# ENHANCEMENT OF SEED QUALITY IN CHILLI (*Capsicum annuum* L.)

By
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## THESIS

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**DEPARTMENT OF OLERICULTURE**
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## DECLARATION

I hereby declare that this thesis entitled **"Enhancement of seed quality in chilli (*Capsicum annuum* L.)"** is a bonafide record of research work done by me during the course of research and that it has not been previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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Certified that this thesis entitled **"Enhancement of seed quality in chilli (*Capsicum annuum* L.)"** is a record of research work done independently by **Ms. Divya Parisa** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma or fellowship to her.

11/7/13

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## CERTIFICATE

We, the undersigned members of the Advisory Committee of **Ms. Diya Parisa,** a candidate for the degree of **Master of Science in Horticulture,** with major field in **Olericulture,** agree that the thesis entitled **"Enhancement of seed quality in chilli (*Capsicum annuum* L.)"** may be submitted by **Ms. Divya Parisa,** in partial fulfillment of the requirement for the degree.

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Divya.P

***Divya parisa***

## CONTENTS

## LIST OF TABLES

# LIST OF FIGURES

# INTRODUCTION

# 1. INTRODUCTION

Chilli (*Capsicum annuum* L.) is an important vegetable cum spice crop that belongs to the family solanaceae. It is usually a glabrous, woody subshrub widely cultivated throughout warm temperate, tropical and subtropical countries and is native of tropical South America or Mexico. It was introduced to India during 17$^{th}$ century by Portugese (Raju and Lackrose, 1991).

Chilli is grown all over the country under varying agro-climatic zones but area under dry chilli is concentrated in southern states. In India, the area under this crop is 7.92 lakh hectares with annual production of 12.23 lakh tonnes and productivity of 41.5 MT ha$^{-1}$ (NHB, 2011). India alone contributes about 50 per cent of world production, out of which 90 per cent is used for domestic consumption and only six per cent is exported to other countries like USA, Bangladesh, Nepal and Mexico.

High quality seed is the key to successful agriculture. Modern agriculture with its bias for technology and precision, demands that each and every seed should germinate and produce a vigorous seedling ensuring high yield. Apart from increased productivity, the seeds should also have better storability to produce good crop during the next season. To accomplish these characters the seed technologists have developed seed invigouration techniques such as seed priming which has significant impact on seed quality. Seed priming is a commercially viable technique for improving seed germination and vigour. It involves imbibition of seeds in water under controlled conditions to initiate early events of germination, followed by drying the seed back to its initial moisture content.

The beneficial effect of the seed priming treatments were reflected in greater cellular membrane integrity, counter action of lipid peroxidation and free radical chain reaction that is often found to be directly correlated with the maintenance of

viability, reduced moisture uptake by hydrated dehydrated seed (Dollypan and Basu, 1985), antipathogenic effects (Powell and Mathews, 1986), repair of biochemical lesions by the cellular enzymatic repair system (Villiers and Edgcumbe, 1975).

Rapid germination and emergence is an important determinant of successful establishment (Hydecker *et al.*, 1973). Harris *et al.* (1999) reported seed priming as 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. Seed priming has presented promising, and even surprising results, for many crop seeds (Bradford, 1986).

In storage, the viability and vigour of the seeds are regulated by many physicochemical factors like moisture content, atmospheric relative humidity, temperature, initial seed quality, physical and chemical composition of seed, gaseous exchange, storage structure, packaging materials, seed production location and techniques, etc. (Doijode, 1990)

As seed storage in controlled environment is costlier alternative methods such as priming of seed and storage can be done. The seeds are primed with a range of chemicals to arrest/slow down seed deterioration during storage and extend storage life of seed (Basu, 1993). A knowledge of proper storage of chilli seeds under ambient conditions at relatively low cost with minimum deterioration in quality for a period of at least one or more seasons will be of immense use to seed industry and farming community. The information on storage life of primed chilli seeds is meagre.

Hence, the present investigation was planned to standardize the methods of priming and storage of chilli seeds under ambient conditions to improve seed germination and seedling vigour.

# REVIEW OF LITERATURE

# 2. REVIEW OF LITERATURE

## 2.1. Seed priming:

Seed priming is a pre sowing treatment that involves the controlled hydration of seed sufficient to allow pre-germinative metabolic events to take place but insufficient to allow radicle protrusion through seed coat (Hydecker, 1972). Its benefits include rapid, uniform and increased germination, improved seedling vigour and growth under a broad range of environments resulting in better stand establishment and alleviation of phytochrome induced dormancy in some crops.

Krarup (1991) reported that the main effect of priming is increased germination percentage.

*Priming is a common practice for seed enhancement in the seed industry* (Taylor *et al.*, 1998).

According to McDonald (1999) priming induces faster and more uniform seed germination over broader temperature ranges in many crop species.

During priming, seeds are partially hydrated so that pre-germinative metabolic activities proceed while radicle protrusion is prevented and are dried back to the original moisture level. The beneficial effects of priming are associated with the repair and build up of nucleic acid, the increased synthesis of protein as well as the repair of membranes (McDonald, 1999).

Rao *et al* (2000) observed that imbibed chilli seeds showed increase in germination percentage at -0.4MPa on $12^{th}$day when compared to untreated seeds. Root growth was significantly higher in the primed seeds at -0.4 M Pa compared to untreated seed.

Seed maturation stage can also be an influential factor in germination performance at low temperatures and response to priming treatment (Demir and Oztokat, 2003).

Priming also enhances the activities of anti-oxidation (Wang et al., 2005; Hsu et al., 2003).

Priming can be a valuable process for improving germination and uniformity of heterogenously matured seed lots (Demir and Mavi, 2004)

Various priming techniques include osmo priming or hydro priming (Caseiro *et al.,* 2004), solid matrix priming (Taylor et al., 1988), steeping priming (Halmer, 2004) and drum priming (Rowse, 1996, Caseiro *et al.,* 2004).

Sand matrix priming was recommended for enhanced vigor in onion and bhindi (Selvarani, 2005 and Nirmala, 2006)

Seed priming may be used as an important tool to improve seed performance and stand establishment in the field, especially during summer (Nascimento and Pereira, 2007).

Seed priming is a pre-sowing treatment for influencing the seedling development and at a later stage by modulating pre-germination metabolic activity prior to protrusion of the radical (Vikas *et.al*, 2011)

Kibinza *et.al.,* (2011) reported that priming repairs damage of aged seeds or seeds exposed to abiotic stresses such as salinity by improving germination.

Chen and Arora (2012) reported that seed priming sets in motion germination-related activities (e.g. respiration, endosperm weakening, and gene transcription and translation, etc.) that facilitate the transition of quiescent dry seeds into germinating state and lead to improved germination potential

The direct benefits of seed priming in all plants include faster emergence, better, more and uniform stands, less need to re-sowing, more vigorous plants, better drought tolerance, earlier flowering, earlier harvest and higher grain yield. (Ghassemi-Golezani *et al.*, 2013)

### 2.1.1. EFFECT OF HYDROPRIMING ON SEED QUALITY PARAMETERS:

When seed is hydrated, physiological and biochemical changes occur. Prolonged seed hydration, particularly at low water potential profoundly influences the rapidity, synchrony and percentage of seeds that germinate. Several seed hydration procedures have been developed to improve the rate and uniformity of seedling emergence. But these may be characterized as germination promotive, dormancy breaking or protective treatments that could be integrated with seed hydration treatments to maximize seed performance.

Jagadish *et al.*, (1994) reported that hydration-dehydration treatment improved germination capacity of slightly deteriorated seeds in tomato, chilli and onion. They reported significant enhancement in germination and seedling growth when these seeds were treated with PEG @ -1.2 MPa.

Vanpijlen, *et al.* (1995) studied the effect of hydration treatments on germination performance, moisture content, DNA synthesis and controlled deterioration tolerance in tomato. Hydropirming of seeds resulted in increased in resistance to deterioration.

Vyakaranahal *et al.*, (1998) suggested technique of hydration-dehydration to improve germininability and vigour of 8 months old sunflower seeds. Water soaked seeds showed considerable increase in germination percent and vigour of seedling over control.

Artola *et al.*, (2003) reported hydropriming resulted to be a valid physiological treatment that significantly improves the vigor of birdsfoof trefoil (*Lotus corniculatus* L) seeds, since it allowed increased germination rate and uniformity, as well as soil emergence of seedling.

Hydropriming was recorded for beet root, mustard and radish (Nirmala, 2006 and Netaji, 2006).

Bassi et.al.,(2007) observed that in brinjal, hot water treatment ($50^0$C for 30minutes) after seed extraction showed higher seed quality in terms of maximum germination(84%) followed by sodium hypochlorite treatment for 30 minutes (79%) as compared to control (59%).

The potential of using seed hydropriming technology to achieve rapid germination and enhanced establishment was demonstrated for three out of four annual cover crop species tested (Snapp *et al.* 2008)

Jamshidi *et al.*, (2012) reported increased activity of amylase and sucrose synthase in the stems and roots of hydroprimed pea seedlings enhanced amylase activity and then conversion of seed reserves to simple compounds increased seedling growth.

Nouman *et al.*, (2012) observed that in drum stick (*Moringa oleifera)* hydropriming (8 h) was more effective in improving emergence, shoot vigor, and chlorophyll b contents.

Hydropriming is a technique that prime seeds with pure water this is a very simple and inexpensive method that stimulates water absorption by controlling the period for which seeds are in contact with water (Ramezani and Sokht-Abandani ,2013)

## 2.1.2. EFFECT OF HALOPRIMING ON SEED QUALITY PARAMETERS:

### 2.1.2.1. NaCl:

Improvement of germination in pepper plant by priming with water and NaCl has been reported (Smith and Cobb, 1991).

Seed priming with NaCl showed improvement in growth and yield mature tomato plants (Cano *et al.*, 1991) asparagus and tomatoes (Pill *et al.*, 1991), and cucumber (Passam and Kakouriotis, 1994).

Manoharan (1999) reported that germination of chilli seeds (Jwalaskhi and Ujjwala) reduced to 52% or below from third month onwards and did not germinate during $9^{th}$ and $10^{th}$ month in absolute control. Priming with NaCl retained germination upto 50% during $10^{th}$ month of storage and germination was early. Sodium chloride was economical when compared to PEG.

Seed priming with different salts, especially NaCl, have shown to improve germination and growth of many crops under stressed conditions (Khan *et al.*, 2009)

It was suggested that the observed effect of NaCl-priming on tomato seed germination is caused by an increase of the $GA_4$ content via GA biosynthetic gene activation and a subsequent increase in the expression of genes related to endosperm cap weakening. Priming with NaCl significantly enhanced the seed germination rate

at 48 h after sowing. Seedling growth, as indicated by plant height, stem diameter and hypocotyl and root length, was also promoted by NaCl priming. Nakaune *et al.*, (2012)

Eskandari (2012) observed that in tomato, seeds primed with salts such as NaCl had improved germination. NaCl priming generally needs to be used in long-term periods and relatively high concentration. However, for short term period, low NaCl concentration also has positive effect on germination rate and field emergence of tomato.

Soughir *et al.*, (2012) observed that in fenugreek (*Trigonella foenumgraecum* L.) primed with NaCl (4 g $L^{-1}$, 36 h) can prepare a suitable metabolic reaction in seeds and can improve seed germination under salinity stress.

**2.1.2.1.2. $CaCl_2$:**

Nagappa (1983) observed that soaking sunflower seeds for 24 h in one per cent calcium chloride increased germination percentage and seedling vigour with an increased proline accumulation under moisture stress condition revealing that calcium chloride imparted drought resistance character to plants.

Pre-soaking of sunflower seeds for 12 h in one per cent calcium chloride increased field emergence by 20 per cent and also seedling vigour. The increased seedling vigour was associated with increased amylase activity and efficiency of mobilizing nutrients from the cotyledons to the embryonic axis (Kathiresan *et al.*, 1984).

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

Based on laboratory studies, germination per cent, vigour index , root length and shoot length were found to be the best when seeds were treated with calcium chloride @ 0.4 per cent and CCC @ 0.2 per cent in sorghum, pigeonpea and cowpea (Rangaswamy *et al.*,1993).

Verma *et al.*, (2006) reported that both fresh as well as one year old mung bean seeds soaked in $CaCl_2$ (2%) for 16-18 h recorded significant increase in germination, seedling dry weight and rapid and uniform field emergence compared to control.

**2.1.2.3. $KNO_3$:**

Bussel and Gray (1976) reported that tomato seeds treated with $KNO_3$ (1.07 MPa) for 5 days accelerated germination and emergence rate at 8-10°C. Acceleration in germination by 24 per cent was reported in tomato seeds when seeds were treated with $KNO_3$ (0.15 M) and $K_2PO_4$ (0.07 M) for five days in tomato (Rumpel and Szudyga, 1978).

Coolbear and Grierson (1980) showed that priming did not cause any change in DNA content of tomato seeds during treatment. Similarly, there was little DNA synthesis prior to radicle protrusion in treated lettuce seeds (Khan *et al.*, 1978). They found that DNA synthesis may not coincide with radicle protrusion and that priming may be associated with processes related to cell elongation and expansion.

Sitoula (1985) stated that soaking the tomato seeds of cv. CO-1 with indole acetic acid @ 100 ppm for 16 h or potassium nitrate at 2 per cent for 48 h increased the germination percentage, seedling establishment, seed yield and quality of resultant seed.

Tomato seeds treated with $KNO_3$ + $KH_2$ $PO_4$ (-1.25 MPa) for 5 days accelerated emergence at all temperatures, increased the rate of germination, seed performance and reduced mean time of emergence by 20 per cent (Argerich *et al.*, 1990).

In tomato cv. Intermech, pre-soaking of seeds in KNO3 at 12°C for 6 days speeded up rate of emergence but there was no significant difference in fruit earliness or yield in any of the treatments (Petrikova, 1991)

Amanullah and Naiz-Hussian (1989) reported that seed treatment with 0.1 per cent $KNO_3$ for 12 hours increased emergence (74.5%) in sunflower. Pepper seeds treated with $KNO_3$ solution gave increased mean rate of germination with advancement of hypocotyl development but seed germination per cent was affected (Sundstorm and Edwards, 1989).

In muskmelon, germination advancement due to priming in $KNO_3$ for three days occurred with no detectable increase in DNA synthesis. Initiation of cell cycle activity is evidently an important event in the development of normal seedling following germination and priming stimulates DNA synthesis and can be used as a marker for priming enhancement (Welbaum and Bradford, 1991).

There was significant difference in germination and seedling vigour index of seeds treated with KNO3 @ 200 ppm, $KH_2PO_4$ @ 150 ppm and $Na_2HPO_4$ @ 150 ppm over untreated control in tomato, capsicum and onion (Jagadish *et al.*, 1994).

Singh and Ramarao (1993) reported that sunflower seeds soaked in potassium nitrate 500 ppm, showed significantly increased germination, seedling length and vigour index over control.

Renugadevi *et al.,* (1994) reported that, soaking of bittergourd seeds with $KNO_3$ (1%) gave maximum germination percentage (100), vigour index (1540) and speed of germination (25.82) compared to control (54, 1209, 9.89, respectively).

Nepolean and Krishnaswamy (1996) reported that, soaking of cassava seeds in potassium nitrate @ 0.5% for 24 hours enhanced germination as well as seedling vigour and Gibberellic acid 100 ppm mproved germination but reduced seedling growth .

Dimov *et al.,* (1997) observed improved field emergence and uniformity of emergence, in tomato and capsicum seeds when presoaked for 3 h in one percent potassium nitrate.

Germination per cent and seedling vigour index in tomato cv. Pusa Ruby were found to be influenced by inorganic salts such as $KNO_3$ @ 1 per cent and $KH_2PO_4$ @ 1 per cent (Gayathri, 2001).

Seed priming treatments using salts such as $KNO_3$ have been effective in improving watermelon germination at low temperatures (Demir and Mavi, 2004)

Yogananda *et al.* (2004) noticed that bell pepper seeds invigorated with $KNO_3$ (1.0%) recorded higher germination, root and shoot length, seedling dry weight, rate of germination and seedling vigour index over control.

Sathishkumar (2005) reported that the brinjal seeds treated with $GA_3$ 200 ppm increased the plant height, number of leaves per plant, fruit yield per plant, fruit length and reduced days for 50 per cent flowering followed by $KNO_3$ (2%) compared to control.

Vishwanath *et al.,* (2006) reported different invigouration treatments of chilli cv. Byadagi. Among treatments, $KNO_3$ (1%) showed maximum improvement in germination (89 %) and field emergence (85 %), respectively followed by 0.5 per cent $KH_2PO_4$ (86 and 83%) compared to control (78 %).

According to Kavitha (2007), seed treatment with $KNO_3$ (1%) for 6 h. as well as biopriming with *Trichoderma viride* (8g/kg) recorded higher seed quality parameters.

Venkatasubramanium and Umarani (2007) reported that seeds of tomato, brinjal and chilli responded equally to different priming methods. Priming bittergourd seeds with $KNO_3$ (150ppm) and pea seeds with -1.0 MPa PEG resulted in maximum germinability and vigour of seedlings (IIVR, 2008).

YanPing (2011) observed that priming seeds in 3% $KNO_3$ solution containing 0.1 mM SA could be used as an effective method to improve low-temperature performance and subsequent seedling growth of eggplant.

Entesari *et al.*, (2012) reported that Potassium nitrate ($KNO_3$) has been associated with an osmotic effect that enhances water uptake by the embryo, nutritional effect on protein synthesis, and increased $O_2$ uptake.

### 2.1.3. EFFECT OF OSMOPRIMING ON SEED QUALITY PARAMETERS:

Osmopriming is a type of seed priming that often uses solutions of polyethylene glycol (PEG) as the priming reagent. As a result, the seed imbibition in PEG solutions is restricted to only partial hydration, and primed seeds tend to have an improved seed performance indicated by greater germination rate and uniformity.

Osmoprimed tomato seeds germinate to higher percentages at 35°C than unprimed seeds and are able to germinate at 10°C whereas control seeds do not germinate at this low temperature

Heydecker *et al.,* (1975) have extensively studied pre-sowing treatments an inert osmoticum, polyethylene glycol (PEG 6000 or 8000). They have reported significant improvement of seed quality parameters in vegetables and flower seeds.

Yaklich and Orzolek (1977) observed early emergence of sweet pepper seeds when pre-soaked in –8 bars solution of PEG-6000 (240 g/l water) and pre-treatment of onion, carrot and tomato seeds with –12 bars of PEG-6000 shortened the germination period by about 25 per cent (Muhyaddin and Wiebe, 1989)

In tomato, one week of priming in PEG 6000 solution was the ideal seed priming period to increase germination rate (Wolfe and Sims, 1982).

Haigh and Barlow (1987) found that PEG (-1.5 MPa and –1.75 MPa) treated seeds had significantly faster rate of germination, shorter time to 50 per cent germination and shorter time spread than the control in onion seeds.

PEG 6000 treatment at –1.2 MPa significantly improved the field establishment in tomato and onion; plant height and number of leaves in tomato, capsicum and onion; number of fruits per plant in tomato and capsicum, bulb diameter and length in onion. The final yield significantly enhanced in onion and capsicum; but not in tomato (Alvarado *et al.*, 1987).

Zhang *et al.* (1988) reported that seed priming with 20-25 per cent PEG offers a means for raising germination percentage and vigour index in various deteriorated peanut seeds.

Jagadish *et al.* (1994) reported significant improvement in germination and seedling length when tomato, capsicum and onion seeds were treated with PEG @ -1.20 MPa.

Yongqing (1996) soaked newly harvested tomato seed with PEG 6000 (-1.0 MPa). Osmotic pre-treatments stimulated germination, increased uniformity of germination and seedling growth. Freshly treated seeds with PEG solution showed better germination.

Passam *et al.* (1997) noticed that pepper seeds treated with PEG @ -1.20 MPa recorded increase in seed quality parameters.

Gayathri (2001) also observed priming of tomato seeds with PEG @ -1.0 MPa recorded maximum germination and vigour index as against PEG @ -1.5 MPa.

Seeds of tomato, Bermuda grass, and cucumber exhibited increased final germination percentage under a saline environment after osmopriming, while PEG-primed spinach seeds had greater chilling and heat tolerance (Chen and Arora, 2011)

Osmopriming involves application of a particular preparation before seeds are planted by soaking in a solution with low osmotic potential containing several chemicals such as poly ethylene glycol (PEG), mannitol and chemical fertilizers such as urea (Ramezani and Sokht-Abandani, 2013)

Ghiyasi and Tajbakhsh (2013) observed that in soybean (*Glaycine max* L.) osmopriming with PEG- 6000 has the greatest impact on mitigating the effects of drought stress on germination and early growth stage.

## 2.1.4. EFFECT OF BIOPRIMING ON SEED QUALITY PARAMETERS:

Application of beneficial microorganisms to seed is a niche that can be exploited commercially to reduce the use of seed-applied pesticides and microbiological seed treatments also can be used by organic growers. Applying beneficial microorganisms to seed during the priming process is commercially realistic, as microorganism suspensions can easily be incorporated into the water used for seed priming. Successful application of selected microorganisms to seed in a commercially viable way is only the first step towards using beneficial microorganisms to improve crop health.

Lifshitz *et al.* (1987) studied the growth promoting activity of *Pseudomonas putida*, strain GR 12-2, in a gnobiotic growth pouch assay, reporting that inoculation of rapeseed with GR 12-2 significantly increased the root length, shoot height and phosphorus uptake, compared with an un-inoculated control.

It is equally important that the microorganisms remain viable and can colonise the developing roots and rhizosphere in order to continue improving plant growth and to potentially control disease. Seed-applied microorganisms have the potential to become established in the rhizosphere of plants, as they may transfer onto the developing root as it emerges from the seed (Harman, 1991).

Inoculation of seeds with biological agents in combination with priming has, in several cases, been reported to enhance and stabilize the efficacy of biological agents (Callan et al., 1990).

These PGPR inhabit plant roots and affect plant growth promotion by mechanisms such as increased solubilization and uptake of nutrients and/or production of plant growth regulators (Kloepper et al., 1989; Arshad and Frankenberger, 1991)

Various strains of *P. fluorescens* have been found to be effective in plant growth promotion (Raj et al., 2004).

Bennett *et al.*, (2009) showed that bacteria and fungi can be successfully applied to carrot and onion seed during the process of drum priming.

Moeinzadeh *et al.*, (2010) stated that biopriming with *Pseudomonas fluorescens* UTPf76 and UTPf86 have provided very well establishment and adherence of bacteria to the seed, before planting, and thus is suggested as a proper treatment for enhancement of seed indices and improvement of seedling growth.

## 2.2. INFLUENCE OF STORAGE CONDITIONS ON SEED QUALITY PARAMETERS:

Generally, seeds stored in moisture impervious sealed containers retain better quality compared to moisture pervious containers under ambient conditions. The prevailing relative humidity and temperature of the storage atmosphere influence greatly on the longevity of seeds since moisture content of the seeds fluctuate more in the moisture pervious containers than the moisture proof containers.

The ideal package material should protect seeds from high moisture, to withstand low temperature and preserve viability for longer periods.

