335 were sown by hand dibbling at 30 x 10 cm spacing in the plots. The seedlings were thinned out at 15 days after sowing in order to maintain one seedling per hill.

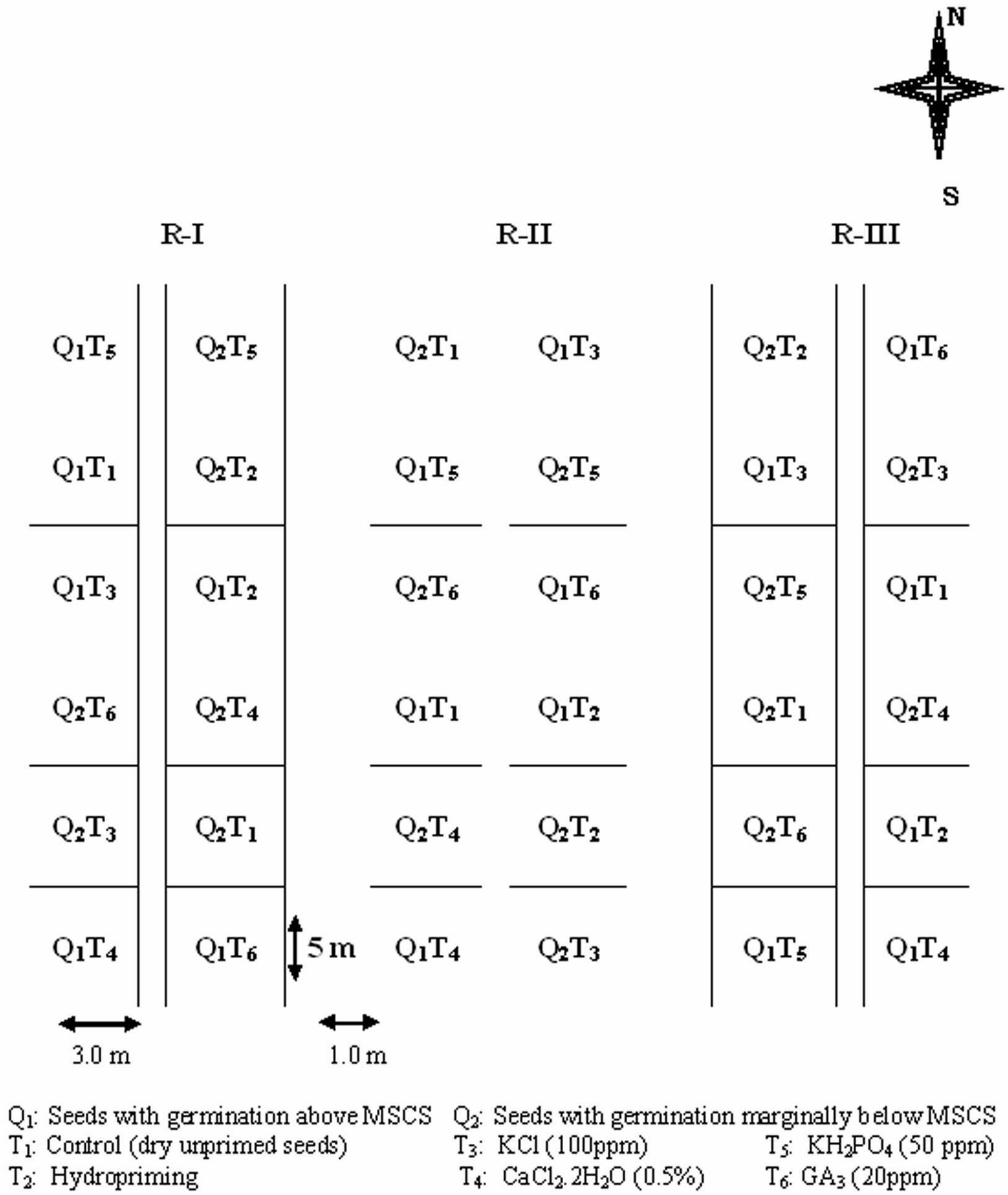

Figure 1. Plan of layout of experimental plot

Figure. 1. Plan of layout of experimental plot

3.2.3.3.4 After care

Two hand weedings were done at 20 and 30 days after sowing along with inter-cultivation. In Northern transitional zone of Karnataka, the occurrence of defoliators such as a Spodoptera (*Spodoptera litura*) and Thysanoplusia and diseases such as leaf rust are common. As a precaution measure against defoliaters and leaf rust, the crop was sprayed with *Nomurea rileyi* @ 1g per litre, Neem gold @ 5 ml per litre and SL NPV @ 2ml per litre at 30, 50 and 75 days after sowing respectively.

3.2.3.3.5 Harvesting

The crop was harvested treatment wise at physiological maturity based on visual observation (yellowing of pods and leaves). The harvested plants from each treatment and replication were sun dried separately and threshed manually by beating with wooden stick. The seeds were cleaned and sun dried to moisture content of eight per cent.

3.2.3.4 Collection of Experimental Data

3.2.3.4.1 Growth parameters

3.2.3.4.1.1 Field Emergence (%)

Field emergence of stored soybean seeds was determined by following the procedure as described under the section 3.2.1.0

3.2.3.4.1.2 Days to 50 % emergence

Days to 50% emergence were calculated from the date of sowing and date of 50 % emergence by counting seedling emergence in each plot daily

3.2.3.4.1.3 Emergence per square meter

Emergence per m^{-2} data was recorded by randomly throwing a 1 m^2 quadrant and counting the number of plants emerged with in the quadrant at three randomly selected places in each plot

3.2.3.4.1.4 Plant height (cm)

The plant height on five randomly selected and tagged plants were measured from the base of the plant to the tip of the shoot apex at 30 and 60 DAS. The average height of five plants was worked out and expressed in centimeters.

3.2.3.4.1.5 Days to 50 per cent flowering

Plants were observed daily for flowering. The day on which 50 per cent of plants showed flowers in the plot was considered as 50 per cent flowing. The number of days taken from the date of sowing to flowering was calculated and expressed in number as days taken for 50 per cent flowering.

3.2.3.4.2 Physiological parameters

3.2.3.4.2.1 Leaf area index (LAI)

Fully expanded leaves from 30 days old plants were submitted to the leaf area meter to determine the sum of leaf area of all leaves (cm^2). And the LAI was calculated as

$$\text{LAI} = \frac{\text{Sum of leaf area of all leave } (cm^2)}{\text{Ground area of field where the leaves have been collected } (cm^2)}$$

3.2.3.4.2.2 Relative water content (RWC)

The experimental field was left unirrigated for three weeks to determine the relative water content (RWC). A composite sample leaf discs, 40 days old, were taken and the fresh weight was determined, followed by floatation in water up to 4 h. The turgid weight was recorded, and the leaves were oven dried to a constant weight at about 85 ^oC.

Relative water content (RWC) was, then, calculated as follows.

$$RWC\ (\%) = \frac{(\text{fresh weight-dry weight})}{(\text{turgid weight- dry weight})} \times 100$$

3.2.3.4.3 Yield and yield component

3.2.3.4.3.1 Number of pods per plant

The number of pods harvested from five randomly selected and tagged plants in each treatment was counted and average was worked out and expressed as number of pods per plant.

3.2.3.4.3.2 Number of seeds per pod

The number of seeds from five randomly selected and tagged plants in each treatment was counted and the average was worked out and expressed as number of seeds per pod.

3.2.3.4.3.3 Seed yield per plant (g)

The matured pods harvested from five randomly selected and tagged plants in each treatment were sun dried and the seeds were separated. The average was worked out and expressed as seed yield per plant in grams.

3.2.3.4.3.4 Seed yield per plot (Kg)

The matured pods harvested from the net plot in each treatment were sun dried and the seeds were separated. The weight of the seeds from net plot area was recorded and expressed as seed yield per plot (kg).

3.2.3.4.3.5 Seed yield per hectare (q)

The seed yield obtained from five randomly selected and tagged plants were added to the seed yield of the net plot area for calculation of seed yield and were recorded as seed yield per hectare (q).

3.2.3.4.3.6 Hundred seed weight (g)

Hundred seed in each treatment was counted manually and the weight was recorded as per the procedure given by ISTA rules (Anon., 1999). The average hundred seed weight was recorded in grams.

3.2.3.4.3.7 Seed quality parameters

The seed quality parameters were assessed by adopting the methods used in the previous experiments.

3.2.3.4.3.8 Statistical analysis

The data were statistically analyzed using analysis of variance appropriate for randomized complete block design. Main and interaction effects were compared using LSD test at 0.05 level of probability, when the F-values were significant (Steel and Torrie, 1984). Correlation analysis was also employed.

4. EXPERIMENTAL RESULTS

The laboratory and field experiments were conducted to standardize the safe priming duration, to study the effect of seed priming on storability, field performance and seed yield and quality of soybean. The results obtained from the studies are presented in this chapter.

4.1 Experiment I: Standardization of seed priming duration in soybean

4.1.1 Seed water imbibition (%)

Data regarding water imbibition rate of soybean seeds are depicted in Fig 2. Analysis of the data revealed that the rate of percent water absorption by seeds primed for, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24 h were 9.1, 16.0, 19.3, 26.0, 30.8, 35.6, 41.8, 43.6, 45.0, 49.9, 60.3, and 72.8 percent respectively.

4.1.2 Speed of Germination

The data on speed of germination as influenced by the priming durations are presented in table 3.

The speed of germination was significantly influenced by the priming durations. Significantly highest (57.10) speed of germination was recorded with 14 h priming duration, followed by 16 h (54.93) and 12 h (54.37) whereas the lowest speed of germination (40.50) was recorded in unprimed dry seeds (control).

4.1.3 Germination (%)

The data on germination percentage as influenced by the priming duration are presented in Table 3.

The germination percentage was significantly influenced by the priming durations. Significantly the highest (97.67 %) germination was recorded in unprimed control (0 h) and was on par with 2h, 4h and 14 h of priming durations in which all recorded 97.00 % germination while the lowest germination (92.33 %) was recorded in the seeds primed for 24h.

4.1.4 Root length (cm)

The data on root length as influenced by the priming durations are presented in Table 3.

The root length was significantly influenced by the priming durations. Significantly highest root length (16.34 cm) was recorded with 14 h priming, followed by 16h (15.53 cm) and 12h (15.50 cm). The lowest root length (13.26 cm) was recorded with seeds primed for 24h.

4.1.5 Shoot length (cm)

The data on shoot length as influenced by the priming durations are presented in Table 3.

The shoot length was significantly influenced by the priming durations. Significantly highest shoot length (13.89 cm) was recorded with 14 h priming which was on par with 16h (13.74 cm), 12h (13.65 cm), 10 h (13.65 cm), 20h (13.51 cm), 18h (13.46 cm) and 8h (13.44 cm). The lowest shoot length (11.50 cm) was recorded with seeds primed for 24h.

4.1.6 Seedling dry weight (mg)

The data on seedling dry weight as influenced by the priming durations are presented in Table 3.

The seedling dry weight was significantly influenced by the priming durations. Significantly highest seedling dry weight (106.00 mg) was recorded with 14 h priming, followed by 12h (97.00 mg) and 16h (96.33 mg) while the lowest seedling dry weight (73.00 mg) was recorded with seeds primed for 24h

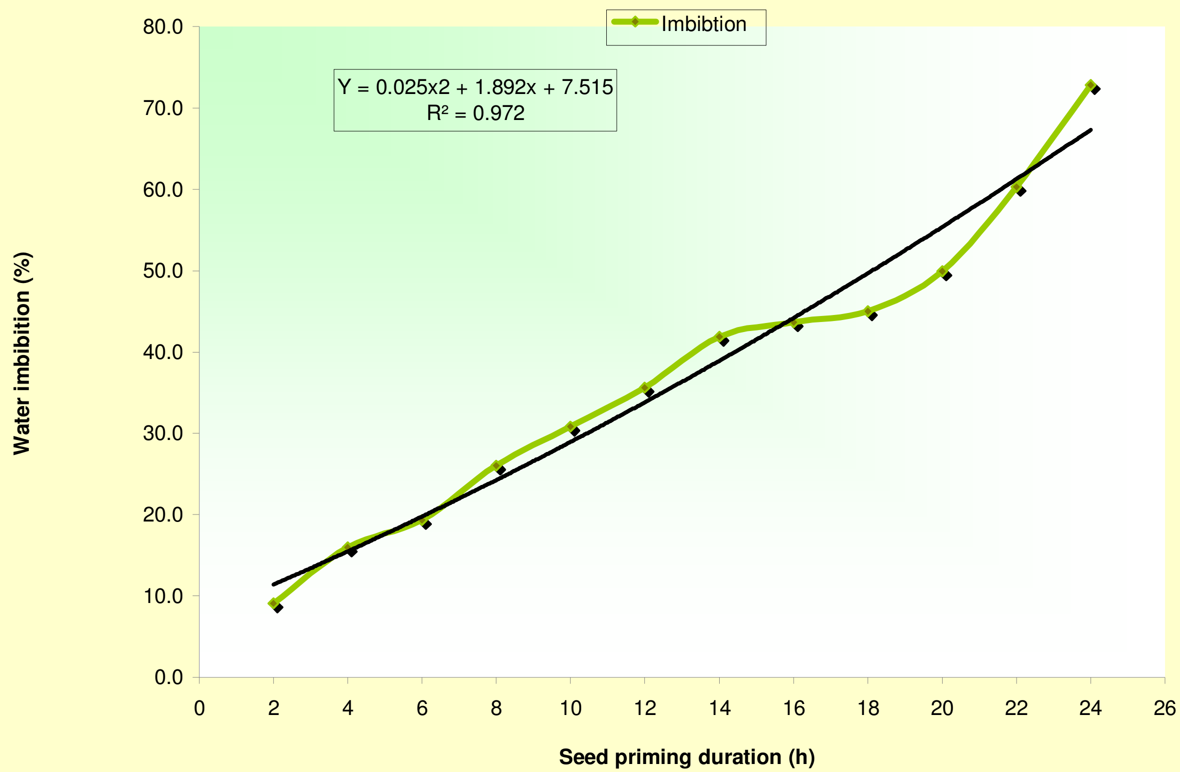

Figure 2. Seed imbibition of soybean as affected by priming duration

Figure 2. Seed imbibition of soybean as affected by priming duration

Table 3: Influence of seed priming duration on speed of germination, standard germination (%), root length (cm), shoot length (cm), seedling dry weight (mg), seedling vigour index, electrical conductivity and field emergence (%).

Priming duration	Speed of Germination	Standard Germination (%)	Root length (cm)	Shoot length (cm)	Seedling dry weight (mg)	Seedling vigour index	Electrical conductivity (dSm^{-1})	Field emergence (%)
Dry unprimed seeds	40.50	97.67 (81.30)	15.15	12.58	95.00	2708	0.653	90.12 (71.79)
2	41.93	97.00 (80.16)	13.90	11.53	88.33	2467	0.670	89.73 (71.42)
4	42.07	97.00 (80.16)	14.33	12.57	82.67	2610	0.683	89.37 (71.14)
6	44.13	96.67 (79.55)	14.24	12.43	87.67	2579	0.691	89.40 (71.04)
8	47.47	96.33 (79.02)	13.34	13.44	84.00	2579	0.694	89.54 (71.18)
10	50.13	94.67 (76.77)	14.28	13.65	84.00	2643	0.671	89.03 (70.78)
12	54.37	95.67 (78.14)	15.50	13.65	97.00	2788	0.674	92.03 (73.73)
14	57.10	97.00 (80.07)	16.34	13.89	106.00	2933	0.670	93.37 (75.15)

Priming duration	Speed of Germination	Standard Germination (%)	Root length (cm)	Shoot length (cm)	Seedling dry weight (mg)	Seedling vigour index	Electrical conductivity (dSm^{-1})	Field emergence (%)
16	54.93	96.00 (78.56)	15.53	13.74	96.33	2810	0.674	91.70 (73.31)
18	50.67	94.33 (76.28)	14.10	13.46	90.00	2599	0.707	89.70 (71.33)
20	48.77	93.33 (75.11)	15.35	13.51	76.67	2693	0.743	89.03 (70.71)
22	46.60	93.33 (75.08)	14.60	12.92	77.00	2568	0.759	88.24 (69.99)
24	44.27	92.33 (74.02)	13.26	11.50	73.00	2286	0.805	88.03 (69.82)
Mean	47.78	95.49 (78.03)	14.61	12.99	87.51	2636	0.700	89.95 (71.65)
SEm±	0.47	0.50	0.19	0.17	1.16	28	0.01	0.56
CD at 5%	1.37	1.46	0.57	0.450	3.39	81	0.03	1.64

* Figures in parenthesis indicate arc sine values

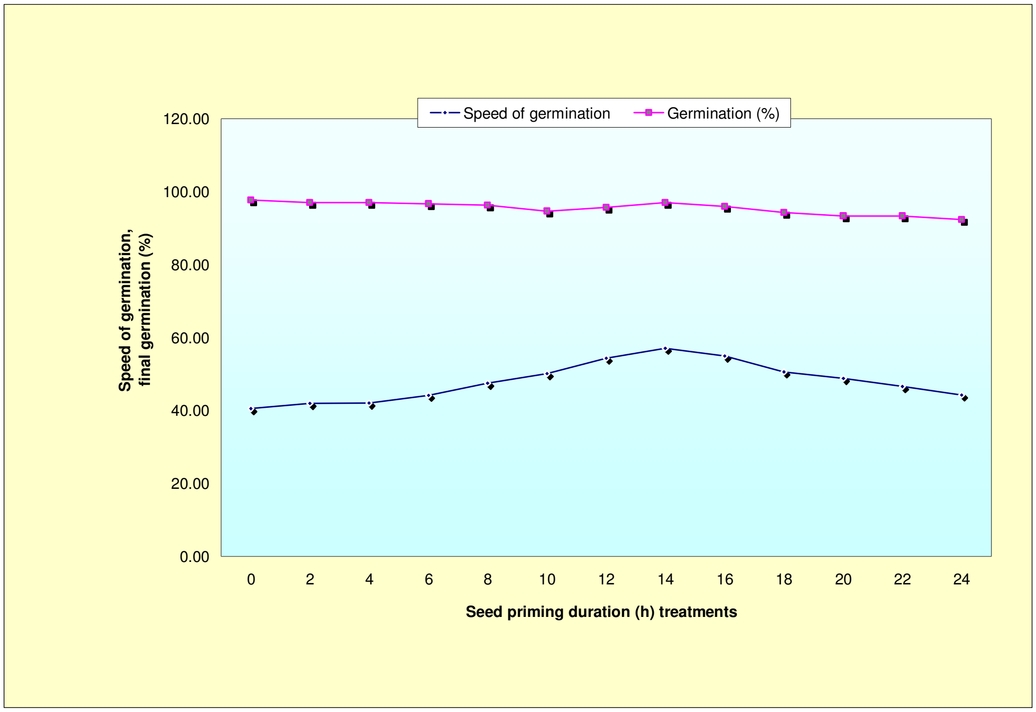

Figure 3. Seed imbibition of soybean as affected by priming duration

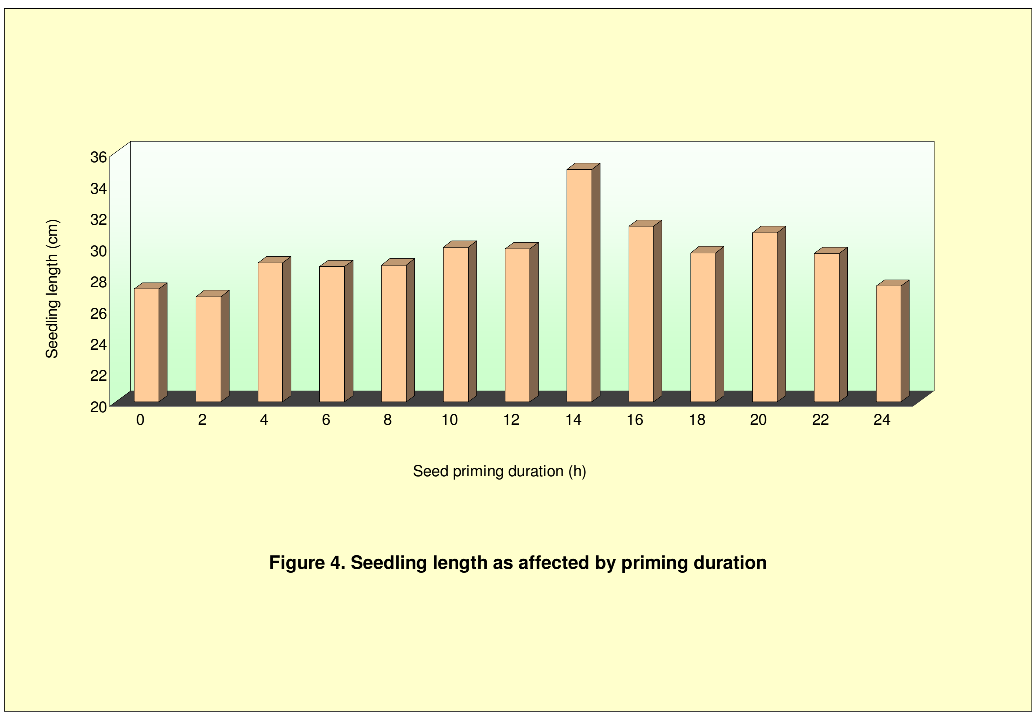

Figure 4. Seedling length as affected by priming duration

4.1.7 Seedling vigour index

The data on seedling vigour index as influenced by the priming durations are presented in Table 3.

The seedling vigour index was significantly influenced by the priming durations. Significantly highest seedling vigour index (2933) was recorded with 14 h priming, followed by 16 h (2810) and 12h (2788); the lowest seedling vigour index (2286) was recorded with seeds primed for 24h.

4.1.8 Electrical Conductivity (dSm^{-1})

The data on electrical conductivity as influenced by the priming durations are presented in Table 3.

The electrical conductivity of seed leachates was significantly influenced by the priming durations. Significantly lowest electrical conductivity (0.653 dSm^{-1}) was recorded with unprimed seeds which was on par with 2h (0.670 dSm^{-1}), 14h (0.670 dSm^{-1}), 10h (0.671 dSm^{-1}), 12h (0.674 dSm^{-1}), and 16h(0.674 dSm^{-1}) whereas significantly highest electrical conductivity (0.805 dSm^{-1}) was recorded with seeds primed for 24 h.

4.1.9 Field Emergence (%)

The data on field emergence percentage as influenced by the priming durations are presented in Table 3.

The field emergence percentage was significantly influenced by the priming durations. Significantly the highest (93.37%) emergence was recorded with 14 h priming duration, followed by 12 h (92.03 %) and 16 h (91.7 %). The lowest emergence (88.03 %) was recorded in seeds primed for 24h.

4.2 Experiment II: Effect of seed quality and priming treatments on storability of soybean seeds

4.2.1 Speed of germination

The results on speed of germination as influenced by seed quality, seed priming and their interaction effects during five months of storage period are presented in Table 4.

Speed of germination declined progressively with the advanced storage period. On an average the speed of germination recorded at the beginning and at the end of storage period was 51.44 and 31.40, respectively.

Speed of germination differed significantly due to seed quality at all months of storage period. At initial month of storage significantly higher speed of germination (58.89) was recorded in higher quality seed lot (Q_1) and lower speed of germination (44.00) was recorded in lower quality seed lot (Q_2). At the end of five months storage higher speed of germination (38.70) was recorded in Q_1 and lower speed germination (24.11) was recorded in Q_2.

