HALOGENATION OF RICE SEEDS TO PROLONG STORABILITY

By

S. SUGANYA

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **'Halogenation of rice seeds to prolong storability'** is a bonafide record of the research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellanikkara
Date: 31/07/2015

S. Suganya
(2013-11-163)

CERTIFICATE

Certified that this thesis entitled **'Halogenation of rice seeds to prolong storability'** is a bonafide record of the research work done independently by **Ms. S. Suganya** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Vellanikkara
Date: 31/7/15

Dr. Rose Mary Francies
(Chairperson)
Associate Professor and Head
Department of Seed Science and Technology
College of Horticulture
Vellanikkara

CERTIFICATE

We, the undersigned members of advisory committee of **Ms. S. Suganya**, a candidate for the degree of **Master of Science in Agriculture** with major field in **Seed Science and Technology**, agree that the thesis entitled **'Halogenation of rice seeds to prolong storability'** may be submitted by **Ms. S. Suganya (2013-11-163)**, in partial fulfilment of the requirement for the degree.

Dr. Rose Mary Francies

Associate Professor (Pl. Br. & Gen.)
and Head
Department of Seed Science and
Technology
College of Horticulture
Vellanikkara
(Chairperson)

31/7/15
Dr. Dijee Bastian

Associate Professor (Pl. Br. & Gen.)
Department of Seed Science and
Technology
College of Horticulture
Vellanikkara
(Member)

Dr. Jiji Joseph

Associate Professor (Pl. Br. & Gen.)
Department of Plant Breeding and Genetics
College of Horticulture
Vellanikkara
(Member)

31.7.15
Dr. Vimi Louis

Associate Professor (Pl. Path.)
Banana Research Station
Kerala Agricultural University
Kannara
(Member)

31/7/15
Dr. Jerlin R.

Professor (Seed Sci. & Tech.)
Agricultural Research Station
TNAU, Bhavanisagar
(External Examiner)

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S. Suganya

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LIST OF ABBREVIATIONS

FAO	- Food and Agricultural Organisation
DES	- Directorate of Economics and Statistics
KAU	- Kerala Agricultural University
^0C	- degree Celsius
mm	- millimetre
g	- gram
kg	- kilogram
cm	- centimetre
mg	- milligram
dSm^{-1}	- desi Siemens per metre

Introduction

1. INTRODUCTION

Among the agricultural commodities produced worldwide, rice ranks the third, after sugarcane and maize (FAO, 2012). Asia accounted for about ninety per cent of world's rice production during 2013. India is the second largest producer and consumer of rice in the world following China. It occupied an area of 43.50 million ha yielding 159.20 million tonnes with an average productivity of 3.66 t/ha during 2013-2014 (FAO, 2014). Rice is the staple food crop in Kerala. During 2012-13, the net cropped area of rice in Kerala was 1.97 lakh hectares with an annual production of 5.08 lakh tonnes and a productivity of 2.57 t /ha (DES, 2014).

Quality seed is the key to successful agriculture. India ranks third in the seed production of rice in the world with a production of about 32 lakh tonnes during 2013 (FAO, 2014). Kerala is a consumer state with respect to the rice seed sector. The average annual requirement of rice seed in Kerala is estimated to be 1.58 million tonnes. More than half the state's rice seed requirement is met by its neighboring states - Karnataka, Tamil Nadu and Andhra Pradesh. It is an absolute necessity that the seed sector in Kerala be strengthened mainly because of the unique rice quality preference of Keralites.

In Kerala, red kernelled rice is preferred over white kernelled rice which is preferred elsewhere in the country. The present seed supply chain caters to the demand of only a few popular high yielding varieties like Mo 16 (Uma), Ptb 39 (Jyothi) and Ptb 50 (Kanchana). However, over a hundred red kernelled rice varieties specifically suitable for the prevailing eco-systems and cropping systems in the state do not find a place in this chain. Hence, it is imperative that the seeds of the traditional rice varieties and other high yielding varieties be produced in the state. Rice seed production in Kerala though remunerative is always under the threat of impending loss of seed viability. Although, around seventy-five per cent of the seed produced is usually used in the next cropping season, the remaining 20 to 25 per cent of seed need to be carried over through one growing season to the next planting time.

Seed growers are confronted with the challenge of maintaining the viability and vigour of seeds in storage. Several factors affect the quality of the seed during storage. These include initial seed quality, moisture content of the seed, temperature and relative humidity of the storage environment, physical and chemical composition of seed, gaseous exchange, storage structure, packing material etc. (Agrawal, 1995). Among them, seed moisture content, relative humidity and temperature are the key factors which influences seed longevity during storage. According to Harrington's thumb rule (1960), good seed storage is achieved when the percentage of relative humidity in storage environment and the storage temperature in degree Fahrenheit add up to one hundred. Therefore, in high humid regions like Kerala, controlled storage environment is advocated for maintaining the vigour and viability of stored seeds over long periods (KAU, 2011).

Theories on seed deterioration points to lipid peroxidation and free radical production in seeds during the storage period (Basu, 1976). The unsaturation of free fatty acid component of lipoprotein in cell membrane render them more susceptible to peroxidative changes thereby causing seed deterioration. Thus, in order to prevent loss of viability during storage, it is imperative that the lipid peroxidation be reduced. Controlled storage environment has proven useful in this direction. However, it is a non-viable and uneconomic option, owing to frequent power failures experienced in the state and the high recurring costs involved. Therefore, to reduce the high cost of seed storage in a controlled environment, alternative methods are advocated. Mid-term hydration-dehydration of seeds, osmopriming, halogenation etc. are few approaches advocated to lower seed deterioration during storage. Of these, treatment of seeds with halogen carrying chemicals during post-harvest processing is more practical and economical.

The halogens act as free radical quenchers and scavengers (Pryor and Lasswell, 1975). It has also been reported that the halogens stabilize the carbon to carbon double bonds and make them less susceptible to peroxidation and free radical reactions which in turn help maintain the seed vigour and viability during storage. Besides this, antimicrobial action of halogens on storage fungi is also partly accounted for its beneficial effect during seed storage (Pelttari *et al.,* 2007).

The storage potential of seeds is also influenced by storage containers as they have pronounced influence on seed moisture content. Generally, farmers store seeds in moisture pervious gunny bags. Storing seeds in moisture impervious containers like double gunny bags, polyethylene bags and poly lined jute bags have been reported to extend storability of seeds by several workers (Doijode, 1988; Raikar *et al.,* 2011; Parisa, 2013).

Hence, it is necessary to ascertain the influence of both halogenation and storage containers on seed quality during storage in high humid conditions of Kerala. The information will be highly helpful to the rice seed growers and marketers of the state. On that account, the present investigation on 'Halogenation of rice seeds to prolong storability' was initiated with the following objectives.

1. To standardize the optimum dose and mode of application of halogens
2. To standardize the packing material
3. To evaluate the storage potential of halogenated seeds under ambient storage condition

Review of Literature

2. REVIEW OF LITERATURE

Maintenance of seed viability and vigour is of prime importance in any seed production programme. Information on approaches to maintain seed quality and prolong viability of rice seeds during storage in the high humid conditions prevailing in Kerala is scanty. Beneficial effects of seed storage under controlled environments in prolonging seed viability during storage have been reported by researchers in several crops. But owing to the high recurring cost and frequent power failures experienced in the state, controlled seed storage is not a viable option. Hence, it is imperative that other less expensive and easier approaches be sought for this purpose. Choice of packing material and seed treatment with chemicals/botanicals has been advocated as viable alternatives. Seed treatment with halogen calcium oxychloride popularly called as bleaching powder is found beneficial in lowering seed deterioration during storage. A clear understanding on the choice of packing materials and dose of halogens are thus necessary and prove beneficial to rice seed growers in Kerala. The literature on the various aspects of storage is reviewed under the following headings.

2.1 Inherent changes in seed during storage

Seed is a living entity and is bound to lose its life due to extrinsic and intrinsic factors (Roberts, 1961). Seed deterioration and senescence is an inexorable, inevitable and irreversible process and is mainly dependent on physical, physiological and chemical composition of seed (Delouche, 1973; Dharmalingam, 1994). Delouche (1973) defined seed deterioration as summation of all physical, physiological, biochemical changes occurring in a seed which ultimately lead to its death. They also characterized seed deterioration as inexorable, irreversible, inevitable and minimal at the time of physiological maturity and vary with the kind of seed, varieties and seed lots of same variety.

Many researchers agreed that the seed deterioration is a progressive process which has far reaching consequences (Ghosh *et al.*, 1981). The seed viability and vigour are maximum at physiological maturity. After physiological maturity, the seeds began to deteriorate at varying rates depending on the conditions of storage environment (Ellis and Roberts, 1981).

Seed deterioration is attributed to several biological activities *viz.,* lipid autoxidation (Koostra and Harrington, 1969) and accumulation of toxic metabolites, free radicle damage, decreased protein synthesis, breakdown in mechanism triggering germination, reduced respiration, changes in polar lipids, decreased contents of glyco and phospholipids, ultra structural damage to cell and its organelles, accumulation of cytotoxic and mutagenic compounds etc., genetic degradations and finally loss of germination or death of the seed (Roberts, 1972).

Delouche (1973) and Copeland (1988) have highlighted increased activity of catalytic enzymes (catalase, peroxidase etc.), decreased activity of enzymes -involved in anabolism, membrane degradation and failure of repair mechanisms apart from accumulation of toxic metabolites, lipid auto-oxidation and genetic degradation as the reasons leading to deteriorative changes in seed leading to loss of germination or death of seed.

Some of the major physiological and biochemical events of deterioration are presented below.

2.1.1 Membrane degradation and leaching loss of seed constituents

It is widely accepted that loss in cellular membrane integrity is one of the chief causes for loss of viability. Presumably a loss in membrane permeability under unfavourable conditions of storage leads to increased leaching of seed constituents and thus loss in viability (Ching and Schoolcraft, 1968; Sen, 1977; Belur, 2009). According to Vieira *et al.* (2008), the electrical conductivity test measures the electrolytes that leach out of seeds when they are immersed in water and this leakage is an indication of seed vigour; the lower the vigour the greater the amount of leaching. The leachate exudates as measured by electrical conductivity were associated with loss of vigour and viability (Perry, 1969; Bradnock and Mathews, 1970; Roberts, 1972; Powell and Mathews, 1986; Verma *et al.,* 2003; Assefa, 2008).

Villers (1980) concluded that the most common and consistent ultra structural changes in all the cell organelles was the loss in integrity of membranes. Further, Kumar (2011) demonstrated in aged seeds that when the seeds were soaked in water, the extent of leakage of cytoplasmic components to the external medium was related to damage to cell membranes.

Phospholipids form the major constituent of cell membrane (Koostra and Harrington, 1969) and a decline in membrane bound phospholipids owing to enzymic and non-enzymic peroxidation may be the cause of leaky cell membrane.

Electrical conductivity and the leaching of free amino acid and sugars significantly increased with the increase in storage periods of maize seeds (Krishnaveni and Ramasamy, 1985). Similarly results were also reported by Dey and Mukherjee (1988), Deshpande (1988) and Dighe *et al.* (1995) in sunflower. Deswal and Sheoran (1993) reported that permeability of membrane increases with increase in storage period and leads to loss of electrolytes, sugars, amino acids and phenols.

Decline in seed germination and seedling vigour was associated with greater electrolytes leakage and higher production of volatile aldehydes, in soybean seeds stored in muslin cloth at 70 per cent relative humidity and 35°C for one to five week

(Shanmugavel *et al.,* 1995). Vieira *et al.* (1999) reported that decline in seed germination, field emergence and seedling vigour was found to be negatively correlated with greater electrolytes leakage in soybean.

It has been well established that with increase in storage period and ageing the membrane integrity of cell and cell organelles is lost on account of non enzymically by lipid autoxidation, enzymically by lipase and lipoxygenase activity and by microbial activity which result in more leachate of sugars, amino acids and organic acids in the seed steep water and causes increased mechanical injury to endosperm resulting in low metabolic activity and reduction in seed quality (Hemashree and Kurdikeri, 2011). The electrical conductivity of seed leachate indicates the membrane integrity and is directly correlated with seed deterioration and inversely correlated with seed quality (Belur, 2009).

The rate of electrolyte leakage was influenced by the type of rice cultivars, the associated fungal spores and the storage period (Singh *et al.,* 2001). They concluded that cultivar RCM-5 was more resistant to leakage of electrolytes than the other cultivars. After 180 days of storage, the maximum electrolyte leakage was induced by *Trichoconis padwickii* in KD-2-6-3, by *Aspergillus flavus* in RCM-5, by *Aspergillus flavus* and *F. moniliforme* in Tombung and by *Helminthosporium oryzae* in Moirangphou. Gradual increase in EC readings with longer storage period was observed in both fungal-treated and control seeds.

Peroxidation of unsaturated fatty acid causing leaching of electrolytes and other solutes as the reason for seed deterioration in soybean was reported by Singh and Dadlani (2003).

Vanitha *et al.* (2008) proved that leakage of electrolytes increased with the increase in the duration of storage, accompanied by loss of viability in cocoa. The rate of decline was higher when seed were stored instead of pods.

According to Geetha and Krishnasamy (2012), seeds of *Cenchrus glaucus* upon accelerated ageing were found to produce more volatile aldehydes as a result of cell damage. While according to Lone *et al.* (2014), maize seeds stored for a period of five months showed a decline in seed germination which was associated with greater electrolytes leakage due to membrane damage.

In *Moringa oleifera*, the decrease in seed viability during storage was associated with a loss in membrane integrity which was evidenced by an increase in electrolyte leakage as reported by Fotouo *et al.* (2015).

2.1.2 Free radical damage

Seed storage subjects lipids to slow consistent attack by oxygen, forming hydro peroxides, other oxygenated fatty acids and free radicals. The free radicals are unstable and may react with and damage nearby molecules. Oxygenated fatty acids in the absence of enzymes activity in the dry seed would accumulate and damage cellular components and leads to deterioration of seeds (Jyoti and Malik, 2013). The total amount of oxygenated fatty acid would be proportional to the age of seed and the rate of formation (Wilson and McDonald, 1986). Begum *et al.*, 2014 reported that the free radical-induced non-enzymatic peroxidation, which has the potential to damage membrane, is likely to be a primary cause of deterioration of stored seeds.

Lipid peroxidation and products resulting from these processes lead to DNA denaturation, prevent translation and protein transcription, and cause oxidation of the most reactive amino acids (Tian *et al.*, 2008). When these types of damages occur in seed, they may cause decrease in vigour and seed germination. Mechanism of oxidative damage is very complex and occurs as two different types of fatty acid changes. The first one is linked to the process of ageing during the first week of storage and includes spontaneous oxidation of unsaturated fatty acids, with no changes occurring in saturated fatty acids. In the second type of damage the seed that has lost its ability to germinate showed oxidation of both saturated and unsaturated fatty acids. Damages resulting from the production of free radicals could cause secondary reactions generating toxic intermediates and breakdown products equally damaging as the free radicals themselves.

Activity of free radicals in seed may depend on water content, seed components (for example the whole seed, cotyledon, embryo, seed lot, species and variety, as well as the aging treatment (Laloi *et al.*, 2004). Different seed components could show different sensitivities to oxidation stress, embryonic axes being more susceptible than other parts.

Effective removal of free radicals formed during normal metabolism could be very important for the well-being of all cells of the stored seeds. ESR spectroscopy and low level chemiluminescence analysis have been mostly used for the detection of free radicals (Udabbal, 2012).

Narayanan *et al.* (2011) revealed that free radicals not only damaged the cells but also attacked the fatty acid compounds of the seed thus making it lose viability at a faster rate. Vinodkumar (2012) also confirmed that ageing is accompanied with free radical production during seed storage.

2.2 Influence of relative humidity, storage temperature and seed moisture content on seed during storage

It is well known that large number of extrinsic and intrinsic factors affect seed viability during storage. Storage potential of seed is mainly a genetic factor but is influenced by several other factors like environment (Roberts, 1972; Wittington, 1978), cultivar differences (Singh and Gill, 1994), period of storage (Reddy, 1985). The relationship between viability and storage conditions, storage containers used, seed moisture, storage temperature and relative humidity has been worked upon extensively. Seed fungi and insects and seed treatments have been well established in deciding storability of seeds. The following is the brief review on the role of various factors that affect viability of seeds during storage.

The general effect of temperature on longevity is that longevity increases as temperature decreases. According to Harrington's thumb rule for seed storage proposed in 1960, the sum of per cent relative humidity and the temperature in degree Fahrenheit should not exceed hundred for safe storage. This rule holds good for orthodox seeds. Harrington (1972) purported that for each 10°F (5.6°C) decrease in temperature, longevity doubles. This rule applies to seeds stored between temperatures of 32°F (0°C) and 122°F (50°C). Seed moisture has a greater effect than temperature on seed longevity. Most seeds also follow some "rules of thumb" regarding moisture and longevity. The general relationship is that for each one percent increase in seed moisture, longevity decreases by half (Harrington, 1972). This rule applies to seed with moisture content between 5 and 13 per cent.

Halder and Gupta (1980) observed that sunflower seed deteriorated completely within 90 days when kept at 95 per cent relative humidity at 28 ± 1°C but remained fully viable for 120 days at 80 per cent relative humidity. Norden (*1981*) indicated that the storage of shelled peanut seed at a controlled temperature of 17 to

23°C kept the seed from deteriorating appreciably for four year period, after which seed viability rapidly diminished. The kernels with higher moisture content (8.11 per cent) when stored had a shorter life span, whereas low moisture content (2-6 per cent) improved longevity.

Dange and Patil (1984) indicated that deterioration of groundnut genotypes in storage at different relative humidity (62, 72, 85 and 93 per cent) differed significantly and they can be stored at 62 per cent relative humidity without loss of viability for considerable time.

Regardless of the type of storage conditions, the moisture content of seed eventually reaches equilibrium with the moisture in the surrounding air. If the seed moisture content is above 13 per cent there is increased activity of seed storage fungi and increased heating due to respiration leading to a decline of longevity at a faster rate. Once seed moisture reaches 18 to 20 per cent increased respiration, and increased activity of microorganisms cause rapid deterioration of the seed. At 30 per cent moisture content, most non-dormant seeds germinate. At the low end of the moisture range, seed stored at 4 to 5 per cent moisture content is unaffected by seed storage fungi, but such seeds have a shorter longevity than seed stored at a slightly higher moisture content (Bewley and Black, 1985).

The seed being hygroscopic in nature, exhibits fluctuation in seed moisture content concomitantly with changes in atmospheric relative humidity and temperature. The seed moisture content was maximum at 4th month of storage due to prevalence of wet weather as indicated by 93.84 per cent relative humidity and 27.62°C temperature. It was minimum at 10th month of storage due to dry weather condition as revealed by 77.19 per cent relative humidity and 29.36 °C temperature. The prevalence of high humidity coupled with low temperature or vice versa was concluded to have intervened in the seed moisture content accordingly during storage of dicoccum wheat seeds under ambient conditions (Uppar, 1998). The fluctuation in seed moisture content as observed in the above study was in conformity with the findings of Agrawal (1974), Khanna and Yadav (1979), Teng (1981) and Vishwaprasad (1997) in maize.

Nautiyal and Joshi (1991) reported that, viability and vigour of the *rabi*/summer groundnut could be maintained satisfactorily for more than eight months by lowering the moisture content using a desiccant like $CaCl_2$.