Brinjal seeds stored in aluminium foil and polyethylene laminated pouches recorded 50 per cent germination at the end of 39 months of storage (Thulasidas *et al.*, 1977).

Vanangamudi *et al.*, (1986) reported that field and vigour potentials of 40 months old field bean seeds stored in 700 gauge polythene bag were superior to those stored in cloth bags.

Doijode (1988) reported that among different containers, polythene bags were promising since, it was effective in preserving the seed viability (81%) and vigour of French bean for longer storage period

Sahee *et al.*, (1994) stored the seeds of tomato in impermeable and permeable packets and noticed the decline in germination per cent below certification standards (70%) before one year in the seeds stored in permeable pack whereas the seeds of impermeable packet maintained higher viability for more than one year.

Doijode (1995) observed that seeds of onion cultivar Nasik Red at 6.5 per cent moisture content when stored with or without silica gel desiccants in a kraft paper bag, a glass container, a polythene bag (700 gauge), the percentage of germination was more in seeds stored in polythene bag (700 gauge) than other container.

Doijode (1997) reported that the tomato seeds could maintain viability upto four years when stored in polythene bags of 700 gauge under ambient temperature of 16-35°C as compared to sub-zero temperature of 2° C.

Sharma *et al.*, (1998) reported the seeds of two varieties of chilli viz., *Pusa Jwala* and *Mathania Local* were sun dried to about six per cent moisture content and stored in polythene bags (700 gauge) and paper bags. The germination decline was higher in seeds stored in paper bags as compared with those in 700 gauge in polythene bags.

Padma and Reddy (2000) reported that the onion seed stored in polythene bag and aluminium foil pouch extended the storage life by five and seven months, respectively, over the seed stored in cloth bag or paper bag which had only 14 months of storage. The germination was highest even after 11 months of storage in laminated bags, whereas, it was less in paper bags.

## 2.3. EFFECT OF PRIMING ON SEED QUALITY DURING STORAGE:

Hydration treatment will not reduce the storability, Dollypan and Basu (1985) observed that, mid-storage hydration dehydration treatment for two hours in carrot seeds very effectively reduced physiological deterioration in storage and ultimately showed better field emergence and yield.

Priming decreased the germination and emergence times, and these effects were maintained even after storage (at around 10°C) for 450 days (Dearman *et al.*, 1987)

Pre-germination hydration-dehydration on seeds of tomato, radish, onion garden peas and cluster bean resulted in better establishment of seedling, higher mobilization of food reserves into growing seedling was noticed in small seeded vegetables. Hydrated onion seeds for 6 h at 20°C followed by drying gave high seed germination and high seedling vigour (Doijode and Raturi, 1987)

Van Pijlen *et al.* (1995) reported that tomato seed, invigourated in solution of KNO3 or PEG 8000 would counteract the adverse effect of storage and reduce the mean time for germination as much as 53 per cent.

Trigo, *et al.* (2000) reported that the nion seed lots (cultivars Aurora and Petrolini) of different vigour levels osmoconditioned for 24 h in aerated solutions of

$KNO_3$ or PEG 6000 at 20°C maintained physiological quality for up to 6 months of storage.

Singh *et al.* (2001) reported that seeds primed with $KNO_3$ (0.35 M) recorded comparable germination and speed of germination than the control at all the equivalent stages of six month storage. So it concludes that the primed seeds can be stored for sufficient long time.

Maximum beneficial effect in terms of enhanced seed performance, storability and seedling production was noticed in IAHS-1 tomato hybrid by invigourating seeds with hydration-dehydration (Gayathri, 2001).

Tamanini *et al.*, (2001) reported that seeds of lettuce cv. Hortência subjected to osmotic priming were packed using paper sack, can, glass and plastic box. After 6 and 24 months, germination and index of germination speed were evaluated. The results showed that primed and coated lettuce seeds maintain their quality for at least 24 months when stored at controlled conditions (15°C and 40% moisture) regardless of the packaging material used.

Srinivasan and Saxena (2001) reported that the effects of priming on partially-aged seeds of radish cv. Chinese pink were retained up to 10 months of storage at ambient conditions .

Tamanini *et al.*, (2002) observed that the seeds of tomato cv. Santa Clara primed in aerated solutions of polyethylene glycol (PEG; 300 g/litre) and potassium monophosphate [potassium dihydrogen phosphate] ($KH_2PO_4$ 0.3 M) for 96 h and in distilled water for 24 and 48 h under ambient temperature maintained the beneficial effects of priming for at least 6 months when stored under controlled conditions

Posse *et al.*, (2004) reported that seeds of sweet pepper (*Capsicum annuum*) hydrated for 24 h and primed with PEG when stored at 5°C maintained high germination and emergence percentages throughout the 4 months of storage, especially when tested at 20°C.

Fonseka *et al.*, (2011) reported that the seeds of bitter gourd (*Momordica charantia* L.) primed in 0.3% $KNO_3$ or 0.2% $KNO_3$ or in household vinegar (pH-3.7) for a 2 h period maintained higher germination of 90 and 80%, respectively. Therefore, it is concluded that bitter gourd seeds stored up to one year maintained high germination percentage but deteriorate rapidly afterwards.

# MATERIALS AND METHODS

# 3. MATERIAL AND METHODS

The present study was conducted to ascertain the influence of seed priming and storage environment on enhanicing quality of chilli (*Capsicum annuum* L.) The experiments were conducted in the Department of Olericulture, College of Horticulture, Vellanikkara during December 2011 to December 2012. The details of the materials used and techniques adopted during the course of investigations are described in this chapter.

## 3.1. Experimental site:

### 3.1.1. Location

The site is located at $10^0$ 31 N latitude, $76^0$ 13 E longitude at an altitude of 22.25 m above mean sea level. The area experiences typical warm humid climate and receives an average rainfall of 2663 mm per year. The soil of the experimental site is grouped under the textural class of sandy clay loam and acidic in reaction.

### 3.1.2. Climatic condition

The mean meteorological data from December 2011 to December 2012 were collected from the meteorological observatory, College of Horticulture, Vellanikkara and presented in Table 1. During the period the mean maximum temperature of 35.1°C was in February 2012 and the mean minimum temperature was 21.3 °C in January 2012. The relative humidity during period varied from 54 per cent to 86 per cent.

## 3.2. Seed source

For the present study, the freshly harvested seeds of high yielding chilli variety Anugraha developed by Kerala Agricultural University was collected from the Department of Olericulture, College of Horticulture, Vellanikkara and stored under ambient conditions.

Table 1: Monthly meteorological data from December 2011 to December 2012.

| Months | Temperature ($^0$c) | | Relative humidity (%) | Rain fall (mm) | Rainy days |
|---|---|---|---|---|---|
| | Mean maximum | Mean minimum | | | |
| December 2011 | 30.9 | 22.0 | 70 | 24.5 | 2.0 |
| January 2012 | 32.7 | 22.2 | 58 | 0 | 3.0 |
| February 2012 | 33.7 | 22.0 | 55 | 77.5 | 2.0 |
| March 2012 | 34.8 | 23.9 | 64 | 10.0 | 5.0 |
| April 2012 | 34.7 | 24.8 | 73 | 101.9 | 8 |
| May 2012 | 32.6 | 25.3 | 76 | 117.3 | 5 |
| June 2012 | 30.1 | 23.9 | 85 | 551.5 | 23 |
| July 2012 | 30.0 | 23.7 | 85 | 375.8 | 19 |
| August 2012 | 29.2 | 23.0 | 86 | 616.5 | 18 |
| September 2012 | 30.4 | 23.3 | 83 | 191.6 | 14 |
| October 2012 | 32.1 | 23.5 | 77 | 145.6 | 10 |
| November 2012 | 32.5 | 22.7 | 69 | 46.7 | 3 |
| December 2012 | 33.0 | 23.2 | 58 | 19.8 | 2 |

### 3.3. Experiment details:

#### 3.3.1. Effect of priming and storage on quality of seeds primed after 3 months of *storage*

The seeds were drawn after three months of storage were primed and stored for eight months and monthly observations were recorded

#### 3.3.2. Effect of priming and storage on quality of seeds primed after 6months of *storage*

The seeds were drawn after six months of storage were primed and stored for five months and monthly observations were recorded.

#### 3.3.3. *Effect of priming and storage on quality of seeds primed after 9 months of storage*

The seeds were drawn after nine months of storage were primed and stored for two months and monthly observations were recorded.

### 3.4. Treatment details

#### 3.4.1. Seed priming:

Freshly harvested seeds of chilli variety Anugraha were stored under ambient conditions from December 2011 to December 2012 (Table 1). Seed samples were drawn after 3, 6 and 9 of storage and treated with the following priming agents for three hours, washed in water and dried under shade to 8% moisture content.

$P_1$ – Control (dry seed)

$P_2$ –Control (water soaking)

$P_3$ –Soaking in NaCl ($10^{-5}$M)

$P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M)

$P_5$ –Soaking in $KNO_3$ (150ppm)

$P_6$ –Soaking in PEG 6000 (-1.5MPa)

$P_7$–Seed treatment with *Pseudomonas fluorescens* (10g/kg seed)

### 3.4.2. Storage:

The treated seeds were packed in cloth bag ($S_1$) and polythene bag (700 gauge) ($S_2$) and stored under ambient condition (Table 1).

Each experiment consisted of 14 treatment combinations laid out in the Completely Randomized Design in three replications.

### 3.5. Collection of experimental data

The observations were recorded on the following quality parameters during the initial three months of storage, immediately after priming, and also after priming and storage at monthly intervals on speed of germination, seedling length (cm.) seedling fresh weight (mg.), seedling dry weight (mg.), days to 4 leaf emergence, electrical conductivity of seed leachate, vigour index I, vigour index II and they are explained below.

### 3.5.1. 100 seed weight

The hundred seed weight in grams was recorded in each treatment combinations as per the procedure given by ISTA.

### 3.5.2. Moisture content (%)

Two replicates of five gram of seed material were taken for determining the moisture content using low constant temperature method. The powdered seed

material was placed in a weighed moisture aluminium cup and after removing the lid and it was placed in hot air oven maintained at 103 ± 2°C for 17 ± 1 hours. Then, the contents were weighed in an electronic balance along with bottle and lid. The moisture content was worked out using the following formula and expressed as percentage (ISTA, 1999).

$$\text{Moisture content (\%)} = \frac{M2 - M3}{M2 - M1} \times 100$$

Where, M1 = weight of the aluminium cup alone

M2 = weight of the aluminium cup + sample before drying

M3 = weight of the aluminium cup + sample after drying

### 3.5.3. Percent Germination

Hundred seeds in three replications were taken from each treatment and the germination test was conducted using sand method as per ISTA rules. Three hundred seeds from each treatment were sown in trays containing sterilized sand (3 replications with 100 seeds per replication). Daily observation of germination was recorded up to $14^{th}$ day. The initial first count was made on $6^{th}$ day of germination. The number of normal seedlings were counted at the end of $14^{th}$ day as count of germination and expressed in percentage.

### 3.5.4. Speed of germination:

Seeds were germinated in sand medium with three replications of hundred seeds each. The number of seeds germinated was recorded daily up to the day of final count. The speed of germination was calculated by adopting the fallowing formula and expressed in number (Maguire, 1962).

$$\text{Rate of germination} = \frac{X1}{Y1} + \frac{(X2-X1)}{Y2} + \frac{Xn-(Xn-1)}{Yn}$$

Where,

Xn – Number of seeds germinated at $n^{th}$ count

Yn – Number of days from sowing to $n^{th}$ count

**3.5.5. Seedling length (cm):**

Ten normal seedlings were taken randomly from each replication at the end of the germination test for measuring the seedling length. The length between the tip of the shoot and the tip of the primary root was measured. The mean value was recorded in cm.

**3.5.6. Seedling fresh weight (mg):**

Randomly ten normal seedlings were selected and uplifted carefully, the seedlings were washed off to remove any loose sand. Seedlings were subjected to blotting to remove the surface moisture and fresh weight of seedlings was recorded in an electronic balance and average weight was computed and expressed in milligrams per seedling.

**3.5.7. Seedling dry weight (mg):**

Randomly taken ten normal seedlings which were used for recording seedling fresh weight measurement were placed in a butter paper bag and dried for 24 hours in a hot air oven maintained at 70°C. The dried seedlings were removed and cooled in a desiccator for 30 minutes and then the dry weight of seedling was recorded in an

electronic balance and average weight was computed and expressed in milligram per ten seedlings.

### 3.5.8. Days to 4 leaf emergence:

Each treatment was observed everyday for emergence of leaves from date of sowing onwards until 4 leaf emergence of seedlings and this day was recorded as days to 4 leaf emergence from the date of sowing.

### 3.5.9. Electrical conductivity ($dsm^{-1}$)

Five grams of seeds were taken at random from each treatment and were soaked in $Hgcl_2$ (0.10%) solution for a minute and washed with distilled water for five times. Then the seeds were soaked in 25.00 ml of distilled water for 24 hr at room temperature. The seed leachate was collected by decanting and the volume was made up to 25.00 ml by adding distilled water and the electrical conductivity of seed leachate was measured in an electrical conductivity bridge (ELICO) with cell constant of 1.00. The estimations were done in four replications and mean value was expressed in dsm-1 (Presley, 1958).

### 3.5.10. Vigour indices:

The vigour index (V I) was calculated by adopting the method suggested by Abdul-Baki and Anderson (1973) and was expressed as pure number.

vigour index (V I) I = (germination (%) x seedling dry weight)

vigour index (V I) II = germination (%) x (seedling length in cm)

**Statistical analysis:**

Statistical analysis of the data was performed in computer using M STAT-C package in factorial completely randomized design.

# RESULTS

# 4. RESULTS

The results of the present study are presented under the following heads.

***4.1. Quality of seeds during storage under ambient conditions (Initial 3 months)***

**4.2. Effect of priming and storage on quality of seeds primed after 3 months of storage**

**4.3. Effect of priming and storage on quality of seeds primed after 6months of storage**

**4.4. Effect of priming and storage on quality of seeds primed after 9 months of storage**

**4.1. Quality of seed during storage under ambient conditions (Initial 3 months):**

The statistically analysed data of 100 seed weight (g), moisture content (%), percent germination, speed of germination, seedling length (cm), seedling fresh weight (mg), seedling dry weight (mg), days to four leaf emergence, electrical conductivity of seed leachate ($dsm^{-1}$), vigour index I and vigour index II are presented in Table-2.

**4.1.1. 100 seed weight (g):**

There was significant increase in 100 seed weight during storage. It increased from 0.60 g to 0.62 g by the end of three months of storage.

**4.1.2. Moisture content (%):**

There was an increase in moisture content (%) of seeds from 7.00 % to 7.21 % by the end of three months of storage.

Table 2: Quality of chilli seeds during initial 3 months under ambient condition.

| Seed quality parameters | $M_0$ | $M_1$ | $M_2$ | $M_3$ | CD |
|---|---|---|---|---|---|
| 100 seed weight (g) | 0.60 | 0.60 | 0.61 | 0.62 | 0.01 |
| Moisture content (%) | 7.00 | 7.11 | 7.18 | 7.21 | 0.01 |
| Germination (%) | 79.33 | 78.00 | 76.00 | 74.00 | 3.02 |
| Speed of germination | 10.43 | 10.26 | 10.04 | 9.88 | 0.11 |
| Seedling length (cm) | 12.65 | 12.41 | 12.33 | 11.51 | 0.40 |
| Seedling fresh weight (mg) | 179.60 | 175.75 | 171.08 | 162.15 | 5.89 |
| Seedling dry weight (mg) | 18.05 | 17.11 | 17.03 | 16.45 | 0.64 |
| Days to four leaf emergence | 9.00 | 9.02 | 9.22 | 9.33 | NS |
| Electrical conductivity of seed leachate | 0.26 | 0.29 | 0.41 | 0.47 | 0.01 |
| Vigour index I | 1432.32 | 1333.87 | 1293.96 | 1217.05 | 52.58 |
| Vigour index II | 1003.52 | 968.54 | 937.19 | 851.45 | 43.57 |

$M_0$ Initial month

$M_1$ One month after storage

$M_2$ Two months after storage

$M_3$ Three months after storage

### 4.1.3. Germination (%):

Significant difference with respect to percent germination was observed during the storage period. It was found to decrease from 79.33% to 74.00%.

### 4.1.4. Speed of germination:

The speed of germination also differed significantly during the storage period and was found to decrease from 10.42 to 9.87.

### 4.1.5. Seedling length (cm):

There was decrease in seedling length during storage. It decreased from 12.65 cm in the initial month to 11.51 at the end three months.

### 4.1.6. Seedling fresh weight (mg):

Significant difference with respect to seedling fresh weight (mg) was observed during the storage. It decreased from 179.60 mg to 162.15 mg during three months storage.

### 4.1.7. Seedling dry weight (mg.):

The seedling dry weight (mg) decreased from 18.05 mg to 16.44 mg by the end of three months storage.

### 4.1.8. Days to four leaf emergence:

There was no significant difference with respect to days to four leaf emergence.

### 4.1.9. Electrical conductivity of seed leachate:

Electrical conductivity of seed leachate was found to increase with increase in storage period. It increased from 0.25 $dsm^{-1}$ to 0.47 $dsm^{-1}$

### 4.1.10. Vigour index:

The vigour index I was also found to decrease with increase in storage period. It decreased from 1432.32 to 1217.05 by the end of third month of storage.

### 4.1.11. Vigour index II:

Vigour index II was also found to decrease with increase in storage period. It decreased from 1003.52 to 851.45 by the end of third month of storage period.

## 4.2. Effect of priming and storage on quality of seeds primed after 3 months of storage.

The statistically analysed data of 100 seed weight (g), moisture content (%), percent germination, speed of germination, seedling length (cm), seedling fresh weight (mg), seedling dry weight (mg), days to four leaf emergence, electrical conductivity of seed leachate ($dsm^{-1}$), vigour index I and vigour index II, immediately after priming and as influenced by priming, storage and their interaction are presented in the (Table 3-3k).

Immediately after priming, seeds primed with $P_6$ (PEG 6000 (-1.5 MPa) recorded the highest 100 seed weight (0.72 g), moisture content (7.35 %), highest germination (81.33 %), speed of germination (12.64), , fresh weight (207.00 mg) and lowest electrical conductivity (0.36 $dsm^{-1}$). P7 recorded the maximum seedling length (15.67 cm), highest dry weight (21.00 mg), vigour index I (1666), vigour index II (1243). P1 (Control) recorded the lowest 100 seed weight (0.62 g), moisture content (7.19 %), germination (72.67 %), speed of germination (9.96), maximum seedling length (11.40 cm), fresh weight (161.66 mg) dry weight (18.00 mg), vigour index I (1308.00), vigour index II (828.23) and highest electrical conductivity (0.50 $dsm^{-1}$).

### 4.2.1. 100 seed weight:

There was significant difference for 100 seed weight during the storage period. During the first month of storage 100 seed weight was lowest (0.65g) and in the eighth month it was highest (0.77g). (Table 3 a)

There was significant effect for priming on 100 seed weight. Seeds primed with NaCl ($10^{-5}$M) ($P_3$) recorded lowest value 0.70g and that with PEG 6000 (-1.5MPa) ($P_6$) recorded the highest value (0.76g).

There was no significant effect for the storage containers on 100 seed weight. The 100 seed weight of seeds stored in cloth bag varied from 0.65g to 0.78g and that of seeds stored in polythene bag (700gauge) ($S_2$) varied from 0.64g to 0.77g.

100 seed weight due to interaction between priming and storage was non-significant. However, it varied from 0.71 g in hydro primed seeds stored in polythene bag (700gauge) ($P_2S_2$) to 0.77g in $P_6S_1$ (PEG 6000(-1.5MPa) and stored in cloth bag).

**4.2.2. Moisture content (%):**

With the advancement of storage period, moisture content (%) increased irrespective of priming, storage and their interaction. The mean moisture content increased from 7.30 % during initial month to 7.85% by the end of storage period (Table 3 b).

Significant difference on moisture content (%) was observed between priming treatments. The highest value 7.68% was recorded in PEG 6000 (-1.5MPa) ($P_6$) and the lowest value 7.52% was recorded in control ($P_1$).

There was significant difference between the storage containers for seed moisture content (%) during the storage period. It varied from 7.32% to 7.89% in cloth bag ($S_1$) and 7.29% to 7.80% in (Polythene bag 700 gauge ($S_2$).