The speed of germination due to the seed priming varied significantly at all the months of storage period. At initial month of storage period significantly highest speed of germination was recorded in GA_3 (20ppm) (T_6) (59.00) primed seeds, followed by $CaCl_2.2H_2O$ (0.5%) (T_4) (56.58) primed seeds while the lowest speed of germination was recorded in KCl (100ppm) (T_3) (45.42) primed seeds. However, T_4 ($CaCl_2.2H_2O$ (0.5%)) significantly out performed T_6 (GA_3 (20ppm) from the second month of storage onwards. At the end of five months of storage period, the highest speed of germination was recorded in T_4 ($CaCl_2.2H_2O$ (0.5%)) (36.54), followed by T_6 (GA_3 (20ppm)) (35.58) and the lowest speed of germination was recorded in primed seeds T_3 (KCl (100ppm)) (25.34).

The speed of germination percentage differed significantly due to interaction of seed quality and seed treatment at all the months of storage period. At initial month of storage period significantly highest speed of germination was recorded in Q_1T_6 (67.33), followed Q_1T_4 (63.00) and Q_1T_5 (60.33) while the lowest speed of germination was recorded in Q_2T_3 (40.00). Similar trend was noticed at all months of storage period except Q_1T_4 was showing significantly higher speed than Q_1T_6 starting from the second month till the end of the storage period. At the end of five months of storage period, the highest speed of germination was

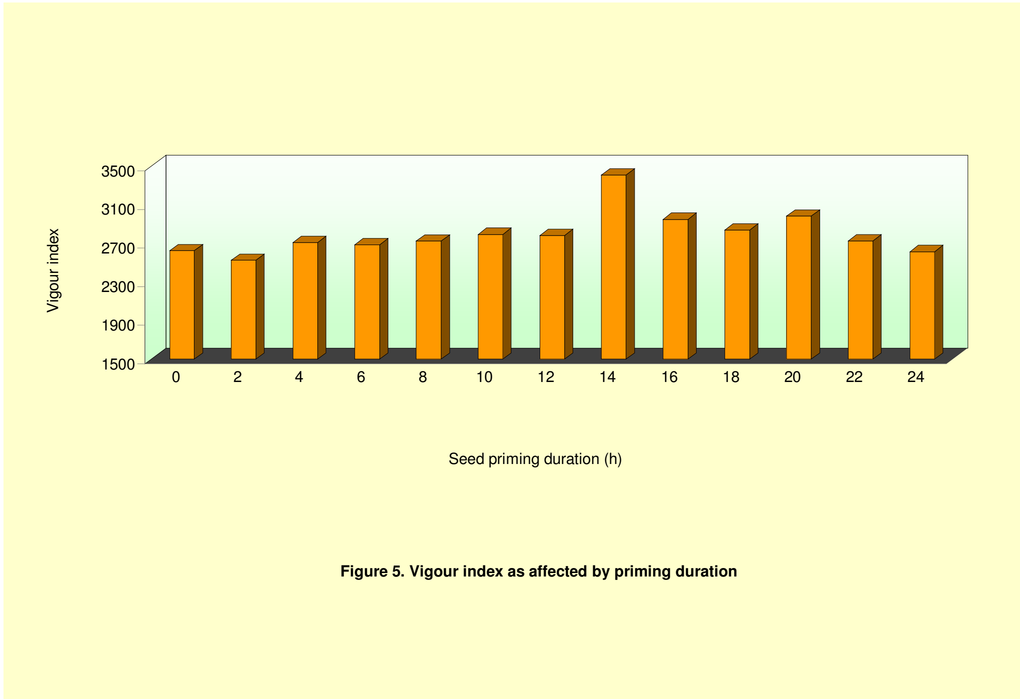

Figure. 5. Vigour index as affected by priming duration

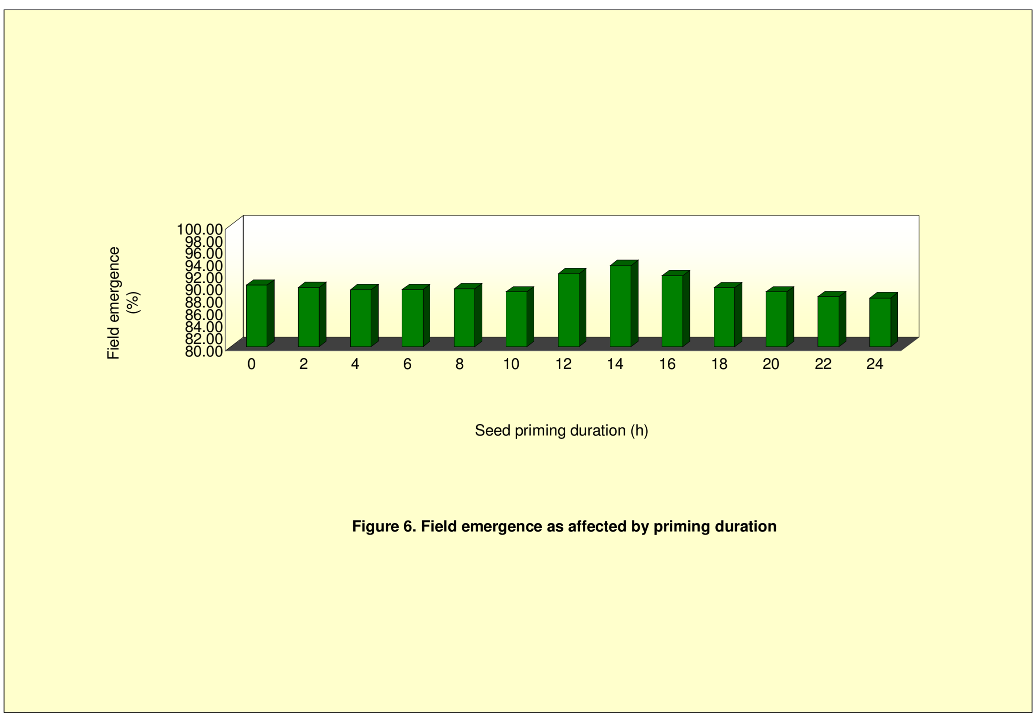

Figure. 6 Field emergence as affected by priming duration

Table 4. Effect of seed priming treatments to different quality seeds on speed of germination in soybean

Treatments	Storage period (months)					
	Initial	1	2	3	4	5
Seed Quality (Q)						
Q_1	58.89	57.79	53.35	50.05	45.53	38.70
Q_2	44.00	43.19	40.10	36.20	30.22	24.11
S.Em $\pm$	0.27	0.22	0.26	0.41	0.19	0.11
CD at 5 %	0.80	0.65	0.77	1.18	0.55	0.31
Priming treatments (T)						
T_1	46.25	45.62	41.97	40.02	34.71	27.02
T_2	50.83	50.29	46.34	42.74	38.22	32.11
T_3	45.42	44.88	41.23	36.41	32.01	25.34
T_4	56.58	55.28	52.31	48.90	42.65	36.54
T_5	50.58	50.04	46.76	42.48	37.96	31.85
T_6	59.00	56.85	51.74	48.20	41.69	35.58
S.Em $\pm$	0.47	0.39	0.46	0.70	0.33	0.19
CD at 5 %	1.38	1.12	1.34	2.05	0.96	0.54
Interactions (Q x T)						
Q_1T_1	52.00	51.46	48.76	48.04	43.52	34.26
Q_1T_2	59.83	59.29	53.62	49.61	45.09	38.98
Q_1T_3	50.83	50.29	48.07	44.87	40.35	33.12
Q_1T_4	63.00	60.94	57.21	54.44	49.92	43.81
Q_1T_5	60.33	59.79	55.46	50.09	45.57	39.46
Q_1T_6	67.33	64.99	57.01	53.23	48.71	42.60
Q_2T_1	40.50	39.79	35.19	31.99	25.89	19.78
Q_2T_2	41.83	41.29	39.07	35.87	31.35	25.24
Q_2T_3	40.00	39.46	34.39	27.96	23.67	17.56
Q_2T_4	50.17	49.63	47.40	43.35	35.38	29.27
Q_2T_5	40.83	40.29	38.07	34.87	30.35	24.24
Q_2T_6	50.67	48.71	46.48	43.16	34.67	28.56
Mean	51.44	50.49	46.73	43.12	37.87	31.40
S.Em $\pm$	0.67	0.54	0.65	0.99	0.46	0.26
CD at 5 %	1.96	1.59	1.89	2.90	1.36	0.77

Q_1: Seeds with germination above MSCS
Q_2: Seeds with germination marginally below MSCS
T_1: Control (dry unprimed seeds) T_3: KCl (100ppm) T_5: KH_2PO_4 (50 ppm)
T_2: Hydropriming T_4: $CaCl_2.2H_2O$ (0.5%) T_6: GA_3 (20ppm)

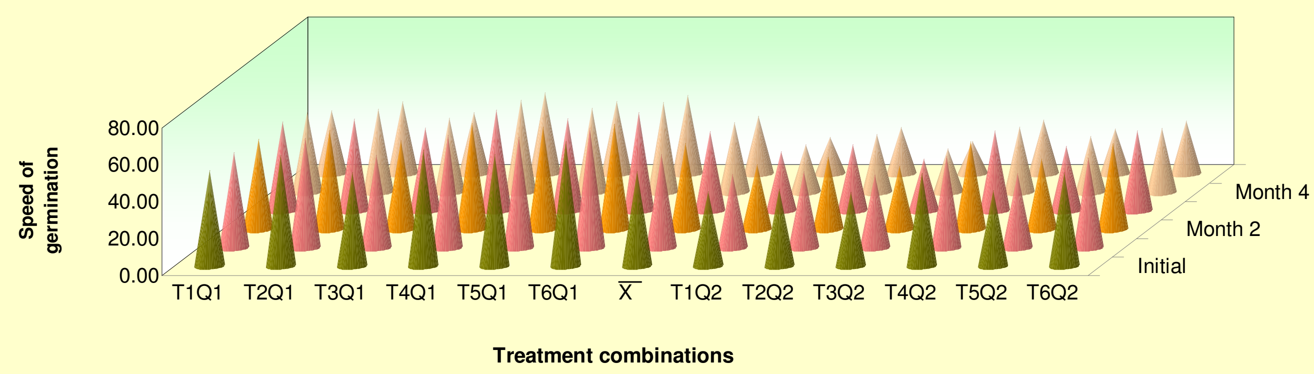

Figure 7. A decline trend in speed of germination during five months of storage

Figure 7. A decline trend in speed of germination during five moths of storage

recorded in Q_1T_4 (43.81), followed by Q_1T_6 (42.60) and Q_1T_5 (39.46) and the lowest speed of germination was recorded in Q_2T_3 (17.56).

4.2.2 Germination (%)

The results on germination percentage as influenced by seed quality, seed priming and their interaction effects during five months of storage period are presented in Table 5.

Germination percentage declined progressively with the advanced storage period. On an average the germination percentage recorded at the beginning and end of storage period was 83.28 and 50.22 per cent, respectively.

The germination percentage differed significantly due to seed quality at all the months of storage period. At initial month of storage, significantly higher germination was recorded in higher quality seed lot (Q_1) (96.06 %) and lower germination was recorded in lower quality seed lot (Q_2) (70.50 %). At the end of five months storage higher germination was recorded in Q_1 (63.13 %) and lower germination was recorded in Q_2 (37.13 %).

The germination percentage due to seed priming varied significantly at all the months of storage period. At initial month of storage period significantly highest germination was recorded in $CaCl_2.2H_2O$ (0.5%) (T_4) (86.67%) primed seeds followed by GA_3 (20ppm) (T_6) (85.33) primed seeds and KH_2PO_4 (50 ppm) (T_5) (83.67%) primed seeds while the lowest germination was recorded in KCl (100ppm) (T_3) (79.33 %) primed seeds. Similar trend was noticed at all months of storage period. At the end of five months of storage period the highest germination was recorded in T_4 ($CaCl_2.2H_2O$ (0.5%)) (54.07 %) followed by T_6 (GA_3 (20ppm)) (52.34%) and the lowest germination was recorded in T_3 (KCl (100ppm)) (46.14%).

The germination percentage showed significant difference due to interaction of seed quality and seed priming treatments at all the months of storage period. At initial month of storage significantly highest germination was recorded in Q_1T_4 (98.00 %) and was on par with Q_1T_6 (97.67%), Q_1T_5 (97.67%), and hydroprimed seeds (Q_1T_2) (97.33%), lowest germination was recorded in Q_2T_3 (66.67 %). At the end of five months of storage the higher germination was recorded in Q_1T_4 (66.00 %), followed by Q_1T_6 (64.87 %) and the lowest germination was recorded in Q_2T_3 (33.48 %).

4.2.3 Root length (cm)

The results on root length as influenced by seed quality, seed priming and their interaction effects during five months of storage period are presented in Table 6.

Root length declined progressively as storage period advanced. On an average the root length recorded at the beginning and end of storage period was 15.34 and 11.11 cm, respectively.

The root length differed significantly due to seed quality at all the months of storage period. At initial month of storage significantly higher root length was recorded in higher quality seed lot (Q_1) (16.39 cm) as compared with lower quality seed lot (Q_2) (14.29 cm). At the end of five months storage higher root length was recorded in Q_1 (11.86 cm) and lower root length was recorded in Q_2 (10.36 cm).

The root length due to the seed priming varied significantly at all the months of storage period. At initial month of storage period significantly highest root length was recorded in $CaCl_2.2H_2O$ (0.5%) (T_4) (17.11cm)) primed seeds, followed by (T_6) (15.85 cm) and KH_2PO_4 (50 ppm) (T_5) (15.55 cm) primed seeds while the root length was recorded in KCl (100ppm) (T_3) (13.95 cm) primed seeds. Similar trend was noticed at all months of storage period. At the end of five months of storage period the highest root length was recorded in T_4 ($CaCl_2.2H_2O$ (0.5%)) (12.45 cm), followed by T_6 (GA_3 (20ppm)) (11.77 cm) and the lowest root length was recorded in T_3 (KCl (100ppm)) (9.77 cm).

The root length showed significant difference due to interaction of seed quality and seed priming treatments at all the months of storage period. At initial month of storage significantly highest root length was recorded in Q_1T_4 (18.54 cm), followed by Q_1T_6 (16.86 cm) and Q_1T_5 (16.66 cm), and the lowest root length was recorded in Q_2T_3 (13.12 cm). At the end of five months of storage the highest root length was recorded in Q_1T_4 (13.65 cm), followed by Q_1T_6 (12.58 cm); lowest root length was recorded in Q_2T_3 (9.17 cm).

Table 5. Effect of seed priming treatments to different quality seeds on germination (%) in soybean

Treatments	Storage period (months)					
	Initial	1	2	3	4	5
Seed Quality (Q)						
Q_1	96.06 (79.14)	90.86 (72.61)	84.40 (66.84)	77.38 (61.66)	71.82 (57.99)	63.13 (52.65)
Q_2	70.50 (57.16)	65.60 (54.14)	58.89 (50.15)	51.82 (46.07)	46.11 (42.79)	37.31 (37.65)
S.Em ±	0.31	0.20	0.15	0.14	0.12	0.12
CD at 5 %	0.90	0.57	0.45	0.40	0.36	0.34
Priming treatments (T)						
T_1	81.33 (65.83)	75.72 (61.20)	69.64 (57.07)	62.61 (52.59)	56.94 (49.15)	48.14 (43.92)
T_2	83.33 (68.54)	78.43 (63.75)	71.64 (58.60)	64.61 (53.93)	58.94 (50.40)	50.14 (45.11)
T_3	79.33 (64.19)	74.43 (60.41)	67.76 (55.85)	60.73 (51.44)	54.94 (47.96)	46.14 (42.73)
T_4	86.67 (71.08)	81.58 (65.75)	75.21 (60.80)	68.07 (55.98)	62.51 (52.49)	54.07 (47.43)
T_5	83.67 (69.09)	78.77 (64.05)	71.98 (58.84)	64.95 (54.15)	59.28 (50.61)	50.48 (45.31)
T_6	85.33 (70.15)	80.43 (65.07)	73.64 (59.81)	66.61 (55.10)	61.18 (51.72)	52.34 (46.41)
S.Em ±	0.53	0.34	0.26	0.24	0.212	0.20
CD at 5 %	1.55	0.99	0.77	0.69	0.62	0.59
Interactions (Q x T)						
Q_1T_1	93.67 (75.47)	87.33 (69.19)	81.98 (64.91)	74.95 (60.00)	69.28 (56.37)	60.48 (51.07)
Q_1T_2	97.33 (80.68)	92.43 (74.08)	85.64 (67.77)	78.61 (62.49)	72.94 (58.69)	64.14 (53.24)
Q_1T_3	92.00 (73.61)	87.10 (68.99)	80.31 (63.69)	73.28 (58.90)	67.61 (55.34)	58.81 (50.10)
Q_1T_4	98.00 (81.91)	92.73 (74.41)	86.54 (68.51)	79.52 (63.13)	74.07 (59.42)	66.00 (54.36)
Q_1T_5	97.67 (81.57)	92.77 (74.49)	85.98 (68.06)	78.95 (62.73)	73.28 (58.91)	64.48 (53.45)
Q_1T_6	97.67 (81.57)	92.77 (74.49)	85.98 (68.06)	78.95 (62.73)	73.74 (59.20)	64.87 (53.68)

Treatments	Storage period (months)					
	Initial	1	2	3	4	5
Q_2T_1	69.00 (56.20)	64.10 (53.22)	57.31 (49.23)	50.28 (45.18)	44.61 (41.93)	35.81 (36.78)
Q_2T_2	69.33 (56.40)	64.43 (53.42)	57.64 (49.42)	50.61 (45.37)	44.94 (42.12)	36.14 (36.97)
Q_2T_3	66.67 (54.76)	61.77 (51.83)	55.21 (48.01)	48.19 (43.98)	42.28 (40.58)	33.48 (35.37)
Q_2T_4	75.33 (60.25)	70.43 (57.09)	63.87 (53.08)	56.61 (48.83)	50.94 (45.56)	42.14 (40.50)
Q_2T_5	69.67 (56.61)	64.77 (53.62)	57.98 (49.62)	50.95 (45.57)	45.28 (42.31)	36.48 (37.17)
Q_2T_6	73.00 (58.73)	68.10 (55.64)	61.31 (51.56)	54.28 (47.48)	48.61 (44.23)	39.81 (39.14)
Mean	83.28 (68.15)	78.23 (63.37)	71.65 (58.49)	64.60 (53.87)	58.97 (50.39)	50.22 (45.15)
S.Em ±	0.75	0.48	0.37	0.33	0.30	0.28
CD at 5 %	2.19	1.40	1.09	0.98	0.88	0.83

* Figures in parenthesis indicate arc sine values

Q_1: Seeds with germination above MSCS

Q_2: Seeds with germination marginally below MSCS

T_1: Control (dry unprimed seeds) T_3: KCl (100ppm) T_5: KH_2PO_4 (50 ppm)

T_2: Hydropriming T_4: $CaCl_2.2H_2O$ (0.5%) T_6: GA_3 (20ppm)

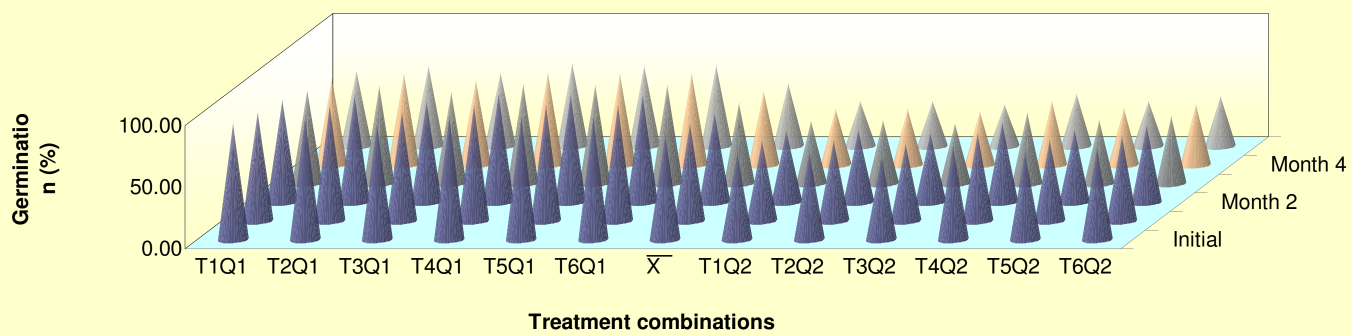

Figure 8 . A decline in seed germination (%) during five months of storage

Figure 8. Adcline in seed germination (%) during five moths of storage

Table 6. Effect of seed priming treatments to different quality seeds on root length (cm) in soybean

Treatments	Storage period (months)					
	Initial	1	2	3	4	5
Seed Quality (Q)						
Q_1	16.39	15.70	14.10	13.71	13.04	11.86
Q_2	14.29	14.12	12.80	12.33	11.65	10.36
S.Em ±	0.07	0.07	0.08	0.08	0.08	0.08
CD at 5 %	0.20	0.21	0.22	0.23	0.23	0.22
Priming treatments (T)						
T_1	14.25	13.97	12.77	12.33	11.65	10.43
T_2	15.36	14.69	13.38	12.92	12.25	11.03
T_3	13.95	13.78	12.33	11.89	11.22	9.77
T_4	17.11	16.71	14.62	14.34	13.66	12.45
T_5	15.55	15.01	13.57	13.04	12.37	11.21
T_6	15.85	15.32	14.05	13.61	12.94	11.77
S.Em ±	0.12	0.13	0.13	0.13	0.14	0.13
CD at 5 %	0.34	0.38	0.39	0.40	0.40	0.38
Interactions (Q x T)						
Q_1T_1	15.12	14.74	13.29	12.85	12.18	10.96
Q_1T_2	16.40	15.22	13.97	13.53	12.86	11.64
Q_1T_3	14.77	14.60	12.70	12.26	11.58	10.36
Q_1T_4	18.54	17.91	15.66	15.53	14.86	13.65
Q_1T_5	16.66	15.75	14.18	13.74	13.07	11.97
Q_1T_6	16.86	15.96	14.81	14.37	13.70	12.58
Q_2T_1	13.37	13.20	12.24	11.80	11.13	9.91
Q_2T_2	14.32	14.15	12.79	12.31	11.64	10.42
Q_2T_3	13.12	12.95	11.96	11.52	10.85	9.17
Q_2T_4	15.67	15.50	13.59	13.15	12.47	11.25
Q_2T_5	14.43	14.26	12.96	12.33	11.66	10.44
Q_2T_6	14.84	14.67	13.29	12.85	12.18	10.96
Mean	15.34	14.91	13.45	13.02	12.35	11.11
S.Em ±	0.16	0.18	0.19	0.19	0.19	0.18
CD at 5 %	0.48	0.53	0.55	0.56	0.57	0.54

Q_1: Seeds with germination above MSCS

Q_2: Seeds with germination marginally below MSCS

T_1: Control (dry unprimed seeds) T_3: KCl (100ppm) T_5: KH_2PO_4 (50 ppm)

T_2: Hydropriming T_4: $CaCl_2.2H_2O$ (0.5%) T_6: GA_3 (20ppm)

4.2.4 Shoot length (cm)

The results on shoot length as influenced by seed quality, seed priming and their interaction effects during five months of storage period are presented in Table 7.

Shoot length declined progressively as storage period advanced. On an average the shoot length recorded at the beginning and end of storage period was 11.22 and 5.83 cm, respectively.

The shoot length differed significantly due to seed quality at all the months of storage period. At initial month of storage shoot length was recorded significantly higher quality seed lot (Q_1) (12.99 cm) over the lower quality seed lot (Q_2) (9.45 cm). At the end of five months storage higher shoot length was recorded in Q_1 (6.95 cm) and lower shoot length was recorded in Q_2 (4.71 cm).