Seeds of five soybean varieties stored at temperature of -4, 0, 4^0C and room condition for eight years to determine their retention capacity of vigour by Gao-Ping Ping *et al.* (1996) They found that the seeds stored at room temperatures showed faster decline in vigour as compared to the seeds at lower temperatures. According to Nkang and Umar (1997) the optimum conditions for better storage of soybean seeds is at a temperature between 25^0-30^0C and a relative humidity of 55-66 per cent.

Choudhary *et al.* (2003) reported that groundnut variety Co-Amber stored at moisture content of 5.85 per cent recorded 71 per cent of germination after eight months of storage. Similar report was obtained by Narayanaswamy (2003) when groundnut seeds were stored at 8.00 to 9.53 per cent moisture content under ambient conditions in Bangalore.

Seeds of four vegetable crops; carrot (*Daucus carota* L. variety Nantes 2-Tito), cucumber (*Cuucumis sativus* L. variety Special), onion (*Allium cepa* L. variety Red Creole) and tomato (*Lycopersicon esculentum* Mill. Variety Tanshet Star) were stored under a wide range of temperature (5, 15, 25 and 35°C) and relative humidity (RH) (11.3, 22.5, 32.5, 43.2, 58.4, 75.3 and 84.3 per cent) conditions for various storage periods (1, 3, 6, 9 and 12 months). Seeds stored at 5°C recored the highest germination per cent. While seeds stored at 35°C had the lowest germination per cent. Seeds at the highest RH levels (75 and 84 per cent) showed a decrease in seed quality including lowered germination (Alhamdan *et al.*, 2011).

Papaya seeds containing six per cent moisture content and stored at 0°C recorded higher germination, lower dormancy and lower seed death compared to the seed in other storage conditions and seed moisture (Zulhisyam *et al.*, 2013).

Mucha et al. (2015) found that higher temperatures during storage of *Populus nigra* seeds reduced the proportion of roots with absorptive function (with primary development).

2.3 Prolonging seed longevity during storage

Seeds of most species may be safely stored for several years by careful control of temperature and relative humidity. Although such conditions are extremely costly for agricultural crops, they may be extremely valuable for preserving germplasm and certain high value seed stocks. In some parts of the country especially in the high humid tropics, conditioned storage is necessary in order to maintain seed viability of some crop species from harvest to planting (Harrington, 1972).

Seed longevity can be altered by many factors including genotype, the type of seed, maturation stage, treatments prior to storage, viability and initial water content of the seeds, temperature and relative humidity, oxygen pressure during storage and degree of infection by fungi and bacteria (Stein *et al.*, 1974).

While most agricultural crops can be successfully stored in controlled storage facilities, routine operation of such facilities is costly and mechanical breakdowns are common (Copeland and McDonald, 2001). Hence, other viable methods are advocated by researchers to prolong the seed longevity during storage.

2.3.1 Packing material

The extent of storability is influenced by the type of packaging material or storage containers used for storage. The packaging materials used are decided by the kind and amount of seed to be packed, the type of package, duration of storage, storage temperature and relative humidity of the storage area. Storage of seeds of rice and related crops pertaining to storage containers are reviewed here under.

It has been the age old practice among the farming community as well as seed industries to store the seeds either in cloth bags or in polythene bags wherever the seed material is limited. Under large scale production and storage, the seeds are normally stored in gunny bags.

The storage studies by Singh and Tripathi (1968) and Chin and Standifer (1969) in maize seeds revealed that, seeds with lower moisture content (10-12 per cent) stored in sealed moisture vapour proof containers maintained viability for longer period than the seeds stored in moisture pervious containers.

Baskin and Delouche (1970) observed that storing the seeds in polythene bags maintained significantly higher germination from six months onwards during storage period (0 to 12 months) as compared to cloth bags. With respect to root and shoot length, seeds stored in polythene bags were found to be superior over cloth bags from two months onwards. Seedling length and vigour index were significantly higher in polythene bags from 4th month onwards. The data further indicated differential influence of containers on germination and seedling characters.

The reason for such differential response between cloth bag and polythene bag could be attributed to optimum seed moisture content in polythene bags maintained since polythene bags are impervious to the exchange of water vapour from the atmosphere. The cloth bag contains minute pores through which there is possibility of gain or loss of seed moisture content and hence the seeds stored in polythene bags can be stored for a longer period without deterioration in the quality as compared to cloth bags (Raikar *et al.*, 2011). Similar observations have been made by Nagarajan and Karivaratharaju (1976) and stated that seeds stored in moisture impervious sealed containers store better compared to moisture pervious containers under ambient storage conditions.

Storing the seeds in polythene bags recorded significantly lower EC values especially during later stages of seed storage (10-12 months) indicating better seed quality with polythene bags as compared to cloth bags. Similar reports of increased EC with the increase in storage period and more in cloth bag than in polythene bag were made in sorghum, maize and bajra by Nagarajan and Karivaratharaju (1976), Krishnaveni and Ramaswamy (1985) and Bharathi (1991) in maize.

Jalote and Vaish (1976) stored IR-8 paddy seeds under ambient conditions with 10, 12, 14 and 16 per cent seed moisture in gunny and polythene bags and observed that storage in gunny bags was better for the seeds of higher moisture content. Whereas, the seeds with ten per cent moisture, stored in polythene bags was found to store better.

The fluctuation in seed moisture content was noticed in seeds stored either in cloth or polythene bag in all the months of storage. Reports in fluctuation of moisture of seeds stored in cloth or polythene bags were also reported by Nagarajan and Karivaratharaju (1976) and Teng (1981) in maize seeds.

Ashokan *et al.* (1980) tested the storability of rice seeds in various containers. Alkathene bags and glass bottles were found to be superior to cloth bags and gunny bags.

Drastic decline in germination of paddy seeds (Tellahamsa) containing 13-15 per cent moisture in polythene bags between 10 and 12 months of storage was observed by Saibabu *et al.* (1983) Further, they reported that the rain damaged seeds of IET-5854 rice maintained germination above certification standard for eight months when stored in cloth bags under ambient conditions with 12 per cent initial seed moisture.

In french bean, Doijode (1985) opined that among the different containers, polythene bag was promising, since it was effective in preserving the germination (81 per cent), shoot length (11.9 cm) and seedling dry weight (109 mg) at 24 months after storage. However, polythene bags were reported to be not completely moisture proof by Marlene and Mumford, (1986).

Baskin *et al.* (1987) reported that polythene bags were superior to cloth and paper bags in maintaining longevity in corn seeds. Similarly, Ashwathaiah and Sadasivamurthy (1986) in sorghum, Baskin *et al.* (1987) in wheat and Vanangamudi and Ramaswamy (1989) in bajra reported that seeds stored in moisture impervious containers (polythene bag) maintained viability longer than in moisture pervious containers (cloth or jute bags).

The field emergence and vigour index potential of 40 months old field bean seed stored in 700 gauge polythene bag was superior to those stored in cloth bags (Vanangamudi and Karivartharaju, 1987).

Dwivedi and Shukla (1990) opined that germination reduction (94.8 to 56.4 per cent) and development of fungal colonies were less in chickpea seeds stored in polythene bags than the cloth bags (94.8 to 51.2 per cent) after twelve months of storage period.

As observed by Siddalingappa (1991), germinability of paddy seeds were higher in seeds stored in polythene bag compared to the ones stored in cloth bag throughout the storage period. While Kurdikeri (1991) reported that maize seeds stored in polythene bags were found to maintain viability for greater period (13 months) compared to cloth bags (7 months).

Angamuthu (1996) observed that moisture pervious containers, *viz.*, cloth bag, gunny bag and mud-pot maintained the seed germinability of 80 per cent in all the lines and hybrid seed of rice for nine months, whereas the moisture resistant containers, *viz.*, polythene bags (300 and 700 gauge) and polylined gunny bag maintained the standard germinability for a period of twelve months without seed treatment. Similarly, Thungeswara (1996) and Yogalakshmi *et al.* (1996) also observed the superiority of polythene bags over cloth bags in storage of rice hybrids and their parental lines.

Packing the ash gourd seeds in 700 gauge polythene bag proved be best and superior to brown paper bag and gada cloth packages in maintaining high germination (61.42 per cent), vigour (1217) and dehydrogenase enzyme activity (0.147) of seeds as suggested by Kannath (1996).

Charjan and Gupta (1996) stated that storage of gram seeds in polythene bags maintained significantly higher germination and fewer invasions of fungi than those stored in gunny or cloth bags after ten months of storage.

The seeds stored in polythene bag recorded higher field emergence percentage as compared to the seeds stored in cloth bag. The reasons for higher field emergence of seeds stored in polythene bag may be due to better seed quality attributes. The similar results were also reported by Vijayabhaskar (1997) in cowpea and he noticed that the seeds stored in polythene bag recorded higher field emergence per cent at 10^{th} and 12^{th} month of storage. The husked seeds showed higher field emergence than dehusked seeds which may be due to intact embryo in husked seeds.

Rice seeds stored in polythene bag recorded higher germination (83.9 per cent), shoot length (7.79 cm), root length (8.44 cm), dry weight of seedlings (122.9 mg) and lower electrical conductivity (293.6 μ mhos/cm) while, these were 79.8 per cent, 6.37 cm, 6.94 cm, 109.3 mg and 305.8 μ mhos/cm respectively in cloth bag at the end of twelve months of storage period (Biradarpatil 1999).

Biradar (2001) stated that greengram seeds stored in polythene bag recorded significantly higher germination (83.9 per cent), shoot length (7.79cm) and root length (8.44 cm) and lower electrical conductivity (293.6 μ mhos/cm) compared to those stored in cloth bags (79.8 per cent, 6.37 cm, 6.94 cm and 305.8 μ mhos/, respectively) at the end of twelve months storage period.

According to Tammanagouda (2002), significantly higher germination (71.15 per cent), root length (11.14 cm), shoot length (8.11 cm) and lower moisture content (9.21 per cent) and infestation (34.10 per cent) were recorded in the green gram seeds stored in polythene bag as compared to those in cloth bag at the end of ten months storage period.

Green gram variety. Chinamung seeds stored in 700 gauge polythene bag revealed significantly less seed infestation, loss in seed weight and moisture content and more hundred seed weight than those stored in cloth bag over the entire storage period (Divyashri, 2006).

In drumstick, Madinur (2007) observed that seeds stored in the polythene bag recorded higher germination, field emergence, speed of germination, root length, shoot length, vigour index and seedling dry weight with lower electrical conductivity compared to cloth bag in all the months of storage.

Sangamnathrao (2009) reported that at the end of twelve months of storage, the seeds of maize hybrid NAH 2049 recorded higher germination in polythene bag (88.7 per cent) and lower germination was recorded in cloth bag (84.9 per cent).

According to Hemashree and Kurdikeri (2011), seeds of Bt and non-Bt cotton varieties stored in aluminium foil pouches maintained higher germination (68.03 per cent), vigour index (1855) with lower electrical conductivity (0.652 dSm^{-1}) and seed infection (9.78 per cent) compared to polythene bag and cloth bag. Among the containers, seeds stored in cloth bag maintained viability for nine months while, seeds stored in polythene bag and aluminium foil pouches each maintained upto twelve months.

KAU (2011) stated that polythene bags of 700 gauge or double gunny bags are preferred for storing paddy seeds. And also polythene bags of 400 gauge density may be preferred for storing paddy seeds when dried to 10 per cent moisture content or less. While, Kumar (2011) revealed that jute seeds stored in polythene bags recorded higher satisfactory germination and seedling vigour parameters upto twelve months of storage compared to cloth bag which maintained upto ten months.

Rudrapal and Nakamura (1988) suggested treatment of fresh brinjal and radish seeds employing chlorine, bromine and iodine vapours for 8-48 h at 25°C which significantly slowed down the deterioration of seeds under natural and accelerated conditions. This might be due to stabilization of unsaturated fatty acid components of lipoprotein molecule of cell membrane.

Iodination of tomato seeds variety PKM 1 and Pusa Ruby for 24 h significantly reduced seed deterioration in artificially aged seeds (Palanisamy *et al.*, 1994).

To improve seed quality, the partially aged and carry over seed can be physiologically elevated by imposing invigouration treatments such as moisture equilibration, simple soaking and drying, halogenation, soaking in chemicals, fungicides, growth regulators, osmotic conditioning to name a few. The commonly used halogens for seed treatment are calcium oxychloride commonly called bleaching powder, iodine crystals and potassium iodide (Dharmalingam, 1994).

Halogenation not only maintains the seed viability, but also protects the seed from various external and internal deterioration factors. Dry dressing of fresh seeds with halogens has conferred beneficial effects in several crops by lowering lipid peroxidation, thereby prolonging the viability and vigour of seeds in storage (Dharmalingam, 1995).

Rudrapal and Basu (1980) observed that mungbean seeds treated with iodine and subjected to ageing (95 per cent RH, 40°C) for 20 days and stress (100°C) for 45 minutes recorded highly beneficial effects on germination, root and shoot lengths of seedlings as compared to control seeds.

In rice, Raikar *et al.* (2011) reported that seeds of cultivar Mugad sugandha treated with calcium oxychloride (5 g kg^{-1}) stored in polythene bag retained seed germination and seedling vigour more than 20 months of storage period under ambient conditions of Dharwad.

Storing seeds in moisture impervious containers is superior to that in pervious containers (Raikar *et al.,* 2011; Parisa, 2013; Narayanan and Prakash, 2014). Due to the impervious nature, the seeds will maintain the moisture content throughout the storage period which reduces the incidence of storage pests and pathogens.

Kumar *et al.* (2014) found that the per cent reduction in germination and field emergence of marigold seeds was lower in double layer polythene bag (48.47 per cent and 36.75 per cent) followed by single layer polythene bag (55.78 per cent and 50.75 per cent) and it was highest in cloth bag.

A rapid increase in the moisture content was observed in the seeds of groundnut variety. VRI 2 stored in cloth bag whereas a very low increase was found in the seeds stored in polythene bags of 700 gauge density (Narayanan and Prakash, 2014).

Onion seeds dried to about 5 per cent moisture and stored in aluminum laminated bags with vacuum packing recorded the highest germination of 89.57 per cent after 12 months of storage and it gradually deceased to 61.7 per cent after 27 months of storage (Tripathi and Lawande, 2014). This will be useful for enhancing the seed replacement rate and higher productivity of onion.

2.3.2 Halogenation *of seeds*

Free radical reactions and lipid peroxidation are believed to be involved in the disruption of cell membranes leading to senescence and death (Tappel, 1973). As the peroxidative changes start at the double bond sites, saturation of the same by halogen (iodine) would make them more resistant to oxidation and prevent formation of free radicals. Iodine rapidly passes into vapour phase is also characterized by its great affinity for double bonds of unsaturated lipid constituent of the cell.

Basu and Rudrapal (1979) reported that 6, 10 and 12 months aged seeds of wheat, jute and mustard, respectively were iodinated for different durations in air tight glass desiccators and subjected for accelerated ageing at 100 per cent RH and 42°C. It was found that the effect of iodination was more prominent in mustard seeds as compared to wheat and jute. In wheat and jute, the optimum duration of iodination was 15 hours above which there was reduction in germinability. Further, the beneficial effect of iodine treatments was also noted in germination, root and shoot length of seedlings. Seeds treated with calcium oxychloride though recorded lower germination percentage, root length, shoot length and vigour index as compared to seeds treated with iodine but were significantly superior over the untreated seeds. Thus, both iodine and calcium oxychloride can be used as safe halogens for improving the seed storability under ambient storage conditions.

According to Basu and Rudrapal (1980), deteriorative senescence of mustard seeds could be substantially slowed down by equilibrating the seeds with iodine vapour for 12-24 h before storage under different ageing conditions. They noticed that halogenation treatment of mustard seeds with iodine vapours reduced the physiological deterioration of seeds significantly. They also reported that maintenance of viability of iodinated seeds was associated with greater activities of α-amylase and dehydrogenase enzymes and integrity of cellular membranes and considerably reduced lipid peroxidation.

Rudrapal and Nakamura (1988) suggested treatment of fresh brinjal and radish seeds employing chlorine, bromine and iodine vapours for 8-48 h at 25°C which significantly slowed down the deterioration of seeds under natural and accelerated conditions. This might be due to stabilization of unsaturated fatty acid components of lipoprotein molecule of cell membrane.

Iodination of tomato seeds variety PKM 1 and Pusa Ruby for 24 h significantly reduced seed deterioration in artificially aged seeds (Palanisamy *et al.*, 1994).

To improve seed quality, the partially aged and carry over seed can be physiologically elevated by imposing invigouration treatments such as moisture equilibration, simple soaking and drying, halogenation, soaking in chemicals, fungicides, growth regulators, osmotic conditioning to name a few. The commonly used halogens for seed treatment are calcium oxychloride commonly called bleaching powder, iodine crystals and potassium iodide (Dharmalingam, 1994).

Halogenation not only maintains the seed viability, but also protects the seed from various external and internal deterioration factors. Dry dressing of fresh seeds with halogens has conferred beneficial effects in several crops by lowering lipid peroxidation, thereby prolonging the viability and vigour of seeds in storage (Dharmalingam, 1995).

Rudrapal and Basu (1980) observed that mungbean seeds treated with iodine and subjected to ageing (95 per cent RH, 40°C) for 20 days and stress (100°C) for 45 minutes recorded highly beneficial effects on germination, root and shoot lengths of seedlings as compared to control seeds.

Tobacco seeds showed more viability when stored in sealed containers with calcium oxychloride than without calcium oxychloride (Bangaraya *et al.*, 1984).

Mandal and Basu (1986) reported that dry dressing treatments of wheat seed with calcium oxychloride 2-5 g kg^{-1} significantly reduced physiological as well as pathological deterioration during storage under accelerated and natural ageing conditions. Besides germination percentage, seed vigour was more in the treated seeds (2 g kg^{-1}) than in untreated seeds.

According to Dey and Mukherjee (1988), dry seed dressing of iodine in a calcium carbonate carrier effectively reduced the physiological germination during storage under elevated temperatures and different humidity regimes in soybean and sunflower seeds.

Pal and Basu (1988) mentioned that exposure of freshly harvested paddy seeds to very low concentration of iodine vapour or chlorine vapour significantly slowed down seed deterioration during storage under ambient conditions for eight months. They also observed that dry dressing freshly harvested paddy seed with bleaching powder @ 3 g kg^{-1} significantly increased germination, root length and shoot length over control. Seed treated with bleaching powder recorded 78.9 per cent germination, 8.6 cm root length and 4.8 cm shoot length, while, these were 54.5 per cent, 7.9 cm and 4.0 cm, respectively in control.

According to Zhang *et al.* (1989), exposure of soybean seeds to iodine fumes for 7 h substantially increased the germination per cent as well as vigour index compared to control.

Bhattacharya and Basu (1990) stated that dry dressing of pea seeds with $CaOCl_2$ @ 3 g kg^{-1} of seeds retained higher vigour (5693) and viability (83 per cent) in ordinary storage for nine months as compared to control (2999 and 64 per cent respectively).

In *Sesamum indicum* variety. TMV 3, the iodine permeation-drying treatment of seeds for 12 h recorded the highest germination per cent. Also it resulted in high seedling vigour assessed by the root length (9.17 cm), dry matter content (39 mg) and vigour index (3387) as compared to rest of the treatment durations (Madanagopal and Dharmalingam, 1993).