Table 3: Effect of priming on seed quality parameters immediately after priming (3 months after storage)

| Seed quality parameters | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ | $P_6$ | $P_7$ | CD |
|---|---|---|---|---|---|---|---|---|
| 100 seed weight (g) | 0.62 | 0.63 | 0.64 | 0.63 | 0.63 | 0.72 | 0.69 | 0.95 |
| Moisture content (%) | 7.19 | 7.19 | 7.27 | 7.25 | 7.29 | 7.35 | 7.24 | 0.95 |
| Germination (%) | 72.67 | 75.33 | 77.67 | 76.33 | 77.33 | 81.33 | 79.33 | 1.26 |
| Speed of germination | 9.96 | 10.87 | 10.71 | 11.3 | 11.37 | 12.64 | 11.18 | 0.11 |
| Seedling length (cm) | 11.4 | 12.33 | 12.33 | 14.67 | 13 | 13.67 | 15.67 | 1.09 |
| Seedling fresh weight (mg) | 161.67 | 169.67 | 173.33 | 184 | 178 | 207 | 204.33 | 10.52 |
| Seedling dry weight (mg) | 18 | 18 | 19 | 18 | 18 | 19.67 | 21 | 0.45 |
| Days to four leaf emergence | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 0.95 |
| Electrical conductivity of seed leachate | 0.50 | 0.46 | 0.37 | 0.39 | 0.42 | 0.36 | 0.47 | 0.95 |
| Vigour index I | 1308 | 1356 | 1475.667 | 1374 | 1392 | 1600 | 1666 | 1012.54 |
| Vigour index II | 828.23 | 928.67 | 957.67 | 1119.33 | 1005 | 1112 | 1243 | 4486.58 |

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M)

$P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M) $P_5$ –Soaking in $KNO_3$ (150ppm) $P_6$ –Soaking in PEG 6000(-1.5MPa)

$P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

Table.3 a: Effect of priming and storage containers on 100 seed weight (g) of seeds primed after 3 months of storage

| Months | M1 | | M2 | | M3 | | M4 | | M5 | | M6 | | M7 | | M8 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Priming | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 0.63 | 0.62 | 0.63 | 0.63 | 0.73 | 0.71 | 0.75 | 0.71 | 0.76 | 0.76 | 0.78 | 0.76 | 0.78 | 0.77 | 0.78 | 0.77 | 0.73 | 0.72 | 0.72 |
| P2 | 0.63 | 0.61 | 0.66 | 0.64 | 0.71 | 0.72 | 0.73 | 0.71 | 0.74 | 0.73 | 0.75 | 0.74 | 0.76 | 0.75 | 0.76 | 0.76 | 0.72 | 0.71 | 0.71 |
| P3 | 0.63 | 0.62 | 0.64 | 0.63 | 0.71 | 0.70 | 0.71 | 0.71 | 0.73 | 0.71 | 0.74 | 0.73 | 0.75 | 0.74 | 0.76 | 0.75 | 0.71 | 0.69 | 0.70 |
| P4 | 0.64 | 0.63 | 0.64 | 0.64 | 0.74 | 0.70 | 0.76 | 0.74 | 0.77 | 0.75 | 0.78 | 0.77 | 0.77 | 0.78 | 0.78 | 0.78 | 0.74 | 0.72 | 0.73 |
| P5 | 0.64 | 0.62 | 0.65 | 0.64 | 0.74 | 0.73 | 0.75 | 0.73 | 0.76 | 0.75 | 0.78 | 0.77 | 0.79 | 0.77 | 0.79 | 0.78 | 0.74 | 0.72 | 0.73 |
| P6 | 0.73 | 0.72 | 0.75 | 073 | 0.74 | 0.69 | 0.76 | 0.75 | 0.78 | 0.75 | 0.79 | 0.77 | 0.79 | 0.78 | 0.79 | 0.79 | 0.77 | 0.75 | 0.76 |
| P7 | 0.69 | 0.67 | 0.69 | 0.75 | 0.75 | 0.72 | 0.77 | 0.76 | 0.75 | 0.74 | 0.76 | 0.75 | 0.77 | 0.76 | 0.78 | 0.77 | 0.75 | 0.73 | 0.74 |
| Mean | 0.65 | 0.64 | 0.67 | 0.73 | 0.73 | 0.711 | 0.75 | 0.73 | 0.75 | 0.74 | 0.77 | 0.76 | 0.77 | 0.77 | 0.78 | 0.77 | 0.73 | 0.72 | |
| | 0.65 | | 0.66 | | 0.72 | | 0.74 | | 0.75 | | 0.76 | | 0.77 | | 0.77 | | | | |

CD (priming) = 0.38 CD (Storage containers) = 0.22 CD (P x S interaction) = NS CD (storage period) = 0. 41

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M) $P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M)

$P_5$ –Soaking in $KNO_3$ (150ppm) $P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1, M2, M3, M4, M5, M6, M7 and M8 (storage period in months after priming)

Table 3 b: Effect of priming and storage containers on moisture content (%) of seeds primed after 3 months of storage

| Months | M1 | | M2 | | M3 | | M4 | | M5 | | M6 | | M7 | | M8 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| priming | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 7.25 | 7.25 | 7.35 | 7.22 | 7.44 | 7.35 | 7.49 | 7.53 | 7.58 | 7.51 | 7.71 | 7.62 | 7.82 | 7.70 | 7.85 | 7.73 | 7.56 | 7.49 | 7.53 |
| P2 | 7.24 | 7.20 | 7.38 | 7.35 | 7.53 | 7.51 | 7.58 | 7.53 | 7.69 | 7.58 | 7.72 | 7.66 | 7.81 | 7.70 | 7.84 | 7.78 | 7.59 | 7.54 | 7.57 |
| P3 | 7.32 | 7.28 | 7.37 | 7.36 | 7.44 | 7.40 | 7.51 | 7.45 | 7.66 | 7.51 | 7.73 | 7.63 | 7.84 | 7.75 | 7.88 | 7.79 | 7.59 | 7.52 | 7.56 |
| P4 | 7.33 | 7.27 | 7.36 | 7.29 | 7.43 | 7.36 | 7.50 | 7.40 | 7.65 | 7.51 | 7.75 | 7.63 | 7.81 | 7.71 | 7.84 | 7.79 | 7.58 | 7.49 | 7.54 |
| P5 | 7.34 | 7.33 | 7.47 | 7.24 | 7.54 | 7.36 | 7.60 | 7.50 | 7.70 | 7.58 | 7.82 | 7.70 | 7.89 | 7.74 | 7.93 | 7.81 | 7.66 | 7.53 | 7.59 |
| P6 | 7.43 | 7.42 | 7.58 | 7.60 | 7.59 | 7.50 | 7.65 | 7.60 | 7.74 | 7.63 | 7.83 | 7.73 | 7.91 | 7.81 | 7.95 | 7.90 | 7.71 | 7.65 | 7.68 |
| P7 | 7.30 | 7.27 | 7.34 | 7.32 | 7.44 | 7.35 | 7.55 | 7.44 | 7.62 | 7.52 | 7.71 | 7.67 | 7.81 | 7.72 | 7.93 | 7.80 | 7.58 | 7.52 | 7.55 |
| Mean | 7.32 | 7.29 | 7.41 | 7.34 | 7.49 | 7.41 | 7.56 | 7.49 | 7.66 | 7.55 | 7.75 | 7.66 | 7.84 | 7.73 | 7.89 | 7.80 | 7.62 | 7.54 | |
| Mean | 7.3 | | 7.38 | | 7.45 | | 7.53 | | 7.61 | | 7.71 | | 7.79 | | 7.85 | | | | |

CD (priming) = 0.01 CD (Storage containers) = 0.63 CD (P x S interaction) = 0.01 CD (storage period ) = 0.01

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M) $P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M)

$P_5$ –Soaking in $KNO_3$ (150ppm) $P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1, M2, M3, M4, M5, M6, M7 and M8 (storage period in months after priming)

Interaction between priming and storage containers on seed moisture was significantly different. The moisture content was highest 7.71 % in $P_6S_1$ (PEG 6000 (-1.5 MPa)) + storage in cloth bag) and lowest (7.49%) in $P_1S_2$ (control + storage in polythene bag 700 gauge).

**4.2.3. Germination (%):**

With the advancement of storage period percent germination reduced from 74.41% to 20.81%. (Table 3c)

There was significant difference in percent germination of seeds primed with different agents. The highest value, 56.31 % was recorded in PEG 6000 (-1.5MPa) ($P_6$) and lowest value, 34.40 % was recorded in $P_1$ (control).

There was significant difference between the storage containers for percent germination of seeds. It decreased from 74.14% to 18.71% for the seeds stored in cloth bag ($S_1$) and from 74.67 % to 22.91 % for that stored in polythene bag 700 gauge ($S_2$).

The interaction between priming and storage was non-significant. It varied from 30.54 % in $P_1S_1$ (control + storage in cloth bag) to 58.17% in $P_6S_2$ (PEG 6000 (-1.5MPa) + storage in polythene bag 700 gauge)

**4.2.4. Speed of germination:**

The overall mean of speed of germination was found to be decreasing from 10.98 during the initial month of storage to 2.87 at the end of storage period. (Table 3d)

Speed of germination differed significantly between various methods of priming. The highest value 8.02 was recorded in $P_6$ (PEG 6000 (-1.5M)) followed by 7.01 in NaCl ($10^{-5}$M) ($P_3$). The treatment $P_1$ (control) recorded the lowest (4.59) speed of germination.

Significant difference between storage containers was observed for speed of germination. During the storage period the speed decreased from 11.07 to 2.55 in $S_1$ (control) and 10.88 to 3.19 in $S_2$ (polythene bag (700gauge))

Table 3 c: Effect of priming and storage containers on germination (%) of seeds primed after 3 months of storage

| Months | M1 | | M2 | | M3 | | M4 | | M5 | | M6 | | M7 | | M8 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Priming | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | $S_1$ | $S_2$ | |
| P1 | 69.33 | 70.67 | 66.00 | 66.33 | 41.67 | 51.67 | 30.00 | 53.33 | 21.67 | 29.33 | 11.67 | 15.00 | 2.00 | 10.00 | 2.00 | 9.67 | 30.54 | 38.25 | 34.39 |
| P2 | 73.33 | 74.33 | 72.67 | 73.33 | 59.33 | 67.67 | 46.67 | 53.33 | 36.67 | 41.67 | 28.33 | 32.00 | 26.33 | 30.00 | 24.00 | 27.67 | 45.92 | 50.00 | 47.96 |
| P3 | 75.67 | 76.33 | 75.67 | 76.33 | 62.00 | 69.67 | 51.67 | 55.67 | 40.00 | 47.33 | 29.67 | 37.33 | 25.00 | 30.33 | 24.00 | 24.00 | 47.92 | 52.13 | 50.04 |
| P4 | 75.67 | 76.33 | 75.00 | 75.00 | 65.00 | 69.67 | 49.67 | 58.67 | 40.33 | 45.33 | 25.33 | 33.67 | 17.67 | 21.33 | 17.00 | 19.33 | 45.46 | 49.92 | 47.69 |
| P5 | 74.00 | 74.67 | 74.00 | 74.00 | 62.67 | 69.00 | 52.67 | 59.33 | 41.67 | 41.67 | 33.00 | 36.00 | 28.33 | 30.00 | 26.67 | 27.00 | 48.92 | 52.50 | 50.79 |
| P6 | 79.33 | 80.00 | 80.00 | 80.00 | 68.33 | 71.67 | 59.33 | 63.33 | 50.00 | 50.00 | 38.33 | 42.33 | 31.67 | 35.67 | 28.67 | 36.67 | 54.46 | 58.17 | 56.31 |
| P7 | 72.00 | 70.33 | 68.67 | 68.67 | 55.00 | 60.00 | 41.67 | 50.00 | 31.67 | 31.67 | 19.00 | 27.00 | 9.67 | 17.33 | 8.67 | 16.00 | 38.25 | 43.13 | 40.69 |
| Mean | 74.14 | 74.67 | 73.38 | 73.38 | 59.14 | 65.62 | 47.38 | 56.24 | 37.43 | 37.43 | 26.48 | 31.91 | 20.09 | 24.95 | 18.71 | 22.91 | 44.50 | 49.16 | |
| Mean | 74.41 | | 73.00 | | 62.38 | | 51.81 | | 40.50 | | 29.19 | | 22.53 | | 20.81 | | | | |

CD (priming) = 1.07 CD (storage containers) = 0.57 CD (P x S interaction) = NS CD (storage period) = 1.15

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M) $P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M)

$P_5$ –Soaking in $KNO_3$ (150ppm) $P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1, M2, M3, M4, M5, M6, M7 and M8 (storage period in months after priming)

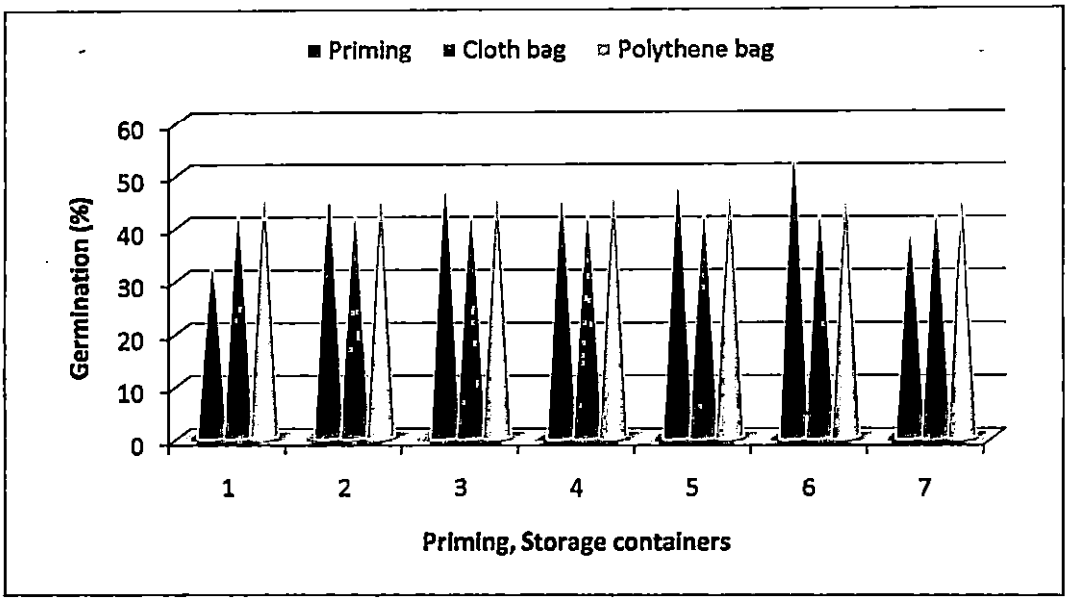


Fig 1. Effect of priming and storage containers on germination (%) of seeds primed after 3 months of storage

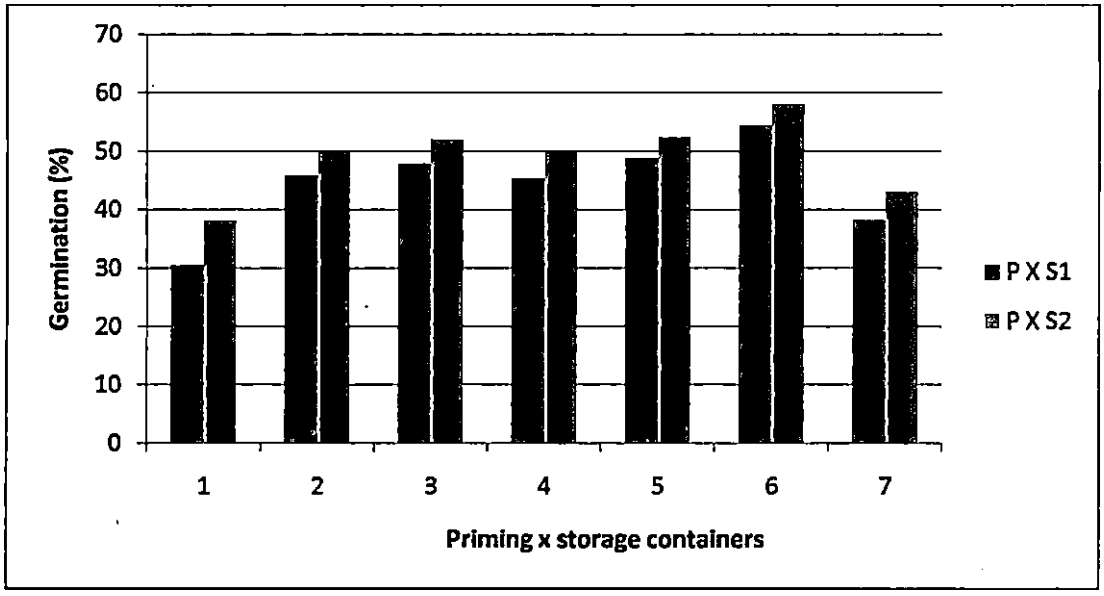


Fig 2. Interaction effect of priming and storage containers on germination (%) of seeds primed after 3 months of storage

Table 3d: Effect of priming and storage containers on speed of germination (%) of seeds primed after 3 months of storage

| M | M1 | | M2 | | M3 | | M4 | | M5 | | M6 | | M7 | | M8 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 9.84 | 9.98 | 9.49 | 9.33 | 5.37 | 6.85 | 3.34 | 6.98 | 2.61 | 3.57 | 1.36 | 1.79 | 0.25 | 1.78 | 0.27 | 1.29 | 4.07 | 5.12 | 4.59 |
| P2 | 10.65 | 10.59 | 10.24 | 10.43 | 8.02 | 8.90 | 6.09 | 6.98 | 5.17 | 5.79 | 3.53 | 3.91 | 3.32 | 3.91 | 3.16 | 3.74 | 6.27 | 6.78 | 6.53 |
| P3 | 11.39 | 11.42 | 11.11 | 11.03 | 8.26 | 9.52 | 6.49 | 7.37 | 5.32 | 6.48 | 4.16 | 4.79 | 3.60 | 4.22 | 3.48 | 3.57 | 6.73 | 7.30 | 7.02 |
| P4 | 11.53 | 11.15 | 10.35 | 11.23 | 8.59 | 9.39 | 6.14 | 7.62 | 5.43 | 6.31 | 3.42 | 4.32 | 2.26 | 2.77 | 2.29 | 2.88 | 6.25 | 6.96 | 6.61 |
| P5 | 11.35 | 10.95 | 10.84 | 11.14 | 8.14 | 9.02 | 6.36 | 7.74 | 5.65 | 6.57 | 4.28 | 4.59 | 3.64 | 3.46 | 3.50 | 3.62 | 6.72 | 7.14 | 6.92 |
| P6 | 11.89 | 12.49 | 12.22 | 12.32 | 9.64 | 9.78 | 8.13 | 8.93 | 6.91 | 7.25 | 5.27 | 4.91 | 4.52 | 5.21 | 3.94 | 4.94 | 7.82 | 8.23 | 8.02 |
| P7 | 10.83 | 9.59 | 9.27 | 9.66 | 7.53 | 8.04 | 5.227 | 6.35 | 4.21 | 4.28 | 2.50 | 3.12 | 1.16 | 2.11 | 1.18 | 2.29 | 5.24 | 5.68 | 5.46 |
| Mean | 11.07 | 10.88 | 10.50 | 10.74 | 7.9 R | 8.79 | 5.97 | 7.43 | 5.04 | 5.75 | 3.50 | 3.92 | 2.68 | 3.26 | 2.55 | 3.19 | 6.16 | 6.75 | |
| Mean | 10.975 | | 10.62 | | 8.36 | | 6.697 | | 5.39 | | 3.71 | | 2.98 | | 2.87 | | | | |

CD (priming) = 0.13 CD (Storage containers) = 0.07 CD (P x S interaction )= 0.19 CD (storage period) = 0.14

M – Months P - Priming

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M) $P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M)

$P_5$ –Soaking in $KNO_3$ (150ppm) $P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1, M2, M3, M4, M5, M6, M7 and M8 (storage period in months after priming)

Significant difference was noticed due to interaction between priming agents and storage containers. It varied from 4.07 in $P_1S_1$ (control + storage in cloth bag) to 8.23 in $P_6S_2$ (PEG 6000(-1.5M)) + storage in polythene bag700 gauge)

**4.2.5. Seedling length (cm)**

There was significant difference for seedling length (cm) during the storage period. It decreased from 13.14cm to 11.43cm. (Table 3 e)

Significant differences on length of the seedling were observed between priming methods. Seeds primed with *P. fluorescens* (10g/kg seed) ($P_7$) and PEG 6000 (-1.5MPa) ($P_6$) recorded highest values of 14.34cm and 13.67cm respectively. Control ($P_1$) recorded the lowest value of 10.49 cm.

There was significant difference between storage containers for seedling length (cm). The mean seedling length decreased from 12.55 cm to 11.25 cm in $S_1$ (control) and from 13.73 cm to 11.61 cm in $S_2$ (polythene bag (700 gauge)) during the storage period.

The interaction effect of priming and storage containers on seedling length (cm) was found to be non-significant. However, it varied from 10.10cm in $P_1S_1$ (control + storage in cloth bag) to 14.63cm in $P_7S_2$ (*P. fluorescens* (10g/kg seed + storage in polythene bag)

**4.2.6. Seedling fresh weight (mg)**

The overall mean of seedling fresh weight (mg) during different months of storage varied significantly. There was a decrease in fresh weight (mg) from 175.31mg in the initial month of storage to 121.43mg by the end of storage period. (Table 3 f).

Table 3 e: Effect of priming and storage containers on seedling length (cm) of seeds primed after 3 months of storage

| M | M1 | | M2 | | M3 | | M4 | | M5 | | M6 | | M7 | | M8 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 10.67 | 11.33 | 10.33 | 10.83 | 10.33 | 11.07 | 10.10 | 12.13 | 10.10 | 10.67 | 9.83 | 10.37 | 9.43 | 10.50 | 9.97 | 10.17 | 10.09 | 10.88 | 10.49 |
| P2 | 12.33 | 13.00 | 12.00 | 12.60 | 12.37 | 12.53 | 12.53 | 12.13 | 11.27 | 11.47 | 10.83 | 11.10 | 10.10 | 10.83 | 10.17 | 10.60 | 11.38 | 11.78 | 11.58 |
| P3 | 12.67 | 14.03 | 13.17 | 13.50 | 12.77 | 13.07 | 12.47 | 13.07 | 11.97 | 12.23 | 11.70 | 11.90 | 12.00 | 11.90 | 11.00 | 11.00 | 12.12 | 12.60 | 12.36 |
| P4 | 13.33 | 13.60 | 12.97 | 13.37 | 12.30 | 12.80 | 12.67 | 13.27 | 12.30 | 12.83 | 11.33 | 11.73 | 11.00 | 11.50 | 10.67 | 11.60 | 12.07 | 12.59 | 12.33 |
| P5 | 13.17 | 14.00 | 13.17 | 14.67 | 12.57 | 12.90 | 12.70 | 13.13 | 12.40 | 12.60 | 11.43 | 11.90 | 10.77 | 11.00 | 10.57 | 10.83 | 12.09 | 12.47 | 12.28 |
| P6 | 10.33 | 14.50 | 14.23 | 14.60 | 14.00 | 13.83 | 14.13 | 14.23 | 14.03 | 13.90 | 12.87 | 14.33 | 13.17 | 14.00 | 13.13 | 13.33 | 13.24 | 14.10 | 13.67 |
| P7 | 15.33 | 15.67 | 14.60 | 15.67 | 14.67 | 15.50 | 14.07 | 14.17 | 13.77 | 14.17 | 13.20 | 13.60 | 13.50 | 14.50 | 13.27 | 13.73 | 14.05 | 14.63 | 14.34 |
| Mean | 12.55 | 13.73 | 12.93 | 13.43 | 12.72 | 13.10 | 12.59 | 13.16 | 12.26 | 12.55 | 11.60 | 12.15 | 11.32 | 12.03 | 11.25 | 11.61 | 12.15 | 12.72 | |
| Mean | 13.14 | | 13.18 | | 12.907 | | 12.88 | | 12.41 | | 11.88 | | 11.68 | | 11.43 | | | | |

CD (priming) = 0.26 CD (Storage containers) = 0.14 CD (P x S interaction) = NS CD (storage period) = 0.28

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M) $P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M)

$P_5$ –Soaking in $KNO_3$ (150ppm) $P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1, M2, M3, M4, M5, M6, M7 and M8 (storage period in months after priming)

M – Months P - Priming

Table 3 f: Effect of priming and storage containers on seedling fresh weight (mg) of seeds primed after 3 months of storage

| M | M1 | | M2 | | M3 | | M4 | | M5 | | M6 | | M7 | | M8 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 152.67 | 159.00 | 137.33 | 147.33 | 130.00 | 134.00 | 120.33 | 144.00 | 117.00 | 126.00 | 110.00 | 114.67 | 68.33 | 106.00 | 101.00 | 105.00 | 117.08 | 129.50 | 123.29 |
| P2 | 163.67 | 168.33 | 155.67 | 160.67 | 146.33 | 150.00 | 135.33 | 144.00 | 128.33 | 135.67 | 123.00 | 129.33 | 114.67 | 124.33 | 110.33 | 116.67 | 134.67 | 141.13 | 137.89 |
| P3 | 169.67 | 171.00 | 162.00 | 168.67 | 153.33 | 159.67 | 147.00 | 150.67 | 134.33 | 141.00 | 127.00 | 134.67 | 118.33 | 124.00 | 134.67 | 117.67 | 143.54 | 145.92 | 144.73 |
| P4 | 171.33 | 171.66 | 169.33 | 168.33 | 163.67 | 167.00 | 156.67 | 162.67 | 146.33 | 154.33 | 137.00 | 148.00 | 127.67 | 135.00 | 117.00 | 126.00 | 148.63 | 154.13 | 151.38 |
| P5 | 174.67 | 175.33 | 166.00 | 169.67 | 158.00 | 160.00 | 142.00 | 159.67 | 137.33 | 149.67 | 129.00 | 137.00 | 125.00 | 126.00 | 117.33 | 120.00 | 143.67 | 149.54 | 146.61 |
| P6 | 185.00 | 194.66 | 178.67 | 184.67 | 167.67 | 174.00 | 159.67 | 164.67 | 150.67 | 161.33 | 148.67 | 152.67 | 136.67 | 145.33 | 123.00 | 130.33 | 156.25 | 163.46 | 159.86 |
| P7 | 197.33 | 200.00 | 189.33 | 196.67 | 182.33 | 189.33 | 176.67 | 188.00 | 163.67 | 175.00 | 158.33 | 168.67 | 148.00 | 150.00 | 136.67 | 144.33 | 169.04 | 176.50 | 172.77 |
| Mean | 173.48 | 177.14 | 165.48 | 170.86 | 157.62 | 162.00 | 148.24 | 159.09 | 139.67 | 148.86 | 133.29 | 140.17 | 119.81 | 130.09 | 120.00 | 122.86 | 144.69 | 151.45 | |
| Mean | 175.31 | | 168.17 | | 159.81 | | 153.67 | | 144.26 | | 137.00 | | 124.95 | | 121.42 | | | | |

CD (priming) = 2.99 CD (Storage containers) = 1.60 CD (P x S interaction) = NS CD (storage period) = 3.20

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M) $P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M)

$P_5$ –Soaking in $KNO_3$ (150ppm) $P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1, M2, M3, M4, M5, M6, M7 and M8 (storage period in months after priming)

M – Months P - Priming

Significant difference among the priming treatments on seedling fresh weight was recorded. The seeds primed with *P. fluorescens* (10g/kg seed) ($P_7$) recorded highest value 172.77mg followed by seeds primed with PEG 6000 (-1.5 MPa) ($P_6$) which recorded 159.85 mg. The lowest value, 123.29mg was recorded in control ($P_1$).