The shoot length due to the seed priming varied significantly at all the months of storage period. At initial month of storage period significantly highest root length was recorded in GA_3 (20ppm) (T_6) (13.27 cm) primed seeds, followed by $CaCl_2.2H_2O$ (0.5%) (T_4) (12.14 cm) and KH_2PO_4 (50 ppm) (T_5) (11.17 cm) primed seeds while the lowest shoot length was recorded in KCl (100ppm) (T_3). (9.03 cm) primed seeds. Similar trend was noticed at all months of storage period. At the end of five months of storage period the highest shoot length (7.16 cm) was recorded in T_6 (GA_3 (20ppm)), followed by T_4 ($CaCl_2.2H_2O$ (0.5%)) (6.83 cm) and T_2 (hydropriming) (6.56 cm) and the lowest shoot length was recorded in T_3 (KCl (100ppm)) (3.46 cm).

The shoot length showed significant difference due to interaction of seed quality and seed priming treatments at all the months of storage period. At initial month of storage significantly highest shoot length was recorded in Q_1T_6 (15.21 cm), followed by Q_1T_4 (13.28 cm) and Q_1T_5 (13.01 cm) and the lowest shoot length was recorded in Q_2T_3 (6.8 cm). At the end of five months of storage the highest shoot length was recorded in Q_1T_6 (8.23 cm), followed by Q_1T_4 (7.83 cm) and the lowest shoot length was recorded in Q_2T_3 (2.46 cm).

4.2.5 Seedling dry weight (mg)

The results on seedling dry weight as influenced by seed quality, seed priming and their interaction effects during five months of storage period are presented in Table 8.

Seedling dry weight declined progressively as storage period advanced. On an average the seedling dry weight recorded at the beginning and end of storage period was 96.48 and 66.76 mg, respectively.

The seedling dry weight differed significantly due to seed quality at all the months of storage period. At initial month of storage significantly higher seedling dry weight was recorded in higher quality seed lot (Q_1) (113.22 mg) over the lower quality seed lot (Q_2) (79.75). At the end of five months storage higher seedling dry weight was recorded in Q_1 (82.53 mg) and lower seedling dry weight was recorded in Q_2 (51.00 mg).

The seedling dry weight due to seed priming varied significantly at all the months of storage period. At initial month of storage period significantly highest seedling dry weight was recorded in $CaCl_2.2H_2O$ (0.5%) (T_4) (106.83 mg) primed seeds, followed by GA_3 (20ppm) (T_6) (103.33 mg) primed seeds while the lowest seedling dry weight (82.78 mg) was recorded in KCl (100ppm) (T_3) (82.78 mg) primed seeds. Similar trend was noticed at all months of storage period. At the end of five months of storage period the highest seedling dry weight was recorded in T_4 ($CaCl_2.2H_2O$ (0.5%)) (81.00 mg), followed by T_6 (GA_3 (20ppm)) (74.80 mg) and the lowest seedling dry weight was recorded in T_3 (KCl (100ppm)) (51.77 mg).

The seedling dry weight showed significant difference due to interaction of seed quality and seed priming treatments at all the months of storage period. At initial month of storage significantly highest seedling dry weight was recorded in Q_1T_4 (128.33 mg), followed by Q_1T_6 (123.00 mg) and Q_1T_5 (113.67 mg), and the lowest seedling dry weight was recorded in Q_2T_3 (69.90 mg). At the end of five months of storage the highest seedling dry weight was recorded in Q_1T_4 (100.61 mg), followed by Q_1T_4 (92.91 mg) and the lowest seedling dry weight was recorded in Q_2T_3 (37.96 mg).

Table 7. Effect of seed priming treatments to different quality seeds on shoot length (cm) in soybean

Treatments	Storage period (months)					
	Initial	1	2	3	4	5
Seed Quality (Q)						
Q_1	12.99	12.76	12.27	11.60	8.02	6.95
Q_2	9.45	9.27	8.84	8.16	5.78	4.71
S.Em ±	0.11	0.11	0.11	0.09	0.06	0.06
CD at 5 %	0.33	0.32	0.33	0.26	0.17	0.18
Priming treatments (T)						
T_1	10.65	10.48	10.02	9.25	5.82	4.74
T_2	11.07	10.89	10.51	9.99	7.63	6.56
T_3	9.03	8.85	8.47	8.02	4.53	3.46
T_4	12.14	11.97	11.58	10.61	7.90	6.83
T_5	11.17	10.99	10.61	10.09	7.30	6.23
T_6	13.27	12.91	12.15	11.32	8.23	7.16
S.Em ±	0.20	0.19	0.20	0.16	0.10	0.11
CD at 5 %	0.58	0.55	0.57	0.46	0.30	0.31
Interactions (Q x T)						
Q_1T_1	12.31	12.14	11.60	10.60	7.40	6.33
Q_1T_2	12.88	12.70	12.32	11.80	8.80	7.73
Q_1T_3	11.26	11.08	10.70	9.65	5.53	4.46
Q_1T_4	13.28	13.10	12.72	12.20	8.90	7.83
Q_1T_5	13.01	12.83	12.45	11.93	8.20	7.12
Q_1T_6	15.21	14.70	13.84	13.42	9.30	8.23
Q_2T_1	8.99	8.81	8.43	7.91	4.23	3.16
Q_2T_2	9.26	9.08	8.70	8.18	6.47	5.39
Q_2T_3	6.80	6.63	6.24	6.39	3.53	2.46
Q_2T_4	11.01	10.83	10.45	9.03	6.90	5.82
Q_2T_5	9.33	9.15	8.77	8.25	6.40	5.33
Q_2T_6	11.33	11.12	10.46	9.21	7.17	6.09
Mean	11.22	11.01	10.56	9.88	6.90	5.83
S.Em ±	0.28	0.27	0.28	0.22	0.14	0.15
CD at 5 %	0.82	0.79	0.80	0.65	0.42	0.44

Q_1: Seeds with germination above MSCS
Q_2: Seeds with germination marginally below MSCS
T_1: Control (dry unprimed seeds) T_3: KCl (100ppm) T_5: KH_2PO_4 (50 ppm)
T_2: Hydropriming T_4: $CaCl_2.2H_2O$ (0.5%) T_6: GA_3 (20ppm)

Table 8. Effect of seed priming treatments to different quality seeds on seedling dry weight (mg) in soybean

Treatments	Storage period (months)					
	Initial	1	2	3	4	5
Seed Quality (Q)						
Q_1	113.22	110.14	105.40	100.04	92.94	82.53
Q_2	79.75	76.67	73.87	68.51	61.41	51.00
S.Em $\pm$	0.48	0.48	0.67	0.67	0.68	0.69
CD at 5 %	1.34	1.41	1.95	1.95	1.99	2.00
Priming treatments (T)						
T_1	87.78	84.71	81.88	76.52	69.42	59.01
T_2	99.95	96.87	88.75	83.39	76.29	65.88
T_3	82.78	79.71	74.64	69.28	62.18	51.77
T_4	106.83	103.76	103.87	98.51	91.41	81.00
T_5	98.22	95.14	90.97	85.61	78.51	68.10
T_6	103.33	100.26	97.67	92.31	85.21	74.80
S.Em $\pm$	0.82	0.84	1.16	1.16	1.18	1.19
CD at 5 %	2.41	2.44	3.37	3.38	3.44	3.47
Interactions (Q x T)						
Q_1T_1	98.97	95.89	95.17	89.81	82.71	72.30
Q_1T_2	119.67	116.59	103.07	97.71	90.61	80.20
Q_1T_3	95.67	92.59	88.45	83.09	75.99	65.58
Q_1T_4	128.33	125.26	123.48	118.12	111.02	100.61
Q_1T_5	113.67	110.59	106.45	101.09	93.99	83.58
Q_1T_6	123.00	119.92	115.78	110.42	103.32	92.91
Q_2T_1	76.60	73.52	68.60	63.24	56.14	45.73
Q_2T_2	80.23	77.16	74.43	69.07	61.97	51.56
Q_2T_3	69.90	66.82	60.83	55.47	48.37	37.96
Q_2T_4	85.33	82.26	84.27	78.91	71.81	61.40
Q_2T_5	82.77	79.69	75.50	70.14	63.04	52.63
Q_2T_6	83.67	80.59	79.57	74.21	67.11	56.70
Mean	96.48	93.41	89.63	84.27	77.17	66.76
S.Em $\pm$	1.17	1.18	1.64	1.64	1.67	1.68
CD at 5 %	3.40	3.45	4.78	4.79	4.87	4.91

Q_1: Seeds with germination above MSCS
Q_2: Seeds with germination marginally below MSCS
T_1: Control (dry unprimed seeds) T_3: KCl (100ppm) T_5: KH_2PO_4 (50 ppm)
T_2: Hydropriming T_4: $CaCl_2.2H_2O$ (0.5%) T_6: GA_3 (20ppm)

4.2.6 Seedling vigour index

The results on seedling vigour index as influenced by seed quality, seed priming and their interaction effects during five months of storage period are presented in Table 9.

The seedling vigour index decreased as storage period increased. On an average the seedling vigour index recorded at the beginning and end of storage period was 2254 and 880, respectively.

The seedling vigour index differed significantly due to seed quality at all the months of storage period. At initial month of storage significantly higher seedling vigour index was recorded in high quality seed lot (Q_1) (2827) over the lower quality seed lot (Q_2) (1680). At the end of five months storage higher seedling vigour index was recorded in Q_1 (1193) and lower seedling vigour index was recorded in Q_2 (567).

The seedling vigour index due to the seed priming varied significantly at all the months of storage period. At initial month of storage period sgnificantly highest seedling vigour index was recorded in $CaCl_2.2H_2O$ (0.5%) (T_4) (2564) primed seeds, followed by GA_3 (20ppm) (T_6) (2521) and KH_2PO_4 (50 ppm) (T_5) (2277) primed seeds while the lowest seedling vigour index was recorded in KCl (100ppm) (T_3) (1861) primed seeds .Similar trend was noticed at all months of storage period. At the end of five months of storage period the highest seedling vigour index was recorded in T_4 ($CaCl_2.2H_2O$ (0.5%)) (1069), followed by T_6 (GA_3 (20ppm)) (1014) and the lowest seedling vigour index was recorded in T_3 (KCl (100ppm)) (631).

The seedling vigour index showed significant difference due to interaction of seed quality and seed priming treatments at all the months of storage period. At initial month of storage significantly highest seedling vigour index recorded in Q_1T_6 (3132) was on par with Q_1T_4 (3118), followed by Q_1T_5 (2897), and the lowest seedling vigour index was recorded in Q_2T_3 (1329). As of the first month of storage Q_1T_4 (2876) performed better than Q_1T_6 (2844); a similar trend was noticed at all months of storage period. At the end of five month of storage Q_1T_4 (1418) showed significantly highest seedling vigour index, followed by Q_1T_6 (1350) and the lowest seedling vigour index was recorded in Q_2T_3 (389).

4.2.7 Electrical conductivity (dSm^{-1})

The results on electrical conductivity as influenced by seed quality, seed priming and their interaction effects during five months of storage period are presented in Table 10.

The electrical conductivity increased as storage period advanced. On an average the electrical conductivity recorded at the beginning and end of storage period was 0.703 and 1.914 dSm^{-1} respectively.

The electrical conductivity differed significantly due to seed quality at all months of storage period. At initial month of storage significantly lower electrical conductivity was recorded in the high quality seed lot (Q_1) (0.490 dSm^{-1}) and higher electrical conductivity was recorded in low quality seed lot (Q_2) (0.917 dSm^{-1}). At the end of five months storage lower electrical conductivity was recorded in Q_1 (1.702 dSm^{-1}) and higher electrical conductivity was recorded in Q_2 (2.126 dSm^{-1}).

The electrical conductivity due to the seed priming varied significantly at all the months of storage period. At initial month of storage period significantly lowest electrical conductivity was recorded in $CaCl_2.2H_2O$ (0.5%) (T_4) (0.517 dSm^{-1}) primed seeds, followed by GA_3 (20ppm) (T_6) (0.551 dSm^{-1}) and KH_2PO_4 (50 ppm) (T_5) (0.659 dSm^{-1}) primed seeds while the highest electrical conductivity was recorded in KCl (100ppm) (T_3) (0.930 dSm^{-1}) primed seeds. Similar trend was noticed at all months of storage period. At the end of five months of storage period the lowest electrical conductivity was recorded in T_4 ($CaCl_2.2H_2O$ (0.5%)) (1.740 dSm^{-1}), followed by T_6 (GA3 (20ppm)) (1.774 dSm^{-1}) and in T_5 (KH_2PO_4 (50 ppm)) (1.849 dSm^{-1}) and the highest electrical conductivity was recorded in T_3 (KCl (100ppm)) (2.134 dSm^{-1}).

The electrical conductivity showed significant difference due to interaction of seed quality and seed priming treatments at all the months of storage period. At initial month of storage significantly lowest electrical conductivity recorded in Q_1T_4 (0.214 dSm^{-1}), followed by Q_1T_6 (0.275 dSm^{-1}) and Q_1T_5 (0.460 dSm^{-1}), and the highest electrical conductivity was

Table 9. Effect of seed priming treatments to different quality seeds on seedling vigour index in soybean

Treatments	Storage period (months)					
	Initial	1	2	3	4	5
Seed Quality (Q)						
Q_1	2827	2589	2230	1963	1518	1193
Q_2	1680	1541	1280	1065	808	567
S.Em $\pm$	11	11	11	7	6	5
CD at 5 %	32	33	31	21	19	16
Priming treatments (T)						
T_1	2056	1879	1613	1374	1021	757
T_2	2242	2039	1745	1514	1197	907
T_3	1861	1723	1442	1234	883	631
T_4	2564	2365	1996	1730	1373	1069
T_5	2277	2084	1775	1537	1188	903
T_6	2521	2300	1960	1696	1318	1014
S.Em $\pm$	19	20	18	12	11	9
CD at 5 %	56	58	53	36	32	27
Interactions (Q x T)						
Q_1T_1	2570	2347	2041	1757	1356	1045
Q_1T_2	2850	2581	2251	1991	1580	1242
Q_1T_3	2394	2237	1879	1605	1157	872
Q_1T_4	3118	2876	2456	2205	1760	1418
Q_1T_5	2897	2652	2290	2027	1559	1232
Q_1T_6	3132	2844	2464	2194	1696	1350
Q_2T_1	1543	1411	1185	991	685	468
Q_2T_2	1635	1497	1239	1037	814	571
Q_2T_3	1329	1210	1005	863	608	389
Q_2T_4	2010	1855	1535	1255	987	720
Q_2T_5	1656	1517	1259	1048	817	575
Q_2T_6	1910	1756	1456	1197	940	679
Mean	2254	2065	1755	1514	1163	880
S.Em $\pm$	27	28	26	18	16	13
CD at 5 %	79	81	75	52	46	38

Q_1: Seeds with germination above MSCS
Q_2: Seeds with germination marginally below MSCS
T_1: Control (dry unprimed seeds) T_3: KCl (100ppm) T_5: KH_2PO_4 (50 ppm)
T_2: Hydropriming T_4: $CaCl_2.2H_2O$ (0.5%) T_6: GA_3 (20ppm)

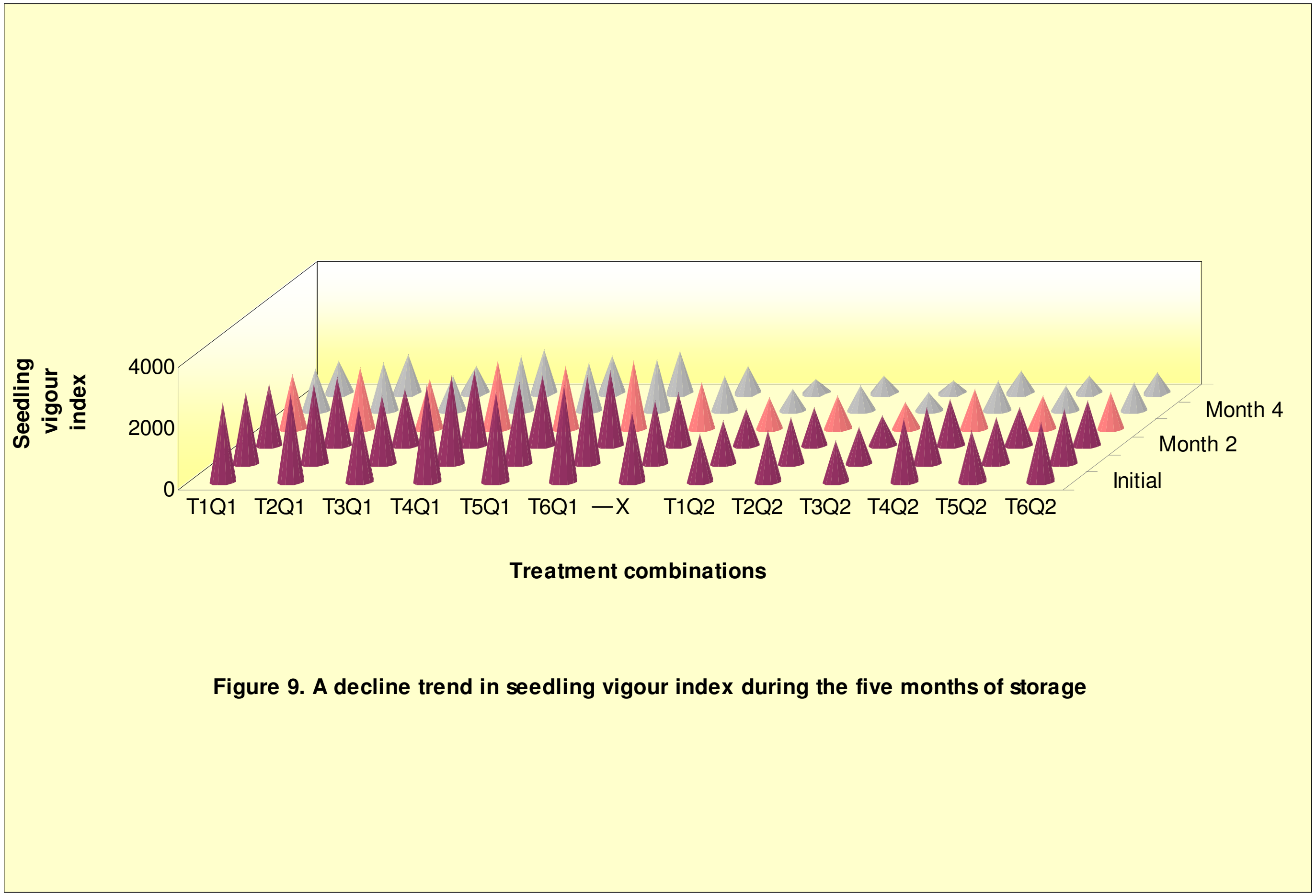

Figure 9. A decline trend in seedling vigour index during the five moths of storage

Table 10. Effect of seed priming treatments to different quality seeds on electrical conductivity (dSm^{-1}) in soybean

Treatments	Storage period (months)					
	Initial	1	2	3	4	5
Seed Quality (Q)						
Q_1	0.490	0.596	0.761	0.981	1.260	1.702
Q_2	0.917	1.023	1.181	1.410	1.689	2.126
S.Em $\pm$	0.008	0.007	0.010	0.012	0.010	0.008
CD at 5 %	0.023	0.020	0.031	0.034	0.030	0.024
Priming treatments (T)						
T_1	0.807	0.949	1.099	1.340	1.619	2.072
T_2	0.756	0.848	0.989	1.213	1.492	1.912
T_3	0.930	1.014	1.197	1.421	1.717	2.137
T_4	0.517	0.617	0.797	1.008	1.270	1.740
T_5	0.659	0.776	0.926	1.150	1.429	1.849
T_6	0.551	0.651	0.817	1.041	1.320	1.774
S.Em $\pm$	0.014	0.012	0.018	0.020	0.018	0.014
CD at 5 %	0.041	0.035	0.053	0.059	0.053	0.041
Interactions (Q x T)						
Q_1T_1	0.639	0.789	0.939	1.163	1.442	1.863
Q_1T_2	0.570	0.653	0.803	1.027	1.306	1.726
Q_1T_3	0.782	0.899	1.049	1.273	1.552	1.972
Q_1T_4	0.214	0.298	0.508	0.705	0.984	1.471
Q_1T_5	0.460	0.576	0.726	0.950	1.229	1.650
Q_1T_6	0.275	0.358	0.541	0.765	1.044	1.531
Q_2T_1	0.975	1.108	1.258	1.516	1.795	2.282
Q_2T_2	0.942	1.044	1.175	1.399	1.678	2.098
Q_2T_3	1.078	1.128	1.345	1.569	1.881	2.301
Q_2T_4	0.820	0.937	1.087	1.311	1.556	2.010
Q_2T_5	0.859	0.975	1.125	1.349	1.628	2.048
Q_2T_6	0.827	0.943	1.093	1.317	1.596	2.016
Mean	0.703	0.809	0.971	1.195	1.474	1.914
S.Em $\pm$	0.020	0.017	0.026	0.028	0.025	0.020
CD at 5 %	0.057	0.049	0.075	0.083	0.074	0.058

Q_1: Seeds with germination above MSCS
Q_2: Seeds with germination marginally below MSCS
T_1: Control (dry unprimed seeds) T_3: KCl (100ppm) T_5: KH_2PO_4 (50 ppm)
T_2: Hydropriming T_4: $CaCl_2.2H_2O$ (0.5%) T_6: GA_3 (20ppm)

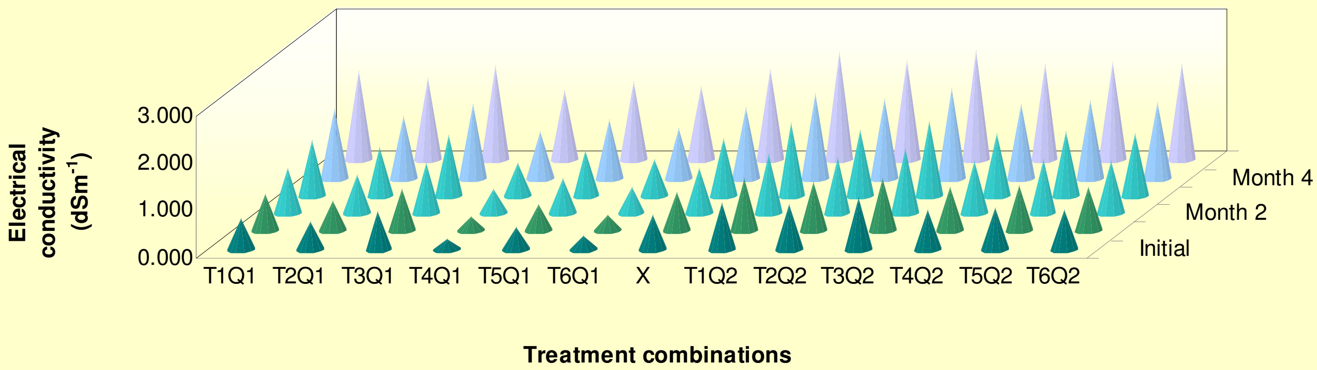

Figure 10 . An increased trend in elctrical conductivity (dSm^{-1}) during five months of storage

Figure 10. An increased trend in electrical conductivity (dSm^{-1}) during five months of storage

recorded in Q_2T_3 (1.078 dSm^{-1}). Similar trend was noticed at all months of storage period. At the end of five month of storage Q_1T_4 (1.471 dSm^{-1}) showed the lowest electrical conductivity, followed by Q_1T_6 (1.531 dSm^{-1}) and Q_1T_5 (0.1.65 dSm^{-1}) and the highest electrical conductivity was recorded in Q_2T_3 (2.301 dSm^{-1}).

4.2.8 Moisture content (%)

The results on moisture content as influenced by seed quality, seed priming and their interaction effect are presented in table 11.

The overall moisture content of seeds recorded 8.94 per cent in the initial month to 7.50 per cent at end of five months storage period. Moreover, the moisture content decreased progressively in the first four months; a moisture gain was observed in the last two months of storage irrespective of seed quality and seed priming treatment.

The moisture content of seed differed significantly due to seed quality at all the months of storage period. At initial month of storage significantly lower moisture content (8.57 %) was recorded in high quality seed lot (Q_1) and a higher in moisture content was recorded in low quality seed lot (Q_2) (9.30 %) At the end of five months storage lower moisture content was recorded in Q_2 (7.24%) and higher moisture content was recorded in Q_1 (7.76 %).