Paddy seeds when dry dressed with $CaOCl_2$ @ 10 g kg^{-1} at 13 per cent moisture content and packed in gunny bags showed better storage response with higher germination and vigour compared to untreated ones after eight months of storage as compared to control (Ravichandran and Dharmalingam, 1994).

Savitri *et al.* (1994) revealed that with increase in storage period upto 18 months, significant reduction in germination and seedling vigour was observed in groundnut seeds. However, there was an increase in moisture content of the seed with increase in storage period.

Fuzzy cotton seeds of cultivars LRA 5166 and MCW when treated with a mixture of calcium oxychloride and calcium carbonate @ 3 g kg^{-1} seeds recorded significantly higher germination and vigour over control (Chitra, 1995). The results confirmed the beneficial effect of seed treatment in terms of maintaining vigour, viability and gave more protection against storage insects and pathogens also.

Halogenation of fresh seeds of cotton variety TCB 209 with a mixture of calcium oxychloride + calcium carbonate + arappu leaf powder at 3 g kg^{-1} prolonged the viability and vigour of seeds as assessed by the accelerated ageing technique (Lakshmi, 1995).

Seed storage studies were conducted by Vasantha (1995) in pigeon pea, green gram, black gram and cowpea with dry dressing of seeds with calcium oxychloride and calcium carbonate mixture @ 3 g kg^{-1} as pre-storage treatments and reported that the halogenation treatment not only prolonged the viability of these seeds but also controlled bruchid infestation in these seeds very effectively.

Bhandopadhyay and Maji (1996) reported that four month old groundnut seeds exposed to iodine or chlorine vapours for 0-24 h effectively increased the germination per cent and seedling growth.

Sorghum seeds dry dressed with halogen mixture ($CaOCl_2$, $CaCO_3$ and arappu leaf powder) @ 3 g kg^{-1} conferred the beneficial effects by maintaining good viability and vigour for 10 months. The field emergence potential was maximum in treated seeds compared to the untreated seeds (Jegathambal, 1996).

Maheshwari (1996) reported that soybean seeds dry dressed with halogen mixture (either chlorine or bromide based) @ 3 g kg^{-1} of seeds controlled the deterioration process effectively during storage.

Fresh seeds of paddy from 36 locations treated with halogen mixture ($CaOCl_2$ and $CaCO_3$) @ 5 g kg^{-1} prolonged the self-life of seeds with high vigour for six months in gunny bag under adverse ambient condition as concluded by Nair (1996). The seed treatment also offered protection against storage pest and pathogen.

Narayanaswamy and Channarayappa (1996) reported that pre-sowing treatment of groundnut seeds with 0.5 per cent $CaCl_2$ for 6 h followed by shade drying for 16 h resulted in significantly higher germination, field emergence, number of graded pods/plant, test weight and also registered an increase in graded pod yield over control during summer and *kharif* seasons.

Improvement in germination and seedling growth following treatment with chlorine or iodine based halogen formulation in bhendi and ribbed gourd (3 g kg^{-1}), tomato and bitter gourd (4 g kg^{-1}), brinjal and chilli (2 g kg^{-1}) and snake gourd (5 g kg^{-1}) was reported by Punitha (1996).

Rajavelu (1996) concluded that chlorine based halogenation dry treatment (3 g kg^{-1}) given to five month old sunflower achenes variety. Modern stored safely under ambient storage conditions and less prone to deterioration as evidenced by higher germination, root and shoot length, dry matter production, vigour index, field emergence and dehydrogenase enzyme activity.

Senthilkumar (1996) working with onion seeds reported that the seeds treated with chlorine based halogen formulation (4 g kg^{-1}) could be stored for six months with a germination potential of 79 per cent against 62 per cent in control.

Groundnut pods and kernels subjected to chlorine, iodine or bromine based halogenation treatment along with *Albizia amara* leaf powder improved the field stand and production potential significantly (Anbazhagi, 1997).

The maize seeds (CO 1 and KH 517) dry dressed with chlorine or iodine based halogen formulation @ 3 g kg^{-1} had withstand deterioration considerably registering high vigour and viability apart from offering protection against storage pests and pathogens (Arumugam, 1997).

Rathinavel (1997) reported that cotton cultivar LRA5166 dry dressed with chlorine or iodine based halogen formulation @ 3 g kg^{-1} maintained over 80 per cent germination ten months after storage. RCH-2 hybrid cotton seeds treated with iodine based halogen formulation applied as slurry maintained high germination (88 per cent), seedling vigour, dry matter production and vigour index (Anjalidevi, 1998).

Seeds of paddy ASD-18 variety treated with $CaOCl_2$ @ 3 g kg^{-1} + $CaCl_2$ @ 4 g kg^{-1} and stored under ambient conditions maintained about 85 per cent germination at the end of one year storage period compared to untreated ones (Indira, 1998). According to Uppar (1998), the chlorine based chemical *i.e.,* calcium oxychloride was found to be effective in prolonging the storage life of dicoccum wheat seeds as compared to untreated seeds.

Sunflower seeds when treated with iodine based halogen formulation containing botanicals maintained higher germination, dry matter production and vigour index as repeotred by Rathnavalli (1998). Malarkodi and Dharmalingam (1999) found that the iodinated pearlmillet seeds showed significant superiority registering the maximum mean height of 185.2 cm at 65 DAS followed by chlorinated seeds.

In chickpea, Arati (2000) reported that, seed treatment with bleaching powder recorded higher test weight (14.44 g), germination (64.85 per cent), seedling dry weight (144 mg), vigour index (1258) and lower EC (1.62 dS/m), whereas the untreated control recorded 13.53 g, 64.17 per cent, 141 mg, 1208 and 1.66 dS/m, respectively at the end of ten months of storage under ambient storage conditions.

Cowpea, black gram, green gram and pigeonpea seeds dried to safe moisture levels were treated with a mixture of $CaOCl_2$ and $CaCO_3$ (3 g kg^{-1}) and kept for one week before artificial aging which showed increased germination, seedling growth, dry matter production, and vigour index in all the pulse seeds studied. There was also a significant reduction in bruchid infestation in treated seeds compared with control (Dharmalingam *et al*., 2000).

Vidyadhar and Gopalsingh (2000) concluded that the fresh and partially aged seeds of maize hybrid BH 1001 treated with the halogen KCl @ 30 mg showed higher seedling vigour, emergence index, early flowering and better crop growth.

According to Vyakaranahal *et al*. (2000) both iodinated (10^{-3} mg for 2 hours) and chlorinated (4 g kg^{-1} seeds) seeds maintained significantly higher seed germination, root and shoot length and vigour index when tested before and after accelerated ageing treatment, in sunflower restorer lines.

In paddy variety. Sonamasuri, dry dressing treatment with calcium oxychloride @ 5 g kg^{-1} of seeds recorded significantly higher germination (77.5 per cent), root length (9.37 cm) and shoot length (8.82 cm) after twelve months of storage (Bukkadeva, 2001).

Rathinavel and Dharmalingam (2001) observed that fresh seeds of uppam cotton, hardened with a mixture of pungam and prosopis leaf extracts (each 1.0 per cent) followed by dry dressing with 3 g chlorine based halogen formulation significantly improved the germination, speed of germination, root length, shoot length, dry matter production, vigour index and field emergence over untreated (control) seeds as assessed through accelerated ageing technique.

In gaillardia seeds variety DGS-1 dry dressing treatment with calcium oxychloride @ 2 g kg^{-1} showed increased germination, shoot length, root length and lower electrical conductivity after eleven months of storage (Bharathi, 2002).

Maraddi (2002) reported that cowpea seeds treated with chlorax @ 4 g/kg of seeds recorded significantly higher germination, root length, shoot length, vigour index and lower electrical conductivity after the ten months of storage.

In cotton, Sandyarani (2002) found that the fresh, six and eight months old seeds when treated with chlorax (5 g kg^{-1}) recorded significantly higher germination and other seed quality parameters in fresh treated seeds than 6 and 8 months old seeds compared to other seed treatments.

Tammanagouda (2002) noticed higher germination (23.61 per cent) and vigour index (1330) in greengram seeds variety Chinamung treated with bleaching powder as compared to control (21.62 per cent and 1168, respectively) at the end of 10 months of ambient storage condition.

According to Vanangamudi *et al.* (2002), *Albizzia lebbeck* seeds treated with calcium oxychloride (bleaching powder) at 2 g kg^{-1} of seeds, significantly reduced the physiological deterioration of seeds inflicted due to storage and maintained germination percentage and vigour in the treated seeds over control.

Rice hybrid (CORH-1, TNRH-16 and TNRH-17) seeds treated with halogen (calcium oxychloride + calcium carbonate at 1:2) and halogen + thiram (@ 2 g kg^{-1}) showed the lowest decline in seed germination, dry matter production, seedling weight, and vigour index. The decrease in dehydrogenase activity was lowest in halogen-treated seeds (Vimala *et al.*, 2002).

Manjunatha and Yogeesha (2003) reported that pre-storage treatment of bell pepper seeds with free radical quenching agent potassium iodide effectively controlled seed deterioration and maintained significantly higher seed quality over untreated seeds at the end of twelve months of storage.

Patil and Deshpande (2004) reported that the loss in germination was more in untreated seeds (16 per cent) of sunflower when compared to halogenated (chlorine and iodine) seeds (5-9 per cent) after 6 months of storage. It was found that chlorinated seeds maintained better viability than the iodinated and untreated seeds.

Slurry coating of chilli seeds with polymer (3 g kg^{-1} of seed) along with carbendazim (2 g kg^{-1} of seed) and halogen mixture (3 g kg^{-1} seed) enhanced the germination and vigour index values by 24.00 per cent, whereas, the pathogen infection was lessened by 1.00 per cent compared to uncoated seeds (Geetharani *et al.*, 2006). This treatment also enhanced the field emergence by 29.00 per cent in the nursery sowing.

Roopa (2006) reported that muskmelon seeds treated with chlorax @ 5 g kg^{-1} recorded significantly higher germination (90.77 per cent), speed of germination (26.63), seedling length (34.37 cm), seedling dry weight (248 mg), vigour index (3124) and lower moisture content after ten months of storage.

Hunje *et al.* (2007) concluded that the seeds of chilli variety Byadagi kaddi treated with potassium iodide (10^{-3} M) and calcium chloride (4 g kg^{-1} of seed) recorded significantly maximum seed germination (71.66 and 70.00 per cent), field emergence (60.34 and 59.46 per cent), root length (5.92 and 7.00cm), shoot length (5.00 and 4.82cm), vigour index (784 and 832) and lower electrical conductivity of seed leachate (2.136 and 2.179 dSm^{-1}) at the end of 20 months storage period.

According to Madinur (2007), drumstick seeds treated with calcium oxychloride and garlic clove paste maintained higher germination (73.50 and 70.50 per cent respectively) after twelve months of storage with higher root length, shoot length, vigour index, seedling dry weight, field emergence and lower moisture content and electrical conductivity.

Jatropha seeds treated with the mixture of halogen + carbendazim (1.0 and 1.5 g kg^{-1} respectively) recorded the greatest germination (75.0 per cent), and dehydrogenase and peroxidase activities, and the lowest seed leachate electrical conductivity (0.982 dS/m) and percentage of reduction in oil content (32.43 per cent) (Kathiravan *et al.*, 2008).

Menaka and Balamurugan (2008) found that the seeds of amaranthus variety. CO 5 treated with halogen mixture @ 3 g kg^{-1} and stored in aluminium foil pouch maintained better viability (78 per cent) and vigour (960) at the end of 6 month storage period.

Seed invigoration of black gram using bleaching powder @ 2 g or iodine crystals @ 100 mg through calcium carbonate as carrier @ 2 g kg^{-1} of seed proved effective which are explained based on cellular corrective functions reflected over lower conductivity and quenching of free radical reactions with lower lipid peroxidation values in treated seeds (Ramamoorthy *et al.*, 2009).

In green gram, Vadgave (2010) reported that seeds treated with chlorox (5 g kg^{-1}) recorded higher germination, shoot length, root length, vigour index and lower electric conductivity and moisture content compared to control at the end of eight months of storage.

Treating okra seeds with bleaching powder (@ 2 g kg^{-1}) showed better results in improving storability, yield and other yield attributes (Guha and Mandal, 2011).

Hemashree and Kurdikeri (2011) revealed that cotton seeds treated with $CaOCl_2$ (3 g kg^{-1}) recorded significantly higher germination (69.98 per cent) and field emergence (per cent) with higher shoot length, root length, vigour index and lower moisture content and EC values, compared to control.

The field stand per cent of crops like sesame and sunflower treated with halogen slurry @ 3 g kg^{-1} and groundnut @ 4 g kg^{-1} were the highest with halogen treated seeds compared to other treatments and control as reported by Narayanan *et al.* (2011).

Raikar *et al.* (2011) found that rice seeds variety Mugad sugandha treated with $CaOCl_2$ (5 g kg^{-1}) recorded significantly higher test weight (2.30 g), seed germination (90.56 per cent), field emergence per cent (80.50 per cent), root length (5.47 cm), shoot length (4.76 cm), seedling dry weight (126 mg), seedling vigour index (923) and lower electrical conductivity value (1.977 dSm^{-1}) at the end of twenty months of storage over untreated seeds. It was also known to decrease autooxidation of lipids and prevents the production of secondary metabolites and free radicals.

According to Adebisi and Ayodele (2013), the seeds of okra variety V-35 dry dressed with bleaching powder have recorded the highest seedling vigour over other treatments including control.

Hot pepper seeds treated with bleaching powder @ 0.1 g/ 10 g of seeds and potassium iodide powder @ 0.1 g/ 10 g of seeds retained viability, vigour, speed of germination, dry weight and moisture content predicted under accelerated ageing conditions for 22 months (Mathew *et al.*, 2013).

Kumar *et al.* (2014) reported that the seeds of marigold variety Orange double treated with calcium oxychloride @ 4 g kg^{-1} recorded higher germination percentage (38.16 per cent), field emergence (32.67 per cent), shoot length (3.09 cm), root length (3.84 cm), seedling dry weight (3.03 mg), vigour index (269) and germination rate index (10.54) with lower electrical conductivity of seed leachate (2.332 dSm^{-1}) at the end of ten month storage period.

Lone (2014) revealed that dry dressing treatments of freshly harvested maize seeds with halogens like bleaching powder (3 g kg^{-1}) and potassium iodide (100 mg kg^{-1}) were very effective in controlling the loss of vigour and viability under subsequent storage conditions.

2.3.3 Combined influence of packing material and halogenation

Interaction effect due to halogens, storage containers and seed conditions indicated that the husked seeds treated with iodine and stored in polythene bags maintained significantly higher seed quality attributes and thus resulted in more viability and vigour even up to 12 months (Rudrapal and Basu, 1981).

Interaction effect due to halogens, storage containers and seed conditions indicated that the husked wheat seeds treated with iodine and stored in polythene bags maintained significantly higher seed quality attributes and thus resulted in more viability and vigour even up to 12 months. The chlorine based chemical i.e. calcium oxychloride was also found to be effective in prolonging the storage life of dicoccum wheat seeds as compared to untreated seeds (Uppar, 1998).

Joeraj (2000) reported that the A, B and R line seeds of sunflower hybrid KBSH-1 treated with either halogen formulation at 3 g kg^{-1} and packed in polylined cloth bag could be stored upto six months under ambient conditions.

Pre-storage dry treatments of freshly harvested safflower seed with bleaching powder at 2g/kg of seed and stored in glass bottles is suggested for the improvement of the germinability (Kapri *et al.*, 2005).

Drumstick seeds were treated with captan, calcium oxychloride, sweet flag leaf powder, neem oil and garlic clove at varying dosages and stored in two containers *viz.,* cloth and polythene bags of 700 G. The interaction effects between seed treatments and containers indicated that seed treated with calcium oxy chloride @ 6g/ kg seed and stored in polythene bag recorded significantly higher germination, speed of germination, root length, shoot length, vigour index, seedling dry weight, field emergence and with the lowest electrical conductivity (Madinur, 2007).

Bt and non Bt cotton seeds were treated with thiram 75 per cent WDP @ 2 g per kg seeds, imidachloprid @ 3 g per kg seeds, calcium oxy chloride @ 3 g per kg seeds and sweet flag rhizome powder @ 10 g per kg seeds and stored in cloth bag, polythene bag (700 gauge) and aluminum foil pouches. Seeds treated with calcium oxychloride and stored in aluminum foil pouches and polythene bags maintained germination as per the minimum Seed certification standards upto twelve months (Hemashree and Kurdikeri, 2011).

Rice seeds produced through organic or INM were treated with different chemicals and fungicide combination. Among them seeds treated with calcium oxychloride (5g/kg of seed) and stored in polythene bag maintained higher seed quality parameters compared to cloth bag throughout the storage period (Raikar, 2011).

Seeds of *Cenchrus glaucus* were stored in cloth and poly bags (700 G) with and without halogen mixture. Seeds dry dressed with halogen mixture @ 3 g/kg of seed and stored in poly bags recorded minimum deterioration during storage (Geetha and Krishnasamy, 2012).

Guha *et al.* (2012) reported that pre-storage dry dressing treatment of okra with bleaching powder @ 2 g/kg of seed and storage in rubber stopper airtight glass bottles may be suggested for improved storability and field performance of high medium vigour okra seed.

Urd bean seeds were dry dressed with aspirin, bleaching powder, iodinated calcium carbonate and red chilli powder and stored in airtight glass bottles. The treatment of bleaching powder @ 2 g/kg of seed and iodinated calcium carbonate @ 3 g/ kg of seed could be helpful for the maintenance of germinability and field performance of high-vigour urd bean seeds for a prolonged period than other treatments involved (Layek *et al.*, 2012).

Narayanan and Prakash (2014) conducted a storage study with groundnut seeds variety. VRI 2 by treating with halogen slurry @ 4 g kg^{-1}. The treated seeds were stored in 700 gauge polythene bag which maintained their germination above minimum seed certification standard till the end of the storage period of ten months. It has also registered low moisture content and electrical conductivity.

Materials & Methods

3. MATERIALS AND METHODS

The present seed storage experiment was conducted in Kerala Agricultural University (KAU) during 2014-2015. The investigation was intended to elucidate the impact of seed treatment with halogen and the packing material on seed viability of rice variety Ptb 39 (Jyothi) during storage under ambient conditions. The study was carried out using seeds from three major cropping season *viz.*, seeds pertaining to *rabi* 2013-14, summer 2013-14 and *kharif* 2014. The storage period extended from December 2013 to May 2015. The details of materials used and the techniques adopted during the course of the study are described hereunder.