There was significant difference between storage containers for seedling fresh weight (mg). It varied from 173.48mg to 120.00mg in $S_1$ (Cloth bag) and in $S_2$ (polythene bag (700gauge)) it varied from 177.14mg to 122.86mg.

No significant difference on seedling fresh weight (mg) was noticed due to interaction between priming and storage containers. The seedling fresh weight varied from 117.08mg in $P_1S_1$ (control + storage in cloth bag) to 176.50mg in $P_7S_2$ (*P. fluorescens* (10g/kg seed) + storage in polythene bag).

**4.2.7. Seedling dry weight (mg):**

The overall mean of seedling dry weight differed significantly. However there was a decline in dry weight from 17.81mg to 12.52mg by the end of storage period. (Table 3 g)

There was significant difference between priming treatments for seedling dry weight (mg). Seeds primed with $P_7$ (*P. fluorescens* (10g/kg seed) recorded the highest value, 17.13mg and $P_1$ (Control) recorded the lowest value, 13.00 mg.

There was significant difference between storage containers for seedling dry weight (mg). In cloth bag ($S_1$) seedling dry weight decreased from 17.52 mg 12.05 mg and in polythene bag (700 gauge) ($S_2$) it decreased from 18.09 mg to 13.00 mg during the storage period.

Significant difference was noticed due to interaction between priming and storage on seedling dry weight (mg). The treatment $P_7S_2$ (*P. fluorescens* (10g/kg

seed) + storage in polythene bag) recorded highest dry weight, 17.42 mg and $P_1S_1$ (control + storage in cloth bag) recorded the lowest 11.92 mg.

### *4.2.8. Days to four leaf emergence*

The overall mean value for days to four leaf emergence varied from 6.69 to 8.88 and was significant. (Table 3 h)

There was significant difference between priming methods for the days to four leaf emergence. The seeds treated with PEG 6000 MPa) ($P_6$) recorded the minimum number of days 7.33 and control ($P_1$) recorded the maximum number of days 8.96 days for four leaf emergence.

There was significant difference between storage containers for the days to four leaf emergence. It varied from 6.67 to 8.91 in $S_1$ (control) and 6.71 to 8.86 in $S_2$ (polythene bag 700 gauge).

The interaction between priming and storage container was not significant. However, it varied from 7.21 in $P_6S_2$ (PEG 6000 -1.5 MPa) + storage in polythene bag) to 9.17 in $P_1S_1$ (control + storage in cloth bag).

### 4.2.9. Electrical conductivity of seed leachate:

The mean values for electrical conductivity (EC) of the seed leachate was significant and it increased from 0.45 $dsm^{-1}$ to 0.89 $dsm^{-1}$ during the storage period (Table 3 i)

There was significant difference between priming treatments for electrical conductivity (EC). Seeds treated with PEG 6000 (-1.5 MPa) ($P_6$) recorded lowest value of 0.61 $dsm^{-1}$ and highest (0.75 $dsm^{-1}$) was recorded in $P_1$ (control).

Significant difference was observed between storage containers for electrical conductivity of seed leachate. The mean values of electrical conductivity ranged from

0.48dsm$^{-1}$ to 0.90dsm$^{-1}$ in $S_1$(cloth bag) and from 0.42 to 0.87 in $S_2$ (polythene bag 700 gauge) during the storage period.

The interaction between priming and storage was also significant and varied from 0.59 dsm$^{-1}$ in $P_6S_2$ (PEG 6000 (-1.5M) + storage in polythene bag700 gauge)) to 0.78 dsm$^{-1}$ in $P_1S_1$ (control + storage in cloth bag)

**4.2.10. Vigour index I**

The mean values of vigour index I differed significantly. During the storage period of 8 months vigour index I decreased from 1324.9 to 263.3. (Table 3 j)

There was significant difference between priming treatments for vigour index I of the seedlings. The seeds treated with PEG 6000 (-1.5 MPa) ($P_6$) recorded the highest value 912.38 whereas control ($P_1$) recorded the lowest value 512.4.

There was significant difference between the storage containers for vigour index I. It decreased from 1299.67 to 226.09 in $S_1$ (cloth bag) and in $S_2$ (polythene bag) it decreased from 1350.14 to 300.52.

The interaction effect of priming and storage container was non-significant. Highest vigour index (962.38) was noticed in $P_6S_2$ (PEG 6000 (-1.5MPa) + storage in polythene bag 700 gauge) and the lowest value (426.04) was recorded in $P_1S_1$ (control + storage in cloth bag).

**4.2.11. Vigour index II:**

The overall mean value for vigour index II differed significantly. There was a decline in vigour index II from 977.77 to 240.22 during the storage period. (Table 3 k)

Table 3 g: Effect of priming and storage containers on seedling dry weight (mg) of seeds primed after 3 months of storage

| M | M1 | | M2 | | M3 | | M4 | | M5 | | M6 | | M7 | | M8 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 16.33 | 18.33 | 14.00 | 15.67 | 13.33 | 16.67 | 12.33 | 13.00 | 11.67 | 12.00 | 11.00 | 11.00 | 6.66 | 10.67 | 10.00 | 10.67 | 11.92 | 14.08 | 13.00 |
| P2 | 18.33 | 17.33 | 18.33 | 18.33 | 16.33 | 17.00 | 15.67 | 17.00 | 15.67 | 16.00 | 13.67 | 14.67 | 13.33 | 13.67 | 12.00 | 13.00 | 15.42 | 15.87 | 15.65 |
| P3 | 18.00 | 18.00 | 16.00 | 16.67 | 15.67 | 16.00 | 15.00 | 15.67 | 14.33 | 14.67 | 14.00 | 14.00 | 12.66 | 13.67 | 12.00 | 13.00 | 14.71 | 15.21 | 14.96 |
| P4 | 16.67 | 16.66 | 16.00 | 17.33 | 15.33 | 16.33 | 14.67 | 15.67 | 14.00 | 14.00 | 13.00 | 14.00 | 12.00 | 13.00 | 12.00 | 13.00 | 14.21 | 15.00 | 14.60 |
| P5 | 17.00 | 18.00 | 16.67 | 18.00 | 15.67 | 16.33 | 14.33 | 15.00 | 14.00 | 15.00 | 13.000 | 14.00 | 12.00 | 13.00 | 11.33 | 12.67 | 14.29 | 15.25 | 14.77 |
| P6 | 17.67 | 18.66 | 17.00 | 17.33 | 16.33 | 17.00 | 15.67 | 16.67 | 15.33 | 16.33 | 14.67 | 15.00 | 13.00 | 14.33 | 12.33 | 13.33 | 15.25 | 16.08 | 15.67 |
| P7 | 18.67 | 19.66 | 18.00 | 18.33 | 17.67 | 18.00 | 17.00 | 18.00 | 16.67 | 17.00 | 16.67 | 17.00 | 15.33 | 16.00 | 14.67 | 15.33 | 16.83 | 17.42 | 17.13 |
| Mean | 17.53 | 18.09 | 16.57 | 17.38 | 15.72 | 16.57 | 14.95 | 16.38 | 14.53 | 15.14 | 13.76 | 14.38 | 12.14 | 13.52 | 12.05 | 13.00 | 14.66 | 15.56 | |
| Mean | 17.81 | | 16.98 | | 16.17 | | 15.67 | | 14.83 | | 14.07 | | 12.83 | | 12.53 | | | | |

CD (priming) = 0.32 CD (storage containers) = 0.17 CD (P x S interaction) = 0.45 CD (storage period ) = 0.34

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M) $P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M)

$P_5$ –Soaking in $KNO_3$ (150ppm) $P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1, M2, M3, M4, M5, M6, M7 and M8 (storage period in months after priming)

M – Months P - Priming

Table 3 h: Effect of priming and storage containers on days to four leaf emergence of seeds primed after 3 months of storage

| M | M1 | | M2 | | M3 | | M4 | | M5 | | M6 | | M7 | | M8 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 9.00 | 8.67 | 8.67 | 8.67 | 9.33 | 8.67 | 9.00 | 8.00 | 9.00 | 9.33 | 9.33 | 9.00 | 9.33 | 9.00 | 9.67 | 8.67 | 9.17 | 8.75 | 8.96 |
| P2 | 7.67 | 7.67 | 7.33 | 7.33 | 7.67 | 7.33 | 8.33 | 8.00 | 8.00 | 7.33 | 7.67 | 7.67 | 7.67 | 9.00 | 9.00 | 9.00 | 7.79 | 7.92 | 7.85 |
| P3 | 6.00 | 6.00 | 6.33 | 6.33 | 8.33 | 7.33 | 8.67 | 8.00 | 7.33 | 8.00 | 8.33 | 8.00 | 8.00 | 8.67 | 8.67 | 8.67 | 7.71 | 7.63 | 7.67 |
| P4 | 6.00 | 6.00 | 6.67 | 6.00 | 7.67 | 7.00 | 9.00 | 8.33 | 7.67 | 8.67 | 9.00 | 6.67 | 8.00 | 8.00 | 8.67 | 9.00 | 7.83 | 7.46 | 7.65 |
| P5 | 6.00 | 6.00 | 6.33 | 6.00 | 8.00 | 8.00 | 9.00 | 8.67 | 9.33 | 9.00 | 8.33 | 9.34 | 8.67 | 8.67 | 9.00 | 9.00 | 8.08 | 7.96 | 8.02 |
| P6 | 6.00 | 6.00 | 6.00 | 6.00 | 7.00 | 6.67 | 7.33 | 6.67 | 7.33 | 8.00 | 8.00 | 7.67 | 9.00 | 8.33 | 9.00 | 8.33 | 7.46 | 7.21 | 7.33 |
| P7 | 6.00 | 6.67 | 8.00 | 7.67 | 8.67 | 8.67 | 9.33 | 9.33 | 9.67 | 9.00 | 9.33 | 9.33 | 9.33 | 9.33 | 9.33 | 9.33 | 8.71 | 8.67 | 8.69 |
| Mean | 6.67 | 6.72 | 7.05 | 6.86 | 8.09 | 7.67 | 8.67 | 8.14 | 8.33 | 8.48 | 8.57 | 8.09 | 8.57 | 8.72 | 8.91 | 8.86 | 8.11 | 7.94 | |
| Mean | 6.69 | | 6.72 | | 7.88 | | 8.41 | | 8.41 | | 8.33 | | 8.64 | | 8.88 | | | | |

CD (priming) = 0.22 CD (storage containers) = 0.11 CD (P x S interaction) = NS CD (storage period) = 0.23

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M) $P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M)

$P_5$ –Soaking in $KNO_3$ (150ppm) $P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1, M2, M3, M4, M5, M6, M7 and M8 (storage period in months after priming)

M – Months P - Priming

Table 3 i: Effect of priming and storage containers on electrical conductivity of the seed leachates of seeds primed after 3 months of storage

| M | M1 | | M2 | | M3 | | M4 | | M5 | | M6 | | M7 | | M8 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 0.57 | 0.51 | 0.64 | 0.60 | 0.66 | 0.59 | 0.74 | 0.68 | 0.82 | 0.79 | 0.89 | 0.81 | 0.95 | 0.91 | 0.97 | 0.94 | 0.78 | 0.73 | 0.76 |
| P2 | 0.50 | 0.49 | 0.60 | 0.59 | 0.66 | 0.61 | 0.70 | 0.68 | 0.81 | 0.77 | 0.77 | 0.73 | 0.82 | 0.80 | 0.85 | 0.83 | 0.72 | 0.69 | 0.70 |
| P3 | 0.42 | 0.39 | 0.51 | 0.49 | 0.56 | 0.51 | 0.59 | 0.55 | 0.69 | 0.71 | 0.71 | 0.69 | 0.83 | 0.86 | 0.86 | 0.84 | 0.65 | 0.62 | 0.64 |
| P4 | 0.43 | 0.39 | 0.52 | 0.51 | 0.56 | 0.51 | 0.65 | 0.57 | 0.71 | 0.82 | 0.81 | 0.77 | 0.89 | 0.85 | 0.91 | 0.86 | 0.69 | 0.66 | 0.67 |
| P5 | 0.48 | 0.41 | 0.58 | 0.54 | 0.61 | 0.59 | 0.69 | 0.68 | 0.79 | 0.71 | 0.85 | 0.78 | 0.91 | 0.88 | 0.93 | 0.89 | 0.73 | 0.69 | 0.71 |
| P6 | 0.40 | 0.32 | 0.49 | 0.45 | 0.51 | 0.49 | 0.63 | 0.52 | 0.63 | 0.60 | 0.77 | 0.71 | 0.82 | 0.80 | 0.85 | 0.83 | 0.64 | 0.59 | 0.61 |
| P7 | 0.53 | 0.44 | 0.60 | 0.59 | 0.65 | 0.61 | 0.69 | 0.71 | 0.71 | 0.69 | 0.81 | 0.78 | 0.92 | 0.89 | 0.95 | 0.91 | 0.73 | 0.71 | 0.72 |
| Mean | 0.48 | 0.42 | 0.56 | 0.54 | 0.59 | 0.56 | 067 | 0.63 | 0.74 | 0.73 | 0.79 | 0.75 | 0.88 | 0.85 | 0.90 | 0.87 | 0.71 | 0.67 | |
| Mean | 0.45 | | 0.55 | | 0.56 | | 0.65 | | 0.73 | | 0.78 | | 0.87 | | 0.89 | | | | |

CD (priming) = 0.60 CD (storage containers) = 0.33 CD (P x S interaction) = 0.85 CD (storage period) = 0.63

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M) $P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M)

$P_5$ –Soaking in $KNO_3$ (150ppm) $P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1, M2, M3, M4, M5, M6, M7 and M8 (storage period in months after priming)

M – Months P - Priming

Table 3 j: Effect of priming and storage containers on Vigour index I of seeds primed after 3 months of storage

| M | M1 | | M2 | | M3 | | M4 | | M5 | | M6 | | M7 | | M8 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 1133.3 | 1295.3 | 925.0 | 1040.3 | 556.6 | 793.3 | 371.6 | 888.3 | 253.3 | 381.3 | 128.3 | 180.0 | 20.0 | 108.6 | 20.0 | 103.0 | 426.0 | 598.7 | 512.4 |
| P2 | 1344.3 | 1288.6 | 1332.3 | 1344.3 | 969.6 | 1150.3 | 730.0 | 906.6 | 573.3 | 666.6 | 386.6 | 468.3 | 349.7 | 410.0 | 288.0 | 359.6 | 746.7 | 824.3 | 785.5 |
| P3 | 1362.0 | 1374.0 | 1210.6 | 1272.6 | 970.3 | 1114.6 | 775.0 | 872.3 | 573.3 | 694.3 | 411.6 | 522.6 | 315.0 | 413.0 | 288.0 | 312.0 | 738.2 | 821.9 | 780.1 |
| P4 | 1255.0 | 1272.6 | 1173.3 | 1300.0 | 993.0 | 1138.0 | 728.3 | 919.3 | 564.6 | 634.6 | 328.6 | 471.3 | 212.0 | 277.3 | 204.0 | 251.3 | 682.3 | 783.0 | 732.7 |
| P5 | 1258.0 | 1344.0 | 1205.3 | 1332.0 | 982.3 | 1127.6 | 754.6 | 890.0 | 583.3 | 750.0 | 440.0 | 504.0 | 340.0 | 390.0 | 302.6 | 341.6 | 733.2 | 834.9 | 784.1 |
| P6 | 1401.3 | 1493.3 | 1360.0 | 1386.6 | 1115.0 | 1218.3 | 929.3 | 1056.6 | 766.6 | 909.6 | 561.6 | 635.0 | 411.6 | 509.3 | 253.3 | 490.0 | 862.3 | 962.3 | 912.3 |
| P7 | 1343.6 | 1383.0 | 1230.0 | 1259.0 | 970.0 | 1080.0 | 708.3 | 900.0 | 526.6 | 606.3 | 316.3 | 459.0 | 148.3 | 277.3 | 126.6 | 246.0 | 671.2 | 776.3 | 723.7 |
| | 1299.6 | 1350.1 | 1205.2 | 1276.4 | 936.7 | 1088.9 | 713.9 | 919.0 | 548.7 | 663.2 | 367.6 | 462.9 | 256.6 | 340.8 | 226.0 | 300.5 | 694.3 | 800.2 | |
| | 1324.9 | | 1240.8 | | 1012.8 | | 816.4 | | 606.0 | | 415.2 | | 298.7 | | 263.3 | | | | |

CD (priming) = 20.27 CD (storage containers) = 10.83 CD (P x S interaction) =NS CD (storage period) =21.67

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M) $P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M)

$P_5$ –Soaking in $KNO_3$ (150ppm) $P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1, M2, M3, M4, M5, M6, M7 and M8 (storage period in months after priming)

M – Months P - Priming

Table 3 k: Effect of priming and storage containers on Vigour index II of seeds primed after 3 months of storage

| M | M1 | | M2 | | M3 | | M4 | | M5 | | M6 | | M7 | | M8 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 740.0 | 800.8 | 682.1 | 718.5 | 430.0 | 572.0 | 285.8 | 647.6 | 218.8 | 312.8 | 114.1 | 154.8 | 18.8 | 105.0 | 19.5 | 98.3 | 315.8 | 426.2 | 371.0 |
| P2 | 904.3 | 966.3 | 872.0 | 924.1 | 734.5 | 848.7 | 558.3 | 647.6 | 413.5 | 477.2 | 307.5 | 355.5 | 266.0 | 325.0 | 244.1 | 293.4 | 537.5 | 604.7 | 571.1 |
| P3 | 958.6 | 1071.2 | 996.1 | 1030.5 | 791.3 | 910.1 | 643.5 | 727.2 | 478.6 | 579.1 | 348.3 | 448.2 | 280.5 | 360.0 | 263.8 | 263.9 | 595.1 | 673.8 | 634.4 |
| P4 | 1004.3 | 1038.2 | 950.1 | 1002.5 | 800.0 | 891.3 | 629.3 | 778.4 | 496.5 | 581.9 | 286.0 | 394.8 | 194.3 | 248.0 | 181.0 | 224.4 | 567.7 | 644.3 | 606.2 |
| P5 | 973.7 | 1045.3 | 952.4 | 989.4 | 787.2 | 890.2 | 669.5 | 779.2 | 516.1 | 629.4 | 377.3 | 428.6 | 304.6 | 327.5 | 281.4 | 292.8 | 607.8 | 672.8 | 640.3 |
| P6 | 1084.0 | 1160.0 | 1138.7 | 1173.3 | 957.5 | 992.5 | 838.0 | 901.6 | 701.6 | 773.7 | 494.3 | 606.3 | 417.5 | 501.3 | 376.7 | 489.1 | 718.2 | 824.5 | 771.3 |
| P7 | 1103.3 | 1101.8 | 997.6 | 1076.0 | 806.6 | 929.6 | 585.1 | 708.3 | 436.3 | 505.0 | 251.3 | 367.3 | 130.5 | 251.3 | 115.1 | 219.2 | 553.2 | 644.8 | 599.0 |
| Mean | 929.2 | 941.4 | 758.1 | 603.924 | 465.9 | 311.2 | 230.3 | 211.6 | 1026.2 | 987.7 | 862.0 | 741.4 | 551.3 | 393.6 | 301.9 | 268.7 | 444.8 | 641.3 | |
| Mean | 977.78 | | 967.59 | | 810.12 | | 672.69 | | 508.65 | | 352.48 | | 266.14 | | 240.22 | | | | |

CD (priming) = 23.03 CD (storage containers) = 12.31 CD (P x S interaction) = NS CD (storage period) = 24.62

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M) $P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M)

$P_5$ –Soaking in $KNO_3$ (150ppm) $P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1, M2, M3, M4, M5, M6, M7 and M8 (storage period in months after priming)

M – Months P - Priming

There was significant difference between seed priming treatments with respect to vigour index II. The seeds treated with $P_6$ (PEG 6000 -1.5MPa) recorded the highest value 771.37 and $P_1$ (control) recorded the lowest value 371.02.

Significant difference was observed between storage containers for vigour index of seedlings. The vigour index II decreased from 929.29 to 301.93 in $S_1$ (cloth bag) and from 941.41 to 268.75 in $S_2$ (polythene bag of 700 gauge).

The interaction between of priming and storage containers was non-significant. It varied from 824.50 in $P_6S_2$ (PEG 6000 (-1.5MPa) + storage in polythene bag 700 gauge) to 315.80 in $P_1S_1$ (control + storage in cloth bag).

**4.3. Effect of priming and storage on quality of seeds primed after 6 months of storage.**

The statistically analysed data of seed quality parameters of seeds primed, 6 months after storage under ambient condition, immediately after priming and as influenced by priming, storage and their interaction are presented in the Table 4 – 4 k.