The moisture content due to the seed priming varied significantly at all the months of storage period. At initial month of storage period significantly lowest moisture content was recorded in $CaCl_2.2H2O$ (0.5%) (T_4) (8.81 %) primed seeds, followed by GA_3 (20ppm) (T_6) (8.89 %) and KH_2PO_4 (50 ppm) (T_5) (8.91 %) primed seeds while the highest moisture content was recorded in KCl (100ppm) (T_3) (9.07 %) primed seeds. At the end of five months of storage period the lowest moisture content was recorded in T_5 (KH_2PO_4 (50 ppm)) (7.42 %), followed by T_3 (KCl (100ppm) (T_3)) (7.45 %) and in T_2(hydroprming) (7.48 %) and the highest moisture content was recorded in untreated T_1((control) 7.65 %).

The moisture content due to interaction of seed quality and seed priming treatments showed significant difference at all the months except at initial and first month of storage period. At initial month of storage nonsignificant lowest moisture content was recorded in Q_1T_4 (8.44 %), followed by Q_1T_6 (8.51 %) and Q_1T_5 (8.57 %) and the highest moisture content was recorded in Q_2T_3 (9.39 %). At the end of five month of storage Q_2T_2 (7.06 %) showed significantly lowest moisture content, followed by Q_2T_5 (7.07 %) and Q_2T_4 (7.08 %) and highest moisture content was recorded in Q_1T_2 (7.85 %).

4.2.9 Field emergence (%)

The results on field emergence percentage as influenced by seed quality, seed priming and their interaction effects during five months of storage period are presented in Table 12.

The field emergence percentage declined progressively with the advanced storage period. On an average the field emergence recorded at the beginning and end of storage period was 80.18 and 44.08 per cent, respectively.

The field emergence percentage differed significantly due to seed quality at all the months of storage period. At initial month of storage significantly higher field emergence was recorded in high quality seed lot (Q_1) (92.96 %) when compared with the low quality seed lot Q_2 (67.40 %). At the end of five months storage higher field emergence was recorded in Q_1 (65.93 %) and lower field emergence was recorded in Q_2 (31.23 %).

The field emergence percentage due to the seed priming varied significantly at all the months of storage period. At initial month of storage period significantly highest field emergence was recorded in $CaCl_2.2H_2O$ (0.5%) (T_4) (83.57 %) primed seeds, followed by GA_3 (20ppm) (T_6) (82.24 %) and KH_2PO_4 (50 ppm) (T_5) (80.57 %) primed seeds while the lowest field emergence was recorded in KCl (100ppm) (T_3) (76.24 %) primed seeds. Similar trend was noticed at all months of storage period. At the end of five months of storage period the highest field emergence was recorded in T_4 (47.46 %), followed by T_6 ($CaCl_2.2H_2O$ (0.5%)) (46.38 %) and T_5 (KH_2PO_4 (50 ppm)) (44.26 %) and the lowest field emergence was recorded in T_3 (KCl (100ppm)) (40.21 %).

The field emergence percentage showed significant difference due to interaction of seed quality and seed priming treatments at all the months of storage period. At initial month

Table 11. Effect of seed priming treatments to different quality seeds on moisture content (%) in soybean

Treatments	Storage period (months)					
	Initial	1	2	3	4	5
Seed Quality (Q)						
Q_1	8.57	8.44	7.03	6.48	7.05	7.76
Q_2	9.30	9.17	6.63	5.61	6.37	7.24
S.Em $\pm$	0.01	0.02	0.02	0.02	0.01	0.02
CD at 5 %	0.03	0.06	0.06	0.05	0.05	0.06
Priming treatments (T)						
T_1	9.01	8.84	6.74	5.85	6.68	7.65
T_2	8.94	8.84	6.82	6.13	6.77	7.48
T_3	9.07	8.88	6.40	5.40	6.30	7.45
T_4	8.81	8.63	7.27	6.44	6.88	7.47
T_5	8.91	8.83	6.75	6.12	6.73	7.42
T_6	8.89	8.82	6.98	6.31	6.90	7.53
S.Em $\pm$	0.02	0.04	0.04	0.04	0.03	0.04
CD at 5 %	0.05	0.11	0.11	0.10	0.09	0.11
Interactions (Q x T)						
Q_1T_1	8.64	8.46	6.82	6.11	6.83	7.68
Q_1T_2	8.58	8.48	6.98	6.62	7.20	7.89
Q_1T_3	8.75	8.55	6.56	5.65	6.47	7.48
Q_1T_4	8.44	8.22	7.75	7.04	7.34	7.85
Q_1T_5	8.53	8.47	6.86	6.60	7.12	7.76
Q_1T_6	8.51	8.46	7.20	6.84	7.32	7.87
Q_2T_1	9.39	9.23	6.67	5.59	6.53	7.63
Q_2T_2	9.30	9.19	6.66	5.64	6.34	7.06
Q_2T_3	9.39	9.21	6.25	5.15	6.13	7.43
Q_2T_4	9.17	9.03	6.78	5.84	6.41	7.08
Q_2T_5	9.29	9.18	6.64	5.65	6.34	7.07
Q_2T_6	9.28	9.18	6.76	5.79	6.48	7.19
Mean	8.94	8.81	6.83	6.04	6.71	7.50
S.Em $\pm$	0.03	0.05	0.05	0.05	0.04	0.05
CD at 5 %	NS	NS	0.15	0.14	0.13	0.15

Q_1: Seeds with germination above MSCS
Q_2: Seeds with germination marginally below MSCS
T_1: Control (dry unprimed seeds) T_3: KCl (100ppm) T_5: KH_2PO_4 (50 ppm)
T_2: Hydropriming T_4: $CaCl_2.2H_2O$ (0.5%) T_6: GA_3 (20ppm)

Table 12. Effect of seed priming treatments to different quality seeds on field emergence (%) in soybean

Treatments	Storage period (months)					
	Initial	1	2	3	4	5
Seed Quality (Q)						
Q_1	92.96 (74.86)	87.81 (69.68)	75.29 (60.25)	70.31 (57.03)	64.40 (53.41)	56.93 (49.01)
Q_2	67.40 (55.23)	62.54 (52.30)	49.44 (44.70)	44.56 (41.89)	38.74 (38.50)	31.23 (33.97)
S.Em $\pm$	0.21	0.14	0.10	0.06	0.04	0.06
CD at 5 %	0.61	0.41	0.30	0.18	0.11	0.18
Priming treatments (T)						
T_1	78.24 (63.23)	73.37 (59.61)	60.25 (55.15)	55.50 (48.29)	49.61 (44.79)	42.11 (40.33)
T_2	80.24 (65.33)	75.22 (61.16)	62.27 (52.46)	57.34 (49.43)	51.55 (45.95)	44.01 (41.45)
T_3	76.24 (61.74)	71.37 (58.26)	58.44 (50.05)	53.56 (47.13)	47.68 (43.65)	40.21 (39.17)
T_4	83.57 (67.61)	78.52 (63.24)	66.25 (54.81)	60.76 (51.42)	54.95 (47.94)	47.46 (43.53)
T_5	80.57 (65.68)	75.52 (61.39)	62.38 (52.54)	57.65 (49.63)	51.81 (46.10)	44.26 (41.58)
T_6	82.24 (66.70)	77.05 (62.26)	64.60 (53.84)	59.78 (50.86)	53.81 (47.28)	46.38 (42.88)
S.Em $\pm$	0.36	0.25	0.18	0.11	0.07	0.10
CD at 5 %	1.06	0.72	0.53	0.31	0.19	0.31
Interactions (Q x T)						
Q_1T_1	90.57 (72.16)	85.70 (67.82)	72.55 (58.43)	67.87 (55.50)	61.93 (51.93)	54.44 (47.57)
Q_1T_2	94.24 (76.16)	89.07 (70.73)	76.44 (60.99)	71.39 (57.69)	65.63 (54.13)	58.14 (49.71)
Q_1T_3	88.90 (70.58)	84.04 (66.48)	70.99 (57.44)	66.13 (54.44)	60.28 (50.96)	52.79 (46.62)
Q_1T_4	94.90 (76.99)	89.67 (71.29)	78.00 (62.06)	72.13 (58.17)	66.28 (54.53)	58.79 (50.09)
Q_1T_5	94.57 (76.64)	89.33 (70.99)	76.55 (61.07)	72.24 (58.21)	66.05 (54.39)	58.58 (49.97)
Q_1T_6	94.57 (76.64)	89.07 (70.14)	77.21 (61.52)	72.10 (57.14)	66.2 (54.50)	58.83 (50.11)

Treatments	Storage period (months)					
	Initial	1	2	3	4	5
Q_2T_1	65.90 (54.30)	61.04 (51.40)	47.99 (43.87)	43.13 (41.07)	37.28 (37.65)	29.79 (33.09)
Q_2T_2	66.24 (54.50)	61.37 (51.60)	48.10 (43.94)	43.28 (41.16)	37.48 (37.77)	29.94 (33.19)
Q_2T_3	63.57 (52.90)	58.70 (50.04)	45.88 (42.66)	40.98 (39.83)	35.08 (36.34)	27.63 (31.73)
Q_2T_4	72.24 (58.23)	67.37 (55.19)	54.44 (47.57)	49.39 (44.67)	43.63 (41.36)	36.14 (36.97)
Q_2T_5	66.57 (54.71)	61.70 (51.80)	48.21 (44.00)	43.10 (41.05)	37.56 (37.82)	29.94 (33.19)
Q_2T_6	69.90 (56.76)	65.04 (53.78)	51.99 (46.17)	47.47 (43.57)	41.39 (40.06)	33.93 (35.65)
Mean	80.18 (65.05)	75.18 (60.99)	62.36 (52.48)	57.47 (49.46)	51.57 (49.95)	44.08 (41.49)
S.Em $\pm$	0.51	0.35	0.26	0.15	0.09	0.15
CD at 5 %	1.50	1.01	0.74	0.44	0.27	0.43

* The figures in parenthesis are arc sine values.

Q_1: Seeds with germination above MSCS
Q_2: Seeds with germination marginally below MSCS
T_1: Control (dry unprimed seeds) T_3: KCl (100ppm) T_5: KH_2PO_4 (50 ppm)
T_2: Hydropriming T_4: $CaCl_2.2H_2O$ (0.5%) T_6: GA_3 (20ppm)

Table 13. Correlation coefficients of seed quality parameters during the storage period

Seed quality parameters	Speed of germination	Germination	Root length	Shoot length	Seedling vigour index	Seedling dry weight	Electrical condutivity	Field emergence
Speed of germination	-							
Germination	0.904	-						
Root length	0.909	0.811	-					
Shoot length	0.954	0.884	0.860	-				
Seedling vigour index	0.954	0.884	0.860	0.971	-			
Seedling dry weight	0.950	0.935	0.930	0.908	0.908	-		
Electrical condutivity	-0.947	-0.884	-0.948	-0.921	-0.921	-0.969	-	
Field emergence	0.904	0.973	0.811	0.884	0.884	0.935	-0.884	-
Speed of germination	-							
Germination	0.926	-						
Root length	0.834	0.737	-					
Shoot length	0.953	0.892	0.814	-				
Seedling vigour index	0.971	0.976	0.847	0.951	-			
Seedling dry weight	0.954	0.939	0.856	0.912	0.975	-		
Electrical condutivity	-0.941	-0.874	-0.900	-0.897	-0.946	-0.970	-	
Field emergence	0.917	0.999	0.732	0.888	0.973	0.932	-0.866	-

Seed quality parameters	Speed of germination	Germination	Root length	Shoot length	Seedling vigour index	Seedling dry weight	Electrical condutivity	Field emergence
	2nd month (March)							
Speed of germination	-							
Germination	0.921	-						
Root length	0.895	0.754	-					
Shoot length	0.967	0.903	0.868	-				
Seedling vigour index	0.966	0.979	0.863	0.957	-			
Seedling dry weight	0.958	0.922	0.946	0.946	0.977	-		
Electrical conductivity	-0.936	-0.885	-0.956	-0.930	-0.956	-0.991	-	
Field emergence	0.923	0.981	0.761	0.904	0.981	0.926	-0.890	-
	3rd month (April)							
Speed of germination	-							
Germination	0.919	-						
Root length	0.881	0.751	-					
Shoot length	0.956	0.923	0.872	-				
Seedling vigour index	0.950	0.977	0.861	0.974	-			
Seedling dry weight	0.959	0.921	0.943	0.968	0.977	-		
Electrical condutivity	-0.929	-0.882	-0.954	-0.961	-0.958	-0.991	-	
Field emergence	0.920	0.989	0.749	0.924	0.977	0.920	-0.880	-

Seed quality parameters	Speed of germination	Germination	Root length	Shoot length	Seedling vigour index	Seedling dry weight	Electrical condutivity	Field emergence
	4th month (May)							
Speed of germination	-							
Germination	0.960	-						
Root length	0.871	0.755	-					
Shoot length	0.894	0.764	0.883	-				
Seedling vigour index	0.984	0.963	0.892	0.888	-			
Seedling dry weight	0.975	0.924	0.943	0.893	0.986	-		
Electrical condutivity	-0.953	-0.882	-0.959	-0.912	-0.970	-0.993	-	
Field emergence	0.958	0.986	0.750	0.760	0.960	0.920	-0.878	-
	5th month (June)							
Speed of germination	-							
Germination	0.947	-						
Root length	0.913	0.770	-					
Shoot length	0.910	0.765	0.904	-				
Seedling vigour index	0.987	0.963	0.901	0.886	-			
Seedling dry weight	0.985	0.927	0.950	0.893	0.988	-		
Electrical condutivity	-0.981	-0.901	-0.950	-0.926	-0.978	-0.990	-	
Field emergence	0.943	0.956	0.759	0.760	0.959	0.920	-0.894	-

Note: r-values are significant at 1 % level

Table 14: Regression equations to predict soybean seed quality in storage

Seed assessment method	Selected treatment combinations	R^2	Regression equation
Speed of germination	High quality seeds treated with GA_3 (20ppm) (Q_1T_6)	0.987**	Y = -0.1679x + 68.235
	Low quality seeds treated with KCl (100ppm) (Q_2T_3)	0.969**	Y = -0.1581x + 42.363
Final germination	High quality seeds treated with $CaCl_2.2H_2O$ (0.5%) (Q_1T_4)	0.997**	Y = -0.2124x + 98.74
	Low quality seeds treated with KCl (100ppm) (Q_2T_3)	0.994**	Y = -0.2204x + 67.795
Root length	High quality seeds treated with $CaCl_2.2H_2O$ (0.5%) (Q_1T_4)	0.942**	Y = -0.0321x + 18.436
	Low quality seeds treated with KCl (100ppm) (Q_2T_3)	0.934**	Y = -0.0253x + 13.491
Shoot length	High quality seeds treated with GA_3 (20ppm) (Q_1T_6)	0.945**	$Y = -0.0003x^2 - 0.0019x + 15.187$
	Low quality seeds treated with KCl (100ppm) (Q_2T_3)	0.929**	$Y = -0.0003x^2 + 0.0134x + 6.6908$
Seedling dry weight	High quality seeds treated with $CaCl_2.2H_2O$ (0.5%) (Q_1T_4)	0.921**	Y = -0.1778x + 131.14
	Low quality seeds treated with KCl (100ppm) (Q_2T_3)	0.969**	Y = -0.2099x + 72.303
Seedling vigour index	High quality seeds treated with $CaCl_2.2H_2O$ (0.5%) (Q_1T_4)	0.994**	Y = -11.528x + 3169.8
	Low quality seeds treated with KCl (100ppm) (Q_2T_3)	0.988**	Y = -6.328x + 1375.2
Electrical conductivity	High quality seeds treated with $CaCl_2.2H_2O$ (0.5%) (Q_1T_4)	0.939**	y = 0.0081x + 0.0866
	Low quality seeds treated with KCl (100ppm) (Q_2T_3)	0.946**	y = 0.0082x + 0.936
Field emergence	High quality seeds treated with $CaCl_2.2H_2O$ (0.5%) (Q_1T_4)	0.982**	y = -0.1758x + 95.816
	Low quality seeds treated with KCl (100ppm) (Q_2T_3)	0.987**	= -0.1747x + 64.412

of storage significantly highest field emergence was recorded in Q_1T_4 (94.90 %) and was on par with Q_1T_6 (94.57 %), Q_1T_5 (94.57 %) and (94.24 %) (Q_1T_2) while the lowest field emergence was recorded in Q_2T_3 (63.57 %). At the end of five months of storage the highest field emergence was recorded in Q_1T_6 (58.58 %) which was on par with Q_1T_4 (58.79 %) and Q_1T_5 (58.58 %) and the lowest field emergence was recorded in Q_2T_3 (27.63 %).

Correlation Matrix: Correlation analysis of the data of five months storage revealed that seed quality parameters were highly correlated with each other. All r-values were significant at 1 % level.

At initial month of storage the speed of germination was highly and positively correlated with the seedling vigour index (r=0.954**) and shoot length (r=0.954**), followed by seedling dry weight (r=0.950**), root length (r=0.909**) germination (r=0.904**) and field emergence (r=0.904**). A higher and negative correlation was also recorded with electrical conductivity (r=-0.947**). A similar trend was noticed through out the storage period.

At initial month of storage the germination was highly and positively correlated with field emergence (r= 0.973**), followed by seedling dry weight (r=0.935**), shoot length (0.884**), seedling vigour index (r=0.884**) and root length (r=0.811**). A strong inverse relationship was also recorded with electrical conductivity (r=-0.884**.). A similar trend was noticed through out the storage period.

Prediction of primed soybean seed quality in storage given a particular time: The treatment combinations which performed best (Q_1T_4 or Q_1T_6) and least (Q_2T_3) showed linear regression equations (except in shoot length) as shown in the table. The speed of germination, standard germination, root length, seedling dry weight, seedling vigour index, electrical conductivity and field emergence were found to exhibit a linear regression equation in both the best and poor performing treatment combinations at R^2 , (0.987**, 0.969**), (0.997**, 0.994**), (0.942**, 0.934**), (0.921**, 0.969**), (0.994**, 0.988**), (0.939**, 0.946**), (0.982**, 0.987**). However, the shoot length exhibited a polynomial equation at R^2 (0.945**, 0.929**).

4.3 Experiment III: Effect of seed quality and priming treatments on seed yield and quality of soybean

4.3.1 Crop establishment and growth parameters

4.3.1.1 Field emergence (%)

The results on field emergence percentage as influenced by seed quality, seed priming and their interaction effects are presented in Table 15.

The field emergence percentage differed significantly due to seed quality. Significantly higher field emergence (89.44 %) was recorded in seeds of higher quality (Q_1) over those seeds of lower quality (Q_2) (65.94 %).

The field emergence percentage due to seed priming treatments was significantly influenced. Significantly highest field emergence was recorded in seeds primed with $CaCl_2.2H_2O$ (0.5%) (T_4) (82.83 %), followed by GA3 (20ppm) (T_6) (79.50 %) and KH_2PO_4 (50 ppm) (T_5) (78.33 %) primed seeds while the lowest field emergence was recorded in seeds primed with KCl (100ppm) (T_3) (72.50 %).

The field emergence percentage showed significant difference due to interaction of seed quality and seed priming treatments. Significantly highest field emergence was recorded in Q_1T_4 (93.00 %) and was on par with Q_1T_6 (92.00 %), followed by Q_1T_5 (90.06 %) and the lowest field emergence was recorded in Q_2T_3 (65.00 %).

4.3.1.2 Days to 50 per cent emergence

The results on days to 50 per cent emergence as influenced by seed quality, seed priming and their interaction effects are presented in Table 15.

Days to 50 per cent emergence differed significantly due to seed quality. Significantly lower number of days to 50 per cent emergence was recorded in seeds of higher quality (Q_1) (7.33) when compared to those seeds of lower quality (Q_2) (8.94).

Q_1T_1

Q_1T_2

Q_1T_3

Q_1T_4

Q_1T_5

Q_1T_6

Plate 3. Effect of seed priming on emergence of high quality seeds

Q_2T_1

Q_2T_2

Q_2T_3

Q_2T_4

Q_2T_5

Q_2T_6

Plate 4. Effect of seed priming on emergence of low quality seeds

Table 15. Effect of seed priming treatments to different quality seeds on field emergence (%), days to 50 per cent emergence, emergence m^{-2} and leaf area index in soybean

Treatments	Field Emergence (%)	Days to 50 % Emergence	Emergence m^{-2}	Leaf area index (LAI)
Seed quality (Q)				
Q_1	89.44 (71.32)	7.33	27.22	2.97
Q_2	65.94 (54.36)	8.94	19.78	2.38
S.Em+	0.23	0.10	0.10	0.01
CD at 5%	0.68	0.29	0.29	0.02
Priming chemicals (T)				
T_1	75.50 (61.12)	8.50	22.50	2.59
T_2	77.50 (62.71)	8.17	23.50	2.68
T_3	72.50 (58.96)	9.67	22.00	2.50
T_4	82.83 (66.62)	7.50	25.33	2.79
T_5	78.33 (63.33)	8.00	23.67	2.70
T_6	79.50 (64.30)	7.00	24.00	2.75
S.Em+	0.40	0.17	0.17	0.01
CD at 5%	1.17	0.50	0.50	0.04
Interaction (Q x T)				
Q_1T_1	87.00 (69.07)	8.00	26.00	2.87
Q_1T_2	90.00 (71.66)	7.67	27.00	2.95
Q_1T_3	84.00 (66.54)	8.33	25.67	2.80
Q_1T_4	93.00 (74.72)	6.67	29.67	3.12
Q_1T_5	90.67 (72.28)	7.33	27.33	2.98
Q_1T_6	92.00 (73.63)	6.00	27.67	3.07
Q_2T_1	64.00 (53.18)	9.00	19.00	2.31
Q_2T_2	65.00 (53.76)	8.67	20.00	2.41
Q_2T_3	61.00 (51.38)	11.00	18.33	2.21
Q_2T_4	72.67 (58.52)	8.33	21.00	2.46
Q_2T_5	66.00 (54.37)	8.67	20.00	2.43
Q_2T_6	67.00 (54.97)	8.00	20.33	2.44
Mean	77.69 (62.84)	8.14	23.50	2.67
S.Em+	0.56	0.24	0.24	0.02
CD at 5%	1.66	0.70	0.71	0.06

* The figures in parenthesis are arc sine values.

Q_1: Seeds with germination above MSCS
Q_2: Seeds with germination marginally below MSCS
T_1: Control (dry unprimed seeds) T_3: KCl (100ppm) T_5: KH_2PO_4 (50 ppm)
T_2: Hydropriming T_4: $CaCl_2.2H_2O$ (0.5%) T_6: GA_3 (20ppm)

Days to 50 per cent emergence due to seed priming treatments was significantly influenced. Significantly minimum days to 50 per cent emergence was recorded in seeds primed with GA_3 (20ppm) (T_6) (7.00) and was on par with seeds primed with $CaCl_2.2H_2O$ (0.5%) (T_4) (7.50), followed by seeds primed with KH_2PO_4 (50 ppm) (T_5) (8.00) while significantly increased days to 50 per cent emergence was recorded in seeds primed with KCl (100ppm) (T_3) (9.67).

Days to 50 per cent emergence percentage showed significant difference due to interaction of seed quality and seed priming treatments. Significantly lowest days to 50 per cent emergence was recorded in Q_1T_6 (6.00) and was on par with Q_1T_4 (6.67) and Q_1T_5 (7.33) and increased days to 50 per cent emergence was recorded in Q_2T_3 (11.00).

4.3.1.3 Emergence per square meter

The results on emergence per square meter as influenced by seed quality, seed priming and their interaction effects are presented in Table 15.