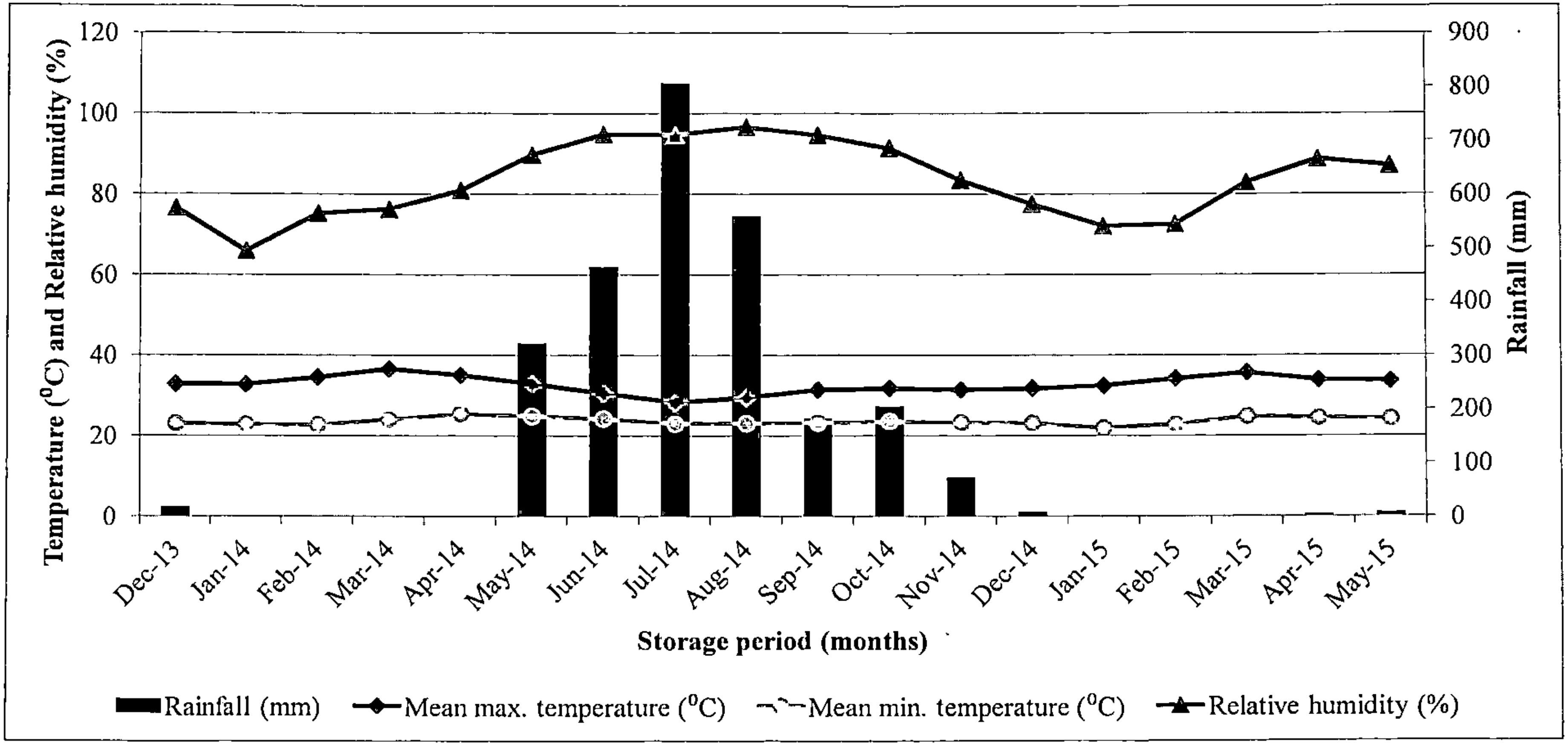
3.1 Location and climate

The storage experiment was conducted under ambient conditions in the Seed processing unit, Department of Seed Science and Technology, College of Horticulture, Kerala Agricultural University (KAU), Vellanikkara P.O., Thrissur 680 656, located 40 m above MSL at 10° 54′ North latitude and 76° 28′ East longitude. Vellanikkara experiences humid tropical climate where the relative humidity remains 80 to 96 per cent for most part of the year. The monthly mean maximum temperatures ranged from 31.5 to 36.7°C, while the range in mean minimum temperature was from 22.1 to 24.9°C. The highest monthly mean maximum temperature (36.7°C) during the study was recorded in March 2014. The highest rainfall and relative humidity of 807.7 mm and 96.7% were recorded in July 2014 and August 2014, respectively (Fig. 1).

3.2 Experimental material

Freshly harvested seed with high germination pertaining to *rabi* 2013-14 (July to October, 2014), summer 2013-14 (January to April, 2014) and *kharif* 2014

Fig. 1: Mean maximum and mean minimum temperature (^oC), relative humidity (%) and rainfall (mm) during the storage period (December 2013 - May 2015)



and (July to October, 2014) were obtained from Department of Seed Science and Technology, College of Horticulture, Vellanikkara to initiate the experiment. The seeds were dried to around 13 per cent and 10 per cent moisture content respectively before treatment and packing in jute bags and polyethylene bags (400G).

3.3 Experimental method

3.3.1 Treatment details

The experiment was conducted as completely randomized blocks design comprising of fourteen treatments with two replications. Each treatment referred to a combination of packing material (P) (Factor 1) with seed halogenation (T) at different doses (Factor 2). The details of treatment combination are given in Table 1. In each replication, five kilogram of seed of variety Jyothi was treated with halogen-calcium oxychloride ($CaOCl_2$) either alone or in combination with carrier calcium carbonate ($CaCO_3$) as specified in Table 1.

Table 1: Treatment details

Factor I: Packing material (P)

Factor II: Seed treatments (T)

Details	Packing material	
	Jute bag (P1)	Polyethylene bag (400G) (P2)
T1: Control (untreated)	P1T1	P2T1
T2: $CaOCl_2$ (3g /kg seed)	P1T2	P2T2
T3: $CaOCl_2$ (6g /kg seed)	P1T3	P2T3
T4: $CaOCl_2$ (9g /kg seed)	P1T4	P2T4
T5: $CaOCl_2$ + $CaCO_3$ (3g each /kg seed)	P1T5	P2T5
T6: $CaOCl_2$ + $CaCO_3$ (6g each /kg seed)	P1T6	P2T6
T7: $CaOCl_2$ + $CaCO_3$ (9g each /kg seed)	P1T7	P2T7

3.3.2 Seed treatment procedure

The chlorine based halogen formulation calcium oxychloride otherwise termed as calcium oxychloride ($CaOCl_2$) was used either alone or in combination with calcium carbonate ($CaCO_3$) to halogenate the seeds. The halogenation mixture for the combination treatment was prepared by mixing the respective quantities of analytical grade calcium hypochlorite ($CaOCl_2$) and dehydrated calcium carbonate ($CaCO_3$). Seeds taken in an airtight container were allowed to impregnate for five days by the halogen/ halogen-carrier mixture before dry dressing seed with the mixture as advocated by Dharmalingam (1995) and Anjalidevi (1998).

3.3.3 Method of storage

The treated seeds along with control (P1T1 and P2T1) were packed in jute bags and polythene bags (400G) at moisture content of $\leq$13 per cent and $\leq$10 per cent respectively. The jute bags were tightly sealed by thread and the polythene bags were heat sealed and stored in ambient storage condition until the germination in the treatments fell below the minimum seed certification standard (MSCS) for rice (80%).

3.4 Observations recorded

The required quantity of seed was drawn randomly from each replication of each treatment at monthly intervals for taking observations on seed quality parameters. Observation on seed microflora was recorded at the start and end of storage period. Seed quality parameters enumerated below were recorded in all the three experiments.

3.4.1 Germination (%)

In each treatment, 400 seeds were randomly sampled from each replication and used for conducting standard germination test per procedure advocated by ISTA for rolled paper towel method. Germination test through between paper was conducted at 25±2°C and 90±3 per cent relative humidity in the presence of light (ISTA, 1999). On 14th day, the total number of normal seedlings were counted and expressed in per cent.

3.4.2 Seedling shoot length (cm)

Ten normal seedlings were selected randomly from each replication of a treatment at the end of the germination test and the shoot length was measured from the base of primary leaf to collar region. The mean shoot length was expressed in centimetre.

3.4.3 Seedling root length (cm)

The ten normal seedlings used for measuring the shoot length were used to record the root length measurement. The root length of each seedling was measured from collar region to the tip of primary root. The average root length was expressed in centimetre.

3.4.4 Seedling dry weight (mg)

On measuring the shoot and root length, the ten normal seedlings were placed in a butter paper cover, dried in a hot air oven maintained at 85±1°C for 24 hrs as per ISTA (2007). Then the seedlings were removed and allowed to cool in desiccators for 30 minutes before weighing in digital balance and expressed in milligram.

3.4.5 Vigour index I

The seedling vigour index was computed by adopting the formula suggested by Abdul-Baki and Anderson (1973) and expressed in whole number.

Vigour index I = Germination (%) x Seedling length (cm)

3.4.6 Vigour index II

The seedling vigour index was computed by adopting the formula suggested by Abdul-Baki and Anderson (1973) and expressed in whole number as detailed below.

Vigour index II = Germination (%) x Seedling dry weight (mg)

3.4.7 Electrical conductivity of seed leachate (dSm^{-1})

The observation on electrical conductivity of seed leachate (EC) was recorded on four replications of five grams seeds of each replication, weighed up to two decimal places. The seeds were treated with mercuric chloride (0.1%) for half a minute and were thoroughly washed in distilled water two to three times. The seeds were soaked in 25 ml distilled water. The containers were placed in an incubator maintained at constant temperature of 25°C ± 1°C for 24 hours. After incubation, leachate was collected in a beaker. The EC of the seed leachate was measured in the EUTECH CON-510 digital conductivity meter with a cell constant of 0.1' and recorded as desi simons per meter (dSm^{-1}) (Presley, 1958).

3.4.8 Seed moisture content (%)

Two replicates of five gram of seed material were taken for determining the moisture content through low constant temperature method as per procedure advocated by ISTA (1993). The seeds were ground to coarse powder using grinding mill. The powdered seed material was placed in a weighed airtight aluminium cup with lid. Removing the lid, the seed material was placed in hot air oven maintained at 103 ± 2°C and allowed to dry for 17 ± 1 hr. After the drying period, the lid was replaced and the contents cooled in a dessicator for 30 minutes before being were weighed in an electronic balance. 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 with lid alone

M2 = weight of the aluminium cup with lid + sample before drying

M3 = weight of the aluminium cup with lid + sample after drying

3.4.9 Seed infection (%)

Storage fungi present on seeds were detected using blotter method as prescribed by ISTA (1999). Twenty five seeds were placed equidistantly on three layered moistened blotter taken in sterilized petriplates. Each treatment was replicated four times. They were incubated at 20°C for seven days with an alternate cycle of 12 hour near ultra violet range and for remaining 12 hours in dark. On eighth day, the plates were examined under stereo binocular microscope for the presence of seed borne fungi. The number of infected seeds were counted and expressed in percentage.

3.5 Statistical analysis

Statistical analysis of the data on various seed quality parameters was performed using SPSS and M STAT-C package for completely randomized design with two factors (packing material and halogenation dose) by Fisher's method of analysis of variance (Gomez and Gomez 1976). Arc sine transformation of data in per cent was done wherever applicable (Snedecor and Cochran, 1967).

3.5.1 ANOVA for factorial design

The data recorded in each experiment was analyzed using Factorial ANOVA so as to estimate the effect of both packing material and halogen treatment on dependent variables. It allows us to determine if there are interactions between the independent variables or factors considered. The mean squares due to different sources of variation were worked out using the following analysis of variance (Gomez and Gomez 1976).

Source	**df**	**Mean square**	**Expected mean squares**
Replication	(r-1)	M_r	M_r/M_e
Main effect (A)	(a-1)	M_A	M_A/M_{e23}
Main effect (B)	(b-1)	M_B	M_B/M_e
Factor (AB)	(a-1) (b-1)	M_{AB}	M_{AB}/M_e
Error	ab (r-1)	M_e	

3.5.2 Pair wise comparison using DMRT test

For experiments that require the evaluation of all possible pairs of treatment means, Duncan's multiple range test (DMRT) is useful. This is especially true when the total number of treatments is large.

The procedure for applying the DMRT is similar to that for the LSD test. DMRT involves the computation of numerical boundaries that allow for the classification of the difference between any two treatment or means as significant or nonsignificant. However, unlike the LSD test in which only a single value is required for any pair comparison at a prescribed level of significance, the DMRT requires computation of a series of values, each corresponding to a specific se, of pair comparisons. The following steps are followed for ranking the data (Gomez and Gomez, 1976).

Step 1: Rank all the treatment means in decreasing (or increasing) order. It is customary to rank the treatment means according to the order of preference.

Step 2: Compute the s_d value following the appropriate procedure

$$s_d = \sqrt{\frac{2s^2}{r}}$$

Step 3: Compute the (t - 1) values of the shortest significant ranges as:

$$R_p = \frac{(r_p)(s_d)}{\sqrt{2}} \quad \text{for } p = 2, 3, \ldots, t$$

where t is the total number of treatments, s, is the standard error of the mean difference computed in step 2, r values are the tabular values of the significant ranges, and p is the distance in rank between the pairs of treatment means to be compared (i.e., p = 2 for the two means with consecutive rankings and p = t for the highest and lowest means).

Step 4: Identify and group together all treatment means that do not differ significantly from each other

Step 5: Use the alphabet notation according to the ranking to present the test results

Results

4. RESULTS

Experiment to elucidate the impact of seed treatment with halogen and the packing material on seed viability of rice variety Ptb 39 (Jyothi) stored under ambient conditions was conducted in Kerala Agricultural University (KAU) during 2013-2015. The results obtained are presented in this chapter.

4.1 Seed longevity of rice variety Jyothi (*rabi*, 2013-14)

The result pertaining to storage of seeds of *rabi* 2013-14 crop stored over a period of fifteen months is enumerated below.

4.1.1 Analysis of variance

The analysis of variance revealed that, there existed significant differences in the impact on seed qualities like germination per cent, seedling shoot and root length, seedling dry weight, seedling vigour index I and II, electrical conductivity of seed leachate, seed moisture content and seed infection per cent among the various packing material, seed halogenation treatments and their interaction during storage.

4.1.2 Seed quality before storage

The seed quality parameters before storage are presented in Table 2. The initial quality parameters of seed stored in P1 (jute bag) and P2 (polyethylene bag of 400G) were moisture content (12.3 % and 10.0 %), germination (97.25 % and 97.75 %), seedling shoot length (19.87 cm and 20.25 cm), seedling root length (30.55 cm and 30.74 cm), seedling dry weight (20.70 mg and 20.75 mg), vigour index I (4903 and 4984), vigour index II (2013 and 2028), electrical conductivity of seed leachate (0.0230 dSm^{-1} and 0.0200 dSm^{-1}), respectively.

Table 2: Seed quality parameters before storage (M0) (*rabi* 2013-14)

Packing material (P)	Moisture content (%)	Germination (%)	Seedling shoot length (cm)	Seedling root length (cm)	Seedling dry weight (mg)	Vigour index I	Vigour index II	EC (dSm^{-1})	Seed infection (%)
P1*	12.5	97.25	19.87	30.55	20.70	4903	2013	0.0230	9.00
P2**	10.0	97.75	20.25	30.74	20.75	4984	2028	0.0200	8.00

*observations were taken after drying the seeds to a moisture content of 12.5%

**observations were taken after drying the seeds to a moisture content of 10.0%

4.1.3 Seed quality during storage

4.1.3.1 Germination (%)

The results of impact of packing material and halogen treatment on germination during storage period are presented in Table 3 and 4 and detailed below.

Due to packing material (P)

Germination declined progressively over the period of storage. Throughout the storage period, the germination of seeds stored in P2 was significantly superior to that stored in P1. .Germination in P1 (jute bag) reduced from 97.25 to 39.81 per cent while the reduction was from 97.75 to 65.61 per cent in P2 (polyethylene bag of 400G). A reduction of 32.88 per cent (P2) and 59.06 per cent (P1) in germination at the end of storage period of fifteen months over initial germination was observed. The germination in P1 and P2 was above the minimum seed certification standards (MSCS) of 80 per cent for eight and eleven months respectively.

Due to halogen treatment

Reduction in germination was observed with increase in storage period. Treatment T5 ($CaOCl_2$ +$CaCO_3$@ 3g each/kg of seed) was superior to other treated and untreated seeds at each month of storage. Germination per cent in T5 at the end of the storage period of fifteen months was the highest (72.82%). T3 ($CaOCl_2$ @ 6 g/kg seed) with a germination of 56.38 per cent was the next best. Treatment T6 recorded the least germination (44.13%) at the end of storage period and was on par with T1 (untreated; 44.32%) and T7 ($CaOCl_2$ + $CaCO_3$ @ 9 g each/kg seed; 44.94%). The per cent reduction varied from 25.31 in T5 to 54.74 in T6 over initial germination. The germination in T5 was retained above the minimum seed certification standards (MSCS) for twelve months compared to nine months in T1, T2, T3 and T4. However, germination was above 80 per cent for eight months in case of T6 and T7.

Table 3: Influence of packing material and halogen treatment on germination (%) during storage in rice (*rabi*, 2013-14)

	Storage period (months)					
	M1	M2	M3	M4	M5	M6
Packing material (P)						
P1	97.20 (76.41)	96.99 (75.91)	96.95 (75.81)	96.92 (75.74)	96.51 (74.82)	95.96 (73.66)
P2	97.61 (77.45)	97.36 (76.81)	97.25 (76.53)	97.25 (76.53)	96.82 (75.51)	96.23 (74.22)
SEm ±	0.50	0.44	0.41	0.37	0.34	0.30
CD (0.05)	NS	NS	NS	NS	NS	NS
Halogen treatment (T)						
T1	97.40 (76.91)	97.10 (76.17)	96.98 (75.88)	96.88 (75.65)	96.43 (74.64)	96.00 (73.74)
T2	97.40 (76.91)	97.24 (76.51)	97.15 (76.29)	97.15 (76.29)	96.73 (75.31)	96.03 (73.80)
T3	97.40 (76.91)	97.28 (76.61)	97.25 (76.53)	97.25 (76.53)	96.81 (75.49)	96.13 (74.01)
T4	97.40 (76.91)	97.08 (76.12)	97.05 (76.05)	97.05 (76.05)	96.59 (74.99)	96.13 (74.01)
T5	97.45 (77.03)	97.30 (76.66)	97.28 (76.61)	97.28 (76.61)	97.08 (76.12)	96.78 (75.42)
T6	97.40 (76.91)	97.21 (76.43)	97.10 (76.17)	97.10 (76.17)	96.83 (75.53)	96.00 (73.74)
T7	97.40 (76.91)	97.05 (76.03)	96.90 (75.70)	96.90 (75.70)	96.23 (74.22)	95.63 (73.00)
SEm ±	0.76	0.73	0.70	0.66	0.64	0.61
CD (0.05)	NS	NS	NS	NS	NS	NS

*Means in each column with at least one letter in common are not significantly different at 5% level of probability

**Values in parentheses are Arc sine transformed values

Table 3: Influence of packing material and halogen treatment on germination (%) during storage in rice (*rabi*, 2013-14) (contd)