Immediately after priming the seeds primed with $P_6$ (PEG 6000 (-1.5 MPa) recorded highest germination (68.00 %), speed of germination (9.23), fresh weight (181.67 mg) vigour index I (1247.33), vigour index II (1036.13) and lowest electrical conductivity (0.41 $dsm^{-1}$). $P_7$ recorded the maximum seedling length (15.26 cm), seedling dry weight (18.66 mg). P1 (Control) recorded the maximum moisture content (7.52 %), lowest germination (28.67 %), speed of germination (3.92), lowest seedling length (10.33 cm), fresh weight (120.66 mg) dry weight (12.00 mg), vigour index I (344 .00), vigour index II (295.90) and highest electrical conductivity (0.72 $dsm^{-1}$)(Table 4)

**4.3.1. 100 seed weight:**

There was an increase in 100 seed weight from 0.69g during the first month of storage to 0.72g during the fifth month of storage after priming. (Table 4 a)

Table 4: Effect of priming on seed quality parameters immediately after priming (6 months after storage)

| Seed quality parameters | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ | $P_6$ | $P_7$ | CD |
|---|---|---|---|---|---|---|---|---|
| 100 seed weight (g) | 0.72 | 0.69 | 0.65 | 0.65 | 0.66 | 0.71 | 0.69 | 0.95 |
| Moisture content (%) | 7.52 | 7.21 | 7.24 | 7.24 | 7.27 | 7.38 | 7.31 | 0.19 |
| Germination (%) | 28.67 | 60.67 | 65.33 | 63 | 62.33 | 68 | 39 | 7.66 |
| Speed of germination | 3.92 | 8.09 | 8.54 | 8.58 | 8.57 | 9.23 | 5.15 | 0.10 |
| Seedling length (cm) | 10.33 | 13.47 | 13.7 | 13.77 | 14.17 | 15.23 | 15.24 | 0.09 |
| Seedling fresh weight (mg) | 120.67 | 163.33 | 166 | 171.33 | 174 | 180.33 | 181.67 | 7.98 |
| Seedling dry weight (mg) | 12 | 17 | 17 | 17.333 | 17.667 | 18.333 | 18.667 | 018 |
| Days to four leaf emergence | 8.67 | 7.33 | 7.33 | 7.33 | 8 | 7 | 8 | 0.18 |
| Electrical conductivity of seed leachate | 0.72 | 0.51 | 0.49 | 0.46 | 0.43 | 0.41 | 0.53 | 0.95 |
| Vigour index I | 344 | 1031.33 | 1110.67 | 1092.33 | 1101 | 1247.33 | 728.33 | 2903.32 |
| Vigour index II | 295.9 | 816.9 | 895.13 | 867.27 | 883.1 | 1036.13 | 595.77 | 1615.3 |

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M)

$P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M) $P_5$ –Soaking in $KNO_3$ (150ppm) $P_6$ –Soaking in PEG 6000(-1.5MPa)

$P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

Table 4 a: Effect of priming and storage on 100 seed weight (g) of seeds primed after 6 months of storage

| M | M1 | | M2 | | M3 | | M4 | | M5 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 0.76 | 0.76 | 0.78 | 0.77 | 0.78 | 0.77 | 0.79 | 0.78 | 0.79 | 0.78 | 0.78 | 0.77 | 0.78 |
| P2 | 0.72 | 0.69 | 0.73 | 0.72 | 0.74 | 0.73 | 075 | 0.74 | 0.75 | 0.75 | 0.74 | 0.73 | 0.73 |
| P3 | 0.66 | 0.66 | 0.67 | 0.67 | 0.68 | 0.67 | 0.69 | 0.67 | 0.70 | 0.68 | 0.68 | 0.67 | 0.68 |
| P4 | 0.66 | 0.65 | 0.67 | 0.66 | 0.68 | 0.67 | 0.69 | 0.67 | 0.69 | 0.69 | 0.68 | 0.67 | 0.67 |
| P5 | 0.67 | 0.65 | 0.68 | 0.67 | 0.68 | 0.68 | 0.69 | 0.69 | 0.71 | 0.69 | 0.69 | 0.68 | 0.68 |
| P6 | 0.72 | 0.70 | 0.73 | 0.72 | 0.74 | 0.73 | 0.75 | 0.74 | 0.75 | 0.75 | 0.74 | 0.73 | 0.73 |
| P7 | 0.71 | 0.69 | 0.72 | 0.71 | 0.73 | 0.72 | 0.74 | 0.73 | 0.74 | 0.74 | 0.73 | 0.72 | 0.72 |
| Mean | 0.69 | 0.69 | 0.71 | 0.69 | 0.72 | 0.71 | 0.73 | 0.72 | 0.74 | 0.73 | 0.72 | 0.71 | |
| Mean | 0.69 | | 0.71 | | 0.72 | | 0.72 | | 0.73 | | | | |

CD (priming) = 1.08 CD (storage containers) = 0.57 CD (P x S interaction) = NS CD (storage period) = 0.57

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M) $P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M)

$P_5$ –Soaking in $KNO_3$ (150ppm) $P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1, M2, M3, M4 and M5 (storage period in months after priming)

M – Months P - Priming

Table 4 b: Effect of priming and storage on percent moisture content (%) of seeds primed after 6 months of storage

| Months | M1 | | M2 | | M3 | | M4 | | M5 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Priming | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 7.59 | 7.51 | 7.71 | 7.63 | 7.82 | 7.80 | 7.85 | 7.85 | 7.89 | 7.28 | 7.77 | 7.73 | 7.75 |
| P2 | 7.34 | 7.28 | 7.43 | 7.34 | 7.55 | 7.46 | 7.62 | 7.57 | 7.20 | 7.35 | 7.44 | 7.37 | 7.41 |
| P3 | 7.33 | 7.23 | 7.47 | 7.34 | 7.53 | 7.43 | 7.65 | 7.56 | 7.75 | 7.66 | 7.55 | 7.45 | 7.50 |
| P4 | 7.35 | 7.29 | 7.43 | 7.33 | 7.55 | 7.45 | 7.64 | 7.55 | 7.74 | 7.66 | 7.54 | 7.46 | 7.50 |
| P5 | 7.35 | 7.32 | 7.44 | 7.38 | 7.53 | 7.43 | 7.68 | 7.54 | 7.74 | 7.67 | 7.55 | 7.47 | 7.51 |
| P6 | 7.43 | 7.39 | 7.53 | 7.44 | 7.61 | 7.53 | 7.73 | 7.63 | 7.83 | 7.74 | 7.62 | 7.55 | 7.59 |
| P7 | 7.36 | 7.33 | 7.43 | 7.39 | 7.52 | 7.44 | 7.64 | 7.58 | 7.73 | 7.65 | 7.54 | 7.45 | 7.51 |
| Mean | 7.39 | 7.33 | 7.48 | 7.39 | 7.57 | 7.49 | 7.68 | 7.56 | 7.76 | 7.69 | 7.58 | 7.45 | |
| Mean | 7.36 | | 7.44 | | 7.53 | | 7.64 | | 7.72 | | | | |

CD (priming) = 0.01 CD (storage containers) = 0.77 CD (P x S interaction) = NS CD (storage period) = 0.38

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M) $P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M)

$P_5$ –Soaking in $KNO_3$ (150ppm) $P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1, M2, M3, M4 and M5 (storage period in months after priming)

There was significant difference between priming treatments with respect to 100 seed weight. Seeds primed with $CaCl_2$ ($10^{-5}$M) ($P_4$) recorded lowest value, 0.67g and control ($P_1$) recorded the highest value 0.77g.

There was significant difference between the storage containers for 100 seed weight. The 100 seed weight of seeds stored in cloth bag ($S_1$) varied from 0.69g to 0.72g and that of seeds stored in polythene bag (700 gauge) ($S_2$) varied from 0.69g to 0.71g.

100 seed weight due to interaction effect between priming and storage was non-significant. However, $P_4S_2$ ($CaCl_2$ ($10^{-5}$M) + storage in polythene bag) recorded the lowest value 0.66g and the highest value 0.79g was observed in $P_1S_1$ (control + storage in cloth bag).

**4.3.2. Moisture content (%):**

With the advancement of storage period, moisture content (%) increased irrespective of priming, storage and their interaction. The mean moisture content increased from 7.36% in the initial month of storage to 7.72 % at the end of storage period. (Table 4 b)

Moisture content (%) differed significantly between the priming treatments. The highest value 7.75% was recorded in control ($P_1$) and the lowest value 7.40 % was recorded in hydro primed seeds ($P_2$).

There was significant difference between storage containers for moisture content (%) during the storage period. It varied from 7.39 % to 7.76 % in cloth bag ($S_1$) and 7.33 % to 7.68% in $S_2$ (polythene bag 700 gauge).

There was no significant difference for moisture content due to interaction effect of priming and storage containers. However, $P_1S_1$ (control + storage in cloth bag) recorded the highest value, 7.77% and $P_2S_2$ (hydro primed seeds + storage in polythene bag) recorded the lowest value of 7.37%.

**4.3.3. Germination (%):**

With the advancement of storage period, percent germination decreased irrespective of priming, storage and their interaction. The mean percent germination decreased from 52.2 % at the initial month of storage to 27.2 % by the end of storage period. (Table 4c)

Table 4c: Effect of priming and storage on germination (%) of seeds primed after 6 months of storage

| Months | M1 | | M2 | | M3 | | M4 | | M5 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Priming | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 22.67 | 29.33 | 15.33 | 15.00 | 5.33 | 13.33 | 2.00 | 9.00 | 1.33 | 10.00 | 9.33 | 15.33 | 12.33 |
| P2 | 55.00 | 60.33 | 49.33 | 52.67 | 33.67 | 41.67 | 29.33 | 38.67 | 24.33 | 31.67 | 38.33 | 45.00 | 41.67 |
| P3 | 59.67 | 64.67 | 54.00 | 56.33 | 46.33 | 52.00 | 39.33 | 46.67 | 31.67 | 40.00 | 46.20 | 51.93 | 49.07 |
| P4 | 57.00 | 59.67 | 45.67 | 49.67 | 44.67 | 46.67 | 37.00 | 40.33 | 29.33 | 38.33 | 42.73 | 46.87 | 44.80 |
| P5 | 56.33 | 59.00 | 46.33 | 53.00 | 37.33 | 43.00 | 34.67 | 39.00 | 30.00 | 32.33 | 40.73 | 45.27 | 43.10 |
| P6 | 65.00 | 68.33 | 58.33 | 61.33 | 50.00 | 53.33 | 42.67 | 50.00 | 36.33 | 43.67 | 50.47 | 55.33 | 52.90 |
| P7 | 35.00 | 38.00 | 29.00 | 35.00 | 22.00 | 31.67 | 17.00 | 21.67 | 14.00 | 18.33 | 23.40 | 29.93 | 26.67 |
| Mean | 50.09 | 54.19 | 42.57 | 46.19 | 34.19 | 40.24 | 28.86 | 35.76 | 23.86 | 30.62 | 35.92 | 41.38 | |
| Mean | 52.14 | | 44.333 | | 37.22 | | 32.32 | | 27.24 | | | | |

CD (priming) = 1.20 CD (storage containers) = 0.64 CD (P x S interaction)= NS CD (storage period) = 1.01

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M) $P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M)

$P_5$ –Soaking in $KNO_3$ (150ppm) $P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1, M2, M3, M4 and M5 (storage period in months after priming)

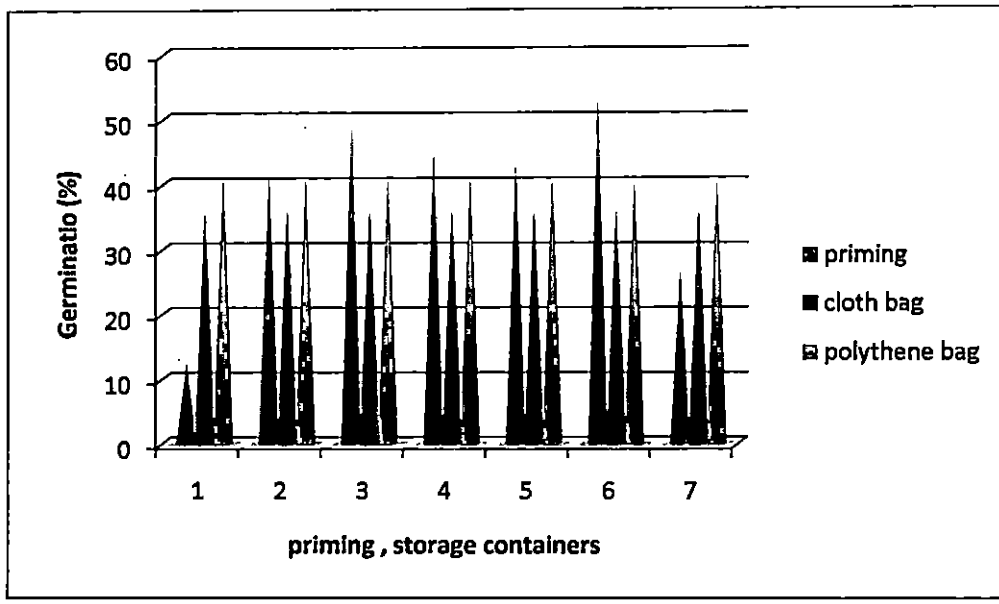


Fig 3. Effect of priming and storage containers on germination (%) of seeds primed after 6 months of storage

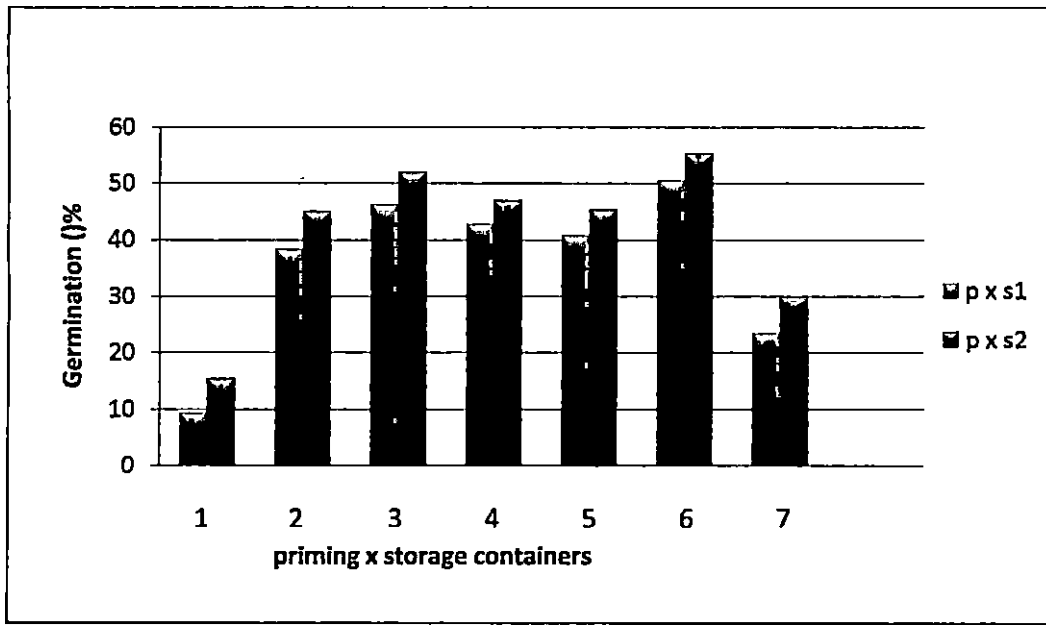


Fig 4. Interaction effect of priming and storage containers on germination (%) of seeds primed after 6 months of storage

Table 4 d: Effect of priming and storage on speed of germination of seeds primed after 6 months of storage

| Months | M1 | | M2 | | M3 | | M4 | | M5 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Priming | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 3.13 | 4.18 | 2.23 | 2.25 | 0.84 | 2.25 | 0.33 | 1.16 | 0.27 | 1.58 | 1.36 | 2.29 | 1.83 |
| P2 | 7.24 | 7.77 | 6.33 | 6.63 | 4.910 | 6.62 | 3.99 | 4.65 | 3.57 | 4.53 | 5.21 | 6.04 | 5.63 |
| P3 | 7.82 | 8.87 | 6.94 | 7.56 | 6.40 | 7.56 | 4.39 | 4.84 | 4.73 | 5.61 | 6.05 | 6.89 | 6.47 |
| P4 | 7.41 | 7.80 | 6.36 | 6.64 | 5.22 | 6.64 | 4.64 | 5.21 | 4.39 | 5.55 | 5.60 | 6.37 | 5.99 |
| P5 | 7.46 | 8.18 | 6.11 | 7.09 | 6.07 | 7.09 | 4.99 | 5.30 | 4.17 | 4.73 | 5.76 | 6.48 | 6.12 |
| P6 | 8.84 | 9.68 | 8.15 | 7.92 | 7.47 | 7.92 | 5.93 | 6.17 | 5.51 | 5.92 | 7.18 | 7.52 | 7.35 |
| P7 | 4.78 | 5.38 | 3.88 | 4.92 | 4.35 | 4.92 | 1.76 | 1.61 | 2.09 | 2.61 | 3.38 | 3.89 | 3.63 |
| Mean | 6.67 | 7.41 | 5.71 | 6.15 | 5.04 | 6.15 | 3.72 | 4.14 | 3.53 | 4.36 | 4.94 | 5.64 | |
| Mean | 7.04 | | 5.93 | | 5.59 | | 3.93 | | 3.95 | | | | |

CD (priming) = 0.19 CD (storage containers) = 0.10 CD (P x S interaction) = NS CD (storage period) = 0.16

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M) $P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M)

$P_5$ –Soaking in $KNO_3$ (150ppm) $P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1, M2, M3, M4 and M5 (storage period in months after priming)

Germination percent was found to be significant due to priming. The highest value 52.90 % was recorded in priming with PEG 6000 (-1.5 MPa) ($P_6$) where as control ($P_1$) recorded the lowest value 12.33 %.

Germination percent due to interaction effect of priming and storage was found to be non-significant. However, the highest value, 55.33% was observed in $P_6S_2$ (PEG 6000 (-1.5 MPa) + storage in polythene bag 700 gauge) and the lowest value, 9.33% was recorded in $P_1S_1$ (control + storage in cloth bag)

**4.3.4. *Speed of germination:***

The speed of germination differed significantly during the storage period and it decreased from 7.04 to 4.36 by the end of storage period. (Table 4 d)

Speed of germination differed significantly among various methods of priming. The seeds treated with PEG 6000 (-1.5 MPa ($P_6$) recorded higher speed of germination 7.3 followed by seeds primed with NaCl ($10^{-5}$M) ($P_3$) which recorded 6.4 and lowest value 1.8 was recorded in control ($P_1$).

Significant difference between storage containers was observed for speed of germination. During the storage period the speed decreased from 6.67 to 3.53 in $S_1$ (cloth bag) and 7.41 to 4.36 in $S_2$ (polythene bag)

Interaction effect of priming and storage containers was found to be non significant.

**4.3.5. Seedling length (cm):**

The seedling length was found to be significant over the months. It decreased from 13.22cm in the initial month to 12.09 cm at the end of storage period. (Table 4 e)

Significant difference on length of the seedling was observed between various methods of priming. Seeds primed with *P. fluorescens* (10g/kg seed) ($P_7$) and PEG 6000 (-1.5MPa) ($P_6$) recorded highest values of 13.92 cm and 13.25 cm respectively. The lowest value, 10.12 cm was recorded in control ($P_1$).

Significant difference between storage containers was observed for seedling length. It decreased from 13.05 to 11.83 in $S_1$ (cloth bag) and from 13.38 to 12.35 in $S_2$ (polythene bag).

The interaction effect of priming and storage containers on seedling length was found to be non-significant.

**4.3.6. Seedling fresh weight (mg):**

There was decrease in fresh weight (mg) at different months of storage varied significantly. There was a decrease in fresh weight (mg) from 159.95 mg in the initial month of storage to 138.31 mg at the end of storage period. (Table 4 f)

Significant difference between priming treatments on seedling fresh weight was observed. The seeds primed with *P. fluorescens* (10g/kg seed) ($P_7$) recorded highest value 165.30mg followed by seeds primed with $P_5$ ($KNO_3$ (150ppm)) which recorded 158.73 mg. control ($P_1$) recorded the lowest value 108.83 mg.

No significant difference was observed between the storage containers for seedling fresh weight.

There was no significant difference due to interaction between priming and storage containers on seedling fresh weight. However, highest (169.00 mg) seedling fresh weight was observed in $P_7S_2$ (*P. fluorescens* (10g/kg seed) + storage in polythene bag) and $P_1S_1$ (control + storage in cloth bag) recorded the lowest value of 106.33 mg.

**4.3.7. Seedling dry weight (mg):**

The overall mean of seedling dry weight differed significantly. However there was a decline in seedling dry weight from 16.43mg at the initial month of storage to 13.59mg by the end of storage period. (Table 4 g)

The significant difference between priming treatments with respect to seedling dry weight (mg) was noticed. Seeds primed with *P. fluorescens* (10g/kg seed) ($P_7$) recorded the highest value 16.90 mg followed by seeds primed with PEG 6000 (-1.5 MPa) ($P_6$) which recorded 16.26 mg and control ($P_1$) recorded the lowest value 11.43mg.

Table 4 e: Effect of priming and storage on seedling length (cm) of seeds primed after 6 months of storage

| Months | M1 | | M2 | | M3 | | M4 | | M5 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Priming | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 10.23 | 10.70 | 9.83 | 10.50 | 9.83 | 10.53 | 9.97 | 10.17 | 9.87 | 10.13 | 9.85 | 10.41 | 10.13 |
| P2 | 13.03 | 13.37 | 12.90 | 13.33 | 12.73 | 13.10 | 12.57 | 12.97 | 12.33 | 12.87 | 12.71 | 13.13 | 12.92 |
| P3 | 13.03 | 13.20 | 12.80 | 13.20 | 12.63 | 13.00 | 12.20 | 12.73 | 11.97 | 12.50 | 12.53 | 12.93 | 12.73 |
| P4 | 12.60 | 13.03 | 12.23 | 12.90 | 12.03 | 12.67 | 11.70 | 12.39 | 11.30 | 12.13 | 11.97 | 12.62 | 12.29 |
| P5 | 13.67 | 13.70 | 12.97 | 13.50 | 12.67 | 13.17 | 12.20 | 12.97 | 12.07 | 12.70 | 12.71 | 13.21 | 12.96 |
| P6 | 14.30 | 14.70 | 13.23 | 13.77 | 12.90 | 13.47 | 12.33 | 13.13 | 12.00 | 12.70 | 12.95 | 13.56 | 13.25 |
| P7 | 14.50 | 14.97 | 13.93 | 14.37 | 13.63 | 14.07 | 13.47 | 13.73 | 13.40 | 13.40 | 13.74 | 14.11 | 13.92 |
| Mean | 13.05 | 13.38 | 12.56 | 13.08 | 12.28 | 12.86 | 12.05 | 12.58 | 12.35 | 12.35 | 12.35 | 12.85 | |
| Mean | 13.22 | | 12.82 | | 12.57 | | 12.31 | | 12.09 | | | | |

CD (priming) = 0.12 CD (storage containers) = 0.06 CD (P x S interaction) = NS CD (storage period) = 0.10

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M) $P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M)

$P_5$ –Soaking in $KNO_3$ (150ppm) $P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1, M2, M3, M4 and M5 (storage period in months after priming)

Table 4 f: Effect of priming and storage on seedling fresh weight (mg) of seeds primed after 6 months of storage

| Months | M1 | | M2 | | M3 | | M4 | | M5 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Priming | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 118.33 | 126.33 | 110.00 | 116.00 | 101.67 | 107.67 | 101.00 | 105.00 | 100.67 | 101.67 | 106.33 | 111.33 | 108.83 |
| P2 | 155.00 | 158.67 | 147.00 | 150.67 | 137.33 | 144.00 | 127.33 | 137.00 | 120.00 | 130.67 | 137.33 | 144.20 | 140.77 |
| P3 | 155.67 | 157.00 | 150.33 | 154.00 | 141.33 | 150.67 | 134.00 | 146.67 | 128.33 | 140.00 | 141.93 | 149.67 | 145.80 |
| P4 | 164.33 | 166.00 | 152.00 | 159.33 | 143.00 | 153.33 | 137.00 | 144.33 | 127.00 | 139.00 | 144.67 | 152.40 | 148.53 |
| P5 | 167.67 | 171.33 | 154.33 | 160.67 | 145.33 | 155.00 | 135.00 | 142.33 | 129.67 | 226.00 | 146.40 | 171.07 | 158.73 |
| P6 | 169.67 | 178.00 | 161.33 | 172.00 | 154.00 | 160.00 | 145.33 | 152.33 | 140.67 | 147.67 | 154.20 | 162.00 | 158.10 |
| P7 | 173.33 | 178.00 | 169.33 | 175.00 | 160.67 | 171.00 | 154.67 | 166.00 | 150.00 | 155.00 | 161.60 | 169.00 | 165.30 |
| Mean | 157.72 | 162.19 | 149.19 | 155.38 | 140.48 | 148.81 | 133.48 | 141.95 | 128.05 | 148.57 | 141.78 | 151.38 | |
| Mean | 159.95 | | 152.29 | | 144.64 | | 137.72 | | 138.31 | | | | |

CD (priming) = 9.16 CD (storage containers) = 4.89 CD (P x S interaction) = NS CD storage period = 7.74

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M) $P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M)

$P_5$ –Soaking in $KNO_3$ (150ppm) $P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1, M2, M3, M4 and M5 (storage period in months after priming)

The effect of storage containers on seedling dry weight (mg) was found to be non-significant.