Emergence per square meter differed significantly due to seed quality. Significantly higher emergence per square meter was recorded in seeds of higher quality (Q_1) (27.22) against the lower emergence per square meter recorded in seeds of lower quality (Q_2) (19.78).

Emergence per square meter due to seed priming treatments was significantly influenced. Significantly highest emergence per square meter was recorded in seeds primed with $CaCl_2.2H_2O$ (0.5%) (T_4) (25.33), followed by seeds primed with GA_3 (20ppm) (T_6) (24.00) and KH_2PO_4 (50 ppm) (T_5) (23.67), while the lowest emergence per square meter was recorded in seeds primed with KCl (100ppm) (T_3) (22.00).

The interaction effect also showed significant difference with the highest emergence per square meter recorded in Q_1T_4 (29.67), followed by Q_1T_6 (27.67) and Q_1T_5 (27.33), while lowest emergence per square meter was recorded in Q_2T_3 (18.33).

4.3.1.4 Plant height at 30 and 60 DAS

4.3.1.4.1 Plant height at 30 DAS

The results on plant height at 30 and 60 DAS as influenced by seed quality, seed priming and their interaction effects are presented in Table 16.

The plant height at 30 DAS differed significantly due to seed quality. Significantly higher plant height was recorded in plots having sown with seeds of higher quality (Q_1) (26.58 cm) as compared to the lower plant height recorded plots having sown with seeds of lower quality (Q_2) (22.56 cm).

The plant height showed significant difference due to seed priming treatments. Significantly highest plant height was recorded in plots having seed primed with GA_3 (20ppm) (T_6) (27.30 cm), followed by plots having sown with $CaCl_2.2H_2O$ (0.5%) (T_4) (25.13 cm) and (24.60 cm) KH_2PO_4 (50 ppm) (T_5) primed seeds while the lowest plant height was recorded in plots having seed primed with KCl (100ppm) (T_3) (22.50 cm).

The plant height showed significant difference due to interaction of seed quality and seed priming treatments. Significantly highest plant height was recorded in Q_1T_6 (31.33 cm), followed by Q_1T_4 (27.20 cm) and Q_1T_5 (26.53 cm) and the lowest plant height was recorded in Q_2T_3 (21.67 cm).

4.3.1.4.2 Plant height at 60 DAS

The plant height at 60 DAS differed significantly due to seed quality. Significantly higher plant height was recorded plots having sown with seeds of lower quality (Q_1) (41.32 cm) when compared to the lower plant height recorded in plots having sown with seeds of lower quality (Q_2) (37.06 cm).

The plant height showed significant difference due to seed priming treatments. Significantly highest plant height was recorded in plots having seed primed with $CaCl_2.2H_2O$ (0.5%) (T_4) (43.33 cm), which was on par with those plots having seed primed with GA_3 (20ppm) (T_6) (41.87 cm) followed by plots having seed primed with KH_2PO_4 (50 ppm) (T_5)

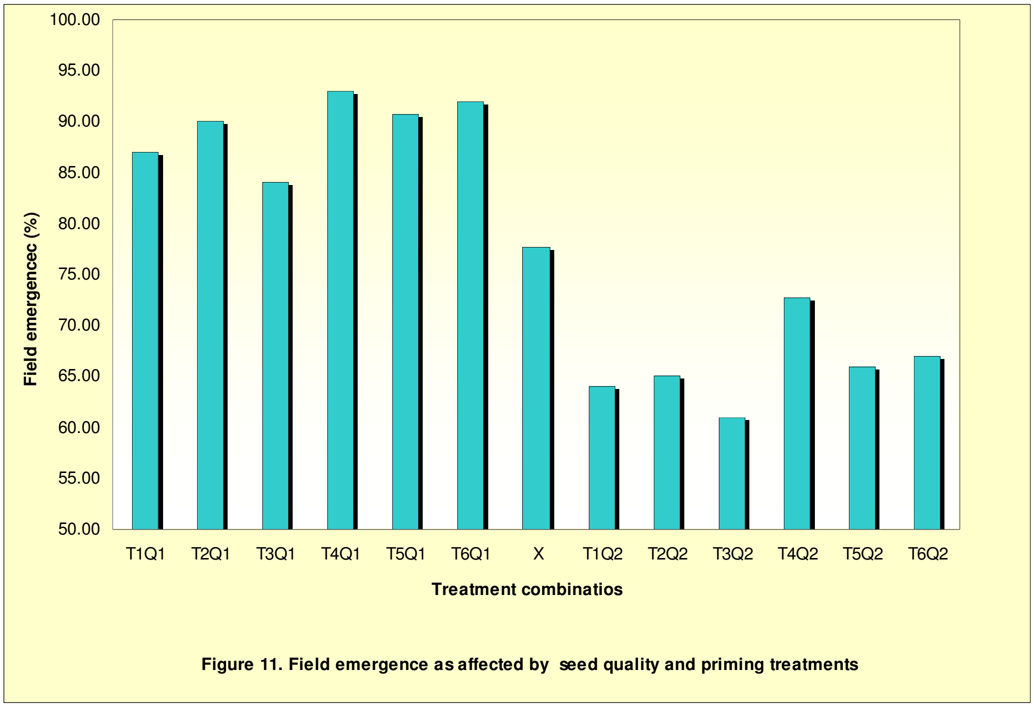

Figure 11. Field emergence as affected by seed quality and priming treatments

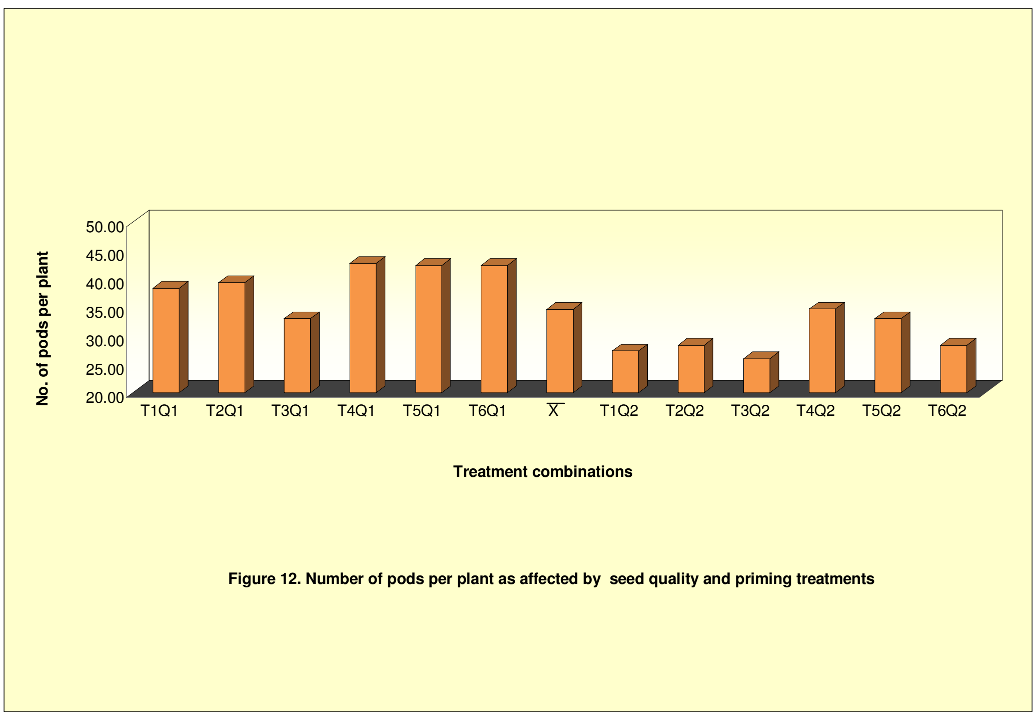

Figure. 12. Number of pods per plant as affected by seed quality and priming treatments

Table 16. Effect of seed priming treatments to different quality seeds on relative water content, plant height (30 and 60 DAS) and number of days to 50 per cent flowering in soybean

Treatments	Relative water content (RWC) (%)	Plant height (cm)		Days to 50%flowering
		30 DAS	60 DAS	
Seed quality (Q)				
Q_1	87.04 (69.04)	26.58	41.32	40.00
Q_2	80.19 (63.80)	22.56	37.06	40.89
S.Em+	0.32	0.34	0.33	0.10
CD at 5%	0.94	1.00	0.96	0.29
Priming chemicals (T)				
T_1	80.09 (63.73)	23.80	36.98	41.67
T_2	83.20 (66.01)	24.07	38.63	40.50
T_3	79.02 (62.92)	22.50	34.90	42.50
T_4	87.85 (69.80)	25.13	43.33	38.33
T_5	86.96 (68.96)	24.60	39.43	40.17
T_6	84.57 (67.09)	27.30	41.87	39.50
S.Em+	0.56	0.59	0.57	0.17
CD at 5%	1.63	1.73	1.66	0.51
Interaction (Q x T)				
Q_1T_1	85.22 (67.43)	25.40	39.60	41.67
Q_1T_2	86.28 (68.45)	25.67	39.93	40.00
Q_1T_3	83.74 (66.26)	23.33	36.20	42.33
Q_1T_4	90.40 (71.98)	27.20	46.47	37.67
Q_1T_5	88.77 (70.47)	26.53	40.67	39.67
Q_1T_6	87.81 (69.67)	31.33	45.07	38.67
Q_2T_1	74.96 (60.04)	22.20	34.37	41.67
Q_2T_2	80.12 (63.58)	22.47	37.33	41.00
Q_2T_3	74.29 (59.59)	21.67	33.60	42.67
Q_2T_4	85.30 (67.61)	23.07	40.20	39.00
Q_2T_5	85.16 (67.45)	22.67	38.20	40.67
Q_2T_6	81.33 (64.52)	23.27	38.67	40.33
Mean	83.62 (66.42)	24.57	39.19	40.44
S.Em$\pm$	0.79	0.83	0.80	0.24
CD at 5%	2.30	2.44	2.35	0.72

* Figures in parenthesis are arc sine values

Q_1: Seeds with germination above MSCS
Q_2: Seeds with germination marginally below MSCS
T_1: Control (dry unprimed seeds) T_3: KCl (100ppm) T_5: KH_2PO_4 (50 ppm)
T_2: Hydropriming T_4: $CaCl_2.2H_2O$ (0.5%) T_6: GA_3 (20ppm)

(39.43 cm), while the lowest plant height was recorded in plots having seed primed with KCl (100ppm) (T_3) (34.90 cm).

The plant height showed significant difference due to interaction of seed quality and seed priming treatments. Significantly highest plant height was recorded in Q_1T_4 (46.47 cm) which was on par with Q_1T_6 (45.07 cm), followed by Q_1T_5 (40.67 cm) and the lowest plant height was recorded in Q_2T_3 (33.60 cm).

4.3.1.5 Days to 50 per cent flowering

The results on days to 50 per cent flowering as influenced by seed quality, seed priming and their interaction effects are presented in Table 16.

The days to 50 per cent flowering was significantly influenced due to seed quality. Significantly lesser number of days to 50 per cent flowering was recorded in plots having sown with seeds of higher quality (Q_1) (40.00) when compared with those sown with seeds of lower quality (Q_2) (40.89).

The number of days to 50 per cent flowering showed significant difference due to seed priming treatments. Significantly minimum number of days to 50 per cent flowering was recorded in plots having seed primed with $CaCl_2.2H_2O$ (0.5%) (T_4) (38.33), followed by those plots having seed primed with GA3 (20ppm) (T_6) (39.50) and KH_2PO_4 (50 ppm) (T_5) (40.17), while maximum number of days to 50 per cent flowering was recorded in plots having seed primed with KCl (100ppm) (T_3) (42.50).

The number of days to 50 per cent flowering showed significant difference due to interaction of seed quality and seed priming treatments. The minimum number of days to 50 per cent flowering was recorded in Q_1T_4 (37.66), which was on par with Q_1T_6 (38.67), followed by Q_2T_4 (39.00) and the maximum number of days to 50 per cent flowering was recorded in Q_2T_3 (42.67).

4.3.2 Physiological parameters

4.3.2.1 Leaf area index (LAI)

The results on leaf area index as influenced by seed quality, seed priming and their interaction effects are presented in Table 15.

The leaf area index differed significantly due to seed quality. Significantly higher leaf area index was recorded in plots having sown with seeds of higher seed quality (Q_1) (2.97) when compared to the lower leaf area index recorded in plots having sown with seeds of lower quality (Q_2) (2.38).

The leaf area index showed significant difference due to seed priming treatments as well. Significantly highest leaf area index was recorded in plots having seed primed with $CaCl_2.2H_2O$ (0.5%) (T_4) (2.79) which was on par with the leaf area index recorded in plots having seed primed with GA_3 (20ppm) (T_6) (2.75), followed by plots having seed primed with KH_2PO_4 (50 ppm) (T_5) (2.70), while the lowest leaf area index (2.50) was recorded in plots having seed primed with KCl (100ppm) (T_3).

The leaf area index showed significant difference due to interaction of seed quality and seed priming treatments. Significantly highest leaf area index was recorded in Q_1T_4 (3.12) which was on par with Q_1T_6 (3.07), followed by Q_1T_5 (2.98) and the lowest leaf area index was recorded in Q_2T_3 (2.21).

4.3.2.2 Relative water content (RWC) (%)

The results on relative water content as influenced by seed quality, seed priming and their interaction effects are presented in Table 16.

The relative water content differed significantly due to seed quality. Significantly higher relative water content was recorded in plots having sown with seeds of higher quality (Q_1) (87.04 %) against the lower relative water content recorded in plots having sown with seeds of lower quality (Q_2) (80.19 %).

The relative water content showed significant difference due to seed priming treatments. Significantly highest relative water content was recorded in plots having seed

Table 17. Effect of seed priming treatments to different quality seeds on number of pods per plant, number of seeds per plant, seed yield per plant, seed yield per plot, seed yield per hectare and hundred seed weight in soybean

Treatments	No. of pods/ plant	No. Seeds/ pod	Seed yield (g/plant)	Seed yield (Kg/plot)	Seed yield (q/ha)	100 Seed weight (g)
Seed quality (Q)						
Q_1	39.67	2.57	12.68	2.03	21.16	12.36
Q_2	29.61	2.26	8.20	1.76	18.34	12.99
S.Em±	0.40	0.01	0.09	0.02	0.18	0.15
CD at 5%	1.16	0.04	0.27	0.05	0.52	0.44
Priming Chemicals (T)						
T_1	32.83	2.32	9.70	1.72	17.90	12.88
T_2	33.83	2.40	10.33	1.87	19.44	12.96
T_3	29.50	2.23	8.54	1.67	17.44	13.46
T_4	38.67	2.58	12.05	2.07	21.61	11.99
T_5	37.67	2.42	10.97	2.01	20.97	12.69
T_6	35.33	2.52	11.06	2.03	21.11	12.04
S.Em+	0.69	0.02	0.16	0.03	0.31	0.26
CD at 5%	2.01	0.07	0.47	0.09	0.90	0.76
Interaction (Q x T)						
Q_1T_1	38.33	2.47	11.56	1.86	19.36	12.29
Q_1T_2	39.33	2.60	12.69	1.92	20.00	12.59
Q_1T_3	33.00	2.33	10.07	1.79	18.67	13.10
Q_1T_4	42.67	2.70	14.54	2.27	23.67	12.63
Q_1T_5	42.33	2.63	13.49	2.15	22.38	12.50
Q_1T_6	42.33	2.67	13.71	2.20	22.89	11.02
Q_2T_1	27.33	2.17	7.84	1.58	16.44	13.47
Q_2T_2	28.33	2.20	7.97	1.81	18.89	13.33
Q_2T_3	26.00	2.13	7.01	1.56	16.22	13.82
Q_2T_4	34.67	2.47	9.55	1.88	19.56	11.35
Q_2T_5	33.00	2.20	8.45	1.88	19.57	12.89
Q_2T_6	28.33	2.37	8.40	1.86	19.33	13.06
Mean	34.64	2.41	10.44	1.90	19.75	12.67
S.Em+	0.97	0.03	0.22	0.04	0.43	0.37
CD at 5%	2.85	0.10	0.66	0.12	1.27	1.07

Q_1: Seeds with germination above MSCS
Q_2: Seeds with germination marginally below MSCS
T_1: Control (dry unprimed seeds) T_3: KCl (100ppm) T_5: KH_2PO_4 (50 ppm)
T_2: Hydropriming T_4: $CaCl_2.2H_2O$ (0.5%) T_6: GA_3 (20ppm)

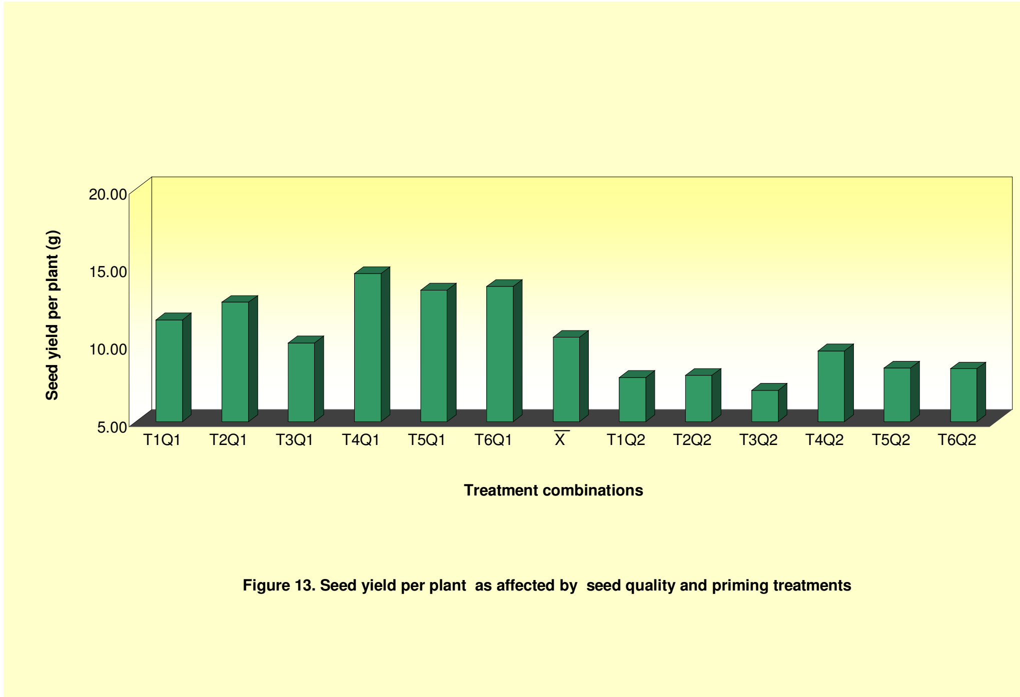

Figure 13. Seed yield per plant as affected by seed quality and priming treatments

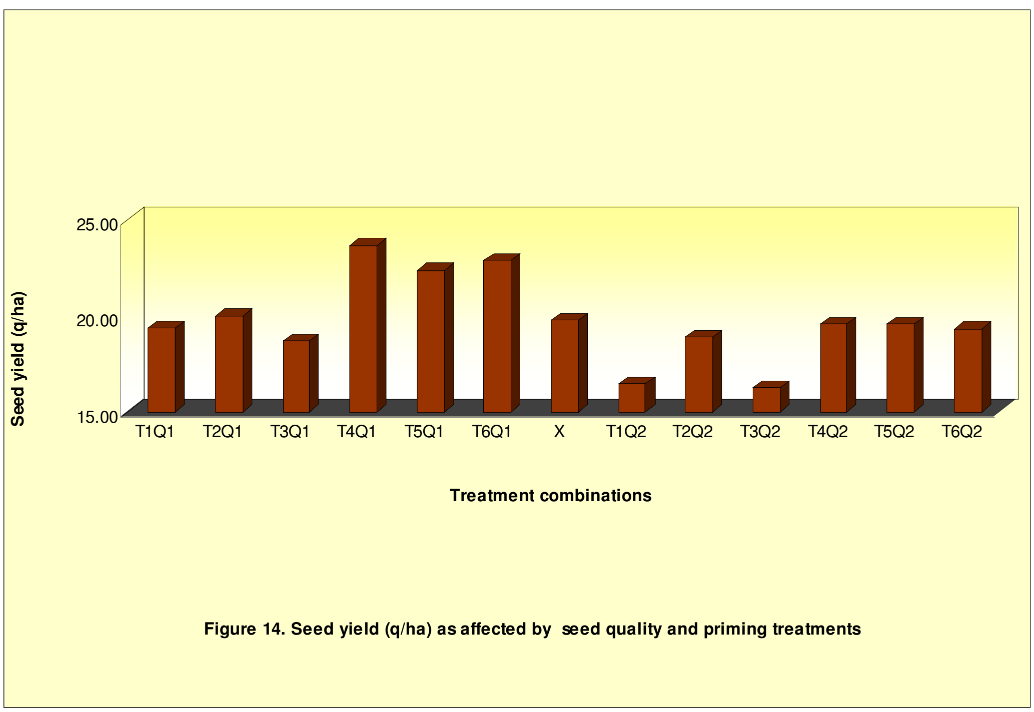

Figure. 14. Seed yield (q/ha) as affected by seed quality and priming treatments

primed with $CaCl_2.2H_2O$ (0.5%) (T_4) (87.85 %), which was on par with plots having seed treated with KH_2PO_4 (50 ppm) (T_5) (86.95 %), followed by plots having seed primed GA_3 (20ppm) (T_6) (84.57 %), while the lowest relative water content was recorded in plots having seed primed with KCl (100ppm) (T_3) (79.02 %).

The relative water content showed significant difference due to interaction of seed quality and seed priming treatments. Significantly highest relative water content was recorded in Q_1T_4 (90.40 %), which was on par with Q_1T_5 (88.77 %), followed by Q_1T_6 (87.81 %) and the lowest relative water content was recorded in Q_2T_3 (74.29 %).

4.3.3 Yield and Yield Components

4.3.3.1 Number of pods per plant

The results on number of pods per plant as influenced by seed quality, seed priming and their interaction effects are presented in Table 17.

The number of pods per plant was significantly influenced due to seed quality. Significantly higher number of pods per plant was recorded in plots having sown with seeds of higher seed quality (Q_1) (39.67) as judged against the lower number of pods per plant recorded in plots having sown with seeds of lower quality (Q_2) (29.61).

The number of pods per plant showed significant difference due to seed priming treatments. Significantly highest number of pods per plant was recorded in plots having seed primed with $CaCl_2.2H_2O$ (0.5%) (T_4) (38.67), which was on par with plots having seed primed with KH_2PO_4 (50 ppm) (T_5) (37.67), followed by plots having seed primed GA3 (20ppm) (T_6) (35.33), while the lowest number of pods per plant was observed in plots having seed primed with KCl (100ppm) (T_3) (29.50).

The number of pods per plant was significantly influenced due to interaction of seed quality and seed priming treatments. Significantly highest number of pods per plant was recorded in Q_1T_4 (42.67) which was on par with Q_1T_5 (42.33 %) and Q_1T_6 (42.33) and the lowest number of pods per plant was recorded in Q_2T_3 (26.00).

4.3.3.2 Number of seeds per pod

The results on number of seeds per pod as influenced by seed quality, seed priming and their interaction effects are presented in Table 17.

The number of seeds per pod was significantly influenced due to seed quality. Significantly higher number of seeds per pod was recorded in plots having sown with seeds of higher quality (Q_1) (2.57) when compared with the lower number of seeds per pod recorded in plots having sown with seeds of lower quality (Q_2) (2.26).

The number of seeds per pod showed significant difference due to seed priming treatments. Significantly highest number of seeds per pod was recorded in plots having seed primed with $CaCl_2.2H_2O$ (0.5%) (T_4) (2.58) which was on par withthe plots having seed primed with GA_3 (20ppm) (T_6) (2.52) followed by KH_2PO_4 (50 ppm) (T_5) (2.42) primed seeds and lowest number of seeds per pod was recorded in plots having seed primed with KCl (100ppm) (T_3) (2.23).