Treatments	Storage period (months)								
	M7	M8	M9	M10	M11	M12	M13	M14	M15
Packing material (P)									
P1	91.97^{b} (66.88)	82.36^{b} (55.45)	75.54^{b} (49.06)	55.88^{b} (33.97)	53.06^{b} (32.05)	47.97^{b} (28.67)	42.86^{b} (25.38)	41.79^{b} (24.70)	39.81^{b} (23.46)
P2	94.47^{a} (70.86)	92.68^{a} (67.94)	90.22^{a} (64.45)	85.04^{a} (58.26)	80.54^{a} (53.65)	76.98^{a} (50.34)	68.50^{a} (43.24)	67.70^{a} (42.61)	65.61^{a} (41.00)
SEm ±	0.27	0.23	0.20	0.15	0.19	0.06	0.09	0.11	0.12
CD (0.05)	0.82	0.70	0.60	0.45	0.57	0.18	0.29	0.34	0.36
Halogen treatment (T)									
T1	90.75^{cd} (65.16)	86.88^{bc} (60.32)	82.32^{d} (55.41)	65.19^{d} (40.69)	62.07^{d} (38.37)	55.94^{e} (34.01)	50.38^{e} (30.25)	46.63^{d} (27.79)	44.32^{e} (26.31)
T2	91.94^{c} (66.84)	85.38^{d} (58.63)	82.94^{cd} (56.04)	69.94^{c} (44.38)	65.82^{c} (41.16)	62.38^{d} (38.59)	55.88^{d} (33.97)	53.76^{e} (32.52)	52.01^{d} (31.34)
T3	95.50^{a} (72.75)	88.00^{b} (61.64)	83.75^{bc} (56.88)	76.19^{b} (49.63)	72.57^{f} (46.53)	66.19^{b} (41.44)	58.44^{b} (35.76)	57.76^{b} (35.28)	56.38^{b} (34.32)
T4	94.13^{b} (70.27)	86.63^{cd} (60.03)	84.25^{b} (57.41)	75.50^{b} (49.03)	71.44^{b} (45.59)	65.63^{c} (41.02)	57.00^{c} (34.75)	55.75^{c} (33.88)	54.38^{c} (32.94)
T5	96.32^{a} (74.41)	94.44^{a} (70.80)	92.76^{a} (68.06)	87.13^{a} (60.61)	85.51^{a} (58.77)	83.19^{a} (56.29)	78.19^{a} (51.43)	76.63^{a} (50.02)	72.82^{a} (46.74)
T6	93.50^{b} (69.23)	85.50^{d} (58.76)	74.88^{f} (48.49)	60.19^{e} (37.01)	55.13^{e} (33.46)	51.69^{g} (31.12)	44.44^{g} (26.38)	46.00^{d} (27.39)	44.13^{e} (26.19)
T7	90.38^{d} (64.66)	85.82^{cd} (59.12)	79.25^{e} (52.42)	59.07^{e} (36.21)	55.07^{e} (33.42)	52.32^{f} (31.55)	45.44^{f} (27.03)	46.69^{d} (27.83)	44.94^{e} (26.71)
SEm ±	0.59	0.48	0.41	0.31	0.40	0.13	0.20	0.23	0.25
CD (0.05)	1.79	1.47	1.26	0.95	1.22	0.39	0.60	0.71	0.77

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

**Values in parentheses are Arc sine transformed values

Table 4: Interaction effect of packing material and halogen treatment on germination (%) during storage in rice (*rabi*, 2013-14)

	Storage period (months)					
	M1	M2	M3	M4	M5	M6
Interaction (P x T)						
P1T1	97.20 (76.41)	96.75 (75.35)	96.70 (75.24)	96.50 (74.80)	96.10 (73.95)	95.50[ab] (72.75)
P1T2	97.20 (76.41)	97.08 (76.12)	97.00 (75.93)	97.00 (75.93)	96.55 (74.91)	95.75[ab] (73.24)
P1T3	97.20 (76.41)	97.10 (76.17)	97.10 (76.17)	97.10 (76.17)	96.50 (74.80)	95.50[ab] (72.75)
P1T4	97.20 (76.41)	97.00 (75.93)	97.00 (75.93)	97.00 (75.93)	96.45 (74.69)	95.75[ab] (73.24)
P1T5	97.20 (76.41)	97.10 (76.17)	97.05 (76.05)	97.05 (76.05)	97.00 (75.93)	96.75[ab] (75.35)
P1T6	97.20 (76.41)	97.02 (75.98)	97.00 (75.93)	97.00 (75.93)	96.80 (75.47)	96.75[a] (75.35)
P1T7	97.20 (76.41)	96.90 (75.70)	96.80 (75.47)	96.80 (75.47)	96.20 (74.15)	95.75[ab] (73.24)
P2T1	97.60 (77.42)	97.45 (77.03)	97.25 (76.53)	97.25 (76.33)	96.75 (75.35)	96.50[ab] (74.80)
P2T2	97.60 (77.42)	97.40 (76.91)	97.30 (76.66)	97.30 (76.66)	96.90 (75.70)	96.30[ab] (74.37)
P2T3	97.60 (77.42)	97.45 (77.03)	97.40 (76.91)	97.40 (76.91)	97.12 (76.22)	96.75[ab] (75.35)
P2T4	97.60 (77.42)	97.15 (76.29)	97.10 (76.17)	97.10 (76.17)	96.73 (75.31)	96.50[ab] (74.80)
P2T5	97.70 (77.69)	97.50 (77.16)	97.50 (77.16)	97.50 (77.16)	97.15 (76.29)	96.80[a] (75.47)
P2T6	97.60 (77.42)	97.40 (76.91)	97.20 (76.41)	97.20 (76.41)	96.85 (75.58)	95.15[b] (72.08)
P2T7	97.60 (77.42)	97.20 (76.41)	97.00 (75.93)	97.00 (75.93)	96.25 (74.26)	95.50[ab] (72.75)
SEm ±	0.91	0.88	0.85	0.82	0.81	0.53
CD (0.05)	NS	NS	NS	NS	NS	1.61

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

**Values in parentheses are Arc sine transformed values

Table 4: Interaction effect of packing material and halogen treatment on germination (%) during storage in rice (*rabi*, 2013-14) (contd)

Treatments	Storage period (months)								
	M7	M8	M9	M10	M11	M12	M13	M14	M15
	Interaction (P x T)								
P1T1	89.00^{gh} (62.87)	82.25^{e} (55.34)	75.75^{g} (49.24)	50.00^{h} (30.00)	48.25^{i} (28.85)	40.25^{k} (23.73)	35.25^{i} (20.64)	33.75^{h} (19.72)	30.75^{i} (17.91)
P1T2	90.63^{fg} (65.00)	78.63^{g} (51.84)	75.63^{g} (49.14)	54.75^{g} (33.20)	50.25^{i} (30.17)	45.50^{j} (27.06)	38.63^{h} (22.72)	37.63^{g} (22.10)	35.88^{h} (21.03)
P1T3	94.25^{cd} (70.48)	80.25^{fg} (53.37)	72.25^{h} (46.26)	61.25^{f} (37.77)	58.88^{g} (36.07)	50.25^{i} (30.17)	45.25^{f} (26.90)	44.38^{e} (26.35)	43.00^{f} (25.47)
P1T4	93.13^{de} (68.64)	78.25^{g} (51.49)	74.25^{g} (47.94)	60.25^{f} (37.05)	55.50^{h} (33.71)	50.13^{i} (30.09)	41.75^{g} (24.68)	41.25^{f} (24.36)	40.13^{g} (23.66)
P1T5	95.88^{ab} (73.50)	93.13^{b} (68.64)	90.63^{c} (65.00)	82.88^{c} (55.98)	80.13^{c} (53.25)	78.13^{e} (51.38)	72.88^{b} (46.79)	71.00^{bc} (45.23)	66.75^{d} (41.87)
P1T6	92.25^{ef} (67.29)	81.25^{ef} (54.34)	65.00^{i} (40.54)	40.25^{i} (23.73)	38.25^{j} (22.49)	35.63^{l} (20.87)	32.63^{j} (19.04)	31.75^{i} (18.51)	30.25^{i} (17.61)
P1T7	88.63^{h} (62.41)	82.75^{e} (55.84)	75.25^{g} (48.81)	41.75^{i} (24.68)	40.13^{j} (23.66)	35.88^{l} (21.03)	33.63^{j} (19.65)	32.75^{hi} (19.12)	31.88^{i} (18.59)
P2T1	92.50^{e} (67.67)	91.50^{c} (66.21)	88.88^{d} (62.72)	80.38^{d} (53.49)	75.88^{d} (49.36)	71.63^{f} (45.75)	65.50^{d} (40.92)	59.50^{d} (36.51)	57.88^{e} (35.37)
P2T2	93.25^{de} (68.83)	92.13^{bc} (67.12)	90.25^{c} (64.49)	85.13^{b} (58.35)	81.38^{c} (54.47)	79.25^{d} (52.42)	73.13^{b} (47.00)	69.88^{c} (44.33)	68.13^{c} (42.95)
P2T3	96.75^{a} (75.35)	95.75^{a} (73.24)	95.25^{a} (72.27)	91.13^{a} (65.69)	86.25^{b} (59.60)	82.13^{b} (55.22)	71.63^{c} (45.75)	71.13^{b} (45.34)	69.75^{b} (44.23)
P2T4	95.13^{bc} (72.05)	95.00^{a} (71.81)	94.25^{b} (70.48)	90.75^{a} (65.16)	87.38^{b} (60.900	81.13^{c} (54.22)	72.25^{bc} (46.26)	70.25^{bc} (44.63)	68.63^{bc} (43.34)
P2T5	96.75^{a} (75.35)	95.75^{a} (73.24)	94.88^{ab} (71.59)	91.38^{a} (66.04)	90.88^{a} (65.34)	88.25^{a} (61.95)	83.50^{a} (56.62)	82.25^{a} (55.34)	78.88^{a} (52.07)
P2T6	94.75^{bc} (71.35)	89.75^{d} (63.83)	84.75^{e} (57.94)	80.13^{d} (53.25)	72.00^{e} (46.05)	67.75^{h} (42.65)	56.25^{e} (34.23)	60.25^{d} (37.05)	58.00^{e} (35.45)
P2T7	92.13^{ef} (67.12)	88.88^{d} (62.72)	83.25^{f} (56.36)	76.38^{e} (49.80)	70.00^{f} (44.43)	68.75^{g} (43.43)	57.25^{e} (34.92)	60.63^{d} (37.32)	58.00^{e} (35.45)
SEm ±	0.73	0.60	0.52	0.39	0.50	0.16	0.25	0.29	0.31
CD (0.05)	2.23	1.84	1.58	1.18	1.52	0.49	0.75	0.89	0.96

Due to interaction (P x T)

P2T5 ($CaOCl_2$ +$CaCO_3$@ 3g each/kg of seed + polyethylene bag of 400G) was superior to other treatments with respect to germination from 6th month of storage. P2T5 recorded a germination of 78.88 per cent at the end of fifteen months of storage. The viability in P2T5 was retained above MSCS for fourteen months of storage whereas it was for twelve months each in case of P2T3 and P2T4. Untreated seeds in polyethylene bags (P2T1) retained viability above MSCS for ten months compared to that in jute bags (8 months).

At the end of storage period, P1T6 and P1T7 recorded the least germination (30.25 and 31.88% respectively) followed by P1T1 (30.75 %). Each retained germination above 80 per cent for eight months. Treatments P1T2 and P1T4 retained viability above MSCS for the least period (7 months).

4.1.3.2 Seedling shoot length (cm)

The results on shoot length as influenced by packing material, halogen treatment and their interaction effects during the storage period are presented in Table 5 and 6.

Due to packing material (P)

Seedling shoot length was observed to decrease with increase in storage period. The shoot length of seeds stored in P2 was found to be maximum and significantly superior over that in P1 from the 7th month of storage. The shoot length decreased from 19.87 to 11.79 cm in P1 (jute bag) while the reduction was from 20.25 to 12.46 cm in P2 (polyethylene bag of 400G).

Table 5: Influence of packing material and halogen treatment on seedling shoot length (cm) during storage in rice (*rabi*, 2013-14)

	Storage period (months)					
	M1	**M2**	**M3**	**M4**	**M5**	**M6**
Packing material (P)						
P1	19.70	19.31	19.02	18.40	17.51	17.25
P2	20.17	19.68	19.25	18.27	18.02	17.77
SEm ±	0.15	0.13	0.11	0.10	0.12	0.10
CD (0.05)	NS	NS	NS	NS	NS	NS
Halogen treatment (T)						
T1	20.01	19.37	19.07	18.46	17.86	17.59
T2	19.98	19.56	19.42	18.62	17.70	17.47
T3	19.97	19.30	18.92	18.47	17.83	17.27
T4	19.87	19.42	19.00	18.11	17.35	17.12
T5	20.04	19.84	19.52	18.59	18.32	18.34
T6	19.85	19.43	19.04	18.04	17.85	17.56
T7	19.86	19.57	18.99	18.07	17.44	17.23
SEm ±	0.12	0.17	0.13	0.15	0.14	0.11
CD (0.05)	NS	NS	NS	NS	NS	NS

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 5: Influence of packing material and halogen treatment on seedling shoot length (cm) during storage in rice (*rabi*, 2013-14) (contd)

Treatments	Storage period (months)								
	M7	M8	M9	M10	M11	M12	M13	M14	M15
Packing materials (P)									
P1	16.04[b]	15.40[b]	14.96[b]	14.34[b]	13.66[b]	13.00[b]	12.19[b]	11.83[b]	11.79[b]
P2	16.84[a]	16.16[a]	15.83[a]	15.25[a]	14.73[a]	14.25[a]	13.84[a]	12.59[a]	12.46[a]
SEm ±	0.04	0.06	0.05	0.05	0.08	0.05	0.07	0.03	0.06
CD (0.05)	0.11	0.19	0.16	0.16	0.25	0.16	0.21	0.10	0.18
Halogen treatments (T)									
T1	16.02[e]	15.47[c]	15.09[cd]	13.67[f]	12.89[d]	12.24[e]	11.09[e]	11.12[e]	11.08[e]
T2	16.06[de]	14.85[d]	14.60[e]	14.05[e]	13.65[c]	13.01[c]	12.39[c]	11.35[d]	11.50[d]
T3	15.90[e]	16.09[b]	15.67[b]	15.40[b]	15.04[b]	14.37[b]	14.04[b]	13.75[b]	13.83[b]
T4	16.28[cd]	15.77[bc]	15.27[c]	15.02[c]	14.67[b]	14.28[b]	13.73[b]	12.68[c]	12.64[c]
T5	17.81[a]	17.55[a]	17.13[a]	16.85[a]	16.58[a]	16.30[a]	16.06[a]	16.03[a]	15.51[a]
T6	16.73[b]	15.07[d]	14.76[de]	14.16[de]	13.29[cd]	12.71[cd]	12.08[cd]	10.20[f]	10.03[f]
T7	16.30[c]	15.67[c]	15.23[c]	14.42[d]	13.28[cd]	12.50[de]	11.72[d]	10.39[f]	10.31[f]
SEm ±	0.08	0.13	0.11	0.11	0.17	0.11	0.14	0.07	0.12
CD (0.05)	0.23	0.39	0.33	0.35	0.53	0.33	0.44	0.21	0.38

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 6: Interaction effect of packing material and halogen treatment on seedling shoot length (cm) during storage in rice (*rabi*, 2013-14)

	Storage period (months)					
	M1	**M2**	**M3**	**M4**	**M5**	**M6**
Interaction (P x T)						
P1T1	19.81	19.23	19.03	18.72	17.72	17.50[a]
P1T2	19.76	19.11	19.05	18.90	17.30	17.13[b]
P1T3	19.80	19.56	19.16	18.80	17.72	17.20[b]
P1T4	19.62	19.34	19.01	18.13	16.71	16.57[b]
P1T5	19.85	19.55	19.15	18.23	18.40	18.23[a]
P1T6	19.55	19.15	18.97	18.12	17.95	17.56[a]
P1T7	19.51	19.25	18.78	17.87	16.77	16.55[b]
P2T1	20.21	19.51	19.11	18.20	18.00	17.67[a]
P2T2	20.20	20.00	19.78	18.34	18.10	17.81[a]
P2T3	20.13	19.03	18.67	18.14	17.94	17.34[a]
P2T4	20.11	19.50	18.98	18.08	17.98	17.66[a]
P2T5	20.22	20.12	19.89	18.94	18.24	18.45[a]
P2T6	20.14	19.70	19.10	17.95	17.75	17.55[a]
P2T7	20.21	19.89	19.19	18.26	18.10	17.91[a]
SEm ±	0.19	0.20	0.17	0.15	0.10	0.34
CD (0.05)	NS	NS	NS	NS	NS	1.04

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 6: Interaction effect of packing material and halogen treatment on seedling shoot length (cm) during storage in rice (*rabi*, 2013-14) (contd)

Treatments	Storage period (months)								
	M7	M8	M9	M10	M11	M12	M13	M14	M15
	Interaction (P x T)								
P1T1	15.53^{f}	14.66^{ef}	14.22^{e}	13.45^{fg}	12.86^{fg}	12.34^{f}	10.64^{g}	10.60^{h}	10.74^{f}
P1T2	15.38^{f}	14.54^{f}	14.25^{e}	13.49^{fg}	12.87^{fg}	12.05^{fgh}	11.67^{f}	11.10^{g}	11.54^{e}
P1T3	15.60^{f}	15.84^{bc}	15.26^{cd}	15.05^{de}	14.75^{cde}	13.75^{de}	13.37^{d}	13.15^{d}	13.35^{c}
P1T4	15.89^{e}	15.62^{cd}	15.09^{cd}	14.95^{e}	14.38^{de}	13.72^{de}	12.72^{e}	12.55^{e}	12.53^{d}
P1T5	17.72^{a}	17.39^{a}	17.06^{a}	16.61^{b}	16.12^{b}	15.75^{b}	15.49^{b}	15.42^{b}	14.60^{b}
P1T6	16.66^{c}	14.60^{f}	14.31^{e}	13.38^{g}	12.48^{fg}	11.76^{gh}	10.79^{g}	9.76^{j}	9.68^{h}
P1T7	15.53^{f}	15.14^{de}	14.50^{e}	13.42^{g}	12.17^{g}	11.66^{h}	10.62^{g}	10.25^{i}	10.10^{gh}
P2T1	16.51^{c}	16.28^{b}	15.95^{b}	13.89^{f}	12.92^{f}	12.14^{fg}	11.54^{f}	11.64^{f}	11.42^{e}
P2T2	16.74^{c}	15.16^{de}	14.95^{d}	14.61^{e}	14.43^{de}	13.97^{d}	13.11^{de}	11.59^{f}	11.46^{e}
P2T3	16.20^{d}	16.33^{b}	16.08^{b}	15.74^{c}	15.32^{c}	14.98^{c}	14.70^{c}	14.34^{c}	14.31^{b}
P2T4	16.67^{c}	15.91^{bc}	15.45^{c}	15.08^{de}	14.95^{cd}	14.83^{c}	14.73^{c}	12.80^{e}	12.74^{d}
P2T5	17.90^{a}	17.70^{a}	17.20^{a}	17.09^{a}	17.03^{a}	16.85^{a}	16.63^{a}	16.64^{a}	16.41^{a}
P2T6	16.80^{bc}	15.54^{cd}	15.21^{cd}	14.94^{e}	14.09^{e}	13.65^{de}	13.37^{d}	10.63^{h}	10.37^{fg}
P2T7	17.06^{b}	16.20^{b}	15.95^{b}	15.42^{cd}	14.39^{de}	13.33^{e}	12.81^{de}	10.52^{h}	10.52^{fg}
SEm ±	0.09	0.16	0.14	0.14	0.22	0.13	0.18	0.09	0.15
CD (0.05)	0.28	0.49	0.42	0.43	0.66	0.41	0.55	0.26	0.47

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Due to halogen treatment (T)

Seedling shoot length decreased over storage irrespective of the halogenation treatment. T5 ($CaOCl_2$ + $CaCO_3$ @ 3 g each/kg seed) recorded the maximum shoot length and was superior to all other treatments from 7^{th} month of storage. T3 was found to be the next best treatment with respect to shoot length (13.83 cm) at the end of storage while it was the least in T6 (10.03cm) and T7 (10.31cm). Untreated seeds (T1) recorded the next lowest shoot length (11.08 cm).