The interaction effect of priming and storage was also found to be non-significant.

**4.3.8. Days to four leaf emergence:**

The overall mean value for days to four leaf emergence over the months varied significantly. The minimum number of days 8.12 was recorded in the initial month of storage and the highest value 9.19 was recorded at the end of storage period. (Table 4 h)

There was significant difference between the priming treatments. The seeds treated with PEG 6000 (-1.5 MPa) ($P_6$) recorded the minimum number of days 8.13 and control ($P_1$) recorded the maximum number of days 9.16.

Significant difference was observed between the storage containers. The number of days increased from 8.24 to 9.38 in $S_1$ (cloth bag) and 8.00 to 9.00 in $S_2$ (polythene bag 700 gauge)

No significant difference was observed due to interaction effect of priming and storage containers. However, minimum number of days (7.86) was observed in (PEG 6000 (-1.5MPa) + storage in polythene bag 700 gauge) and the maximum number of days 9.40 was observed in $P_1S_1$ (control + storage in cloth bag).

**4.3.9. Electrical conductivity of seed leachate:**

The overall mean value of electrical conductivity of seed leachate (E.C) over the months varied significantly and it was found to be increasing from 0.527dsm$^{-1}$ to 0.581dsm$^{-1}$ during the storage period. (Table 4 i)

The significant difference between the priming treatments with respect to electrical conductivity of the seed leachate was observed. The seeds treated with PEG 6000 (-1.5 MPa) ($P_6$) recorded the lowest value 0.449dsm$^{-1}$followed by seeds treated with $KNO_3$ (150ppm) ($P_5$) which recorded 0.460 dsm$^{-1}$ and maximum electrical conductivity, 0.922dsm$^{-1}$ was observed in control ($P_1$).

Table 4 g: Effect of priming and storage on seedling dry weight (mg) of seeds primed after 6 months of storage

| Months | M1 | | M2 | | M3 | | M4 | | M5 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| priming | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 12.33 | 13.00 | 11.00 | 13.00 | 10.67 | 12.33 | 10.00 | 11.67 | 10.00 | 10.33 | 10.80 | 12.07 | 11.43 |
| P2 | 16.00 | 16.33 | 15.00 | 15.67 | 14.33 | 15.00 | 13.00 | 14.00 | 12.67 | 13.33 | 14.20 | 14.87 | 14.53 |
| P3 | 16.33 | 16.67 | 15.33 | 16.00 | 15.00 | 16.00 | 14.00 | 15.00 | 13.33 | 14.00 | 14.80 | 15.53 | 15.17 |
| P4 | 17.00 | 17.00 | 16.00 | 16.00 | 16.00 | 16.00 | 14.00 | 15.00 | 13.00 | 14.00 | 15.20 | 15.60 | 15.40 |
| P5 | 17.00 | 17.67 | 16.00 | 16.67 | 15.67 | 16.00 | 14.33 | 15.33 | 14.00 | 14.67 | 15.40 | 16.07 | 15.73 |
| P6 | 17.00 | 18.00 | 16.67 | 17.33 | 15.67 | 17.00 | 15.00 | 16.00 | 14.67 | 15.33 | 15.80 | 16.73 | 16.27 |
| P7 | 17.67 | 18.00 | 17.00 | 18.00 | 17.00 | 17.33 | 16.00 | 17.00 | 15.00 | 16.00 | 16.53 | 17.27 | 16.90 |
| Mean | 16.19 | 16.67 | 15.29 | 16.09 | 14.91 | 15.67 | 13.76 | 14.86 | 13.24 | 13.95 | 14.67 | 15.45 | |
| Mean | 16.43 | | 15.69 | | 15.29 | | 14.31 | | 13.59 | | | | |

CD (priming) = 0.20 CD (storage containers) = 0.10 CD (P x S interaction) = NS CD (storage period) = 0.16

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M) $P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M)

$P_5$ –Soaking in $KNO_3$ (150ppm) $P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1, M2, M3, M4 and M5 (storage period in months after priming)

Table 4 h: Effect of priming and storage on days to four leaf emergence of seeds primed after 6 months of storage

| Months | M1 | | M2 | | M3 | | M4 | | M5 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Priming | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 9.00 | 8.33 | 9.33 | 9.00 | 9.33 | 9.00 | 9.67 | 8.67 | 9.67 | 9.40 | 9.40 | 8.93 | 9.17 |
| P2 | 8.33 | 8.00 | 8.33 | 8.00 | 9.33 | 8.67 | 9.00 | 8.67 | 9.67 | 8.93 | 8.93 | 8.47 | 8.70 |
| P3 | 8.00 | 8.00 | 8.33 | 8.00 | 9.00 | 8.00 | 9.00 | 8.33 | 9.67 | 8.80 | 8.80 | 8.27 | 8.53 |
| P4 | 8.00 | 8.00 | 8.33 | 8.00 | 9.00 | 8.33 | 9.00 | 8.33 | 9.67 | 8.80 | 8.80 | 8.33 | 8.57 |
| P5 | 8.00 | 8.00 | 8.33 | 8.00 | 9.00 | 8.33 | 8.67 | 8.67 | 9.00 | 8.60 | 8.60 | 8.40 | 8.50 |
| P6 | 8.00 | 7.33 | 8.00 | 8.00 | 8.67 | 8.00 | 8.00 | 8.00 | 8.00 | 8.40 | 8.40 | 7.87 | 8.13 |
| P7 | 8.33 | 8.33 | 9.33 | 8.67 | 9.33 | 9.00 | 8.67 | 8.67 | 9.33 | 9.20 | 9.20 | 8.80 | 9.00 |
| Mean | 8.24 | 8.00 | 8.57 | 8.24 | 9.09 | 8.48 | 9.09 | 8.48 | 9.00 | 9.00 | 8.88 | 8.44 | |
| Mean | 8.12 | | 8.41 | | 8.79 | | 8.79 | | 9.19 | | | | |

CD (priming) = 0.21 CD (storage containers) = 0.11 CD (P x S interaction) = NS CD (storage period) = 0.17

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M) $P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M)

$P_5$ –Soaking in $KNO_3$ (150ppm) $P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1, M2, M3, M4 and M5 (storage period in months after priming)

Significant difference was noticed between the storage containers. The electrical conductivity of the seed leachate increased from 0.53dsm$^{-1}$ to 0.59dsm$^{-1}$ in $S_1$ (cloth bag) and from 0.52 dsm$^{-1}$ to 0.58 dsm$^{-1}$ in $S_2$ (polythene bag 700 gauge)

The interaction effect of priming and storage containers on electrical conductivity was found to be significant. The overall mean value was found to be high in $P_1S_1$ (control + storage in cloth bag) 0.922 dsm$^{-1}$ and lowest value 0.44 dsm$^{-1}$ was recorded in $P_6S_2$ (PEG 6000 (-1.5MPa) + storage in polythene bag 700 gauge).

**4.3.10. Vigour index I:**

The overall mean value of vigour index I differed significantly. There was a decline in vigour index I from 871.48 during the initial month of storage to 381.95 at the end of storage period. (Table 4 j)

Significant differences between priming treatments with respect to vigour index I was noticed. The seeds treated with PEG 6000 (-1.5 MPa) ($P_6$) recorded the highest value 870.37 followed by $P_3$ (NaCl ($10^{-5}$M)) which recorded 754.13 whereas, control ($P_1$) recorded the lowest value 148.93.

The significant difference between the storage containers was observed. The vigour index I decreased from 826.38 to 326.91 in $S_1$ (cloth bag) and 916.57 to 437.00 in $S_2$ (polythene bag 700 gauge)

The interaction effect between priming and storage containers was found to be non-significant.

**4.3.11. Vigour index II:**

The overall mean value of Vigour index II differed significantly. There was a decline in vigour index I from 699.57 during the initial month of storage to 335.08 at the end of storage period. (Table 4 k)

Table 4 i: Effect of priming and storage on electrical conductivity ($dsm^{-1}$) of the seed seed leachate of seeds primed after 6 months of storage

| Months | M1 | | M2 | | M3 | | M4 | | M5 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Priming | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 0.82 | 0.79 | 0.88 | 0.81 | 0.95 | 0.81 | 0.97 | 0.95 | 0.99 | 0.96 | 0.92 | 0.86 | 0.89 |
| P2 | 0.52 | 0.51 | 0.53 | 0.51 | 0.54 | 0.52 | 0.55 | 0.53 | 0.55 | 0.55 | 0.54 | 0.53 | 0.53 |
| P3 | 0.50 | 0.49 | 0.51 | 0.50 | 0.52 | 0.50 | 0.53 | 0.53 | 0.55 | 0.54 | 0.52 | 0.51 | 0.52 |
| P4 | 0.47 | 0.45 | 0.48 | 0.46 | 0.49 | 0.46 | 0.49 | 0.48 | 0.50 | 0.49 | 0.49 | 0.47 | 0.48 |
| P5 | 0.45 | 0.45 | 0.45 | 0.45 | 0.46 | 0.45 | 0.48 | 0.46 | 0.49 | 0.48 | 0.47 | 0.46 | 0.46 |
| P6 | 0.44 | 0.4 | 0.45 | 0.44 | 0.45 | 0.44 | 0.47 | 0.46 | 0.48 | 0.47 | 0.46 | 0.44 | 0.45 |
| P7 | 0.53 | 0.53 | 0.54 | 0.53 | 0.55 | 0.53 | 0.56 | 0.55 | 0.57 | 0.57 | 0.55 | 0.54 | 0.55 |
| Mean | 0.53 | 0.52 | 0.55 | 0.53 | 0.57 | 0.53 | 0.58 | 0.57 | 0.59 | 0.58 | 0.56 | 0.54 | |
| Mean | 0.53 | | 0.54 | | 0.55 | | 0.57 | | 0.58 | | | | |

CD (priming) = 0.19 CD (storage containers) = 0.11 CD (P x S interaction) = 0. 27 CD (storage period) = 0.16

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M) $P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M)

$P_5$ –Soaking in $KNO_3$ (150ppm) $P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1, M2, M3, M4 and M5 (storage period in months after priming)

Table 4 j: Effect of priming and storage on Vigour index I of seeds primed after 6 months of storage

| Months | M1 | | M2 | | M3 | | M4 | | M5 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Priming | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 280.33 | 381.33 | 168.67 | 196.67 | 58.00 | 163.33 | 20.00 | 104.33 | 13.33 | 103.33 | 108.07 | 189.80 | 148.93 |
| P2 | 888.00 | 986.33 | 740.00 | 824.33 | 481.33 | 625.00 | 381.33 | 541.33 | 308.00 | 421.67 | 558.13 | 679.33 | 618.93 |
| P3 | 974.67 | 1078.00 | 827.33 | 901.33 | 695.00 | 832.00 | 550.67 | 700.00 | 422.33 | 560.00 | 694.00 | 814.27 | 754.13 |
| P4 | 969.00 | 1014.33 | 730.67 | 789.33 | 714.67 | 746.00 | 518.00 | 605.00 | 381.33 | 536.67 | 662.73 | 738.40 | 700.57 |
| P5 | 957.67 | 1042.00 | 741.33 | 884.00 | 584.00 | 688.00 | 496.33 | 597.67 | 420.00 | 476.67 | 640.00 | 737.07 | 688.53 |
| P6 | 1105.00 | 1230.00 | 973.00 | 1062.00 | 783.33 | 906.67 | 640.00 | 800.00 | 533.33 | 670.33 | 806.93 | 933.80 | 870.37 |
| P7 | 618.00 | 684.00 | 493.00 | 630.00 | 374.00 | 548.33 | 272.00 | 453.33 | 210.00 | 293.33 | 393.40 | 521.80 | 457.60 |
| Mean | 826.38 | 916.57 | 667.72 | 755.38 | 527.29 | 644.29 | 411.19 | 543.09 | 326.91 | 437.00 | 551.89 | 659.27 | |
| Mean | 871.48 | | 711.55 | | 585.79 | | 47.15 | | 381.95 | | | | |

CD (priming) = 19.53 CD (storage containers) = 10.44 CD (P x S interaction) = NS CD (storage period) = 16.51

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M) $P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M)

$P_5$ –Soaking in $KNO_3$ (150ppm) $P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1, M2, M3, M4 and M5 (storage period in months after priming)

Table 4k: Effect of priming and storage on Vigour index II of seeds primed after 6 months of storage

| Months | M1 | | M2 | | M3 | | M4 | | M5 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Priming | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 232.07 | 313.80 | 150.67 | 157.67 | 48.20 | 140.40 | 19.533 | 91.67 | 13.07 | 101.33 | 92.71 | 160.97 | 126.84 |
| P2 | 716.57 | 806.17 | 636.50 | 701.63 | 428.27 | 545.77 | 368.00 | 501.50 | 300.00 | 406.83 | 489.87 | 592.38 | 541.13 |
| P3 | 777.70 | 853.67 | 691.60 | 744.00 | 585.17 | 676.03 | 479.433 | 589.67 | 379.17 | 500.00 | 582.72 | 672.67 | 627.69 |
| P4 | 718.33 | 777.70 | 559.43 | 636.33 | 457.27 | 591.33 | 433.100 | 497.43 | 331.33 | 465.10 | 499.89 | 593.58 | 546.74 |
| P5 | 769.70 | 808.27 | 643.50 | 715.57 | 472.80 | 566.17 | 424.300 | 505.77 | 362.07 | 410.57 | 531.47 | 601.27 | 567.87 |
| P6 | 934.33 | 1009.73 | 772.20 | 810.37 | 645.00 | 718.30 | 526.167 | 656.63 | 435.87 | 554.37 | 662.71 | 749.88 | 706.29 |
| P7 | 507.23 | 568.80 | 404.10 | 502.73 | 299.83 | 445.37 | 227.200 | 366.27 | 185.63 | 245.77 | 324.80 | 425.79 | 375.29 |
| Mean | 665.13 | 734.02 | 551.15 | 609.76 | 419.55 | 526.19 | 354.00 | 458.42 | 286.73 | 383.43 | 455.31 | 542.36 | |
| Mean | 699.58 | | 580.45 | | 472.85 | | 406.26 | | 335.08 | | | | |

CD (priming) = 14.90 CD (storage container) = 7.96 CD (P x S interaction) = NS CD (storage period) = 12.59

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M) $P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M)

$P_5$ –Soaking in $KNO_3$ (150ppm) $P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1, M2, M3, M4 and M5 (storage period in months after priming)

The significant difference between priming treatments with respect to Vigour index II was observed. The seeds treated with PEG 6000 (-1.5 MPa) ($P_6$) recorded the highest value 706.29 followed by $P_3$ (NaCl ($10^{-5}$M)) which recorded 627.69 where as control ($P_1$) recorded the lowest value126.84.

Significant difference between the storage containers was observed. Vigour index II decreased from 665.13 to 286.73 in $S_1$ (cloth bag) and 734.01 to 383.42 in $S_2$ (polythene bag 700 gauge)

The interaction effect of priming and storage was found to be non-significant.

**4.4. Effect of priming and storage on quality of seeds primed after 9 months of storage.**

The statistically analysed data of seed quality parameters, of seeds primed 9 months after storage under ambient condition, immediately after priming and as influenced by priming, storage and their interaction are presented in the table 5 – 5 k.

Immediately after priming ,the seeds primed with $P_6$ (PEG 6000 (-1.5 MPa) recorded highest germination (44.00 %), speed of germination (6.14), fresh weight (158.33 mg) vigour index I (748.00), vigour index II (636.53) and lowest electrical conductivity (0.41 $dsm^{-1}$), maximum seedling length (15.26 cm), seedling dry weight (17.00 mg). $P_1$ (Control) recorded the maximum moisture content (7.70 %) , germination (11.67 %), speed of germination (1.32), lowest seedling length (9.83 cm), fresh weight (110.00 mg) dry weight (11.00 mg), vigour index I (128.33), vigour index II (114.17) and highest electrical conductivity (0.89 $dsm^{-1}$).

Table 5: Effect of priming on seed quality parameters immediately after priming (9 months after storage)

| Seed quality parameters | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ | $P_6$ | $P_7$ | CD |
|---|---|---|---|---|---|---|---|---|
| 100 seed weight (g) | 0.77 | 0.71 | 0.73 | 0.73 | 0.75 | 0.75 | 0.77 | 0.95 |
| Moisture content (%) | 7.71 | 7.35 | 7.35 | 7.39 | 7.40 | 7.56 | 7.65 | 0.95 |
| Germination (%) | 11.67 | 29 | 35.67 | 36.67 | 37.33 | 44 | 12.67 | 5.53 |
| Speed of germination | 1.32 | 4.08 | 5.03 | 5.15 | 5.13 | 6.14 | 1.57 | 0.67 |
| Seedling length (cm) | 9.83 | 12.5 | 12.97 | 13.9 | 13.97 | 14.47 | 12.17 | 0.87 |
| Seedling fresh weight (mg) | 111 | 138 | 140.33 | 143 | 148.33 | 158.33 | 115.33 | 5.35 |
| Seedling dry weight (mg) | 11 | 14.33 | 14 | 15 | 15 | 17 | 12 | 0.04 |
| Days to four leaf emergence | 9.33 | 9 | 8.67 | 9 | 8.67 | 8.33 | 9.33 | NS |
| Electrical conductivity of seed leachate | 0.89 | 0.82 | 0.79 | 0.79 | 0.78 | 0.77 | 0.88 | 0.95 |
| Vigour index I | 128.33 | 417 | 499.33 | 550 | 560 | 748 | 152 | 1299.80 |
| Vigour index II | 114.17 | 361.83 | 462.33 | 509.8 | 521.467 | 636.53 | 154.67 | 796.29 |

Table 5 a: Effect of priming and storage on 100 seed weight (g) of seeds primed after 9 months of storage

| Months | M1 | | M2 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|
| Priming | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 0.78 | 0.77 | 0.79 | 0.77 | 0.78 | 0.77 | 0.78 |
| P2 | 0.72 | 0.72 | 0.74 | 0.73 | 0.73 | 0.72 | 0.73 |
| P3 | 0.74 | 0.73 | 0.74 | 0.73 | 0.74 | 0.73 | 0.74 |
| P4 | 0.74 | 0.74 | 0.75 | 0.74 | 0.74 | 0.74 | 0.74 |
| P5 | 0.76 | 0.75 | 0.76 | 0.75 | 0.76 | 0.75 | 0.75 |
| P6 | 0.76 | 0.76 | 0.77 | 0.76 | 0.77 | 0.76 | 0.76 |
| P7 | 0.78 | 0.76 | 0.78 | 0.77 | 0.78 | 0.77 | 0.77 |
| Mean | 0.75 | 0.75 | 0.76 | 0.75 | 0.75 | 0.77 | |
| Mean | 0.74 | | 0.75 | | | | |

CD (priming) = 0.38 CD (storage containers) = 0. 19 CD (P x S interaction) = NS

CD (storage period) = 0.19

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M)

$P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M) $P_5$ –Soaking in $KNO_3$ (150ppm)

$P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1and M2 (storage period in months after priming)

Table 5 b: Effect of priming and on moisture content (%) of seeds primed after 9 months of storage

| *Months* | M1 | | M2 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|
| **Priming** | **S1** | **S2** | **S1** | **S2** | **S1** | **S2** | |
| **P1** | 7.82 | 7.75 | 7.85 | 7.77 | 7.84 | 7.76 | 7.80 |
| **P2** | 7.47 | 7.39 | 7.56 | 7.42 | 7.51 | 7.41 | 7.46 |
| **P3** | 7.46 | 7.39 | 7.53 | 7.46 | 7.50 | 7.42 | 7.46 |
| **P4** | 7.57 | 7.41 | 7.64 | 7.51 | 7.61 | 7.46 | 7.53 |
| **P5** | 7.53 | 7.49 | 7.62 | 7.57 | 7.58 | 7.53 | 7.53 |
| **P6** | 7.63 | 7.60 | 7.72 | 7.64 | 7.68 | 7.62 | 7.65 |
| **P7** | 7.74 | 7.70 | 7.76 | 7.74 | 7.75 | 7.72 | 7.74 |
| **Mean** | 7.61 | 7.53 | 7.67 | 7.59 | 7.64 | 7.56 | |
| **Mean** | 7.57 | | 7.63 | | | | |

CD (priming) = 0.02 CD (storage period) = 0.01 CD (storage containers) = 0.13

CD (P x S interaction) = 0.36

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M)
$P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M) $P_5$ –Soaking in $KNO_3$ (150ppm)

$P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1and M2 (storage period in months after priming)

### 4.4.1. 100 Seed Weight (g):

The overall mean value for 100 seed weight over the months varied significantly. The 100 seed weight was found to be increasing from 0.75g to 0.76g at the end of storage period. (Table 5a)

The significant difference between priming treatments with respect to 100 seed weight was noticed. Hydro primed seeds ($P_2$) and NaCl ($10^{-5}$M) ($P_3$) recorded the lowest value, 0.73g where as $P_1$ (control) seeds recorded the highest value 0.77g.

Significant difference between the storage containers for 100 seed weight was observed. It increased from 0.75g to 0.76g in $S_1$ and 0.75g to 0.75g in $S_2$.