The number of seeds per pod was significantly influenced due to interaction of seed quality and seed priming treatments. Significantly highest number of seeds per pod was recorded in Q_1T_4 (2.70) which were on par with Q_1T_6 (2.67) and Q_1T_5 (2.63) and the lowest number of seeds per pod was recorded in Q_2T_3 (2.13).

4.3.3.3 Seed yield per plant (g)

The results on seed yield per plant as influenced by seed quality, seed priming and their interaction effects are presented in Table 17.

The seed yield per plant was significantly influenced due to seed quality. Significantly higher seed yield per plant was recorded in plots having sown with seeds of higher quality (Q_1) (12.68 g) over those plots having sown with seeds of lower quality (Q_2) (8.20 g).

The seed yield per plant showed significant difference due to seed priming treatments. Significantly highest seed yield per plant was recorded in plots having seed rimed

Table 18: Correlation coefficients of field parameters

	Field emergence (%)	Days to 50% emergence	Emergence m^{-2}	LAI	RWC	Plant height 30 DAS	Plant height 60 DAS	Days to 50% flowering	No. pods /plant	No. Seeds /pod	Yield /plant (g)	Yield /plot (Kg)	Yield /ha (q)	100 Seed wt (g)
Field emergence (%)	-													
Days to 50% emergence	-0.806	-												
Emergence m^{-2}	0.990	-0.807	-1											
LAI	0.989	-0.851	0.995	-										
RWC	0.835	-0.845	0.836	0.856	-									
Plant height 30 DAS	0.834	-0.867	0.823	0.863	0.722	-								
Plant height 60 DAS	0.756	-0.894	0.776	0.804	0.871	0.847	-							
Days to 50% flowering	-0.538^{ns}	0.785	-0.553^{ns}	-0.583^{ns}	-0.754	-0.667*	-0.911	-						
No.pods/plant	0.940	-0.834	0.925	0.940	0.920	0.859	0.858	-0.703*	-					
No.Seeds/pod	0.915	-0.866	0.901	0.913	0.868	0.858	0.890	-0.788	0.934	-				
Yield /plant (g)	0.968	-0.855	0.969	0.976	0.868	0.884	0.860	-0.699*	0.973	0.959	-			
Yield /plot (Kg)	0.790	-0.898	0.815	0.842	0.920	0.837	0.953	-0.863	0.888	0.887	0.886	-		
Yield /ha (q)	0.840	-0.903	0.856	0.873	0.905	0.864	0.959	-0.869	0.909	0.933	0.921	-	-	
100 Seed wt (g)	-0.580*	0.711	-0.608*	-0.555*	-0.687*	-0.716	-0.727	0.681*	-0.700*	-0.711	-0.610*	-0.644*	-0.696*	-

Note: Unless specified r-values are significant a 1% level with $CaCl_2.2H_2O$ (0.5%) (T_4) (12.05 g), followed by the plots having seed primed with GA_3 (20ppm) (T_6) (11.06 g) and KH_2PO_4 (50 ppm) (T_5) (10.96 g) while the lowest seed yield per plant was recorded in plots having seed primed with KCl (100ppm) (T_3) (8.54 g).

The seed yield per plant was significantly influenced due to interaction of seed quality and seed priming treatments. Significantly highest seed yield per plant was recorded in Q_1T_4 (14.54 g), followed by Q_1T_6 (13.71 g) and Q_1T_5 (13.49 g) and the lowest seed yield per plant was recorded in Q_2T_3 (7.01 g).

4.3.3.4 Seed yield per plot (Kg)

The results on seed yield per plot as influenced by seed quality, seed priming and their interaction effects are presented in Table 17.

The seed yield per plot was significantly influenced due to seed quality. Significantly higher seed yield per plot was recorded in plots having sown with seeds of higher quality (Q_1) (2.03 Kg) as compared to the plots having sown with seeds of lower quality (Q_2) (1.73 Kg).

The seed yield per plot showed significant difference due to seed priming treatments. Significantly highest seed yield per plot was recorded in plots having seed primed with $CaCl_2.2H_2O$ (0.5%) (T_4) (2.07 Kg) which was on par with plots having seed primed with GA_3 (20ppm) (T_6) (2.03 Kg) and KH_2PO_4 (50 ppm) (T_5) (2.01 Kg), while the lowest seed yield per plot was recorded in plots having seed primed with KCl (100ppm) (T_3) (1.67 Kg).

The seed yield per plot was significantly influenced due to interaction of seed quality and seed priming treatments. Significantly highest seed yield per plot was recorded in Q_1T_4 (2.27 Kg) which was on par with Q_1T_6 (2.20 Kg) and Q_1T_5 (2.15 Kg) and the lowest seed yield per plot was recorded in Q_2T_3 (1.56 Kg).

4.3.3.5 Seed yield (q/ha)

The results on seed yield per hectare as influenced by seed quality, seed priming and their interaction effects are presented in Table 17.

The seed yield per hectare was significantly influenced due to seed quality. Significantly higher seed yield per hectare was recorded in plots having sown with seeds of higher quality (Q_1) (21.16 q/ha) against the lower seed yield per hectare obtained in plots having sown with seeds of lower quality (Q_2) (18.34 q/ha).

The seed yield per hectare showed significant difference due to seed priming treatments. Significantly highest seed yield per hectare was recorded in plots having seed primed with $CaCl_2.2H_2O$ (0.5%) (T_4) (21.61 q/ha), which was on par with plots having seed primed with GA_3 (20ppm) (T_6) (21.11 q/ha) and KH_2PO_4 (50 ppm) (T_5) (20.58 q/ha) while the lowest seed yield per hectare was recorded in plots having seed primed with KCl (100ppm) (T_3) (17.44 q/ha).

The seed yield per hectare was significantly influenced due to interaction of seed quality and seed priming treatments. Significantly highest seed yield per hectare was recorded in Q_1T_4 (23.67 q/ha), which was on par with Q_1T_6 (22.89 q/ha), followed Q_1T_5 (22.38 q/ha) and the lowest seed yield per hectare was recorded in Q_2T_3 (16.22 q/ha).

4.3.3.6 Hundred seed weight (g)

The results on hundred seed weight as influenced by seed quality, seed priming and their interaction effects are presented in Table 17.

Hundred seed weight was significantly influenced due to seed quality. Significantly higher hundred seed weight was recorded in plots having sown with seeds of lower quality (Q_2) (12.99 g) when compared with plots having sown with seeds of higher quality (Q_1) (12.36 g).

The hundred seed weight showed significant difference due to seed priming treatments. Significantly highest hundred seed weight was recorded in plots having seed primed with KCl (100ppm) (T_3) (13.46 g), which was on par with plots having seed hydroprimed (T_2) (12.96 g) and unprimed controlled (T_1) (12.88 g), while the lowest hundred seed weight was recorded in plots sown with ($CaCl_2.2H_2O$ (0.5%) (T_4) (11.99 g) primed seeds.

The hundred seed weight was significantly influenced due to interaction of seed quality and seed priming treatments. Significantly highest hundred seed weight was recorded in Q_2T_3 (13.83 g), which was on par with Q_2T_1 (13.47 g) and Q_2T_2 (13.33 g), while the lowest hundred seed weight was recorded in Q_1T_6 (11.02 g).

Correlation matrix: Seed yield (q/ha) showed very high positive and significant correlation with field emergence (0.840^{**}), emergence per m^{-2} (0.856^{**}), LAI (0.873^{**}), RWC (0.905^{**}), plant height 30 DAS (0.864^{**}), plant height 60 DAS (0.959^{**}), number of pods per plant (0.909^{**}), number of seeds per pod (0.933^{**}), yield per plant (0.921^{**}) and yield /plot (1.00^{**}). More over, days to 50% emergence ($-0.90.3^{**}$), days to 50% flowering (-0.869^{**}) and 100 seed weight (-0.696^{*}) were also significantly correlated with seed yield (q/ha).

4.3.4 Seed quality parameters

4.3.4.1 Germination (%)

The data on the influence of seed quality, seed priming and their interaction effects on the germination percentage of the resultant seeds are presented in Table 19.

The germination percentage of the seeds harvested from primed seeds did not show significant difference due to seed quality, priming treatments and their interaction effect. Nevertheless, higher germination percentage was recorded by seeds raised from seeds of lower quality (Q_2) (97.56 %) as compared with seeds harvested from plots having sown with higher seed quality (Q_1) (97.39 %). With respect to the priming treatments, the seeds harvested from plots having seeds primed with $CaCl_2.2H_2O$ (0.5%) (T_4) (97.83 %) recorded non-significantly highest germination percentage, followed by the resultant seeds harvested from plots having seeds primed with GA_3 (20ppm) (T_6) (97.50 %) and KH_2PO_4 (50 ppm) (T_5) (97.50 %), while the lowest germination was observed in plots having seeds primed KCl (100ppm) (97.17 %). The interaction effect also showed non-significant difference on germination of the resultant seeds. Yet, Q_2T_4 (98.00 %) recorded highest germination percentage, followed by Q_1T_4 (97.61 %) and Q_2T_6 (97.67 %), while the lowest value was recorded in Q_2T_1 and Q_1T_3 (97.00 %).

4.3.4.2 Root length (cm)

The data on the influence of seed quality, seed priming and their interaction effects on the root length of the resultant seeds are presented in Table 19.

Seed quality and the interaction effect had no significant influence on the root length of the resultant seed, conversely seed priming showed a significant effect. The seeds obtained from lower quality seeds (Q_2) (18.66 cm) recorded higher root length over those obtained from higher quality seeds (Q_1) (18.58 cm). However, on the other hand, priming treatments showed a significant influence on root length of the resultant seed with seeds harvested from plots having seeds primed with $CaCl_2.2H_2O$ (0.5%) (T_4) recorded the highest root length (19.56 cm), followed by those harvested from seed having primed with GA_3 (20ppm) (T_6) (18.55 cm) and KH_2PO_4 (50 ppm) (T_5) (18.53 cm) and the lowest root length was recorded in seeds harvested from plots having seeds unprimed (T_1) (18.30 cm). The interaction effect had also non-significant effect on root length of the resultant seed with Q_2T_4 (19.88 cm) recording the highest root length, followed by Q_1T_4 (19.26 cm) and Q_2T_5 (18.71 cm), while the lowest was recorded in Q_2T_1 (18.08 cm).

4.3.4.3 Shoot length (cm)

The data on the influence of seed quality, seed priming and their interaction effects on the root length of the resultant seeds are presented in Table 19.

Seed quality and the interaction effect had no significant influence on the shoot length of the resultant seed, conversely seed priming showed a significant effect. The seeds obtained from lower quality seeds (Q_2) recorded higher shoot length (15.21 cm) over those obtained from lower quality seeds (Q_1) (15.03 cm). However, on the other hand, priming treatments showed a significant influence on shoot length of the resultant seed with seeds harvested from plots having seed primed with $CaCl_2.2H_2O$ (0.5%) (T_4) (15.59 cm) recording the highest shoot length and was on par with those harvested from plots having seed primed with GA_3 (20ppm) (T_6) (15.55 cm) and KH_2PO_4 (50 ppm) (T_5) (15.16 cm) and the lowest shoot length was equally recorded in seeds harvested from plots having seed treated with KCl

Table 19: Seed germination (%), root length (cm), shoot length (cm), Vigour index, seedling dry weight (mg), electrical conductivity (dSm^{-1}) as influenced by priming treatments applied to different quality seeds

Treatments	Germination (%)	Root length (cm)	Shoot length (cm)	SVI	Seedling dry weight (mg)	EC (dSm^{-1})
Seed Quality (Q)						
Q_1	97.39 (80.80)	18.58	15.03	3273	109.65	0.324
Q_2	97.56 (81.21)	18.66	15.21	3304	110.12	0.321
S.Em±	0.31	0.11	0.10	16	0.17	0.003
CD at 5%	NS	NS	NS	NS	NS	NS
Priming treatments (T)						
T_1	97.33 (80.73)	18.30	14.75	3217	109.06	0.354
T_2	97.50 (81.08)	18.40	14.90	3246	109.20	0.324
T_3	97.17 (80.42)	18.39	14.75	3220	109.08	0.344
T_4	97.83 (81.70)	19.56	15.59	3439	111.72	0.300
T_5	97.50 (80.99)	18.53	15.16	3285	109.26	0.312
T_6	97.50 (81.13)	18.55	15.55	3324	110.98	0.302
S.Em±	0.54	0.19	0.17	28	0.30	0.005
CD at 5%	NS	0.55	0.50	83	0.89	0.014
Interactions (Q x T)						
Q_1T_1	97.67 (81.30)	18.51	14.86	3259	109.07	0.351
Q_1T_2	97.33 (80.68)	18.43	14.81	3235	109.18	0.326
Q_1T_3	97.00 (80.16)	18.43	14.86	3230	109.05	0.348
Q_1T_4	97.67 (81.30)	19.26	15.39	3385	111.11	0.304
Q_1T_5	97.33 (80.68)	18.35	14.90	3237	109.25	0.314
Q_1T_6	97.33 (80.68)	18.49	15.34	3292	110.21	0.304

Treatments	Germination (%)	Root length (cm)	Shoot length (cm)	SVI	Seedling dry weight (mg)	EC (dSm^{-1})
Q_2T_1	97.00 (80.16)	18.08	14.65	3176	109.04	0.356
Q_2T_2	97.67 (81.48)	18.36	14.98	3257	109.22	0.322
Q_2T_3	97.33 (80.68)	18.34	14.65	3211	109.12	0.341
Q_2T_4	98.00 (82.09)	19.86	15.79	3494	112.33	0.297
Q_2T_5	97.67 (81.57)	18.71	15.42	3333	109.26	0.310
Q_2T_6	97.67 (81.30)	18.60	15.76	3356	111.74	0.299
Mean	97.47 (81.01)	18.62	15.12	3289	109.88	0.323
S.Em$\pm$	0.76	0.27	0.24	40	0.43	0.007
CD at 5%	NS	NS	NS	NS	NS	NS

Q_1: Seeds with germination above MSCS
Q_2: Seeds with germination marginally below MSCS
T_1: Control (dry unprimed seeds) T_3: KCl (100ppm) T_5: KH_2PO_4 (50 ppm)
T_2: Hydropriming T_4: $CaCl_2.2H_2O$ (0.5%) T_6: GA_3 (20ppm)

(100ppm) (T_3) (14.75 cm) and from those unprimed (T_1) (14.75 cm). The interaction effect had also non-significant effect on shoot length of the resultant seed with Q_2T_4 (15.79 cm) recording the highest root length, followed by Q_2T_4 (15.76 cm) and Q_2T_5 (15.42 cm), while the lowest was equally recorded in Q_2T_1 and Q_2T_3 (14.65 cm).

4.3.4.4 Vigour index

The data on the influence of seed quality, seed priming and their interaction effects on the seedling vigour index of the resultant seeds are presented in Table 12.

Seed quality and the interaction effect had no significant influence on the seedling vigour index of the resultant seed, conversely seed priming showed a significant effect. The seeds obtained from lower quality seeds (Q_2) (3304) recorded higher seedling vigour index over those obtained from lower quality seeds (Q_1) (3273). However, on the other hand, priming treatments showed a significant influence on seedling vigour index of the resultant seed with seeds harvested from plots having seed primed with $CaCl_2.2H_2O$ (0.5%) (T_4) recorded the highest seedling vigour index (3439), followed by those harvested from plots having seed primed with GA_3 (20ppm) (T_6) (3324) and KH_2PO_4 (50 ppm) (T_5) (3285) and the lowest seedling vigour index was recorded in seeds harvested from plots having unprimed seed (T_1) (3217). The interaction effect had also insignificant effect on seedling vigour index of the resultant seed with Q_2T_4 (3494) recording the highest seedling vigour index, followed by Q_1T_4 (3385) and Q_2T_6 (3356) while the lowest was recorded in Q_2T_1 (3176).

4.3.4.5 Seedling dry weight (mg)

The data on the influence of seed quality, seed priming and their interaction effects on the seedling dry weight of the resultant seeds are presented in Table 12.

Seed quality and the interaction effect had no significant influence on the seedling dry weight of the resultant seed, conversely seed priming showed a significant effect. The seeds obtained from lower quality seeds (Q_2) (110.12 mg) recorded higher seedling dry weight over those obtained from higher quality seeds (Q_1) (109.65 mg). However, on the other hand, priming treatments showed a significant influence on seedling dry weight of the resultant seed with seeds harvested from plots having seed primed with $CaCl_2.2H_2O$ (0.5%) (T_4) (111.72 mg) recorded the highest seedling dry weight and was on par with those harvested from plots having seed primed with GA_3 (20ppm) (T_6) (110.98 mg), followed by KH_2PO_4 (50 ppm) (T_5) (109.26 mg) primed plots while the lowest seedling dry weight was recorded in seeds harvested from plots having seed unprimed (T_1) (109.06 mg). The interaction effect had also non-significant effect on seedling dry weight of the resultant seed with Q_2T_4 (112.33 mg) recording the highest seedling dry weight, followed by Q_2T_6 (111.73 mg) and Q_1T_4 (111.11 mg) while the lowest was recorded in Q_2T_1 (109.04 mg).

4.3.4.6 Electrical conductivity (dSm^{-1})

The data on the influence of seed quality, seed priming and their interaction effects on the electrical conductivity of the resultant seeds are presented in Table 12.

Seed quality and the interaction effect had no significant influence on the electrical conductivity of the resultant seed, conversely seed priming showed a significant effect. The seeds obtained from lower quality seeds (Q_2) (0.321 dSm^{-1}) recorded lower electrical conductivity when compared with those obtained from higher quality seeds (Q_1) (0.324 dSm^{-1}). However, on the other hand, priming treatments showed a significant influence on electrical conductivity of the resultant seed with seeds harvested from plots having seed primed with $CaCl_2.2H_2O$ (0.5%) (T_4) recorded the least electrical conductivity (0.300 dSm^{-1}), which was on par with those harvested from plots having seed primed with GA_3 (20ppm) (T_6) (0.302 dSm^{-1}) and KH_2PO_4 (50 ppm) (T_5) (0.312 dSm^{-1}) primed plots, while the highest electrical conductivity was recorded in seeds harvested from plots having seed unprimed (T_1) (0.354 dSm^{-1}). The interaction effect had also non-significant effect on the electrical conductivity of the resultant seed with Q_2T_4 (0.294 dSm^{-1}) recording the least electrical conductivity, followed by Q_2T_6 (0.299 dSm^{-1}) and Q_1T_4 (0.304 dSm^{-1}), while the highest was recorded in Q_2T_1 (0.356 dSm^{-1}).

Paired t-test: The t-test indicated and noticeable variation in the quality of the resultant seed irrespective of seed quality and seed priming treatments. A highly significant improvement was observed in quality of the harvested seeds. Grand means of the original treated seeds and the resultant harvested seeds were significantly different with germination (83.28, 97.47 %), root length (15.34 cm, 18.61cm), shoot length (11.22, 15.11 cm), seedling dry weight (96.48, 109.88 mg), Vigour index (1153, 3288), and electrical conductivity (0.703, 0.322 dSm^{-1}), respectively.

Table 20. Effect of the seed treatment on the resultant seeds

Parameters	Original means	Resultant means	Paired t-test $P_{(0.05)}$
Standard germination (%)	83.28 (68.15)	97.47 (81.01)	0.003
Root length (cm)	15.34	18.62	0.000
Shoot length (cm)	11.22	15.12	0.000
Seedling dry weight (mg)	96.48	109.88	0.039
Vigour index	2254	3289	0.000
Electrical conductivity (dSm^{-1})	0.703	0.323	0.000

5. DISCUSSION

Exposure to environmental stress often induces injury to cellular membrane systems in the plant cell. Among several stresses, increased leakage of cytoplasmic solutes follows the exposure of sensitive crop seeds to hydration and dehydration injury. Soybean is one among the pulses sensitive to water injury and it is considered as a poor storer owing to structural and physiological delicacy and high oil content. Considering the above mentioned points, for the purpose of this study, priming was done by putting the seeds between moist papers, instead of soaking directly in to water. Meanwhile, the storability of seeds is an important aspect of seed vigour which can speak about the quality supporting and/or in the absence of data on field performance or field potentiality (Perry, 1978 and McDonald, 1980). The present study was, therefore, undertaken to determine the optimum duration for priming of soybean seeds to imbibe enough water to allow pre-germination metabolic activities to occur but without radicle emergence, to study the effect of seed priming on storability and seed yield and quality of soybean.

5.1 Experiment I: Standardization of seed priming duration in soybean

The study of the imbibition curve is very important, especially for the development of pre-germination techniques aimed at improving seed physiological quality (Lopes *et al*., 2000) by detecting the reversion point of the imbibition process without damaging the embryo. This is the basic principle of the osmoconditioning technique which consists of allowing pre-germination metabolic activities to occur but without the radicle emerging (Bradford, 1986). The osmoconditioning or "priming" can be used for increasing the germination rate, uniformity of emergence, and the capacity of seeds to withstand adverse environmental effects (Nath *et al*., 1991; Khan, 1992; Braccini *et al*., 1997).

The curve of imbibition of soybean seeds in tap water (Fig. 2) showed that the water uptake in soybean seeds follows the triphasic pattern as proposed by Bradford (1995). The percent water absorption from 9.1 to 35.6 were considered phase-I of germination stages where rapid water absorption occurred followed by a lag phase (Phase-II) with little change in water content from 41.8 to 45.0 %. A subsequent increase in water content ranged from 49.9 to 72.8%. As very few radicle protrusions were observed with the 60.3 and 72.8% water imbibed seeds, the last category was considered as phase-III of the germination.

The seed priming regime was determined according to the report of Bewely and Black (1978) which reads “in seed priming regime, seed water potential is maintained at a level sufficient enough to initiate metabolic events in phase-II of germination process, but prevent radicle emergence.” Thus, the range from 41.8 to 49.9 percent water absorption was taken as a priming regime, otherwise beyond which, the seeds would germinate. This result agrees with the report that soybean must absorb 50 % of its weight in moisture to germinate (Hatam and Abbasi, 1994).

The speed of germination increased as the priming duration increased from 0h (40.50) to 14h (57.10), afterwards decreased rapidly with increasing priming duration with the least (44.27) was recorded in the 24^{th} h. The final germination showed a decreasing trend from 0h (97.67) to 24h (92.33) except 14 h priming recorded higher (97.00) against the tendency. This results of germination agreed with the result reported by Dasgupta *et al.* (1982), McKersie and Stinson (1980) and McKersie and Tomes (1980), which reads as “in the early stages of germination, seeds of a wide variety of plants can be dried to 10 % moisture without loss of viability, but if they are dried after radicle emergence, the seeds are not able to germinate”. Moreover, analyzing the results of percentage and rate of germination, it was seen that the priming duration affected the rate more than the final percentage of germination, which agreed with the results found by Ashraf and Abu-Shakra (1978) and Nassiff and Perez (1997) in *Senna occidentalis.*

The priming of seed for 14 h was found significantly superior for root length (16.34 cm), shoot length (13.83 cm), seedling dry weight (106.00 mg), seedling vigour index (2933) and field emergence (93.37 %), however, the least was observed in 24 h priming duration (13.26 cm, 11.50 cm, 73.00 mg, 2286, 88.03 % , respectively) . The probable reason for early and higher germination of seeds soaked for 14h may be the completion of pre-germinative metabolic activities making the seed ready for radical protrusion consequently the seed germinated soon after incubating for germination test compared to the other priming durations and to the unprimed control. Emergence enhancement may be attributed to metabolic repair processes, a build up of germination metabolites during 14h duration priming.

The inverse relationship ($r=-0.855^{**}$) observed between germination and electrical conductivity might be attributed to dehydration injury of soybean seeds which are delicate in nature caused due to increase in cell size during radicle emergence. According to Meryman (1974) model of freezing injury, a cell is injured when the cell volume is reduced below a critical size. The strain on membranes as the cell dehydrates and shrinks would induce lateral compression of the membrane leading to dehydration injury. This may suggest the change in sensitivity to dehydration coincided with the initiation of cell elongation and radicle emergence observed in phase-III (Fig.1).