Due to interaction (P x T)

P2T5 was superior to all other treatments with respect to shoot length from 6^{th} month of storage period. The shoot length in P2T5 varied from 20.22 cm (M1) to 16.41 cm (M15). P1T5 (14.60 cm) and P2T3 (14.31 cm) were the next best treatments. At the end of storage, the shoot length of untreated seeds packed in jute bag and polyethylene bag were 10.74 cm and 11.42 cm respectively. The lowest shoot length was recorded in P1T6 (9.68 cm) followed by P1T7 (10.10 cm). P1T6 and P1T7 were on par with each other.

4.1.4 Seedling root length (cm)

The results on root length as influenced by packing material, halogen treatment and their interaction effects during the storage period are presented in Table 7 and 8.

Due to packing material (P)

Seedling root length decreased over the period of storage. The root length of seeds stored in P2 was found to be maximum and superior over that in P1 from 9^{th} month of storage. Root length of seedling decreased from 30.55 to 20.86 cm in P1 (jute bag) whereas the reduction was from 30.74 to 21.69 cm in P2 (polyethylene bag of 400G).

Table 7: Influence of packing material and halogen treatment on seedling root length (cm) during storage in rice (*rabi*, 2013-14)

	Storage period (months)					
	M1	**M2**	**M3**	**M4**	**M5**	**M6**
Packing material (P)						
P1	30.39	29.96	28.64	27.77	27.03	27.07
P2	30.63	30.09	28.65	27.82	27.49	27.15
SEm ±	0.11	0.10	0.10	0.09	0.08	0.09
CD (0.05)	NS	NS	NS	NS	NS	NS
Halogen treatment (T)						
T1	30.56	30.07	28.57	27.20^{bc}	26.26^{c}	25.88^{c}
T2	30.57	30.07	28.77	27.36^{bc}	26.86^{c}	26.51^{d}
T3	30.52	29.95	28.07	26.95^{c}	26.40^{c}	26.27^{d}
T4	30.39	29.94	28.24	27.30^{bc}	26.20^{c}	26.25^{d}
T5	30.50	30.04	28.79	28.11^{b}	27.88^{b}	27.42^{c}
T6	30.58	30.04	29.28	29.32^{a}	29.10^{a}	29.24^{a}
T7	30.47	30.06	28.79	28.37^{a}	28.12^{b}	28.24^{b}
SEm ±	0.09	0.12	0.13	0.31	0.23	0.19
CD (0.05)	NS	NS	NS	0.96	0.71	0.58

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 7: Influence of packing material and halogen treatment on seedling root length (cm) during storage in rice (*rabi*, 2013-14) (contd)

Treatments	Storage period (months)								
	M7	M8	M9	M10	M11	M12	M13	M14	M15
Packing materials (P)									
P1	26.91^{a}	25.49^{a}	25.68^{a}	24.75^{a}	23.51^{b}	22.87^{b}	21.68^{b}	21.28^{b}	20.86^{b}
P2	26.59^{b}	25.30^{a}	25.42^{b}	24.40^{b}	24.31^{a}	23.51^{a}	22.38^{a}	22.04^{a}	21.69^{a}
SEm ±	0.04	0.32	0.04	0.05	0.06	0.04	0.06	0.08	0.08
CD (0.05)	0.12	NS	0.13	0.15	0.17	0.13	0.19	0.25	0.24
Halogen treatments (T)									
T1	25.25^{e}	24.58^{d}	24.18^{d}	24.45^{c}	24.14^{c}	23.72^{c}	21.86^{d}	21.69^{cd}	21.19^{d}
T2	26.27^{d}	26.05^{b}	25.51^{b}	24.71^{c}	23.83^{c}	23.47^{cd}	22.59^{c}	22.18^{c}	21.81^{c}
T3	26.11^{d}	24.75^{d}	24.78^{c}	24.60^{c}	24.11^{c}	23.20^{d}	21.98^{d}	21.69^{cd}	21.39^{cd}
T4	25.47^{c}	24.93^{cd}	24.44^{d}	23.99^{d}	23.46^{d}	22.74^{e}	21.67^{c}	21.52^{d}	20.90^{d}
T5	27.23^{c}	24.77^{d}	26.70^{a}	25.16^{b}	25.15^{b}	24.53^{b}	23.77^{b}	23.08^{b}	22.59^{b}
T6	28.95^{a}	27.15^{a}	26.49^{a}	26.81^{a}	26.22^{a}	25.88^{a}	24.25^{a}	23.78^{a}	23.65^{a}
T7	28.00^{b}	25.58^{bc}	26.76^{a}	22.31^{e}	20.48^{e}	18.79^{f}	18.09^{e}	17.70^{e}	17.42^{e}
SEm ±	0.08	0.22	0.09	0.10	0.12	0.09	0.13	0.17	0.17
CD (0.05)	0.24	0.67	0.27	0.31	0.37	0.28	0.41	0.53	0.51

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 8: Interaction effect of packing material and halogen treatment on seedling root length (cm) during storage in rice (*rabi*, 2013-14)

	Storage period (months)					
	M1	M2	M3	M4	M5	M6
	Interaction (P x T)					
P1T1	30.45	30.01	29.00	27.18	26.28^{cd}	25.88^{d}
P1T2	30.44	30.03	28.73	27.42	26.72^{c}	26.71^{c}
P1T3	30.33	29.89	28.02	27.13	26.28^{cd}	25.98^{d}
P1T4	30.23	29.78	28.08	27.23	25.63^{d}	26.13^{cd}
P1T5	30.33	29.91	28.51	27.67	26.81^{bc}	26.41^{cd}
P1T6	30.46	29.98	29.15	28.97	28.87^{a}	29.24^{a}
P1T7	30.50	30.10	28.97	28.82	28.62^{a}	29.14^{a}
P2T1	30.67	30.13	28.14	27.21	26.23^{cd}	25.88^{d}
P2T2	30.70	30.10	28.80	27.30	27.00^{bc}	26.31^{cd}
P2T3	30.71	30.01	28.11	26.76	26.52^{c}	26.55^{cd}
P2T4	30.55	30.10	28.40	27.36	26.76^{bc}	26.36^{c}
P2T5	30.66	30.16	29.06	28.54	28.94^{a}	28.42^{b}
P2T6	30.70	30.10	29.40	29.67	29.33^{a}	29.23^{a}
P2T7	30.44	30.01	28.61	27.92	27.62^{b}	27.33^{c}
SEm ±	0.16	0.19	0.21	0.15	0.29	0.24
CD (0.05)	NS	NS	NS	NS	0.88	0.72

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 8: Interaction effect of packing material and halogen treatment on seedling root length (cm) during storage in rice (*rabi*, 2013-14) (contd)

Treatments	Storage period (months)								
	M7	M8	M9	M10	M11	M12	M13	M14	M15
	Interaction (P x T)								
P1T1	25.45^{f}	24.71^{efghi}	24.00^{d}	24.70^{d}	23.94^{fg}	23.64^{d}	21.60^{de}	21.39^{def}	20.62^{g}
P1T2	26.69^{cd}	26.59^{b}	25.58^{b}	25.69^{b}	24.06^{fg}	23.75^{d}	22.53^{c}	22.13^{c}	21.57^{ef}
P1T3	25.68^{ef}	24.53^{fghi}	25.69^{b}	24.73^{d}	23.59^{gh}	22.80^{fg}	21.45^{e}	21.30^{ef}	21.09^{fg}
P1T4	25.91^{e}	24.02^{i}	24.50^{c}	24.01^{fg}	23.12^{h}	22.53^{g}	21.22^{e}	21.03^{f}	20.50^{g}
P1T5	26.64^{cd}	25.27^{defg}	26.76^{a}	25.13^{c}	25.35^{c}	24.41^{c}	23.69^{b}	23.01^{b}	22.42^{cd}
P1T6	28.97^{a}	27.94^{a}	26.47^{a}	26.76^{a}	25.96^{b}	25.54^{b}	24.13^{ab}	23.37^{b}	23.21^{b}
P1T7	29.06^{a}	25.39^{def}	26.77^{a}	22.21^{h}	18.56^{j}	17.40^{i}	17.12^{g}	16.76^{h}	16.60^{i}
P2T1	25.05^{g}	24.44^{ghi}	24.35^{c}	24.20^{ef}	24.33^{ef}	23.80^{d}	22.12^{cd}	21.98^{cde}	21.75^{ef}
P2T2	25.84^{e}	25.50^{cde}	25.43^{b}	23.73^{g}	23.59^{gh}	23.18^{e}	22.64^{c}	22.22^{c}	22.05^{de}
P2T3	26.53^{d}	24.96^{defgh}	23.86^{d}	24.46^{de}	24.62^{de}	23.60^{d}	22.50^{c}	22.08^{cd}	21.69^{ef}
P2T4	25.02^{g}	25.84^{bcd}	24.38^{c}	23.96^{fg}	23.79^{g}	22.94^{ef}	22.11^{cd}	22.00^{cde}	21.30^{f}
P2T5	27.81^{b}	24.27^{hi}	26.64^{a}	25.18^{c}	24.94^{cd}	24.65^{c}	23.85^{ab}	23.15^{b}	22.75^{bc}
P2T6	28.92^{a}	26.35^{bc}	26.51^{a}	26.85^{a}	26.48^{a}	26.21^{a}	24.37^{a}	24.19^{a}	24.09^{a}
P2T7	26.94^{c}	25.76^{bcd}	26.75^{a}	22.41^{h}	22.40^{i}	20.17^{h}	19.05^{f}	18.63^{g}	18.23^{h}
SEm ±	0.10	0.28	0.11	0.13	0.15	0.11	0.17	0.22	0.21
CD (0.05)	0.31	0.84	0.34	0.39	0.46	0.35	0.51	0.66	0.63

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Due to halogen treatment (T)

As in seedling shoot length, seedling root length also decreased over storage irrespective of halogen treatment. T6 was superior from all other treatments with respect to root length from 4th month of storage. T5 was found to be the next best treatment with respect to root length (22.59 cm) at the end of storage.

Treatment T7 recorded the least root length (17.42 cm) at the end of storage period. However, untreated seeds (T1) recorded a root length of 21.19 cm and was on par with T4 (20.90 cm).

Due to interaction (P x T)

Maximum root length of 24.09 cm was recorded in P2T6 followed by P1T6 (23.21cm) at the end of storage period. P2T6 was on par with P2T5 (22.75 cm). The lowest root length was recorded in P1T7 (16.60 cm) at the end of storage period.

4.1.5 Seedling dry weight (mg)

The results on seedling dry weight as influenced by packing material, halogen treatment and their interaction effects during the storage period are presented in Table 9 and 10.

Due to packing material (P)

Seedling dry weight was influenced negatively due to increase in period of storage. Results indicated that seedling dry weight in P1 was superior over P2 from 7th month of storage. In P1, the seedling dry weight varied from 20.70 to 11.98 mg during storage while in P2 it varied from 20.75 to 13.03 mg.

Table 9: Influence of packing material and halogen treatment on seedling dry weight (mg) during storage in rice (*rabi*, 2013-14)

	Storage period (months)					
	M1	M2	M3	M4	M5	M6
	Packing material (P)					
P1	20.46	20.05	19.53	18.81	17.51	17.69
P2	20.59	20.24	20.03	19.49	18.38	18.80
SEm ±	0.09	0.08	0.06	0.05	0.07	0.09
CD (0.05)	NS	NS	NS	NS	NS	NS
	Halogen treatment (T)					
T1	20.55	20.13	19.78	18.73	16.85^{d}	16.65^{e}
T2	20.60	20.15	19.88	19.13	17.55^{c}	17.55^{d}
T3	20.43	20.08	19.70	18.90	17.08^{cd}	17.73^{d}
T4	20.35	20.00	19.55	18.95	16.78^{d}	17.13^{e}
T5	20.70	20.40	20.15	19.95	19.75^{a}	20.20^{a}
T6	20.43	20.18	19.83	19.10	18.48^{b}	18.93^{c}
T7	20.65	20.10	19.58	19.30	19.15^{a}	19.55^{b}
SEm ±	0.13	0.12	0.10	0.14	0.21	0.17
CD (0.05)	NS	NS	NS	NS	0.65	0.53

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 9: Influence of packing material and halogen treatment on seedling dry weight (mg) during storage in rice (*rabi*, 2013-14) (contd)

Treatments	Storage period (months)								
	M7	M8	M9	M10	M11	M12	M13	M14	M15
Packing materials (P)									
P1	17.34[b]	16.87[b]	16.41[b]	14.87[b]	14.36[b]	13.80[b]	12.56[b]	12.24[b]	11.98[b]
P2	18.57[a]	18.00[a]	17.33[a]	15.31[a]	15.24[a]	14.59[a]	13.81[a]	13.35[a]	13.03[a]
SEm ±	0.06	0.05	0.07	0.06	0.07	0.07	0.07	0.08	0.06
CD (0.05)	0.18	0.16	0.20	0.19	0.21	0.20	0.21	0.25	0.17
Halogen treatments (T)									
T1	16.25[e]	15.55[f]	15.75[d]	14.00[e]	13.65[e]	13.35[e]	12.65[cd]	12.55[bc]	12.25[cd]
T2	17.35[d]	16.50[e]	16.90[c]	14.00[e]	13.85[e]	13.30[e]	12.23[d]	12.20[cd]	11.90[de]
T3	17.50[d]	17.00[cd]	16.00[d]	15.00[c]	14.65[cd]	14.00[cd]	13.15[b]	13.10[b]	12.83[b]
T4	16.50[e]	16.75[de]	15.10[e]	14.55[d]	14.50[d]	13.70[de]	13.05[bc]	12.98[b]	12.60[bc]
T5	20.10[a]	20.00[a]	19.50[a]	17.00[a]	16.60[a]	16.00[a]	14.95[a]	14.93[a]	14.65[a]
T6	18.75[c]	19.00[b]	17.50[b]	15.75[b]	15.35[b]	14.60[b]	13.20[b]	11.83[d]	11.65[e]
T7	19.25[b]	17.25[c]	17.35[b]	15.35[bc]	15.00[bc]	14.40[bc]	13.05[bc]	11.98[d]	11.65[e]
SEm ±	0.12	0.11	0.14	0.13	0.14	0.14	0.14	0.18	0.12
CD (0.05)	0.38	0.34	0.43	0.40	0.44	0.42	0.44	0.54	0.37

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 10: Interaction effect of packing material and halogen treatment on seedling dry weight (mg) during storage in rice (*rabi*, 2013-14)

	Storage period (months)					
	M1	M2	M3	M4	M5	M6
			Interaction (P x T)			
P1T1	20.50	20.10	19.70^{bcd}	18.40^{d}	16.50^{fg}	15.40^{g}
P1T2	20.65	20.15	19.75^{bcd}	19.15^{c}	18.40^{d}	17.90^{d}
P1T3	20.40	20.00	19.50^{cde}	18.80^{cd}	17.60^{e}	17.10^{ef}
P1T4	20.15	19.75	19.15^{e}	18.75^{cd}	16.00^{g}	15.60^{g}
P1T5	20.70	20.20	19.75^{b}	19.45^{bc}	19.90^{b}	19.15^{bc}
P1T6	20.15	20.05	19.55^{cde}	18.25^{d}	17.80^{e}	17.10^{e}
P1T7	20.70	20.10	19.30^{de}	18.90^{c}	19.25^{c}	18.75^{c}
P2T1	20.60	20.15	19.85^{bc}	19.05^{c}	17.90^{de}	17.20^{ef}
P2T2	20.55	20.15	20.00^{b}	19.10^{c}	17.20^{f}	16.70^{f}
P2T3	20.45	20.15	19.90^{b}	19.00^{c}	17.85^{de}	17.05^{e}
P2T4	20.55	20.25	19.95^{b}	19.15^{c}	18.25^{de}	17.95^{d}
P2T5	20.70	20.60	20.55^{a}	20.45^{a}	20.50^{a}	20.35^{a}
P2T6	20.70	20.30	20.10^{b}	19.95^{ab}	20.05^{ab}	19.85^{ab}
P2T7	20.60	20.10	19.85	19.70^{b}	19.85^{b}	19.55^{b}
SEm ±	0.18	0.21	0.13	0.18	0.17	0.16
CD (0.05)	NS	NS	0.41	0.55	0.53	0.50

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 10: Interaction effect of packing material and halogen treatment on seedling dry weight (mg) during storage in rice (*rabi*, 2013-14) (contd)

Treatments	Storage period (months)										
	M7	M8	M9	M10	M11	M12	M13	M14	M15	Mean	Per cent reduction of dry weight
Interaction (P x T)											
P1T1	15.00^{f}	15.60^{gh}	15.70^{f}	13.50^{g}	13.00^{g}	13.20^{hi}	12.10^{i}	12.05^{fgh}	11.90^{g}	13.56	41.95
P1T2	17.70^{d}	17.00^{e}	16.80^{d}	14.50^{f}	13.50^{fg}	12.80^{i}	11.50^{i}	11.40^{h}	11.05^{h}	14.03	46.10
P1T3	17.50^{de}	16.50^{f}	15.50^{f}	14.50^{f}	14.00^{ef}	13.50^{gh}	12.80^{fgh}	12.75^{def}	12.45^{def}	14.39	39.27
P1T4	15.00^{f}	15.50^{h}	14.20^{g}	13.90^{g}	14.00^{ef}	13.20^{hi}	12.50^{ghi}	12.35^{ef}	12.10^{fg}	13.64	40.98
P1T5	19.70^{b}	20.00^{a}	19.00^{b}	16.50^{b}	16.00^{b}	15.50^{b}	14.20^{b}	14.15^{b}	14.00^{b}	16.56	31.71
P1T6	17.50^{de}	18.00^{c}	17.00^{d}	15.50^{cde}	15.00^{d}	14.30^{def}	12.30^{hi}	11.50^{gh}	11.25^{h}	14.71	45.12
P1T7	19.00^{c}	15.50^{h}	16.70^{d}	15.70^{cd}	15.00^{d}	14.10^{ef}	12.50^{ghi}	11.45^{gh}	11.10^{h}	14.56	45.85
P2T1	17.50^{de}	15.50^{h}	15.80^{f}	14.50^{f}	14.30^{e}	13.50^{gh}	13.20^{def}	13.05^{cde}	12.60^{de}	14.44	38.54
P2T2	17.00^{e}	16.00^{g}	17.00^{d}	13.50^{g}	14.20^{e}	13.80^{fg}	12.95^{efg}	13.00^{cde}	12.75^{cd}	14.47	37.80
P2T3	17.50^{de}	17.50^{d}	16.50^{de}	15.50^{cde}	15.30^{cd}	14.50^{cde}	13.50^{de}	13.45^{bcd}	13.20^{c}	15.22	35.61
P2T4	18.00^{d}	18.00^{c}	16.00^{ef}	15.20^{de}	15.00^{d}	14.20^{def}	13.60^{cd}	13.60^{bc}	13.10^{c}	15.19	36.10
P2T5	20.50^{a}	20.00^{a}	20.00^{a}	17.50^{a}	17.20^{a}	16.50^{a}	15.70^{a}	15.70^{a}	15.30^{a}	17.60	25.37
P2T6	20.00^{b}	20.00^{a}	18.00^{c}	16.00^{bc}	15.70^{bc}	14.90^{c}	14.10^{bc}	12.15^{fg}	12.05^{fg}	15.88	41.22
P2T7	19.50^{b}	19.00^{b}	18.00^{c}	15.00^{ef}	15.00^{d}	14.70^{cd}	13.60^{cd}	12.50^{ef}	12.20^{efg}	15.50	40.49
SEm ±	0.16	0.14	0.17	0.16	0.18	0.17	0.18	0.22	0.15		
CD (0.05)	0.48	0.42	0.53	0.50	0.56	0.52	0.56	0.67	0.46		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Due to halogen treatment (T)

Seedling dry weight decreased over storage irrespective of the halogenation treatment. T5 ($CaOCl_2$ + $CaCO_3$ @ 3 g each/kg seed) recorded the maximum seedling dry weight and was superior to all other treatments from 5th month of storage. T3 was found to be the next best treatment with respect to seedling dry weight (12.83 mg) at the end of storage while it was the least in T6 (11.65 mg) and T7 (11.65 mg). Treatments T6 and T7 were on par with each other at the end of storage period.