The interaction effect of priming and storage containers on 100 seed weight was found to be non- significant. However, lowest value, 0.72g was recorded in $P_2S_2$ (Hydro primed seeds stored in polythene bag) and highest value, 0.78g was observed in $P_1S_1$ (control seed stored in cloth bag)

### 4.4.2. Moisture content (%):

With the advancement of storage period, moisture content (%) increased irrespective of priming, storage and their interaction. The mean moisture content (%) increased from 7.56% to 7.62% at the end of the storage period. (Table 5 b)

Moisture content (%) differed significantly between various priming treatments. The highest value 7.79% was recorded in control ($P_1$) the lowest value 7.46% was recorded in seeds treated with NaCl ($10^{-5}$M) ($P_3$) and hydro primed seeds ($P_2$).There was significant effect of storage containers on percent moisture content (%). It increased from 7.61 % to 7.67 % in $S_1$ (Cloth bag) and 7.53 % to 7.59 % in $S_2$ (polythene bag 700 gauge).

Table 5 c: Effect of priming and on germination (%) of seeds primed after 9 months of storage

| Months | M1 | | M2 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|
| Priming | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 0.33 | 1.17 | 0.33 | 1.22 | 0.33 | 1.19 | 0.76 |
| P2 | 3.99 | 4.66 | 3.34 | 3.96 | 3.66 | 4.31 | 3.99 |
| P3 | 3.92 | 4.40 | 4.84 | 4.64 | 4.16 | 4.62 | 4.39 |
| P4 | 4.02 | 4.58 | 5.21 | 4.99 | 4.33 | 4.90 | 4.61 |
| P5 | 4.02 | 4.88 | 5.30 | 5.93 | 4.50 | 5.09 | 4.80 |
| P6 | 5.93 | 6.18 | 4.71 | 5.39 | 5.32 | 5.79 | 5.55 |
| P7 | 1.76 | 1.61 | 1.30 | 1.44 | 1.53 | 1.53 | 1.53 |
| Mean | 3.72 | 4.14 | 3.08 | 3.70 | 3.40 | 3.92 | |
| Mean | 3.930 | | 3.390 | | | | |

CD (priming) = 1.08 CD (storage containers) = 0.57 CD (P x S interaction) = 1.53

CD (storage period) = 0.57

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M)

$P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M) $P_5$ –Soaking in $KNO_3$ (150ppm)

$P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1and M2 (storage period in months after priming)

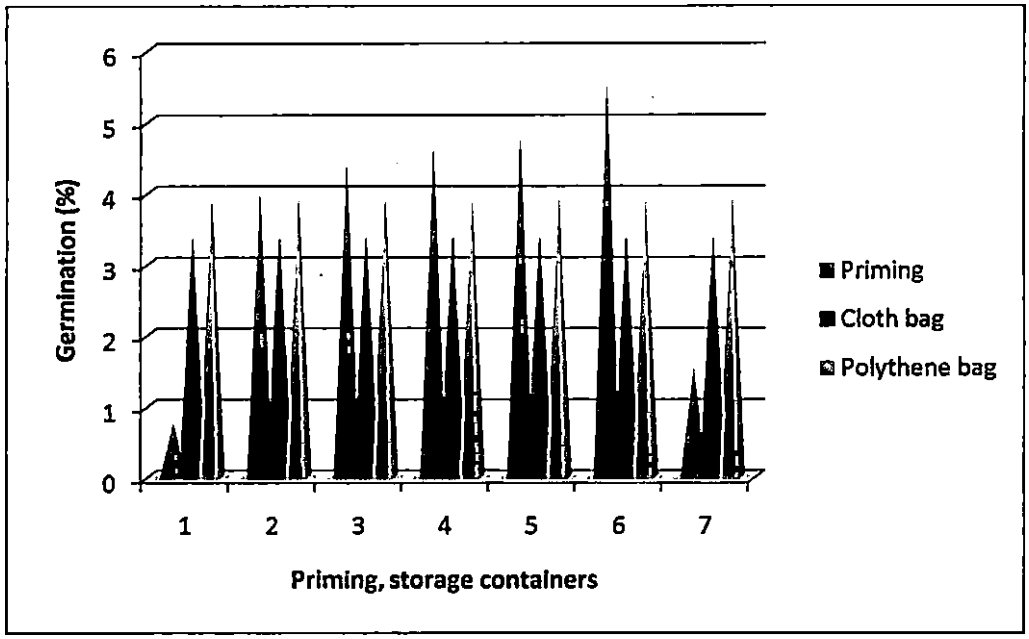


Fig 5. Effect of priming and storage containers on germination (%) of seeds primed after 9 months of storage

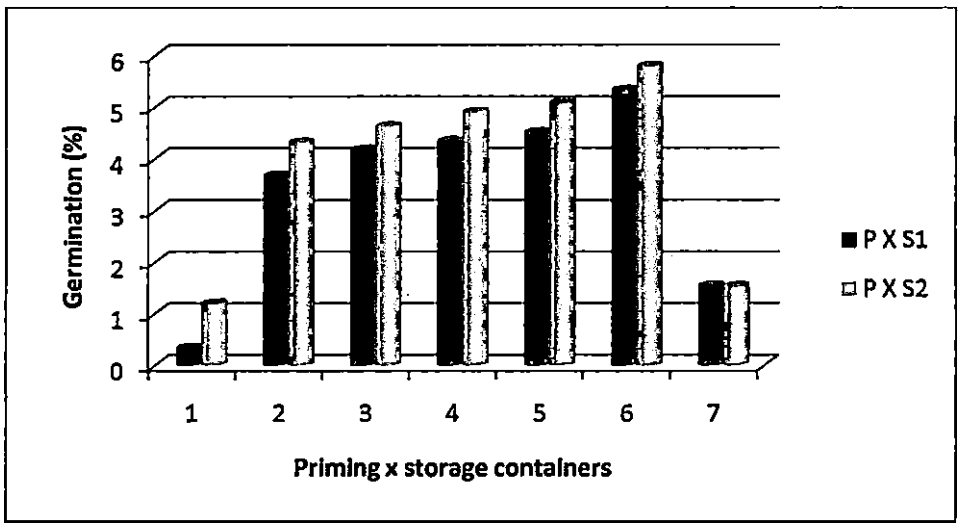


Fig 6. Interaction effect of priming and storage containers on germination (%) of seeds primed after 9 months of storage

Table 5 d: Effect of priming and storage on speed of germination of seeds primed after 9 months of storage

| Months | M1 | | M2 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|
| Priming | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 2.00 | 7.33 | 2.00 | 6.00 | 2.00 | 6.67 | 4.33 |
| P2 | 29.33 | 33.33 | 23.33 | 29.33 | 26.33 | 31.33 | 28.83 |
| P3 | 31.67 | 34.33 | 28.33 | 31.33 | 30.00 | 32.83 | 31.42 |
| P4 | 33.67 | 37.00 | 39.00 | 32.33 | 31.33 | 34.67 | 33.00 |
| P5 | 28.00 | 34.00 | 37.33 | 40.33 | 31.67 | 35.83 | 33.75 |
| P6 | 40.33 | 43.33 | 28.33 | 38.67 | 34.33 | 41.00 | 37.67 |
| P7 | 11.67 | 12.33 | 9.33 | 10.67 | 10.50 | 11.50 | 11.00 |
| Mean | 26.29 | 29.29 | 21.19 | 26.10 | 23.74 | 27.69 | |
| Mean | 27.79 | | 23.64 | | | | |

CD (priming) = 0.15 CD (storage containers) = 0.08 CD (P x S interaction) = 0.21

CD (storage period) = 0.82

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M)

$P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M) $P_5$ –Soaking in $KNO_3$ (150ppm)

$P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1and M2 (storage period in months after priming)

The interaction effect of priming and storage containers on moisture content (%) was found to be significant. $P_1S_1$ (Control + storage in cloth bag) recorded the highest value 7.83 % and $P_2S_2$ (Hydro primed seeds + storage in polythene bag) recorded the lowest value 7.40 %.

**4.4.3. Germination percent (%):**

The overall mean value of percent germination over the months varied significantly. The percent germination was found to decrease from 27.79 % to 23.64 % by the end of the storage period. (Table 5c)

Significant difference was observed between the priming treatments. The seeds primed with (PEG 6000 (-1.5MPa) ($P_6$) recorded the highest value 37.7% followed by seeds treated with $P_5$ ($KNO_3$ (150ppm)) 33.7 %. However lowest percent germination was recorded in Control ($P_1$) 4.3 %.

Significant difference between the storage containers was observed. It decreased from 26.28 % to 21.19 % in $S_1$ (cloth bag) and from 29.29 % to 26.09 % in $S_2$ (polythene bag 700 gauge)

Percent germination due to interaction effect of priming and storage was found to be significant. $P_6S_2$ (Seeds treated with PEG 6000 -1.5 M Pa + storage in polythene bag) recorded the highest value 37.6 % followed by $P_5S_2$ ($KNO_3$ (150ppm) + storage in polythene bag) whereas $P_1S_1$ (Control + storage in cloth bag) recorded the lowest percent germination 2.0 %.

**4.4.4. Speed of germination:**

The overall mean value of speed of germination over the months varied significantly. It decreased from 3.93 in the initial month of storage period to 3.39 by the end of storage period. (Table 5d)

Table 5 e: Effect of priming and on seedling length (cm) of seeds primed after 9 months of storage

| Months | M1 | | M2 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|
| Priming | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 9.00 | 9.50 | 9.97 | 10.33 | 9.48 | 9.92 | 9.70 |
| P2 | 11.80 | 12.00 | 11.00 | 11.80 | 11.40 | 11.90 | 11.65 |
| P3 | 11.93 | 12.57 | 11.23 | 11.60 | 11.58 | 12.08 | 11.83 |
| P4 | 13.57 | 13.90 | 13.03 | 13.27 | 13.30 | 13.58 | 13.44 |
| P5 | 13.40 | 13.57 | 12.93 | 13.50 | 13.17 | 13.53 | 13.85 |
| P6 | 13.87 | 14.00 | 13.63 | 13.90 | 13.75 | 13.95 | 13.85 |
| P7 | 11.17 | 11.67 | 13.37 | 10.83 | 12.27 | 11.25 | 11.76 |
| Mean | 12.11 | 12.46 | 12.17 | 12.18 | 12.14 | 12.32 | |
| Mean | 12.28 | | 12.17 | | | | |

CD (priming) = 0.73 CD (storage containers) = 0.39 CD (P x S interaction) = NS

CD (storage period) = NS

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M)
$P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M) $P_5$ –Soaking in $KNO_3$ (150ppm)

$P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1 and M2 (storage period in months after priming)

Table 5 f: Effect of priming and storage on seedling fresh weight (mg) of seeds primed after 9 months of storage

| Months | M1 | | M2 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|
| Priming | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 101.67 | 105.67 | 101.00 | 106.67 | 101.33 | 106.17 | 103.75 |
| P2 | 135.33 | 135.33 | 125.33 | 130.33 | 130.33 | 132.83 | 131.58 |
| P3 | 136.00 | 137.67 | 126.00 | 134.00 | 131.00 | 135.83 | 133.42 |
| P4 | 139.67 | 141.00 | 130.00 | 137.00 | 134.83 | 139.00 | 136.92 |
| P5 | 143.00 | 147.00 | 133.33 | 143.00 | 138.17 | 145.00 | 141.58 |
| P6 | 151.33 | 156.67 | 141.33 | 153.00 | 143.33 | 154.83 | 150.58 |
| P7 | 108.67 | 112.00 | 105.00 | 111.00 | 106.83 | 111.50 | 109.17 |
| Mean | 130.81 | 133.17 | 123.14 | 130.72 | 126.98 | 132.17 | |
| Mean | 132.22 | | 126.93 | | | | |

CD (priming) = 1.68 CD (PXS interaction) = NS CD storage containers = 0.90 CD (storage period) = 0.90

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M)

$P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M) $P_5$ –Soaking in $KNO_3$ (150ppm)

$P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1and M2 (storage period in months after priming)

Speed of germination was significant due to priming. The highest speed of germination was observed in PEG 6000 -1.5MPa ($P_6$) 5.55 followed by $KNO_3$ (150 ppm) ($P_5$) 4.8. Whereas control ($P_1$) recorded the lowest value 0.762.

Significant difference was observed between the storage containers. The speed of germination decreased from 3.72 to 3.09 in $S_1$ (Cloth bag) and 4.13 to 3.69 in $S_2$ (polythene bag 700 gauge).

Speed of germination due to interaction effect of priming and storage was found to be significant. $P_6S_2$ (PEG -6000 -1.5 MPa) + storage in polythene bag) recorded the highest value 5.8 followed by $P_6S_1$ (PEG -6000 -1.5 MPa) + storage in cloth bag) 5.32. The lowest value was recorded in $P_1S_1$ (control + storage in cloth bag) 0.33

**4.4.5. Seedling length (cm):**

No significant difference with respect to seedling length (cm) was observed during the storage period. However seedling length (cm) decreased from 12.28 cm to 12.17 cm. (Table 5e)

Significant difference on seedling length was observed among various methods of priming. Seeds primed with PEG -6000 (-1.5 MPa) ($P_6$) recorded the highest value 13.85cm followed by $CaCl_2$ ($10^{-5}$M) ($P_4$) 13.44 cm and control ($P_1$) recorded the lowest value 9.7cm.

No significant difference was observed between the storage containers was observed.

The interaction effect of priming and storage was found to be non significant.

**4.4.6. Fresh weight (mg):**

Significant difference on seedling fresh weight was observed between the storage containers. It decreased from 132.22mg in the initial month of storage to 126.93mg at the end of storage period. (Table 5f)

Significant difference was observed between the priming treatments with respect to seedling fresh weight (mg). The seeds primed with p6 recorded the highest

Table 5 g: Effect of priming and storage on seedling dry weight (mg) of seeds primed after 9 months of storage

| Months | M1 | | M2 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|
| Priming | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 11.00 | 11.00 | 10.00 | 11.00 | 10.50 | 11.00 | 10.75 |
| P2 | 14.00 | 14.00 | 13.00 | 13.00 | 13.50 | 13.50 | 13.50 |
| P3 | 14.00 | 14.00 | 13.33 | 13.67 | 13.67 | 13.83 | 13.75 |
| P4 | 14.00 | 14.00 | 13.00 | 14.00 | 13.50 | 14.00 | 13.75 |
| P5 | 14.67 | 15.00 | 13.67 | 14.67 | 14.17 | 14.83 | 14.50 |
| P6 | 15.33 | 16.00 | 14.33 | 15.00 | 14.83 | 15.50 | 15.17 |
| P7 | 11.33 | 11.00 | 11.00 | 11.00 | 11.17 | 11.00 | 11.08 |
| Mean | 13.48 | 13.57 | 12.62 | 13.19 | 13.05 | 13.38 | |
| Mean | 13.53 | | 12.91 | | | | |

CD (priming) = 0.24 CD (storage containers) = 0.13 CD for comparing P x S= NS

CD.(storage period) = 0.13

$P_1$ – *Control (dry seed)* $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M) $P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M) $P_5$ –Soaking in $KNO_3$ (150ppm)

$P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1and M2 (storage period in months after priming)

Table 5 h: Effect of priming and storage on days to 4 leaf emergence of seeds primed after 9 months of storage

| Months | M1 | | M2 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|
| Priming | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 10.00 | 10.00 | 9.67 | 9.67 | 9.83 | 9.83 | 9.83 |
| P2 | 9.33 | 9.00 | 9.33 | 9.00 | 9.00 | 9.17 | 9.17 |
| P3 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 |
| P4 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 |
| P5 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 |
| P6 | 8.67 | 8.67 | 9.00 | 9.00 | 8.83 | 8.83 | 8.33 |
| P7 | 9.67 | 9.67 | 9.67 | 9.33 | 9.67 | 9.50 | 9.58 |
| Mean | 9.24 | 9.24 | 9.19 | 9.140 | 9.22 | 9.19 | |
| Mean | 9.24 | | 9.17 | | | | |

CD (priming) = 0.27 CD (storage containers) = 0.14 CD (P x S interaction) = NS

CD (storage period) = 0.14

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M)
$P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M) $P_5$ –Soaking in $KNO_3$ (150ppm)

$P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1and M2 (storage period in months after priming)

value 150.58mg followed by $KNO_3$ (150ppm) ($P_5$) 141.58mg. Whereas control ($P_1$) recorded the lowest value 103.75mg.

Significant difference was observed between the storage containers. Seedling fresh weight decreased from 130.81mg to 123.15 mg in $S_1$ (cloth bag) and from 133.17mg to 130.72 mg in $S_2$ (polythene bag 700 gauge)

The interaction effect of priming and storage was found to be non significant.

**4.4.7. Dry weight (mg/ seedling):**

There was significant difference of seedling dry weight (mg) during the storage period. It decreased from 13.53 mg to 12.91 mg. (Table 5 g)

The significant difference among priming with respect to seedling dry weight was noticed. Seeds primed PEG 6000 (-1.5 MPa) ($P_6$) recorded the highest value 15.16 followed by $KNO_3$ (150ppm) ($P_5$) 14.50. Control ($P_1$) recorded the lowest value 10.75mg.

Significant difference between the storage containers was observed. The seedling dry weight (mg) decreased from 13.48 mg to 12.62mg in $S_1$ (cloth bag) and from 13.57mg to 13.19 mg in $S_2$ (polythene bag 700 gauge).

The interaction effect of priming and storage was found to be non significant.

**4.4.8. Days to four leaf emergence:**

The number days to four leaf emergence varied significantly and were found to increase from 9.24 to 9.17 during the storage period. (Table 5 h)

The significant difference among priming with respect to days to four leaf emergence was noticed. Seeds primed with PEG 6000 (-1.5 MPa) ($P_6$) recorded the lowest number of days 8.33 and control ($P_1$) recorded the highest value 9.83.

Table 5 i: Effect of priming and storage on electrical conductivity of seed leachate of seeds primed after 9 months of storage

| Months | M1 | | M2 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|
| Priming | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 0.95 | 0.93 | 0.95 | 0.93 | 0.95 | 0.93 | 0.94 |
| P2 | 0.83 | 0.82 | 0.83 | 0.82 | 0.83 | 0.82 | 0.83 |
| P3 | 0.82 | 0.80 | 0.81 | 0.80 | 0.82 | 0.80 | 0.81 |
| P4 | 0.80 | 0.79 | 0.80 | 0.79 | 0.80 | 0.79 | 0.79 |
| P5 | 0.81 | 0.80 | 0.81 | 0.80 | 0.81 | 0.80 | 0.81 |
| P6 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 |
| P7 | 0.91 | 0.90 | 0.91 | 0.90 | 0.91 | 0.90 | 0.90 |
| Mean | 0.84 | 0.83 | 0.84 | 0.83 | 0.84 | 0.83 | |
| Mean | 0.84 | | 0.84 | | | | |

CD (priming) = 0.36 CD (storage containers) = 0.19 CD (P x S interaction) = NS

CD (storage period) = NS

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M)
$P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M) $P_5$ –Soaking in $KNO_3$ (150ppm)

$P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1and M2 (storage period in months after priming)

Table 5 j: Effect of priming and storage on vigour index I (V I) of seeds primed after 9 months of storage

| Months | M1 | | M2 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|
| Priming | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 22.00 | 80.67 | 20.00 | 66.00 | 21.00 | 73.33 | 47.17 |
| P2 | 410.67 | 466.67 | 303.00 | 381.33 | 357.00 | 424.00 | 390.50 |
| P3 | 443.33 | 480.67 | 377.67 | 428.67 | 410.50 | 454.67 | 432.58 |
| P4 | 471.33 | 518.00 | 377.00 | 452.67 | 424.17 | 485.33 | 454.75 |
| P5 | 518.33 | 560.00 | 382.33 | 503.33 | 450.33 | 531.67 | 491.00 |
| P6 | 618.67 | 693.33 | 406.67 | 503.33 | 512.67 | 636.67 | 574.67 |
| P7 | 132.67 | 135.67 | 102.67 | 117.67 | 117.67 | 126.50 | 122.08 |
| Mean | 373.86 | 419.29 | 281.38 | 361.33 | 327.62 | 390.31 | |
| Mean | 396.57 | | 321.360 | | | | |

CD (priming) = 16.83 CD storage containers = 8.99 CD (P x S interaction) = 23.81

CD (storage period) = 8.99

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M)
$P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M) $P_5$ –Soaking in $KNO_3$ (150ppm)

$P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1and M2 (storage period in months after priming)

No significant difference between the storage containers with respect to days to four leaf emergence was observed during the storage period.

The interaction effect of priming and storage was found to be non significant.

**4.4.9. Electrical conductivity of seed leachate:**

The electrical conductivity during the storage period was found to be non-significant. (Table 5 i)

The significant difference between priming treatments with respect to electrical conductivity was noticed. The seeds treated with PEG 6000 (-1.5 MPa) ($P_6$) recorded the lowest value 0.79 and $P_1$ (control) recorded the highest value 0.94.

Significant difference between the storage containers was observed. The highest value, 0.84 was recorded in $S_1$ (cloth bag) and the lowest value 0.83 was recorded in $S_2$ (polythene bag 700 gauge)

The interaction effect of priming and storage was found to be non significant.

**4.4.10. Vigour index I:**

The vigour index I during the storage period was found to be significant. It decreased from 396.57 in the initial month of storage to 321.36 by the end of storage period. (Table 5 j).

Significant differences among seed priming with respect to vigour index I was observed. The seeds treated with PEG 6000 (-1.5 MPa) ($P_6$) recorded the highest value 574.67 followed by seeds treated with $KNO_3$ (150ppm) ($P_5$) 491.0 $P_1$ (control) recorded the lowest value 47.17.

The significant difference between the storage containers was noticed during the storage period. The vigour index I decreased from 373.86 to 281.38 in $S_1$ (cloth bag) and from 419.29 to 361.33 in $S_2$ (polythene bag 700 gauge).

The interaction effect of priming and storage containers was found to be significant.

**4.4.11. Vigour index II:**

Significant difference for vigour index II was noticed during the storage period. It decreased from 359.63 to 298.82 by the end of storage period. (Table 5 k)

Significant differences between priming treatments with respect to vigour index II was noticed. The seeds primed with PEG 6000 (-1.5 MPa) ($P_6$) recorded highest value 533.94 followed by $KNO_3$ (150ppm) ($P_5$) 451.36. control ($P_1$) recorded the lowest value 42.60.

Significant difference between the storage containers was observed during the storage period. The vigour index II decreased from 337.56 to 266.63 in $S_1$ (cloth bag) and from 381.71 to 331.01 in $S_2$ (polythene bag 700 gauge).

The interaction effect of priming and storage was found to be non significant. However, $P_6S_2$ (PEG 6000 (-1.5 MPa) + storage in polythene bag 700 gauge) recorded the highest value 572.08 and $P_1S_1$ (control + storage in cloth bag) recorded the lowest value 19.20.