Thus based on the above clarifications, the priming of soybean seeds for 14h in between germination paper was found optimum (standard) because 1. It was found to lie in phase-II of the ambition curve 2. The per cent of seed imbibed water was 41.80 % which is below the 50 % (at which germination occurs) and 3. It was proved to be significantly superior when tested with the seed quality parameters. There fore 14h priming duration was carried out for the subsequent storage and field experiments.

5.2 Experiment-II: Effect of seed quality and priming treatments on storability of soybean seeds

Several intrinsic and extrinsic factors influence the viability of seeds during storage. Among intrinsic and extrinsic factors, seed moisture content, relative humidity, temperature of storage, pests and diseases and oxygen availability are more important. Deterioration of seed is a natural process which is inevitable, inexorable and irreversible but the rate of deterioration of seed may differ due to genetic factor (Robert, 1972 and Wittington, 1978), storage environment (Roberts, 1961), period of storage (Reddy, 1985) and seed treatment (Zhang *et al*., 1989) etc.

Besides faster emergence, uniformity and synchrony several reports mention that chemical primed seeds can be rinsed and carefully dried for restorage. Keeping this in view, a laboratory experiment was initiated under ambient condition for five months storage period and the results are discussed herewith.

Noticeable and consistent variation in seed quality parameters were observed in the entire five months of storage period irrespective of seed quality level and seed priming treatments. Speed and final germination, root length, shoot length, seedling dry weight, seedling vigour index and field emergence were significantly maximum (51.44, 83.28 %, 15.34 cm, 11.22 cm, 96.48 mg, 2254, 80.18 %, respectively) at the initial period but declined gradually to minimum value (31.40, 50.22 %, 11.11 cm, 5.83 cm, 66.76 mg, 880 and 44.08 %, respectively) at the end of five months of storage period. Whereas, the initial EC value (0.703 dSm^{-1}) increased to 1.914 dSm^{-1}. Moisture content of seed (8.94, 8.81, 6.63, 6.04, 6.71, and 7.50 %) showed great deal of fluctuation across the storage period. The marked decrease in the seed quality parameters under advancing storage period may be attributed to seed coat characters (Delouhe *et al* , 1973), age induced physicochemical seed deterioration, lipid peroxidation leading to production of toxic metabolites that act upon cell and cell organelles (Maguire, 1977, Tappel, 1980 and Sohal, 1987) denaturation of proteins and enzymes (Roberts, 1972).

Influence of seed quality

Irrespective of seed treatment, seed quality parameters differed significantly due to seed quality through out the five months storage period. The speed of germination, germination percentage, root length, shoot length, seedling dry weight and field emergence showed significant difference due to seed quality. Seeds of higher quality (Q_1) recorded higher seed quality parameters (58.89, 96.06 %, 16.39 cm, 12.99 cm, 113.22 mg, 2827 and 92.96 %, respectively) over the lower quality seeds (44.00, 70.50 %, 29 cm, 9.45 cm, 79.75 mg, 1680 and 67.4 %, respectively) at the initial month of storage. The gradual reduction in these quality parameters with the increase in storage period was noticed in both seed quality levels. At the end of five months storage higher quality parameters were recorded in seeds of higher quality (38.70, 63.13 %, 11.86 cm, 6.95 cm, 82.53 mg, 1193, and 56.93 %, respectively) as compared to the seeds of lower quality (24.11, 37.31 %, 10.36 cm, 4.71 cm, 51.00 mg, 567, and 31.23 %, respectively).

Similarly, a variation in electrical conductivity of seed leachates and in seed moisture content due to seed quality was observed at all the months of storage period. At initial month of storage lower electrical conductivity (0.490 dSm^{-1}) was recorded in Q_1 and higher (0.917 dSm^{-1}) was recorded in Q_2. At the end of five months of storage lower electrical conductivity (1.702 dSm^{-1}) was recorded in Q_1 and higher (2.126 dSm^{-1}) was recorded in Q_2. Moisture content of the seed showed no consistent trend throughout the storage period. A gradual loss ($Q_{1:}$ 8.57, 8.44, 7.03, 6.48; $Q_{2:}$ 9.30, 9.17, 6.63, 5.61 %) in moisture content was observed during the first three months of storage but a gain ($Q_{1:}$ 7.04, 7.76; $Q_{2:}$ 6.37, 7.24 %) in the last two.

Influence of seed priming

Irrespective of seed quality, seed quality parameters differed significantly due to seed priming treatments through out the five months storage period

The variation in speed of germination showed significant difference due to seed priming at all months of the storage period. Seeds primed with GA_3 (20 ppm) (T_6) recorded significantly higher speed of germination (59.00, 56.85, 51.74, 48.20, 41.69, 35.58) at initial and first month but was out performed (56.58, 55.28, 52.31, 48.90, 42.65, 36.54) by $CaCl_2.2H_2O$ (0.5%) (T_4) primed seeds in the rest of the storage periods. The lowest speed of germination at both initial and end of the storage period was exhibited by KCl (100ppm) primed seeds (T_3), (45.42, 25.34, respectively).

The superiority GA_3 to record higher speed of germination may be due to its stimulation effect in the formation of enzymes which are important in the early phases of germination which helps for a fast readicle protrusion and hence and hypocotyl elongation (Riedell *et al*., *1985*; Mislevy *et al*., 1988; Bensen *et al*., 1990; Kumar & Neelakandan, 1992 and Maske *et al*., 1997). Ak *et al.* (1995) and Feng *et al.* (1997) also reported the use of GA_3 in germination of soybean seeds, suggesting that gibberellic acid would play an important role during the germination process of seeds. Khan (1981) reported GA_3 added to the PEG priming solution replaced the light effect in speeding germination and in preventing dormancy induction in lettuce and celery. Further work showed that aminoethoxyvinyle glycine (AVG), a specific inhibitor of the conversion of S-adenosyle methionine to 1-aminocyclopropane-1-carboxylic acid (ACC) in the ethylene biosynthetic pathway (Yang and Hoffman, 1984) failed to inhibit the germination advancement effect of osmotic priming in the light or in the presence of GA_3 in the dark. Soybean seeds responded similarly, in that the combined effect of matric priming and GA_3 was greater than that of matric priming alone (Khan, 1992). However, the germination speeding effect of GA_3 did not sustain to the end of the storage period. A similar result was reported by Anil *et al.* (1998) stating pretreatment of cowpea with GA_3 stimulated the rate of germination provided they were not stored for longer period. The $CaCl_2.2H_2O$ and KH_2PO_4 primed seeds were also found to relatively speed up germination may be due to their role in the germination process as discussed below.

The germination percentage and field emergence also showed significant difference due to seed priming. Seeds primed with $CaCl_2.2H_2O$ (0.5%) (T_4) recorded the highest germination and field emergence (86.67% and 83.57%, respectively), followed by GA_3 (20ppm) (T6) and KH_2PO_4 (50 ppm) primed seeds (T_5) and lowest (79.93 and 76.24%, respectively) and lowest in KCl (100ppm) primed seeds (T_3) at the initial month of storage. At this outset $CaCl_2.2H_2O$, GA_3, KH_2PO_4, and hydro- primed seeds recorded (5.34, 5.33 %), (4.03, 4.00 %), (2.34, 2.30 %) and (2.03, 2.00 %) increments in germination and field emergence when judged against the control, respectively. KCl (100ppm) was found deleterious to the seeds. A gradual reduction in germination percentage and field emergence with the increase in storage period was noticed across all treatments. At the end of five months storage the highest germination and field emergence (54.07 % and 47.46 %, respectively) were recorded in T_4 and lowest (46.14 % and 40.21 %, respectively) in T_3. Even though $CaCl_2.2H_2O$ (0.5%) (T_4), GA_3 (20ppm) (T6) and KH_2PO_4 (50 ppm) primed seeds showed higher germination, all were found to maintain satisfactory germination as per the minimum seed certification standard (70 %) up to the second months of storage only.

The higher germination noticed in $CaCl_2.2H_2O$ (0.5%) (T_4), primed seeds might be due to the role of calcium in membrane integrity. Christiansen and Foy (1979) and Hecht-Buchholz (1979) reported seed calcium concentration and germination percentage were positively related suggesting the role of calcium as an important component in membrane stabilization and as an enzyme cofactor. Kathiresan *et al*. (1984a), Kulkarni and Eshanna (1988), Nagappa (1983) reported similar beneficial results on germination and field emergence of sunflower by osmoprimimng in calcium chloride. Moreover, beneficial effects of calcium chloride seed treatments were reported in ragi (Karivartharaju and Ramakrishinan, 1985) and wheat (Bhati and Rathore, 1988).

Beneficial effects of KCl have been reported by Vijayakumar (1982) in blackgram, Rajandran (1982) in redgram, Basha (1982) in greengram and Vanangamudi and Karivaratharaju (1986) in blackgram and greengram. However, in the present study KCl showed low germination and other quality parameters which may be attributed to the soaking injury caused to the seed as potassium chloride when dissolved in water produces KOH which is a strong alkali and may be toxic to embryo. The slower germination in seeds treated with KCl might also be impaired for this reason.

GA_3 (20ppm) (T_6) and KH_2PO_4 (50 ppm) (T_5) primed seeds also recorded relatively higher germination and field emergence percentage. This may be attributed to the key role of gibberellins in germination (Metivier, 1986) which are involved both in the break of dormancy and in the control of reserve hydrolysis on which the growing embryo depends. Sharma & Dhillon (1986) suggested a decline in the endogenous levels of gibberellins was the limiting factor for the maintenance of viability and/or germination of seeds. According to Salisbury and Ross (1992), gibberellic acid is the growth regulator that truly acts on seed germination, showing a favourable action on the breaking of dormancy. Furthermore, Bradford et al. (2000) proposed that endogenous GAs control germination through two processes: a decrease in the mechanical resistance of the tissues surrounding the embryo and promotion of the growth potential of the embryo.

KH_2PO_4 also showed a relatively positive effect presumably because phosphorous activates the respiratory enzymes involved in the biosynthesis of seed and extends the seed storability. According to (Graf *et al*, 1987), phosphorous reserves in the seed play very important role in the metabolism of germinating seed. The major phosphorous reserve in the seed, phytic acid, in addition to its nutritional role, is believed to act as a natural antioxidant. As such, deficiency of phosphorous would be expected to adversely affect pre-and poststorage germineablity. The higher germination and emergence can also be due to beneficial effect of the k^+ in retaining viability as demonstrated by Petruzzeli *et al*. (1982) in wheat seed during ageing and the effect of k^+ (fusicoccin) on the proton extrusion capacity of aged embryos was related to the restorative effect on viability.

Hydroprimed seeds also showed better storability when compared with the unprimed seeds (control). The beneficial effects of soaking soybean seeds in water were also reported by Nalawadi *et al*., (1973) and Basu and Choudhury (2005).

Significant variation in root length, shoot length, seedling dry weight, seedling vigour index were observed due to different seed priming treatments at all the months of storage. A gradual reduction in these parameters was noticed with increase in storage period. At the initial month highest root length (17.11 cm), seedling dry weight (106.8 mg) and vigour index (2564) were recorded in T_4; and lowest (13.95 cm, 82.80 mg and 1861, respectively) were recorded in T_3. At this outset $CaCl_2.2H_2O$, GA_3, KH_2PO_4, and hydro- primed seeds recorded (21.70, 24.70 %), (17.78, 22.62 %) (11.90, 10.75 %) and (13.80, 9.05 %) increments in seedling dry weight and vigour index when judged against the control, respectively. KCl (100ppm) was found deleterious to the seeds. At the end of five months storage highest root length (12.45 cm), seedling dry weight (81.00 mg) and vigour index (1069) were recorded in T_4; lowest (9.77 cm, 51.80 mg and 631 respectively) were recorded in T_3. However, T_6 performed better than T_4 with regard to shoot length in all months of storage. At the initial month highest shoot length (13.27 cm) was recorded in T_6; the lowest (9.03 cm) in was recorded in T_3. At the end of five months storage highest shoot length (7.16 cm) in T_6 and lowest (3.46cm) were recorded in T_3. The above explanation regarding the superiority of $CaCl_2.2H_2O$ (0.5%) (T_4), GA3 (20ppm) (T6) and KH_2PO_4 (50 ppm) primed seeds are plausible for the root length, shoot length, seedling dry weight and seedling vigour index as a higher positive correlation exists among them (Table 13).

The variation in electrical conductivity of seed leachates due to seed priming was observed at all the months of storage period. At initial month of storage least electrical conductivity (0.517 dSm^{-1}) was recorded in T_4 and highest (0.930 dSm^{-1}) was recorded in T_3. At the end of five months of storage least electrical conductivity (1.740 dSm^{-1}) was recorded in T_4 and highest (2.137 dSm^{-1}) was recorded in T_3. The strong negative correlation (r= -0.884**, -0.874**, -0.885**, -0.882**, 0.882** and 0.901**) of germination and electrical conductivity through out the storage period could explain the positive effect of $CaCl_2.2H_2O$ (0.5%) due to the role of Ca^{++} in membrane integrity. Powell, (1986) reported that seed quality of soybean was significantly correlated with several seed nutrients; however, only Ca was correlated with germination and electrolytic conductivity, which relates to membrane integrity.

The moisture content of the seed was found to vary in concomitant with fluctuation of ambient atmosphere. A gradual loss ($T_{4:}$ 8.81, 8.36, 7.27, 6.44; $T_{3:}$ 9.07, 8.88, 6.4, 5.4 %) in moisture content was observed during the first three months of storage but a gain ($T_{4:}$ 6.88, 7.47; T3$_{:}$ 6.30, 7.45 %) in the last two. Though no treatment showed consistent change, a better stability in seed moisture change was observed in $CaCl_2.2H_2O$ (0.5%) (T_4) treated seed. This may be due to the role of calcium as an important component in membrane stabilization (Christiansen and Foy, 1979).

Interaction

Interaction effect between seed quality and seed priming treatments was found to differ significantly for quality parameters throughout storage period.

The variation in speed of germination showed significant difference due to the interaction between seed quality and seed priming at all months of the storage period. Highest speed of germination was recorded in Q_1T_6 (67.33, 64.99, 57.01, 53.23, 48.71 and 42.60) in the first two months but was out performed (63.00, 60.94, 57.21, 54.44, 49.92, and 43.81) by Q_1T_4 in the rest of the storage periods. The lowest (40.00, 17.50 respectively) speed of germination at both initial and end of the storage period was exhibited in Q_2T_3.

The germination percentage and field emergence also showed significant difference due to the interaction between seed quality and seed priming at all months of the storage period. Highest germination percentage and field emergence (98.00% and 94.90%, respectively) in Q_1T_4 and lowest (66.67% and 63.57%, respectively) in Q_2T_3 were recorded at the initial month of storage. The gradual reduction in germination percentage and field emergence with the increase in storage period was noticed across all treatment combinations. At the end of five months storage the highest germination and field emergence (66.00% and 58.79 %, respectively) were recorded in Q_1T_4 and lowest (33.48 % and 27.63 %, respectively in Q_2T_3.

The root length, shoot length, seedling dry weight and seedling vigour index showed significant variation due to the interaction between seed quality and seed priming at all months of the storage period. A gradual reduction in these parameters was noticed with increase in storage period. At the initial month highest root length (18.54 cm), seedling dry weight (128.3 mg) and vigour index (3118) were recorded in Q_1T_4; lowest (13.12 cm, 69.9 mg and 1329, respectively) were recorded in Q_2T_3. At the end of five months storage highest root length (13.65 cm), seedling dry weight (100.6 mg) and vigour index (1418) were recorded in Q_1T_4; lowest (9.17 cm, 38.00 mg and 389 respectively) were recorded in Q_2T_3. However, Q_1T_6 performed better than Q_1T_4 with regard to shoot length in all months of storage. At the initial month, the highest shoot length (15.21 cm) in Q_1T_6 and lowest in Q_2T_3 (6.80 cm) were recorded. At the end of five months storage highest shoot length in Q_1T_6 (8.23 cm) and lowest (2.46 cm) in Q_2T_3 were recorded.

The variation in electrical conductivity of seed leachates due to the interaction between seed quality and seed priming was highly significant among treatment combinations at all months of the storage period. At initial month of storage least electrical conductivity (0.214 dSm^{-1}) was recorded in Q_1T_4 and highest (1.078 dSm^{-1}) was recorded in Q_2T_3. At the end of five months of storage least electrical conductivity (1.471 dSm^{-1}) was recorded in Q_1T_4 and highest (2.301 dSm^{-1}) was recorded in Q_2T_3.

Moisture content of the seed showed significant difference, due to the interaction between seed quality and seed priming, in all months of the storage period except in the first month. Inconsistent change in moisture content of the seed was observed during the storage period. A gradual loss (Q_1T_4: 8.44, 8.22, 7.75, 7.04 %; Q_2T_3: 9.39, 921, 6.21, 5.15, %) in moisture content was observed during the first three months of storage but a gain (Q_1T_4: 7.34, 7.85; Q_2T_3:6.13, 7.43 %) in the last two.

Prediction of primed soybean seed quality in storage over time

Prediction of soybean seed quality given a particular priming treatment in a particular period of time is important to evaluate the viability and quality status of a seed lot by establishing equations for predicting seed quality.

The prediction of soybean seed quality depends on understanding the relationships between three factors, *viz*., seed moisture content, storage temperature and storage time which effecting seed viability and have produced numerous prediction equations. However, in this study an attempt was made to predict seed quality over time by storing the seeds at room temperature only.

The regression equation, developed with a time series of 1-150 days, indicated that there was a linear deterioration as storage time advanced except for shoot length. The non-linear relation regression equation of the shoot length might be due to the non-sustaining advantage of GA_3 on shoot length during storage.

5.3 Experiment III: Effect of seed quality and priming treatments on seed yield and quality of soybean

The quality of seeds has a profound influence on the economic production of agricultural crops of all species. The seed priming treatment not only improves the seed quality but also the planting value of seeds. This study aims to illustrate how seed quality and priming treatments and their interaction influence crop establishment, growth and seed yield and quality. The plants raised from such primed seeds are reported to perform better in the field by exhibiting increased field emergence, early establishment, vigorous growth and increased seed yield and quality.

5.3.1 Crop establishment and growth parameters

Modern seed production systems require a high degree of precision in crop establishment. The need for high plant population densities and uniform plant stand requires seeds of high quality that will consistently produce rapid and uniform seedling emergence from each seed sown. Seed quality, seed priming treatments and their interaction significantly affected days to 50 per cent emergence. Seeds of higher quality took significantly lesser days to 50 per cent emergence (7.33) as compared with the seeds of lower quality (8.94 days). With regard to priming treatment effect, the seeds treated with GA_3 (20ppm) (T_6) (7.00) emerged faster which was on par with $CaCl_2.2H_2O$ (0.5%) primed seeds (T_4) (7.50 days), followed by KH_2PO_4 (50 ppm) primed seeds (T_5) while most delayed emergence was observed in seeds primed with KCl (100ppm) (T_3) (9.67). The interaction effect also showed significant influence with the fastest emergence by Q_1T_6 (6.00) being on par with Q_1T_4 (6.67), followed by Q_1T_5; the most delayed emergence was shown in Q_2T_3 (11.00). The faster emergence of seeds in primed with GA_3 may be due to its stimulation effect in the formation of enzymes which are important in the early phases of germination which help for a fast radicle protrusion and hence and hypocotyl elongation to penetrate the soil up.

Seed productivity is widely limited by poor stand establishment and nutrient deficiencies. Particularly in drought prone areas, germination tends to be irregular and can extend over longer period of time (Bougne, *et al*., 2000). The resulting poor crop tends leave gaps in the canopy, which are rapidly filed by vigorously growing weeds with the onset of the short rainy season. These weeds compete the crop plants for light, water and limiting nutrients (Kroft and Van, 1993). Accelerating and homogenizing the germination process is a prerequisite for a good crop establishment process, the efficient use of resources and eventually to increase yields (Harris, 1996). In this study the field emergence percentage and emergence per m^2 differed significantly due to seed quality, priming treatments and their interaction effect which showed very high positive ($r=0.990^{**}$) correlation. Higher field emergence and emergence per m^2 (89.44 %, 27.22) were recorded in seeds with higher seed quality (Q_1) over the seeds with lower seed quality (Q_2) (65.94 %, 19.78). The seeds primed with $CaCl_2.2H_2O$ (0.5%) (T_4) recorded highest field emergence and emergence per m^2 (82.83

%, 25.33), followed by GA_3 (20ppm) (T_6) and KH_2PO_4 (50 ppm) (T_5) while the lowest field emergence and emergence m^{-2} (72.50 %, 22.00) were recorded in KCl (100ppm) (T_3) primed seeds. CaCl2.2H2O, GA3, KH2PO4, and hydro- primed seeds recorded (7.33, 12.58 %), (4.00, 6.67 %), (2.80, 5.20 %) and (2.00, 4.40 %) increments in field emergence and emergence per square meter when judged against the control, respectively. KCl (100ppm) was found deleterious to the seeds. The interaction effect was also significant with the highest field emergence and emergence m^{-2} (93.00 %, 29.67) recorded in Q_1T_4 and was on par with Q_1T_6 (92.00 %, 27.67 (not on par)), followed by Q_1T_5 and the lowest field emergence and emergence m^{-2} (61.00 %, 18.33) were recorded in Q_2T_3.

Seed quality, priming treatments and their interaction significantly affected plant height at both 30 and 60 DAS. The plants raised form seeds of higher quality (Q_1) showed significantly higher plant height (26.58, 41.32 cm, respectively) over those raised from seeds of lower (Q_2) (22.56, 37.06 cm, respectively). In respect of seed priming treatments, significantly higher plant height 30 DAS (27.30 cm) was recorded in GA_3 (20ppm) primed seeds (T_6), followed by $CaCl_2.2H_2O$ (0.5%) primed seeds (T_4) (25.13 cm) KH_2PO_4 (50 ppm) (T_5) while the lowest plant height (22.50 cm) was recorded in KCl (100ppm) primed seeds (T_3). However, higher plant height at 60 DAS was observed in plants raised from $CaCl_2.2H_2O$ (0.5%) (43.33 cm) primed seeds which was on par with the plants raised from GA_3 (20ppm) (41.87 cm) primed seeds, followed by those raised from KH_2PO_4 (50 ppm) primed seeds. The shortest plants were observed in those grown from the seeds treated with KCl (100ppm) (34.90 cm). At 60 DAS, $CaCl_2.2H_2O$, GA_3, KH_2PO_4, and hydro- primed seeds recorded (17.17 %), (13.22 %), (6.63 %) and (4.46 %) increments in plant height when judged against the control, respectively. KCl (100ppm) was found deleterious. The significant interaction effect at 30 DAS indicated the superiority of plants raised from the high quality seeds treated with GA_3 (20ppm) (Q_1T_6) (31.330) followed by Q_1T_4 (27.20 cm,) and Q_1T_5 (26.53 cm) and the lowest plant height (21.67 cm) was recorded in Q_2T_3. At 60 DAS, the Q_1T_4 (46.47 cm) showed insignificantly greater height over Q_1T_6 (45.07 cm) while Q_2T_3 showed the shortest plants. The beneficial effect of exogenous application of GA_3 to seeds might be due to the translocation of GA_3 to the aerial part of plants, and this perhaps occurs to an extent that is enough to increase hypocotyl size and the consequent increase in first node height hence sufficient to positively affect plant height. Bensen *et al.* (1990), demonstrate the hypocotyl growth rate is directly associated with the amount of GA_3. The enhanced plant height may also be due to the improved and faster plant emergence in GA_3, $CaCl_2.2H_2O$ and KH_2PO_4 primed seed plots which created cooperative competition among the plants for light and resulted in taller plants. The results agree with Harris et al., (2000) who reported that seed priming of ten rice varieties resulted in taller plants (108 cm vs 94 cm) in two years.