Due to interaction (P x T)

P2T5 was superior to all other treatments with respect to seedling dry weight from 3rd month of storage. The seedling dry weight in P2T5 varied from 20.70 mg (M1) to 15.30 mg (M15). P1T5 (14.00 mg) was the next best treatment. At the end of fifteen months of storage, the seedling dry weight of untreated seeds packed in jute bag (P1T1) was 11.90 mg and that in polyethylene bag (400G) (P2T1) was 12.60 mg. The lowest seedling dry weight was recorded in P1T2 (11.05 mg), P1T7 (11.10 mg) and P1T6 (11.25 mg). P1T2, P1T7 and P1T6 were on par with each other.

4.1.6 Vigour index I

The results on seedling vigour index I as influenced by packing material, halogen treatment and their interaction effects during the storage period are presented in Table 11 and 12.

Due to packing material (P)

Seedling vigour index I was observed to decrease with increase in storage period. The seedling vigour index I of seeds stored in P2 was found to be maximum and significantly superior over that in P1 from 7th month of storage. The seedling vigour index I decreased from 4903 to 1321 in P1 (jute bag) while the reduction was

Table 11: Influence of packing material and halogen treatment on vigour index I during storage in rice (*rabi*, 2013-14)

	Storage period (months)					
	M1	**M2**	**M3**	**M4**	**M5**	**M6**
Packing material (P)						
P1	4869	4779	4620	4475	4299	4253
P2	4960	4845	4657	4483	4406	4323
SEm ±	48	44	45	51	49	48
CD (0.05)	NS	NS	NS	NS	NS	NS
Halogen treatment (T)						
T1	4926	4801	4620	4423	4254	4173[b]
T2	4924	4825	4681	4467	4310	4223[b]
T3	4917	4790	4569	4417	4282	4185[b]
T4	4895	4792	4584	4406	4206	4168[b]
T5	4924	4852	4699	4542	4484	4428[a]
T6	4911	4808	4691	4598	4546	4492[a]
T7	4902	4816	4629	4500	4384	4348[ab]
SEm ±	102	96	87	78	85	82
CD (0.05)	NS	NS	NS	NS	NS	250

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 11: Influence of packing material and halogen treatment on vigour index I during storage in rice (*rabi*, 2013-14) (contd)

Treatments	Storage period (months)								
	M7	M8	M9	M10	M11	M12	M13	M14	M15
Packing materials (P)									
P1	3963[b]	3345[b]	3023[b]	2141[b]	1918[b]	1696[b]	1414[b]	1403[b]	1321[b]
P2	4084[a]	3779[a]	3619[a]	3281[a]	3119[a]	2848[a]	2428[a]	2333[a]	2213[a]
SEm ±	36	43	41	46	41	40	40	17	19
CD (0.05)	111	132	125	139	125	123	122	52	59
Halogen treatments (T)									
T1	3756[d]	3448[b]	3185[b]	2516[cd]	2336[c]	2013[a]	1592[cd]	1552[e]	1464[e]
T2	3937[cd]	3516[b]	3212[b]	2631[bc]	2444[bc]	2234[cd]	1898[b]	1747[d]	1602[d]
T3	4033[bc]	3555[b]	3230[b]	2922[b]	2714[b]	2385[c]	2031[b]	2033[b]	1984[b]
T4	3882[cd]	3423[b]	3099[b]	2264[de]	2228[c]	2081[d]	1764[bc]	1890[c]	1818[c]
T5	4371[a]	3977[a]	3901[a]	3699[a]	3548[a]	3352[b]	3032[a]	2977[a]	2749[a]
T6	4203[ab]	3545[b]	3343[b]	2795[bc]	2459[bc]	2211[cd]	1793[bc]	1575[e]	1493[de]
T7	3986[bcd]	3469[b]	3281[b]	2151[e]	1904[d]	1629[e]	1337[d]	1307[f]	1262[f]
SEm ±	77	91	102	96	86	85	85	36	41
CD (0.05)	234	279	312	294	264	261	259	109	124

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 12: Interaction effect of packing material and halogen treatment on vigour index I during storage in rice (*rabi*, 2013-14)

	Storage period (months)					
	M1	M2	M3	M4	M5	M6
			Interaction (P x T)			
P1T1	4885	4764	4645	4429	4228	4143[b]
P1T2	4879	4771	4635	4493	4250	4198[b]
P1T3	4873	4802	4581	4460	4246	4124[b]
P1T4	4845	4765	4568	4400	4084	4089[b]
P1T5	4877	4803	4625	4455	4385	4319[ab]
P1T6	4861	4767	4668	4568	4532	4528[a]
P1T7	4861	4782	4622	4520	4367	4375[ab]
P2T1	4966	4837	4595	4416	4279	4203[b]
P2T2	4968	4880	4727	4441	4370	4249[ab]
P2T3	4962	4779	4556	4373	4318	4246[ab]
P2T4	4944	4819	4601	4412	4328	4248[ab]
P2T5	4971	4902	4773	4629	4584	4537[a]
P2T6	4962	4851	4714	4629	4560	4456[a]
P2T7	4943	4850	4637	4479	4401	4320[ab]
SEm ±	123	115	109	105	98	102
CD (0.05)	NS	NS	NS	NS	NS	312

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 12: Interaction effect of packing material and halogen treatment on vigour index I during storage in rice (*rabi*, 2013-14) (contd)

Treatments	Storage period (months)									
	M7	M8	M9	M10	M11	M12	M13	M14	M15	Mean	Per cent reduction of VI I
Interaction (P x T)											
P1T1	3688^{e}	3230^{de}	2904^{e}	1984^{e}	1767^{e}	1439^{fg}	1029^{f}	1086^{i}	1004^{h}	2015	78.13
P1T2	3870^{cde}	3208^{e}	2869^{e}	2194^{e}	1921^{e}	1718^{ef}	1437^{e}	1263^{h}	1192^{g}	2186	74.04
P1T3	3963^{bcde}	3229^{de}	2785^{e}	2307^{e}	1993^{c}	1682^{ef}	1532^{de}	1516^{g}	1446^{f}	2273	68.50
P1T4	3929^{bcde}	3171^{e}	2851^{e}	1403^{f}	1201^{f}	1140^{gh}	950^{f}	1343^{h}	1321^{fg}	1923	71.23
P1T5	4170^{bc}	3925^{a}	3681^{b}	3423^{bc}	3319^{b}	3052^{b}	2664^{b}	2690^{b}	2443^{bc}	3263	46.79
P1T6	4198^{bc}	3404^{bcde}	3097^{cde}	2247^{c}	1997^{e}	1791^{e}	1397^{e}	1060^{i}	987^{h}	2242	78.50
P1T7	3923^{bcde}	3245^{cde}	2974^{de}	1426^{f}	1231^{f}	1047^{h}	889^{f}	864^{j}	855^{h}	1828	81.38
P2T1	3823^{de}	3665^{abcd}	3466^{bc}	3047^{cd}	2905^{cd}	2587^{c}	2154^{c}	2017^{e}	1924^{d}	2843	58.53
P2T2	4003^{bcde}	3824^{ab}	3554^{b}	3067^{cd}	2966^{c}	2749^{bc}	2359^{bc}	2231^{d}	2011^{d}	2974	56.66
P2T3	4102^{bcd}	3881^{a}	3674^{b}	3537^{b}	3434^{b}	3087^{b}	2530^{b}	2549^{c}	2521^{b}	3257	45.67
P2T4	3835^{de}	3675^{abcd}	3346^{bcd}	3124^{cd}	3254^{bc}	3021^{b}	2578^{b}	2436^{c}	2315^{c}	3065	50.11
P2T5	4571^{a}	4029^{a}	4121^{a}	3974^{a}	3777^{a}	3652^{a}	3400^{a}	3263^{a}	3055^{a}	3760	34.16
P2T6	4208^{b}	3686^{abc}	3588^{b}	3343^{bc}	2921^{cd}	2631^{c}	2189^{c}	2089^{e}	1998^{d}	2961	56.94
P2T7	4048^{bcd}	3692^{abc}	3587^{b}	2875^{d}	2576^{d}	2211^{d}	1784^{d}	1749^{f}	1668^{e}	2688	64.05
SEm ±	96	135	127	120	108	107	106	45	51		
CD (0.05)	293	411	389	367	330	326	323	137	155		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

from 4984 to 2213 mg in P2 (polyethylene bag of 400G).

Due to halogen treatment (T)

Seedling vigour index I decreased over storage irrespective of the halogenation treatment. T5 ($CaOCl_2$ + $CaCO_3$ @ 3 g each/kg seed) recorded the maximum seedling vigour index I and was superior to all other treatments from 6th month of storage. T3 was

found to be the next best treatment with respect to seedling vigour index I (1984) at the end of storage. The least seedling vigour index I was recorded in T1 (1464).

Due to interaction (P x T)

P2T5 was superior to all other treatments with respect to seedling vigour index I from 6th month of storage. The seedling vigour index I in P2T5 varied from 4971 (M1) to 3055 (M15). P2T3 (2521) and P1T5 (2443) were the next best treatments. P2T3 and P1T5 were on par with each other. The lowest seedling vigour index I was recorded in P1T7 (855) and P1T6 (987) which were on par with each other. At the end of storage, the seedling vigour index I of untreated seeds packed in jute bag (P1T1) was 1004 and that in polyethylene bag (400G) (P2T1) was 1924.

4.1.7 Vigour index II

The results on seedling vigour index II as influenced by packing material, halogen treatment and their interaction effects during the storage period are presented in Table 13 and 14.

Due to packing material (P)

Seedling vigour index II was observed to decrease with increase in storage period. The seedling vigour index II of seeds stored in P2 was found to be maximum and significantly superior to that in P1 from 6th month of storage. The seedling vigour

Table 13: Influence of packing material and halogen treatment on vigour index II during storage in rice (*rabi*, 2013-14)

	Storage period (months)					
	M1	**M2**	**M3**	**M4**	**M5**	**M6**
	Packing material (P)					
P1	1989	1945	1893	1824	1690	1698[b]
P2	2010	1971	1948	1895	1779	1809[a]
SEm ±	33	29	31	26	29	32
CD (0.05)	NS	NS	NS	NS	NS	97
	Halogen treatment (T)					
T1	2002	1954	1918	1814	1625[b]	1598[b]
T2	2006	1959	1931	1858	1698[b]	1685[b]
T3	1989	1953	1916	1838	1653[b]	1704[b]
T4	1982	1942	1897	1839	1620[b]	1646[b]
T5	2017	1985	1960	1941	1917[a]	1955[a]
T6	1989	1961	1925	1855	1789[ab]	1817[a]
T7	2011	1951	1897	1870	1843[a]	1869[a]
SEm ±	59	51	53	45	65	48
CD (0.05)	NS	NS	NS	NS	197	146

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 13: Influence of packing material and halogen treatment on vigour index II during storage in rice (*rabi*, 2013-14) (contd)

Treatments	Storage period (months)								
	M7	M8	M9	M10	M11	M12	M13	M14	M15
Packing material (P)									
P1	1600^{b}	1384^{b}	1224^{b}	816^{b}	737^{b}	644^{b}	520^{b}	518^{b}	486^{b}
P2	1747^{a}	1640^{a}	1523^{a}	1270^{a}	1218^{a}	1099^{a}	924^{a}	901^{a}	845^{a}
SEm ±	16	17	20	19	15	17	17	10	15
CD (0.05)	48	52	62	58	45	53	52	30	46
Halogen treatment (T)									
T1	1480^{e}	1337^{d}	1277^{cd}	932^{c}	870^{cd}	751^{c}	617^{c}	597^{cd}	556^{cd}
T2	1614^{cd}	1416^{cd}	1354^{bc}	947^{c}	906^{cd}	818^{bc}	670^{bc}	647^{c}	582^{c}
T3	1680^{bc}	1483^{c}	1287^{bcd}	1103^{b}	1022^{b}	891^{b}	741^{b}	752^{b}	724^{b}
T4	1534de	1412^{cd}	1183^{d}	859^{c}	854^{d}	754^{c}	652^{bc}	724^{b}	688^{b}
T5	1951^{a}	1880^{a}	1738^{a}	1500^{a}	1414^{a}	1316^{a}	1143^{a}	1140^{a}	1059^{a}
T6	1726^{b}	1600^{b}	1420^{b}	1075^{b}	955^{bc}	835^{bc}	655^{bc}	549^{d}	518^{d}
T7	1733^{b}	1456^{c}	1358^{bc}	885^{c}	825^{d}	739^{c}	581^{c}	559^{d}	531^{cd}
SEm ±	33	36	43	41	31	37	36	21	17
CD (0.05)	102	110	131	124	95	112	109	63	52

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 14: Interaction effect of packing material and halogen treatment on vigour index II during storage in rice (*rabi*, 2013-14)

	Storage period (months)					
	M1	**M2**	**M3**	**M4**	**M5**	**M6**
Interaction (P x T)						
P1T1	1993	1945	1905	1776	1586[b]	1471[c]
P1T2	2007	1956	1916	1858	1777[a]	1714[b]
P1T3	1983	1942	1893	1825	1650[b]	1681[bc]
P1T4	1959	1916	1858	1819	1505[b]	1532[c]
P1T5	2012	1961	1917	1888	1858[a]	1925[a]
P1T6	1959	1945	1896	1770	1655[b]	1722[b]
P1T7	2012	1948	1868	1830	1804[a]	1843[a]
P2T1	2011	1964	1930	1853	1664[b]	1727[b]
P2T2	2006	1963	1946	1858	1618[b]	1656[bc]
P2T3	1996	1964	1938	1851	1656[b]	1727[b]
P2T4	2006	1967	1937	1859	1736[a]	1761[b]
P2T5	2022	2009	2004	1994	1977[a]	1984[a]
P2T6	2020	1977	1954	1939	1922[a]	1910[a]
P2T7	2011	1954	1925	1911	1882[a]	1896[a]
SEm ±	92	89	87	84	83	81
CD (0.05)	NS	NS	NS	NS	254	212

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 14: Interaction effect of packing material and halogen treatment on vigour index II during storage in rice (*rabi*, 2013-14) (contd)

Treatments	Storage period (months)								
	M7	M8	M9	M10	M11	M12	M13	M14	M15
Interaction (P x T)									
P1T1	1350^{c}	1279^{hi}	1194de	703^{ef}	624^{ef}	529^{f}	388^{e}	410^{g}	381^{e}
P1T2	1628^{d}	1327^{ghi}	1209de	813^{e}	703^{def}	614^{ef}	484de	434^{fg}	398^{e}
P1T3	1680^{cd}	1320^{ghi}	1055^{ef}	842^{e}	728de	622^{ef}	563^{d}	561^{e}	523^{d}
P1T4	1410^{e}	1240^{i}	1022^{f}	500^{g}	448^{g}	371^{g}	350^{e}	494^{ef}	484^{d}
P1T5	1852^{b}	1840^{ab}	1596^{b}	1354^{b}	1279^{b}	1179^{b}	967^{b}	991^{b}	924^{b}
P1T6	1610^{d}	1439^{fg}	1291^{d}	869^{e}	779^{d}	686^{e}	491de	368^{g}	337^{e}
P1T7	1672^{cd}	1240^{i}	1203de	629^{fg}	600^{f}	507^{fg}	400^{e}	367^{g}	355^{e}
P2T1	1610^{d}	1395^{fgh}	1359^{cd}	1160^{cd}	1116^{c}	972^{d}	845^{bc}	783^{cd}	731^{c}
P2T2	1599^{d}	1505^{ef}	1498^{bc}	1081^{d}	1108^{c}	1021^{cd}	855^{bc}	859^{c}	765^{c}
P2T3	1680^{cd}	1646^{cde}	1518^{bc}	1364^{b}	1316^{b}	1160^{bc}	919^{b}	943^{b}	925^{b}
P2T4	1657^{cd}	1584de	1343^{cd}	1217^{bcd}	1259^{b}	1136^{bc}	953^{b}	953^{b}	891^{b}
P2T5	2050^{a}	1920^{a}	1880^{a}	1645^{a}	1548^{a}	1452^{a}	1319^{a}	1288^{a}	1194^{a}
P2T6	1841^{b}	1760^{bc}	1549^{b}	1280^{bc}	1131^{c}	984^{d}	818^{bc}	729^{d}	699^{c}
P2T7	1794^{bc}	1672^{cd}	1512^{bc}	1140^{cd}	1049^{c}	970^{d}	762^{c}	750^{d}	707^{c}
SEm ±	42	45	54	51	39	46	45	26	21
CD (0.05)	128	137	164	155	118	140	137	79	64

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

index II decreased from 2013 to 486 in P1 (jute bag) while the reduction was from 2028 to 845 mg in P2 (polyethylene bag of 400G).

Due to halogen treatment (T)

Seedling vigour index II decreased over storage irrespective of the halogenation treatment. T5 ($CaOCl_2$ + $CaCO_3$ @ 3 g each/kg seed) recorded the maximum seedling vigour index II and was superior to all other treatments from 5th month of storage. Treatments T3 (724) and T4 (688) were found to be the next best treatment with respect to seedling vigour index II at the end of storage. The least seedling vigour index II was recorded in T6 (518), T7 (531) and T1 (556) which were on par with each other.

Due to interaction (P x T)

P2T5 was superior to all other treatments with respect to seedling vigour index II from 5th month of storage. The seedling vigour index II in P2T5 varied from 2022 (M1) to 1194 (M15). P2T3 (925), P1T5 (924) and P2T4 (891) were the next best treatments. P2T3, P1T5 and P2T4 were on par with each other. The lowest seedling vigour index II was recorded in P1T6 (337), P1T7 (355), P1T1 (381) and P1T2 (398) which were on par with each other. At the end of storage, the seedling vigour index II of untreated seeds packed in polyethylene bag (400G) (P2T1) was 731.

4.1.8 Electrical conductivity of seed leachate (dSm^{-1})

The results on electrical conductivity as influenced by packing material, halogen treatment and their interaction effects during the storage period are presented in Table 15 and 16.