Table 5 k: Effect of priming and storage and their interaction effect on vigour index II of seeds primed *after 9 months of storage*

| Months | M1 | | M2 | | Mean | | Mean |
|---|---|---|---|---|---|---|---|
| Priming | S1 | S2 | S1 | S2 | S1 | S2 | |
| P1 | 18.87 | 70.00 | 19.53 | 62.00 | 19.20 | 66.00 | 42.60 |
| P2 | 346.13 | 400.03 | 253.33 | 346.13 | 301.23 | 373.08 | 337.16 |
| P3 | 378.00 | 431.43 | 318.20 | 363.43 | 348.10 | 397.43 | 372.77 |
| P4 | 456.73 | 514.30 | 378.03 | 429.00 | 417.38 | 471.65 | 444.52 |
| P5 | 473.43 | 506.47 | 362.07 | 463.50 | 417.75 | 484.98 | 451.37 |
| P6 | 559.27 | 606.70 | 432.33 | 537.47 | 495.80 | 572.08 | 533.94 |
| P7 | 130.50 | 143.00 | 99.90 | 115.53 | 115.20 | 129.27 | 122.23 |
| Mean | 337.56 | 266.63 | 381.71 | 331.01 | 302.10 | 356.36 | |
| Mean | 359.63 | | 298.82 | | | | |

CD (priming) = 13.94 CD (storage containers) = 7.45 CD (P x S interaction) = NS

CD (storage period) = 7.45

$P_1$ – Control (dry seed) $P_2$ –Control (water soaking) $P_3$ –Soaking in NaCl ($10^{-5}$M)
$P_4$ –Soaking in $CaCl_2$ ($10^{-5}$M) $P_5$ –Soaking in $KNO_3$ (150ppm)

$P_6$ –Soaking in PEG 6000(-1.5MPa) $P_7$–Seed treatment with *P. fluorescens* (10g/kg seed)

$S_1$ – cloth bag $S_2$ Polythene bag (700 gauge)

M1and M2 (storage period in months after priming)

# DISCUSSION

# 5. DISCUSSION

Seed is an important basic and crucial input in agriculture. The most important aspects in the seed production programme are production and storage of genetically pure seed and maintenance of continuous supply of high quality seeds to farmers. It is well established that high quality seed respond in a better way than all other inputs and management practices. Therefore, maintenance of high quality during storage is of great significance.

Seed quality is one of the key factors affecting the successful farming, but it declines during prolonged storage. Poor quality seeds generally show decrease in germination and emergence of vigorous seedlings, leading to problems in successful crop production (Powell *et al.*, 2000).

The requirement of high quality seed is becoming very essential to achieve optimum plant stand but the maintenance of viability and control of rapid deterioration of seeds pose serious problems in the seed industry. Loss of viability and vigour of seeds is associated with ageing and results in poor performance. In the last three decades, seed priming has become a common seed quality enhancement treatment to increase the rate of uniformity of emergence under varied field conditions.

Malnassy (1971) described pre-sowing treatments to enhance germination and increase in uniformity of seedling emergence under adverse environmental conditions and Heydecker *et al.* (1973) acknowledged the use of the term "priming" of seeds.

Since agriculture is season bound, the storage of seed has become inevitable for farmers, seed producers and seed businessmen. It is a quite phenomenon that the seed loses its viability and vigour during storage like any other biological material.

The loss of viability due to seed deterioration is inexorable, irreversible and inevitable but, the rate of deterioration could be slowed down to a greater extent during storage by manipulating storage conditions or by imposing certain seed priming treatments before storage.

Keeping this in view, an experiment for "Enhancement of seed quality in chilli (*Capsicum annuum* L.)" was taken up at the Department of Olericulture, College of Horticulture, Vellanikkara during December 2011 to December 2012.

In the present study the effect of priming and storage on seed quality of chilli variety Anugraha was studied. The freshly harvested seeds were stored under ambient condition and the quality parameters namely, 100 seed weight (g), moisture content (%), percent germination, speed of germination, seedling length (cm), seedling fresh weight (mg), seedling dry weight (mg), days to four leaf emergence, electrical conductivity of seed leachate ($dsm^{-1}$), vigour index I and vigour index II were observed from the first month of storage. After third, sixth and ninth month of storage, seed samples were drawn and subjected to priming ($P_1$ to $P_7$) and stored in two types of containers ($S_1$ and $S_2$) for 8, 5 and 2 months respectively. Since water was used as the medium for preparation of priming agents, the treatment $P_2$ (hydro priming) was taken as second control. These seeds were evaluated for their quality parameters immediately after priming and also at monthly intervals during the storage period. There was significant difference between treatments (priming, storage and interaction) for the seeds primed after 3 months, 6 months and 9 months of storage.

### 5.1. Quality of seeds during storage under ambient conditions (Initial 3 months)

During the initial three months of storage there was decrease in percent germination, speed of germination, seedling length, seedling fresh weight and vigour indices probably due to increase in moisture content of the seeds and higher electrical conductivity of the seed leachate.

**5.2. Effect of priming on seed quality parameters (3 months after storage)**

When seeds were primed after 3 months storage, it was observed that immediately after priming and also from the first month of storage up to the end of eighth month the seed priming with PEG 6000 (-1.5 MPa) had a significant effect on germination (%), speed of germination and seedling fresh weight. These finding are in agreement with results obtained by Passam *et al.* (1997) in pepper, Yongqing *et al.* (1996) in tomato, Zhang *et al.* (1988) in peanut, Gayatri (2000) in tomato.

Germination percent, speed of germination and vigour indices of the seedlings were high for the seeds primed with $P_6$ (PEG 6000 (-1.5MPa)) three months after storage under ambient condition. It may be due to the fact that during osmopriming the transition of seeds from dry stage to germination represses the antioxidant pathways that involve CAT (catalase) and SOD (superoxide dismutase) enzymes and stimulates another pathway involving ascorbate peroxidase (APX) required for germination and seedling establishment. In control where no priming was done low germination percent, speed of germination and low vigour index I and vigour index II of the seedlings recorded may be due to excessive leakage of chemicals from the seeds. This is evident from the high value for electrical conductivity in control. The results are in conformity with the findings of Delouche (1973) who has reported that the increase in electrical conductivity in unprimed seeds was due to rapid loss of electrolytes from the seed due to membrane damage during imbibition.

Seeds treated with *Pseudomonas fluorescens* (10g/kg seed) recorded maximum seedling length (14.33 cm), seedling fresh weight (172.77 mg) and seedling dry weight (17.12 mg) probably because the bacteria has the potential to proliferate, colonize and produce plant growth regulators (PGR's) during priming. Harman (1991) had also reported that the seeds treated with beneficial microorganisms have the potential to become established and get transferred to the developing root as it emerges from the seed.

Electrical conductivity of seed leachate was the highest (0.75 $dsm^{-1}$) in control, and the lowest in seeds treated with PEG 6000 (-1.5MPa). During germination there will be leaching of potassium, phosphates, sugars and amino acids out of the seeds due to membrane damage. The high values of electrical conductivity in control are an indication of leaching out of higher amounts of salts and this is associated with low germination percent and seedling vigour. These results are in accordance with the findings of (Abdul-Baki and Anderson, 1970) in barley.

The seeds stored under ambient condition for three months, when primed with PEG 6000 (-1.5 MPa), retained the minimum seed certification standards of 60 % germination up to eighth month of storage.

**5.3. Effect of priming on seed quality parameters (6 months after storage)**

When seeds were primed after 6 months storage, it was observed that immediately after priming and also during the following five months of storage the seed quality parameters were higher in PEG 6000 (-1.5 MPa) when compared to control.

The seeds exhibited maximum 100 seed weight in control and minimum in seeds primed with $CaCl_2$ $10^{-5}$ M. This may be because calcium chloride acts as a protectant and prevents further absorption of moisture. $CaCl_2$ has got anti-oxidant properties. The percent moisture content of seeds after priming was the lowest in hydro primed seeds probably because they got dried up faster than other priming agents. The germination percent and speed of germination were higher and the number of days taken to four leaf emergence was minimum in seeds treated with PEG 6000 (-1.5 MPa) probably because of DNA repair and activation of enzymatic processes during priming as reported by Osborne, (1983), Dell'aquilla *et al.* 1998.

The seedling length (cm), seedling fresh weight (mg) and seedling dry weight (mg) were high in seeds primed with *P. fluorescens* (10g/kg seed) probably because of the production of growth promoting substances. Similar results were reported

earlier in sesamum (Saxena *et al.*, 1985), in sunflower (Ravinder, 1990) and in cotton (Sandhyarani *et al.* 2002). The vigour index I and II of the seedlings were also higher in seeds primed with PEG 6000 (-1.5 MPa) because of high percent germination.

The minimum seed certification standards of 60 percent germination was maintained up to ninth month of storage when the seeds were primed with PEG 6000 (-1.5 MPa) after six months of storage under ambient condition.

### 5.4. Effect of priming on seed quality parameters (9 months after storage)

When seeds were stored for 9 months under ambient conditions and primed, the 100 seed weight and moisture content (%) were the highest in unprimed seeds. The low germination percent of unprimed seeds is due to high moisture content of seeds and high electrical conductivity of the seed leachate which gives an indication of poor quality of the seeds. High germination in seeds primed with PEG 6000(-1.5 MPa) can be expected because of the low moisture content and low electrical conductivity of the seeds.

Even though the germination (%) for the best treatment was less than 60 % (minimum standard for certified seed) this will be useful in getting the precious seeds of the germplasm germinated even after 12 months of storage under ambient conditions.

### 5.5. Effect of storage containers on seed quality

The important factors that determine the longevity of seeds are moisture content of seed, temperature and relative humidity in storage. The seed being hygroscopic in nature, exhibits fluctuation in seed moisture content due to changes in the atmospheric relative humidity and temperature. So, it is essential to store the seeds in suitable moisture proof containers which prevent the entry of moisture from outside.

The 100 seed weight, electrical conductivity and moisture content (%) increased with increase in storage period. However, the seeds stored in $S_2$ (Polythene bag 700 gauge) recorded low level of moisture content when compared to that stored in cloth bag ($S_1$). Harrington (1973) opined that high moisture and temperature are injurious to seed storage and recommended to store chilli seeds in polyethylene bags under ambient conditions.

The electrical conductivity was found to be high in seeds stored in cloth bag ($S_1$) when compared to that stored in polythene bag ($S_2$). This may be due to alterations in membrane integrity that led to enhanced exudation of leachates. Similar results were reported in soybean seeds by (Schoettle and Leopold, 1984). Doijode (1986) and Karivaratharaju and Palanisamy (1991) also observed increase in leaching of electrolytes in Okra and tomato seed respectively with increased period of storage.

Among the different storage containers used, seeds stored in polyethylene bags at ambient condition, exhibited relatively high percentage of germination. This may be due to semi pervious nature of storage container, which restricted entry of moisture, vapour and other gases in to the container to some extent.

Even though there was decrease in germination percent, root length, shoot length, vigour index, seedling dry weight, and speed of germination in both types of containers during storage, it was low for seeds stored in polythene bag (700 gauge) The increase in moisture content might have led to deterioration in the quality of seeds stored in cloth bag ($S_1$). These results are in conformity with the reports of Karivaratharaju *et al.* (1987) in brinjal, Elizabeth and Warham (1986) in onion, Palanisamy and Vanagamudi (1987) and Doijode (1986) in okra and Doijode (1997) in tomato.

Seed storage forms an important component of genetic conservation owing to simpler means and wider adaptation. Seed quality is dependent on age and nature of

seeds (Harrington and Satyati-Harjadi, 1966) and method of storage (Popovska et.al., 1981).

### 5.6. Interaction effect of priming and storage containers (3 months after storage)

Significant difference on seed quality parameters like speed of germination, electrical conductivity of seed leachate and vigour index I was observed. Speed of germination was found to be higher in seeds treated with PEG 6000 (-1.5 MPa) and stored in polythene bag (8.22) when compared to unprimed seeds stored in cloth bag ($P_1S_1$) which had the lowest value (4.06). All other treatment combinations were better than control. The interaction effect between priming and storage containers did not significantly influence 100 seed weight, percent moisture content, percent germination, and days to 4 leaf emergence and vigour index II. However, quality of seed in terms of above mentioned parameters was high in Seeds treated with PEG 6000 (-1.5 MPa) + storage in polythene bag.

Seeds treated with *P. fluorescens* (10g/kg seed) and stored in polythene bag recorded highest seedling length (14.62 cm), seedling fresh weight (172.77 mg) and seedling dry weight (17.41mg). These enhancements could be attributed to either direct suppression of deleterious pathogens or indirectly through production of growth hormones and increase in uptake, solubilization and translocation of less-available minerals (Windham et. al., 1986; Tronsmo and Hjeljord, 1998 and Harman, 2005).

### 5.7. Interaction effect of priming and storage containers (6 months after storage)

The 100 seed weight was low (0.67 g) in seeds primed with $CaCl_2$ ($10^{-5}$M) and stored in polythene bag ($P_4S_2$) and untreated stored in cloth bag ($P_1S_1$) recorded the maximum value (0.78 g).

The high germination (%) was observed in seeds treated with PEG 6000

(-1.5MPa) and stored in polythene bag of 700 gauge) resulted in higher vigour indices of the seedlings. $P_1S_1$ (Control stored in cloth bag) recorded the lowest value of germination (9.3 %).

The electrical conductivity was found to be high (0.922 $dsm^{-1}$) in control seeds stored in cloth bag ($P_1S_1$). The lowest value 0.443 was recorded in $P_6S_2$ PEG 6000 (-1.5 MPa) and stored in polythene bag of 700 gauge probably because during osmopriming, the accumulation of by-products of lipid peroxidation ( peroxidase and hexanals) is low. The electrical conductivity was higher in $P_1S_1$, because the detrimental changes in bio membranes occurred during storage decreased the membrane integrity. The present results are in conformity with the reports of Kalappa (2002) in sunflower.

The speed of germination was reported to be higher (7.35) in $P_6S_2$ (PEG 6000(-1.5MPa) and stored in polythene bag (700gauge)) and the lowest value of 1.82 was recorded in control seed stored in cloth bag. The increase in speed of germination in primed seed may be due to early reserve breakdown as well as reserve mobilization in primed seeds. It might also be due to possible early activation of cell wall degrading enzymes (Hisashi and Francisco, 2005). The results are in line with Tzortzakis (2009) and Sarihan et al., 2005.

The number of days to four leaf emergence was minimum in $P_6$ $S_2$ and the speed of germination was high .Seedling fresh weight (mg) and seedling dry weight (mg) were highest (165.3 mg) in $P_7S_2$ (*P. fluorescens* (10g/kg seed) and stored in polythene bag 700 gauge ) and $P_1S_1$ (Control seeds + storage in cloth bag) recorded the lowest value 108.8 mg.

### 5.8. Interaction effect of priming and storage containers (9 months after storage)

The percent germination, seedling fresh weight (mg), seedling dry weight (mg), vigour indices were the highest in $P_6S_2$ (PEG 6000(-1.5MPa) + storage in

polythene bag (700 gauge). Maximum level of deterioration was noticed in $P_1S_1$ (Control + seeds stored in cloth bag) and all the other treatment combinations performed better than $P_1S_1$ (Control + seeds stored in cloth bag).

Speed of germination, which is an indication of seed quality, was recorded to be high (5.7) in $P_6S_2$ (PEG 6000 -1.5MPa + storage in polythene bag of 700 gauge) followed by $P_5S_2$ ($KNO_3$ (150ppm) + storage in polythene bag of 700 gauge) and $P_1S_1$ (Control + storage in cloth bag) recorded very low value (0.33). The difference in sensitivity between primed and unprimed (control) seeds may be due to their development stage. Priming treatments may cause physiological change which effect sensitivity to water stress.

The seedling length (13.8 cm), seedling fresh weight (150.58 mg) and seedling dry weight (15.5 mg) were high in $P_6S_2$ (PEG 6000 (-1.5MPa) + storage in polythene bag (700 gauge)). The control seeds + storage in cloth bag ($P_1S_1$) recorded the lowest values of seedling length (cm), seedling fresh weight (mg), seedling dry weight (mg).

Electrical conductivity of seed leachate has negative effect on seed quality. This parameter was studied for different seed priming treatments throughout the storage period. During the storage period lowest electrical conductivity was recorded in $P_6S_2$ (PEG 6000(-1.5MPa) + storage in polythene bag 700 gauge) and highest was recorded in $P_1S_1$ (Control + storage in cloth bag). The differential EC values recorded among the seed treatments indicate that the nature and extent of membrane protection offered may not be the same for all seed priming treatments, thus resulting in difference in EC values as stated by Kurdikeri (1991) and Sandyarani *et al.* (2002) in cotton.

**Future line of work:**

1. Standardization of soaking hours of promising pre-sowing chemicals of present study may be initiated.
2. Seed priming using other bio priming agents shall be taken up.
3. Combination effect of biopriming and osmo priming agents can be studied.
4. The effect of priming and storage under refrigerated conditions on seed quality can be studied.
5. Field evaluation may be done to study the effect of priming on growth and yield of chilli

# SUMMARY

## 6. SUMMARY

The investigations were carried out with objective of standardizing the methods of priming and storage to improve seed germination and seedling vigour of chilli seeds (variety Anugarha) .The experiment was conducted in the Department of Olericulture, College of Horticulture for a period of twelve months from December-2011 to December-2012. The results of the experiments are summarized below.

1. During the initial 3 months of storage under ambient conditions, seed samples were drawn at monthly interval for recording seed quality parameters. There was decrease in percent germination from 79.3 % to 74.0 %, fresh weight from 179.60 mg to 162.15 mg, dry weight from 18.05 mg to 16.44 mg, vigour index I from 1432.32 to 1217.05 and vigour index II from 1003.51 to 851.45.

2. There was an increase in moisture content of seeds from 7.0 % to 7.2 % and electrical conductivity from 0.257 $dsm^{-1}$ to 0.470 $dsm^{-1}$ from the first month to third month of storage.

3. When the seeds were primed three months after storage, it was observed that priming with $P_6$ (PEG 6000 (-1.5 MPa) recorded the highest germination (81.33 %), speed of germination (12.64), , fresh weight (207.00 mg) and lowest electrical conductivity of the seed leachate (0.36 $dsm^{-1}$) immediately after priming

4. Priming of chilli seeds with PEG 6000 (-1.5 MPa) after 3 months recorded the highest mean germination (56.3 %), speed of germination (8.0), vigour index I (912.3) and vigour index II (771.3) during storage.

5. When seeds were primed after six and nine months of storage it was found that priming with PEG 6000 (-1.5 MPa) enhanced germination, speed of

germination and vigour indices immediately after priming and also during storage.

6. When seeds were primed with *Pseudomonas fluorescens* (10g/kg seed) after three, six and nine months of storage under ambient condition ,highest seedling length (14.33 cm), seedling fresh weight (172.77 mg) and seedling dry weight (17.12 mg)were observed.

7. In storage experiment, the seed samples were drawn at monthly intervals for estimating seed quality parameters. It was found that seeds stored in polythene bag (700 gauge) recorded better performance through higher germination percentage (49.1 %), seedling length (12.72 cm), seedling fresh weight (151.45 mg), seedling dry weight (15.56 mg), vigour index I (800.2), vigour index II (641.39) and lower electrical conductivity (0.668 dSm-1) as compared to germination percentage (44.5 %), seedling length (12.15 cm), seedling fresh weight (144.69 mg), seedling dry weight (14.66 mg), vigour index I (694.3), vigour index II (444.82) and higher electrical conductivity (0.704 $dsm^{-1}$) in control.\

8. Among the storage containers polythene bag (700gauge) was ideal for maintaining the seed quality standards.

9. The seeds stored under ambient conditions for 3, 6 and 9 months when primed with PEG 6000 (-1.5 MPa) and stored in polythene bag recorded high germination (%), speed of germination, seedling fresh weight, seedling dry weight and seedling length (cm).

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# ENHANCEMENT OF SEED QUALITY IN CHILLI (*Capsicum annuum* L.)

By
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## ABSTRACT OF THESIS

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## ABSTRACT

Chilli (*Capsicum annuum*) is one of the important vegetable crops of the world and is widely cultivated throughout the tropical and subtropical countries. There has been a great competition in the world market for chilli and hence it is necessary to increase production and productivity. The availability of quality seed is essential to achieve optimum crop stand in the field. The most important aspect in the seed production programme is maintenance of regular supply of high quality seeds to farmers. Under ambient conditions of storage, chilli loses its viability within a year. In Kerala situation is still worse because of the prevailing high humidity. Therefore a study was conducted to standardise the methods for seed quality enhancement in chilli by priming and storage in the Dept. of Olericulture, College of Horticulture,Vellanikkara during December 2011 to December 2012.

Freshly harvested seeds of chilli var. Anugraha were stored under ambient condition for 12 months. Seed samples were drawn after 3, 6 and 9 months of storage and subjected to priming treatments *viz.* Control ($P_1$), Water soaking ($P_2$), NaCl ($10^{-5}$M) ($P_3$), $CaCl_2$ ($10^{-5}$M), ($P_4$) $KNO_3$ (150ppm) ($P_5$), PEG 6000 (-1.5MPa) ($P_6$) and *Pseudomonas fluorescens* (10g/kg seed) ($P_7$). The primed seeds were stored in two types of storage containers i.e. cloth bag ($S_1$) and polythene bag (700 gauge) ($S_2$).

The seeds subjected to priming, after 3 months of storage, with PEG 6000 (-1.5 MPa) and stored in polythene bag (700 gauge) recorded the maximum germination (56.3 %), speed of germination (8.2), vigour indices and minimum electrical conductivity of the seed leachate (0.704 $dsm^{-1}$). Highest seedling length (14.62 cm), seedling fresh weight (172.77 mg) and seedling dry weight (17.42 mg) were observed in the seeds treated with *P. fluorescens* (10 g/kg of seed) and stored in polythene bag (700 gauge). In control, germination (30.54%), speed of germination (4.07), and vigour indices were low

After 6 months of storage, when the seeds were treated with PEG 6000 (-1.5 M Pa) and stored in polythene bag (700 gauge) the maximum germination (55.3 %), speed of germination (7.5), vigour indices and minimum electrical conductivity of the seed leachates (0.443 $dsm^{-1}$) were recorded. Maximum seedling length (13.85 cm), seedling fresh weight (165.3 mg) and seedling dry weight (16.90 mg) were observed in seeds treated with *P. fluorescens* (10 g/kg of seed).

There was significant difference between treatments for percent germination (%), speed of germination and vigour indices when priming was done 9 months after storage. Seeds treated with PEG 6000 (-1.5 MPa) and stored in polythene bag recorded highest percent germination (37.6 %), speed of germination (5.5), seedling length (13.85 cm), seedling fresh weight (150.5 mg) and seedling dry weight (15.5 mg).

The seed quality parameters of stored seeds (3, 6 and 9 months) recorded higher values of percent germination and seedling vigour indices immediately after priming with PEG 6000 (-1.5 MPa).

The unprimed (control) seeds maintained minimum seed certification standards for certified seeds only up to sixth month. The seeds primed with PEG 6000 (-1.5 M Pa) and stored in polythene bag (700 gauge) after 3 months and 6 months of storage (ambient conditions) maintained seed certification standards up to eighth month and ninth month of storage respectively.