Initiation of flower buds is considered a shift from vegetative to reproductive stage of the seed crop growth. Seed quality, seed priming treatments and their interaction significantly affected days to 50 per cent flowering. The plots sown with seeds of higher quality took significantly lesser days (40.00) to 50 per cent flowering as compared (40.89) to the plots sown with lower quality seeds. Plots having seed primed with $CaCl_2.2H_2O$ (0.5%) (T_4) significantly accelerated flowering, followed by plots having seed primed with GA_3 (20ppm) (T_6) (39.50) and KH_2PO_4 (50 ppm) (T_5) while most delayed flowering was exhibited in plots having seed primed with KCl (100ppm) (T_3) (42.50). The interaction effect also showed significant influence with the earlier flowering exhibited by Q_1T_4 (37.68) which was on par with Q_1T_6 (38.67), followed by Q_1T_5 while the most delayed flowering (42.67) was observed in Q_2T_3. $CaCl_2.2H_2O$ (0.5%) (T_4), GA_3 (20ppm) (T_6), and KH_2PO_4 (50 ppm) (T_5) primed plots showed significantly early flowering. This could be because of their effect in the fast emergence of the seeds at the beginning as the correlation between the days to 50 % emergence and days to 50% flowering ($r = 0.785^{**}$) was significantly higher and positive.

5.3.2 Physiological parameters

The importance of leaf area in determining canopy and water used by a crop is well recognized. Formation and maintenance of active leaf area is essential for continued production of photosynthate to maintain carbon and energy flow to both developing seed and plant tissues. The leaf area index differed significantly due to seed quality, seed priming treatments and their interaction effect. Significantly higher leaf area index (2.97) was recorded in plots sown with seeds of higher quality (Q_1) over the plots sown with seeds of lower quality (Q_2) (2.38). The plots having seed primed with $CaCl_2.2H_2O$ (0.5%) (T_4) showed higher leaf area index (2.79) which was on par with plots having seed primed with (2.75) GA3 (20ppm) (T_6), followed by those primed with (2.70) KH_2PO4 (50 ppm) (T_5) while the lowest leaf area index (2.50) was recorded in plots having seed primed with KCl (100ppm) (T_3). The interaction had also a significant effect with the highest leaf area index recorded in Q_1T_4 (3.12) which was on par with Q_1T_6 (3.07), followed by Q_1T_5 (2.98) and the lowest leaf area index (2.21) was recorded in Q_2T_3.

Water is among the most widespread abiotic stresses limiting seed crop productivity. A seed crop's response, raised from primed seeds, to drought tolerance may be assessed using relative water content as a tool. The relative water content (RWC) is good indicator of drought tolerance induced by osmopriming. The results on relative water content as influenced by seed quality, seed priming and their interaction effects showed significant difference. Significantly highest relative water content was recorded in leaves obtained from plots sown with seeds of higher quality (87.04 %) (Q_2) over those obtained from plots sown with seeds of lower quality (Q_2) (80.18 %). The plots having seed primed with $CaCl_2.2H_2O$ (0.5%) (T_4) showed the highest relative water content (87.85 %) and was on par with plots having seed primed with (86.96 %) KH_2PO_4 (50 ppm) (T_5) followed by those primed with GA3 (20ppm) (T_6) (84.57%), while significantly lower relative water content (79.02 %) was recorded in plots having seed primed with KCl (100ppm) (T_3).Plant leaves obtained from $CaCl_2.2H_2O$, GA_3, KH_2PO_4, and hydro- primed seeds recorded (7.76 %), (4.48 %), (6.87 %) and (3.88 %) increments in relative water content of leaves when judged against those obtained from the control (unprimed) seeds, respectively. KCl (100ppm) was found deleterious. The interaction had also significant effect with the highest relative water content recorded in Q_1T_4 (90.40 %) and was on par with Q_1T_5 (88.77 %), followed by Q_1T_5 (87.81 %) while lower relative water content (74.29) was recorded in Q_2T_3. The highest leaf water content of plots treated with seed having osmoprimed with $CaCl_2.2H_2O$ (0.5%) may be due to the contribution of calcium to initiate the development of root hairs or/and due to the possible role of calcium in inducing membrane stability and maintenance of higher water status as calcium is the main constituent of middle lamella of cell-wall. Sashidhar *et al*. (1977) reported increased in yield in groundnut when seeds were treated with one per cent calcium chloride for eight hours with high free proline accumulation which is an adaptive mechanism of drought tolerance. Malathi *et al*. (1986) reported a similar finding on the effect of calcium in the water relations and tolerance to moisture deficits was tested in groundnut and cowpea. In both species, enrichment of tissue with calcium resulted in maintenance of a higher water status under stress associated with low proline accumulation. The extent of membrane damage (as reflected by the absorbance at 273 nm) was lesser in leaves of plants fed with higher levels of Ca^{++} when subjected to simulated stress. The rate of water loss from the leaves of Ca^{++}-enriched plants was also lower. Anjum (2002) also inferred that salinity induces accumulation of proline that might help in osmoregulation of the plant, and that proline in cells works as an osmolyte is proved by its increased accumulation with application of calcium chloride by creating a hypertonic soil environment giving way to more accumulation of proline. The relatively higher relative water content recorded by KH_2PO_4 (50 ppm) may be due to the role of potassium to maintain water-balance, hydration of protoplasm and control over permeability of cytoplasm. It may also be due to phosphorous which favours healthy root growth by helping the translocation of solutes.

5.3.3 Yield and yield Components

The number of pods per plant and the number of seeds per pod are the major yield components and determine the final seed yield; those significantly contribute to the seed yield and represent reproductive efficacy of a seed crop. The statistically analyzed results showed that seed quality, seed priming treatments and their interaction significantly influenced number of pods per plant, number of seeds per plant, seed yield per plant, seed yield per plot and yield per hectare. The plants raised from the seeds of higher quality (Q_1) recorded significantly greater number of pods per plant, number of seeds per plant, seed yield per plant, seed yield per plot and yield per hectare (39.67, 2.57, 12.68 g, 2.03 kg, and 21.16 q, respectively) over those raised from the lower quality seeds (Q_2) (29.61, 2.26, 8.20 g, 1.76, kg 18.34 q, respectively).

The plots having seed primed with $CaCl_2.2H_2O$ (0.5%)(T_4) showed significantly highest number of pods per plant, number of seeds per plant, seed yield per plant, seed yield per plot and yield per hectare (38.67, 2.58, 12.05 g, 2.07 kg and 21.61 q, respectively) followed by plots having seed primed with GA_3 (20ppm) (T_6) and KH_2PO_4 (50 ppm) (T_5) while the lowest were recorded in plots having sown with seed primed with KCl (100ppm) (T_3) (29.50, 2.23, 8.54g, 1.67 kg and 17.44 q, respectively). The plots sown with seeds primed with CaCl2.2H2O, GA3, KH2PO4, and hydroprimed seeds recorded (17.79, 20.73 %), (7.61, 17.93 %), (4.74, 17.15 %) and (3.05,8.6 %) increments in number of pods per plant and seed yield per hectare when judged against those obtained from those plots sown with control (unprimed) seeds, respectively. KCl (100ppm) was found deleterious.

The interaction effect was significant in Q_1T_4 recorded highest number of pods per plant, number of seeds per plant, seed yield per plant, seed yield per plot and yield per hectare (42.67, 2.70, 14.54 g, 2.27 kg, 23.67 q, respectively), followed by Q_1T_6 and Q_1T_5 and the lowest values were recorded in (26.00, 2.13, 7.01 g, 1.56 kg, 16.22 q, respectively) Q_2T_3. Seed yield (q/ha) showed high positive and significant correlation with number of pods per plant (0.909**), number of seeds per pod (0.933**) and yield per plant (0.921**). These results are in line with the report of Aldesuquy and Ibrahim (2000) who have reported that seed treatment with shikimic acid improved yield and yield components of cowpea plants by increasing the number of pods per plant and number of seeds per pod. Similar results were also reported by Basara *et al*. (2003) in canola and Rashid *et al*. (2004) in mungbean that primed seed plants produced more grains pod per pod

Results on hundred seed weight were observed to significantly favour the seeds obtained from the least performed plots in the field. This is presumably due to the least number of plants per plot observed which allows the plants to scavenge nutrients and water with the least competition. This could be supported by the highly significant negative correlation values of hundred seed weight with almost all field performance assessment parameters.

5.3.4 Seed quality parameters

Quality parameters assessed on the resultant seeds did not differ significantly due to the difference in initial seed quality. Higher germination (97.56 %), root length (18.66 cm), shoot length (15.21 cm), seedling dry weight (109.12 mg), and seedling vigour index (3304) were recorded in the seed harvested from the plots sown with the seeds of lower quality over (97.39 %, 18.58 cm, 15.03 cm, 108.65 mg and 3273, respectively) seeds harvested from plots sown with seeds of higher quality. The better performance of seeds obtained from lower quality ones tested for seed quality parameters after harvest, is presumably due to the advantage drawn from the lower population effect of no or minimum competition for nutrient and spacing which contributed to greater accumulation of assimilates in plots sown with initially lower seed quality. A significant negative correlation of hundred seed weight with emergence per square meter (-0.608 *) and yield (r = -0.644*) may support this explanation indicating higher seed weight recorded in the plots where low emergence and yield were reported. Non-significant results of leachate of electrolytes were also in favour of those seeds obtained from plots sown with seeds of lower quality (0.321 dSm^{-1}) over those harvested from plots sown with seeds of higher quality (0.324 dSm^{-1}).

The priming treatments had significant influence in the resultant seed across all the parameters tested but not in germination percentage. Significantly higher germination percentage was recorded in seeds obtained from plots having seed primed with $CaCl_2.2H_2O$ (0.5%) (T_4) (97.83 %), followed by the resultant seeds harvested from plots having seeds primed with GA_3 (20ppm) (T_6) (97.50 %) and KH_2PO_4 (50 ppm) (T_5) (97.50 %), however the results were non-significant. The lowest was observed in plots having seeds primed KCl (100ppm) (97.17 %). However, root length, shoot length, seedling dry weight, vigour index and electrical conductivity were significantly affected. These tested seed quality parameters were all in favour of the resultant seeds obtained from plots sown with seed having primed with $CaCl_2.2H_2O$ (0.5%) (T_4), (19.56 cm, 15.59 cm, 110.72 mg, 3439, 0.300 dSm^{-1}, respectively), followed by those obtained from plots sown with GA_3 (20ppm) (T_6) (18.55 cm, 15.55 cm, 109.98 mg, 3324, 0.302 dSm^{-1}, respectively) primed seeds as judged against the least favoured resultant seeds obtained from plots sown with unprimed seeds, control (T_1) (18.30 cm, 14.75 cm , 108.06 mg , 3217, 0.354 dSm^{-1}, respectively). The possible reason for such differences in quality of the resultant seeds may be ascribed to significant carry over effect of the chemicals on the vigour and viability of seeds produced by plants from the pre-primed seeds.

The interaction effect had also no significant influence on the tested seed quality parameters. Yet, seeds obtained from the plot Q_2T_4 were privileged with better performance in germination percentage, root length, shoot length, seedling dry weight , vigour index and electrical conductivity (98.00 % , 19.86 cm, 15.79 cm, 111.33 mg, 3494, 0.297 dSm^{-1}, respectively), followed by Q_1T_4 and Q_2T_6 while the least performing resultant seeds seed were obtained from plot Q_2T_1 (97.00 %, 18.08 cm, 14.65 cm, 108.05 mg, 0.356 dSm^{-1} , respectively).

In general the harvested resultant seed showed a significant quality improvement when compared to the quality test results of the treated seeds before sowing. The paired t-test showed a significant variation with germination (83.28 and 97.47 %), root length (15.34 and 18.61cm), shoot length (11.22 and 15.11 cm), seedling dry weight (96.48 and 109.88 mg), vigour index (1153and 3288), and electrical conductivity (0.703 and 0.322 dSm^{-1}) rerecorded in the original seed and the resultant seeds, respectively.

Practical utility of the project

Based on the results of the field and laboratory experiments the following are of practical application.

- Seeds of soybean CV. JS-335 can be primed safe by putting between moistened germination paper for 14 hours.
- Fresh soybean seeds primed with $CaCl_2.2H_2O$ (0.5%), GA_3 (20ppm), KH_2PO_4 (50 ppm) and hydroprimed ones can be stored up to four months maintaining a satisfactory germination as per above the minimum seed certification standard (70 %).
- Old and fresh seeds of soybean can be treated with $CaCl_2.2H_2O$ (0.5%), GA_3 (20ppm) and KH_2PO_4 (50 ppm) for invigoration purpose.
- Old and fresh seeds of soybean may be treated with $CaCl_2.2H_2O$ (0.5%), GA_3 (20ppm) and KH_2PO_4 (50 ppm) for faster emergence, uniformity and synchrony in flowering and maturity and hence better seed yield and quality could be obtained. The resultant seed yield increase was significant and showed a better carry-over effect.

Future line of work

Based on the above results, it is felt that the following aspects may be investigated to strengthen the present conclusions.

- Evaluation of the effects of osmotic potential on the water uptake curve to analyze the effects of dehydration and storage on primed seed germination can not be overemphasized.
- The pre-sowing seed priming treatment with KCl may be tested for their storability and field performance across different concentrations.
- The contribution of seed priming by calcium salts for drought tolerance should be investigated for soybean.
- Other chemicals, growth regulators, fungicides etc. may be tested for their effect on storability and field performance.
- There is a need to assess the biochemical changes associated with seed priming of different soybean seeds immediately after treatment and after storage for different periods of time.

6. SUMMARY AND CONCLUSIONS

A laboratory and field experiments were carried out to standardize the safe duration for soybean seed priming, to study the influence of seed quality levels and seed priming chemicals on storability and seed yield and quality of soybean Cv. JS-335. The field experiment was conducted at Water and Land Use Management Institute (WALMI) Farm, Dharwad during late *rabi*, 2008. The storage experiment was carried out in the Seed Research Laboratory, National Seed Project, University of Agricultural Sciences, Dharwad. The results of the investigation are summarized under this chapter.

5.1 Standardization of priming duration for soybean seeds

- The study of the imbibition curve is very important, especially for the development of pre-germination techniques aimed at improving seed physiological quality. Priming soybean seeds for 14 h was found to be optimum.

5.2 Effect of seed quality and priming treatments on storability of soybean

- Seed quality parameters except for electrical conductivity and moisture content of seed exhibited significantly decreasing trend throughout five months period of storage irrespective of seed priming treatments and seed quality. The moisture content of the seed was found to vary in concomitant with fluctuation of ambient atmosphere.
- Speed of germination, germination percentage, root length, shoot length, seedling dry weight and field emergence showed significant difference due to seed quality. At the end of five months storage higher seed quality parameters were recorded in the seed lot of higher quality over lower quality seed lot. Electrical conductivity was also significantly in favour of the superior seed lot.
- Seeds primed with GA_3 (20 ppm) showed significantly higher speed of germination soon after the priming was imposed and after one month of storage followed by $CaCl_2.2H_2O$ (0.5%) primed seed. Significantly delayed germination was seen in KCl (100ppm) primed seeds.
- $CaCl_2.2H_2O$ (0.5%) primed seeds significantly favoured final germination, root length, seedling dry weight, vigour index, electrical conductivity and field emergence throughout the storage period followed by GA_3 (20 ppm) and KH_2PO_4 (50 ppm) primed seeds. Significant low performance was observed in KCl (100ppm) primed seeds with regard to the above parameters.
- GA_3 (20 ppm) primed seed showed significantly increased shoot length throughout the storage period followed by $CaCl_2.2H_2O$ (0.5%) primed seeds.
- Higher speed of germination was recorded in higher quality seeds primed with GA_3 (20 ppm) for first two months of storage but was overtaken by those lower quality seeds primed with $CaCl_2.2H_2O$ (0.5%) to the end of the storage period. The slower speed of germination was observed in lower quality seeds primed with KCl (100ppm) throughout the storage period.
- The higher quality seeds primed with $CaCl_2.2H_2O$ (0.5%) was significantly privileged to have a better germination, root length, seedling dry weight, vigour index, electrical conductivity and field emergence throughout the storage period followed by GA_3 (20 ppm) and KH_2PO_4 (50 ppm) primed seeds. Significantly low performance was observed in lower quality seeds primed with KCl (100ppm).
- The higher quality seeds primed with GA_3 (20 ppm) showed significantly increased shoot length throughout the storage period followed by those $CaCl_2.2H_2O$ (0.5%) primed higher quality seeds.

5.3 Effect of seed quality and priming treatments on seed yield and quality of soybean

- The seed lot with higher quality took significantly lesser days to 50 per cent emergence as compared to the lower quality seed lot. The seeds primed with GA_3 (20ppm) emerged faster which was on par with $CaCl_2.2H_2O$ (0.5%) primed seeds (T_4), followed by KH_2PO_4 (50 ppm) primed seeds; significantly delayed emergence was observed in seeds primed with KCl (100ppm). The interaction effect also showed significant influence with the fastest emergence recorded by higher quality seeds primed with GA_3 (20ppm) which was on par with the same level quality seeds primed with $CaCl_2.2H_2O$ (0.5%) and the most delayed emergence was shown in initially inferior seeds treated with KCl (100ppm).

- Significantly higher field emergence and emergence per m^2 were recorded in plots sown with seeds of higher quality over those with lower seed quality. The plots having seed primed with $CaCl_2.2H_2O$ (0.5%) recorded significantly higher field emergence and emergence per m^2 followed by GA_3 (20ppm) and KH_2PO_4 (50 ppm) primed seeds while the lowest field emergence and emergence per m^2 were recorded in plots having seed primed with KCl (100ppm). The interaction effect was also significant with the highest field emergence and emergence per m^2 recorded in plots sown with higher quality seeds primed with $CaCl_2.2H_2O$ (0.5%) which was on par with same level quality seeds primed with GA_3 (20ppm) when tested for germination.

- The plants raised from the seeds with higher quality showed significantly greater height in both 30 DAS and 60 DAS over those raised from the lower quality seeds. In respect of seed priming treatments, significantly taller plant plants were observed in plots having seed primed with GA_3 (20ppm) at 30 DAS, followed by $CaCl_2.2H_2O$ (0.5%) primed seeds while significantly shortest plant height was recorded in plots sown with KCl (100ppm) primed seeds. However, significantly taller plant height at 60 DAS was observed in plants raised from $CaCl_2.2H_2O$ (0.5%) primed seeds which were on par with the plants raised from (GA_3 (20ppm) primed seed and significantly shortest plants were observed in plots grown from seeds primed with KCl (100ppm). Interaction effect on plant height at 30 and 60 DAS indicated the superiority of plants raised from higher quality seeds primed with GA_3 (20) and $CaCl_2.2H_2O$ (0.5%), respectively.

- The seeds with higher quality took significantly lower days to 50 per cent flowering as compared to lower quality seeds. Plots having seed primed with $CaCl_2.2H_2O$ (0.5%) significantly accelerated flowering, followed by plots having seed primed with GA_3 (20ppm) and KH_2PO_4 and significantly delayed flowering was exhibited in plots having seed primed with KCl (100ppm). The interaction also showed significant influence with the earliest flowering observed in plots having sown with higher seed quality primed with $CaCl_2.2H_2O$ (0.5), which was on par with plots sown with same quality seeds primed with GA_3 (20).

- Significantly higher leaf area index was recorded in seeds with higher seed quality over those with lower seed quality. The plots having seed primed with $CaCl_2.2H_2O$ (0.5%) showed significantly highest leaf area index which was on par with plots having seed primed with GA_3 (20ppm), followed by those primed with KH_2PO_4 (50 ppm), while the lowest leaf area index was recorded in plots having seed primed with KCl (100ppm). The interaction had also a significant effect with the highest leaf area index recorded in plots sown with higher quality seeds primed with $CaCl_2.2H_2O$ (0.5) which was on par with plots sown with same quality seeds primed with GA_3 (20).

- Significantly higher relative water content was recorded in leaves obtained from plots sown with higher quality seeds as compared to those obtained from plots sown with lower quality seeds. The leaves obtained from plots having seed primed with $CaCl_2.2H_2O$ (0.5%) showed significantly highest relative water content which was on par with the leaves from plots having seed primed with KH_2PO_4 (50 ppm) followed by leaves obtained from plots having seed primed with GA_3 (20ppm) (T_6) (84.57%) while the lowest relative water content (79.02 %) was recorded in leaves obtained from plots having seed primed with KCl (100ppm). The interaction effect had also a significant effect with the highest relative water content recorded in leaves obtained from plots sown with the higher quality seeds treated by $CaCl_2.2H_2O$ (0.5).

- The plots raised from the seeds with higher quality recorded significantly greater number of pods per plant, number of seeds per plant, seed yield per plant, seed yield per plot and yield per hectare over those raised from the lower quality seeds. The plots having seed primed with CaCl2.2H2O (0.5%) showed significantly highest number of pods per plant, number of seeds per plant, seed yield per plant, seed yield per plot and yield per hectare followed by plots having seed treated with GA_3 (20ppm) and KH_2PO_4 (50 ppm) and while the lowest were recorded in plots having seed primed with KCl (100ppm). The interaction effect was also significant with plots sown with lower quality seeds primed by $CaCl_2.2H_2O$ (0.5) recording highest number of pods per plant, number of seeds per plant, seed yield per plant, seed yield per plot and yield per hectare.
- Results on hundred seed weight was observed to significantly favour seeds obtained from the least performed plots in the field.
- The seed priming treatments had significant influence on the test parameters except germination while the seed quality and interaction effects were non-significant. Yet, a significant improvement in seed quality was observed in progeny seeds.

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EFFECT OF SEED PRIMING ON STORABILITY, SEED YIELD AND QUALITY OF SOYBEAN [*Glycine max* (L.) Merill]

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ABSTRACT

Laboratory and field experiments were conducted to standardize the optimum duration for soybean seed priming and to study the effect of seed quality and seed priming chemicals on storability, seed yield and quality of soybean Cv. JS – 335 at Seed Research Laboratory, National Seed Project (Crops), University of Agricultural Sciences, Dharwad and at Water and Land Use Management Institute (WALMI) Farm, Dharwad, respectively.

The lag phase (Phase-II) with little change in water content from 41.8 to 45.0% (14, 16 and 18 h) was found as a priming regime. The 14 h priming duration showed consistently higher performance with the quality tests.

Significantly higher germination (98.00-66.00 %), field emergence (94.90-58.79 %) and vigour index (3118-1418) were recorded in seeds of higher quality primed with $CaCl_2.2H_2O$ (0.5%) followed by GA_3 (20ppm) and KH_2PO_4 (50ppm) primed seeds. Lower electrical conductivity were recorded in the seeds of higher quality primed with $CaCl_2.2H_2O$ (0.5%) (0.214 - 1.471 dSm^{-1}) during the storage period.

Significantly lower days to 50 % emergence was recorded in seeds of higher quality primed with GA_3 (20ppm) (6.00) which was on par with the same seeds primed with $CaCl_2.2H_2O$ (0.5%) (6.67). Significantly higher field emergence (93.00 %) was recorded in seeds of higher quality primed with $CaCl_2.2H_2O$ (0.5%) which was on par with seeds of higher quality primed with GA_3 (20ppm) (92.00 %).

Significantly higher yield per ha (23.67 q) was recorded in the plots sown with seeds of higher quality primed with $CaCl_2.2H_2O$ (0.5%), followed by those plots with GA_3 (20ppm) and KH_2PO_4 (50ppm). Seed yield (q/ha) showed high positive and significant correlation with number of pods per plant (0.909**), number of seeds per pod (0.933**) and yield per plant (0.921**). Seed quality parameters were significantly higher in the progeny seeds harvested from lower quality seed primed with $CaCl_2.2H_2O$, GA_3, and KH_2PO_4.