Table 15: Influence of packing material and halogen treatment on electrical conductivity of seed leachate (dSm^{-1}) during storage in rice (*rabi*, 2013-14)

	Storage period (months)					
	M1	M2	M3	M4	M5	M6
Packing material (P)						
P1	0.0245	0.0295	0.0324	0.0351[a]	0.0393[a]	0.0445[a]
P2	0.0240	0.0290	0.0320	0.0346[b]	0.0390[b]	0.0442[b]
SEm ±	0.0022	0.0019	0.0017	0.0016	0.0011	0.0012
CD (0.05)	NS	NS	NS	0.0050	0.0040	0.0049
Halogen treatment (T)						
T1	0.0226	0.0255	0.0282	0.0313	0.0321	0.0334
T2	0.0226	0.0235	0.0252	0.0265	0.0281	0.0291
T3	0.0233	0.0251	0.0269	0.0285	0.0317	0.0341
T4	0.0237	0.0262	0.0327	0.0386	0.0441	0.0513
T5	0.0209	0.0217	0.0214	0.0215	0.0223	0.0228
T6	0.0242	0.0334	0.0362	0.0378	0.0445	0.0518
T7	0.0248	0.0350	0.0408	0.0444	0.0537	0.0616
SEm ±	0.0015	0.0011	0.0007	0.0006	0.0005	0.0007
CD (0.05)	NS	NS	0.0020	0.0017	0.0014	0.0018

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 15: Influence of packing material and halogen treatment on electrical conductivity of seed leachate (dSm^{-1}) during storage in rice (*rabi*, 2013-14) (contd)

Treatments	Storage period (months)								
	M7	M8	M9	M10	M11	M12	M13	M14	M15
Packing material (P)									
P1	0.0483^{a}	0.0537^{a}	0.0555^{a}	0.0601^{a}	0.0662	0.0669^{a}	0.0684^{a}	0.0706^{a}	0.0802^{a}
P2	0.0397^{b}	0.0437^{b}	0.0475^{b}	0.0532^{b}	0.0745	0.0624^{b}	0.0634^{b}	0.0646^{b}	0.0671^{b}
SEm ±	0.0005	0.0009	0.0006	0.0005	0.0120	0.0005	0.0007	0.0007	0.0007
CD (0.05)	0.0014	0.0027	0.0018	0.0015	NS	0.0014	0.0022	0.0022	0.0022
Halogen treatment (T)									
T1	0.0338^{c}	0.0365^{d}	0.0378^{d}	0.0404^{e}	0.0466	0.0449^{e}	0.0465^{cd}	0.0475^{e}	0.0521^{e}
T2	0.0305^{d}	0.0323^{d}	0.0332^{e}	0.0365^{f}	0.0365	0.0415^{f}	0.0448^{d}	0.0471^{e}	0.0498^{e}
T3	0.0358^{c}	0.0439^{c}	0.0415^{d}	0.0446^{d}	0.0470	0.0510^{d}	0.0508^{c}	0.0530^{d}	0.0592^{d}
T4	0.0556^{b}	0.0587^{b}	0.0597^{c}	0.0682^{c}	0.0826	0.0847^{c}	0.0870^{b}	0.0866^{c}	0.0898^{c}
T5	0.0233^{e}	0.0263^{e}	0.0292^{f}	0.0293^{g}	0.0307	0.0319^{g}	0.0321^{e}	0.0358^{f}	0.0391^{f}
T6	0.0579^{b}	0.0602^{b}	0.0648^{b}	0.0717^{b}	0.0869	0.0885^{b}	0.0904^{b}	0.0936^{b}	0.1052^{b}
T7	0.0711^{a}	0.0830^{a}	0.0945^{a}	0.1060^{a}	0.1140	0.1103^{a}	0.1098^{a}	0.1096^{a}	0.1205^{a}
SEm ±	0.0010	0.0018	0.0013	0.0010	0.0224	0.0010	0.0016	0.0015	0.0015
CD (0.05)	0.0030	0.0055	0.0039	0.0032	NS	0.0030	0.0049	0.0046	0.0046

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 16: Interaction effect of packing material and halogen treatment on electrical conductivity of seed leachate (dSm^{-1}) during storage in rice (*rabi*, 2013-14)

	Storage period					
	M1	M2	M3	M4	M5	M6
Interaction (P x T)						
P1T1	0.0241	0.0275	0.0297^{d}	0.0328^{d}	0.0331^{f}	0.0343^{g}
P1T2	0.0239	0.0256	0.0289^{d}	0.0311^{de}	0.0341^{f}	0.0356^{g}
P1T3	0.0245	0.0271	0.0298^{d}	0.0324^{d}	0.0378^{e}	0.0413^{e}
P1T4	0.0251	0.0278	0.0342^{c}	0.0416^{b}	0.0471^{c}	0.0527^{c}
P1T5	0.0211	0.0221	0.0210^{g}	0.0209^{g}	0.0211^{i}	0.0213^{k}
P1T6	0.0259	0.0378	0.0412^{ab}	0.0435^{ab}	0.0512^{b}	0.0645^{a}
P1T7	0.0267	0.0389	0.0423^{a}	0.0431^{b}	0.0507^{b}	0.0619^{b}
P2T1	0.0210	0.0235	0.0267^{e}	0.0298^{e}	0.0311^{g}	0.0324^{h}
P2T2	0.0212	0.0214	0.0215^{g}	0.0218^{g}	0.0221^{hi}	0.0225^{jk}
P2T3	0.0220	0.0231	0.0240^{f}	0.0245^{f}	0.0256	0.0268^{i}
P2T4	0.0222	0.0245	0.0312^{d}	0.0356^{c}	0.0411^{d}	0.0499^{d}
P2T5	0.0207	0.0212	0.0218^{g}	0.0221^{g}	0.0234^{h}	0.0243^{j}
P2T6	0.0224	0.0289	0.0311^{d}	0.0321^{d}	0.0378^{e}	0.0391^{f}
P2T7	0.0229	0.0311	0.0393^{b}	0.0456^{a}	0.0567^{a}	0.0612^{b}
SEm ±	0.0012	0.0011	0.0009	0.0007	0.0005	0.0007
CD (0.05)	NS	NS	0.0025	0.0022	0.0018	0.0022

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 16: Interaction effect of packing material and halogen treatment on electrical conductivity of seed leachate (dSm^{-1}) during storage in rice (*rabi*, 2013-14) (contd)

Treatments	Storage period (months)								
	M7	M8	M9	M10	M11	M12	M13	M14	M15
***Interaction* (P x T)**									
P1T1	0.0347^{fg}	0.0377^{ef}	0.0394^{e}	0.0400^{c}	0.0488	0.0473^{d}	0.0491^{cd}	0.0500^{fg}	0.0582^{de}
P1T2	0.0382^{ef}	0.0390^{ef}	0.0396^{e}	0.0473^{d}	0.0471	0.0495^{d}	0.0532^{c}	0.0570^{e}	0.0616^{d}
P1T3	0.0432^{d}	0.0512^{cd}	0.0479^{d}	0.0498^{d}	0.0494	0.0506^{d}	0.0513^{c}	0.0540^{ef}	0.0637^{d}
P1T4	0.0568^{c}	0.0583^{c}	0.0594^{c}	0.0700^{c}	0.0848	0.0873^{b}	0.0877^{b}	0.0866^{d}	0.0910^{c}
P1T5	0.0210^{j}	0.0286^{gh}	0.0320^{fg}	0.0308^{f}	0.0322	0.0340^{f}	0.0336^{e}	0.0396^{hi}	0.0444^{fg}
P1T6	0.0747^{a}	0.0757^{b}	0.0749^{b}	0.0756^{b}	0.0885	0.0883^{b}	0.0907^{b}	0.0921^{cd}	0.1153^{b}
P1T7	0.0695^{b}	0.0855^{a}	0.0955^{a}	0.1070^{a}	0.1125	0.1115^{a}	0.1130^{a}	0.1146^{a}	0.1270^{a}
P2T1	0.0329^{g}	0.0353^{fg}	0.0362^{ef}	0.0408^{c}	0.0444	0.0424^{c}	0.0439^{d}	0.0449^{gh}	0.0460^{f}
P2T2	0.0228^{ij}	0.0255^{h}	0.0268^{g}	0.0257^{g}	0.0258	0.0335^{f}	0.0364^{e}	0.0372^{ij}	0.0380^{gh}
P2T3	0.0283^{h}	0.0365^{efg}	0.0351^{ef}	0.0393^{c}	0.0445	0.0514^{d}	0.0502^{cd}	0.0520^{ef}	0.0546^{e}
P2T4	0.0543^{c}	0.0591^{c}	0.0599^{c}	0.0663^{c}	0.0803	0.0821^{c}	0.0863^{b}	0.0865^{d}	0.0886^{c}
P2T5	0.0255^{hi}	0.0240^{h}	0.0264^{g}	0.0278^{fg}	0.0291	0.0298^{f}	0.0306^{e}	0.0319^{j}	0.0337^{h}
P2T6	0.0411^{de}	0.0447^{de}	0.0547^{c}	0.0678^{c}	0.0852	0.0886^{b}	0.0900^{b}	0.0950^{c}	0.0950^{c}
P2T7	0.0727^{ab}	0.0805^{ab}	0.0934^{a}	0.1050^{a}	0.1155	0.1090^{a}	0.1065^{a}	0.1045^{b}	0.1140^{b}
SEm ±	0.0014	0.0026	0.0018	0.0013	0.0966	0.0014	0.0022	0.0021	0.0021
CD (0.05)	0.0043	0.0080	0.0054	0.0040	NS	0.0043	0.0067	0.0065	0.0065

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Due to packing material (P)

The electrical conductivity of seed leachate was observed to increase with increase in storage period. The electrical conductivity of seed leachate of seeds stored in P2 was found to be minimum and significantly superior over that in P1 from 4th month of storage except 11th month. The electrical conductivity of seed leachate increased from 0.0230 dSm^{-1} to 0.0802 dSm^{-1} in P1 (jute bag) while the increase was from 0.0200 dSm^{-1} to 0.0671 dSm^{-1} in P2 (polyethylene bag of 400G).

Due to halogen treatment (T)

Electrical conductivity of seed leachate increased over storage irrespective of the halogenation treatment. At each month of storage, T5 ($CaOCl_2$ + $CaCO_3$ @ 3 g each/kg seed) recorded the minimum electrical conductivity of seed leachate and was superior to all other treatments from 3rd month of storage except 11th month. T2 (0.0498 dSm^{-1}) and T1 (0.0521 dSm^{-1}) were found to be the next best treatment with respect to electrical conductivity of seed leachate at the end of storage. T1 and T2 were on par with each other. The highest electrical conductivity of seed leachate was recorded in T7 (0.1205 dSm^{-1}) followed by T6 (0.1052 dSm^{-1}).

Due to interaction (P x T)

P2T5 was superior to all other treatments with respect to electrical conductivity of seed leachate from 3rd month of storage except 11th month. The electrical conductivity of seed leachate in P2T5 varied from 0.0207 dSm^{-1} (M1) to 0.0337 dSm^{-1} (M11). At the end of fifteen months of storage, P2T2 (0.0380 dSm^{-1}) was the next best treatment which was on par with P2T5 followed by P1T5 (0.0444 dSm^{-1}). The highest electrical conductivity of seed leachate was recorded in P1T7 (0.1270 dSm^{-1}) followed by P1T6 (0.1153 dSm^{-1}) and P2T6 (0.1140 dSm^{-1}). P1T6 and P2T6 were on par with each other. At the end of storage, the electrical conductivity of seed leachate of untreated seeds packed in jute bag (P1T1) was 0.0582 dSm^{-1} and that in polyethylene bag (P2T2) was 0.0460 dSm^{-1}.

4.1.9 Moisture content

The results on seed moisture content as influenced by packing material, halogen treatment and their interaction effects during the storage period are presented in Table 17 and 18.

Due to packing material (P)

The moisture content of seed was observed to increase with increase in storage period. The moisture content of seeds stored in P2 was found to be minimum and significantly superior over that in P1 during each month of storage. The seed moisture content increased from 12.5 to 14.3 per cent in P1 (jute bag) while the increase was from 10.0 to 10.7 per cent in P2 (polyethylene bag of 400G).

Due to halogen treatment (T)

Seed moisture content increased over storage irrespective of the halogenation treatment. Treatment T5 ($CaOCl_2$ + $CaCO_3$ @ 3 g each/kg seed) recorded the minimum seed moisture content and was superior to all other treatments from 2nd month of storage. T2 (12.1%) was found to be the next best treatment with respect to seed moisture content at the end of storage. The highest seed moisture content was recorded in T7 (13.3%).

Due to interaction (P x T)

P2T5 was superior to all other treatments with respect to seed moisture content throughout the storage period. The moisture content of seed in P2T5 varied from 10.0 per cent (M1) to 10.5 per cent (M11). All the treatment combinations involving polyethylene bag maintained the moisture content throughout the storage period. The highest seed moisture content was recorded in P1T7 (15.7%).

Table 17: Influence of packing material and halogen treatment on moisture content (%) during storage in rice (*rabi*, 2013-14)

	Storage period (months)					
	M1	**M2**	**M3**	**M4**	**M5**	**M6**
Packing material (P)						
P1	12.4[a]	13.0[a]	13.8[a]	14.6[a]	15.4[a]	16.2[a]
P2	10.0[b]	10.0[b]	10.0[b]	10.0[b]	10.1[b]	10.1[b]
SEm ±	0.46	0.34	0.45	0.50	0.49	0.65
CD (0.05)	1.06	0.76	1.04	1.15	1.14	1.56
Halogen treatment (T)						
T1	11.2	11.4[b]	11.6[c]	11.9[c]	12.3[c]	13.1[ab]
T2	11.2	11.5[b]	11.9[bc]	12.4[ab]	12.6[bc]	12.9[b]
T3	11.2	11.4[b]	12.0[b]	12.3[bc]	12.7[bc]	12.9[b]
T4	11.3	11.9[a]	12.5[a]	12.8[a]	13.3[a]	13.6[a]
T5	11.2	11.4[b]	11.5[c]	12.1[bc]	12.4[bc]	13.0[b]
T6	11.2	11.4[b]	11.9[bc]	12.4[b]	12.8[b]	13.2[ab]
T7	11.3	11.7[a]	12.1[b]	12.7[a]	13.2[a]	13.6[a]
SEm ±	0.08	0.09	0.11	0.13	0.13	0.21
CD (0.05)	NS	0.27	0.38	0.41	0.41	0.56

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 17: Influence of packing material and halogen treatment on moisture content (%) during storage in rice (*rabi*, 2013-14) (contd)

Treatments	Storage period (months)								
	M7	M8	M9	M10	M11	M12	M13	M14	M15
Packing materials (P)									
P1	16.6^{a}	16.2^{a}	16.0^{a}	16.1^{a}	15.2^{a}	14.1^{a}	14.2^{a}	14.3^{a}	14.3^{a}
P2	10.1^{b}	10.2^{b}	10.3^{b}	10.3^{b}	10.4^{b}	10.4^{b}	10.5^{b}	10.6^{b}	10.7^{b}
SEm ±	0.09	0.08	0.08	0.05	0.05	0.07	0.08	0.08	0.08
CD (0.05)	0.23	0.20	0.21	0.16	0.15	0.17	0.20	0.19	0.21
Halogen treatment (T)									
T1	13.3^{b}	13.3^{b}	12.9^{c}	12.7^{c}	12.4^{c}	12.3^{c}	12.3^{c}	12.5^{c}	12.5^{d}
T2	13.0^{c}	12.9^{c}	12.6^{d}	12.4^{d}	12.3^{d}	11.9^{de}	11.9^{d}	12.1^{d}	12.1^{f}
T3	13.0^{c}	12.9^{c}	13.2^{b}	13.5^{b}	12.7^{b}	12.5^{b}	12.5^{b}	12.6^{bc}	12.6^{c}
T4	13.7^{a}	13.7^{a}	13.8^{a}	14.0^{a}	13.7^{c}	12.0^{d}	12.0^{d}	12.1^{d}	12.2^{e}
T5	13.1^{c}	12.7^{d}	12.6^{d}	12.7^{c}	12.4^{d}	11.8^{e}	11.9^{d}	12.0^{d}	12.0^{g}
T6	13.4^{b}	13.3^{b}	13.0^{c}	13.4^{b}	12.7^{bc}	12.4^{bc}	12.5^{b}	12.7^{b}	12.8^{b}
T7	13.8^{a}	13.8^{a}	13.9^{a}	13.9^{a}	13.2^{a}	13.0^{a}	13.1^{a}	13.1^{a}	13.3^{a}
SEm ±	0.13	0.19	0.20	0.10	0.11	0.20	0.21	0.11	0.14
CD (0.05)	0.40	0.52	0.53	0.40	0.43	0.53	0.55	0.42	0.48

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 18: Interaction effect of packing material and halogen treatment on moisture content (%) during storage in rice (*rabi*, 2013-14)

	Storage period (months)					
	M1	M2	M3	M4	M5	M6
Interaction (P x T)						
P1T1	12.4[b]	12.8[c]	13.1[c]	13.7[c]	14.5[c]	16.0[b]
P1T2	12.3[c]	12.9[c]	13.8[b]	14.7[b]	15.1[b]	15.6[b]
P1T3	12.4[b]	12.7[c]	13.9[b]	14.5[b]	15.2[b]	15.7[b]
P1T4	12.5[a]	13.8[a]	15.0[a]	15.5[a]	16.5[a]	17.0[a]
P1T5	12.4[b]	12.7[c]	13.0[c]	14.1[c]	14.8[c]	15.9[b]
P1T6	12.4[b]	12.8[c]	13.7[b]	14.8[b]	15.4[b]	16.3[b]
P1T7	12.5[a]	13.3[b]	14.1[b]	15.2[a]	16.3[a]	17.1[a]
P2T1	10.0[d]	10.0[d]	10.0[d]	10.1[d]	10.1[d]	10.1[c]
P2T2	10.0[d]	10.0[d]	10.0[d]	10.0[d]	10.0[d]	10.1[c]
P2T3	10.0[d]	10.0[d]	10.0[d]	10.0[d]	10.1[d]	10.1[c]
P2T4	10.0[d]	10.0[d]	10.0[d]	10.0[d]	10.1[d]	10.1[c]
P2T5	10.0[d]	10.0[d]	10.0[d]	10.1[d]	10.0[d]	10.0[c]
P2T6	10.0[d]	10.0[d]	10.0[d]	10.0[d]	10.1[d]	10.1[c]
P2T7	10.0[d]	10.0[d]	10.0[d]	10.1[d]	10.1[d]	10.1[c]
SEm ±	0.16	0.11	0.15	0.18	0.17	0.32
CD (0.05)	0.48	0.34	0.47	0.52	0.51	0.70

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 18: Interaction effect of packing material and halogen treatment on moisture content (%) during storage in rice (*rabi*, 2013-14) (contd)

Treatments	Storage period (months)								
	M7	M8	M9	M10	M11	M12	M13	M14	M15
	Interaction (P x T)								
P1T1	16.4^{bc}	16.2^{c}	15.4^{d}	15.0^{e}	14.2^{f}	14.0^{d}	14.0^{d}	14.2^{c}	14.2^{d}
P1T2	15.9^{d}	15.7^{d}	15.0^{e}	14.6^{f}	14.5^{e}	13.5^{e}	13.6^{e}	13.7^{d}	13.6^{e}
P1T3	16.0^{d}	15.4^{e}	16.0^{b}	16.6^{c}	15.1^{c}	14.7^{b}	14.6^{b}	14.7^{b}	14.6^{c}
P1T4	17.3^{a}	17.2^{a}	17.4^{a}	17.8^{a}	17.1^{a}	13.6^{e}	13.7^{e}	13.7^{d}	13.6^{e}
P1T5	16.2^{cd}	15.3^{e}	15.1^{e}	15.3^{e}	14.6^{e}	13.4^{e}	13.4^{f}	13.5^{e}	13.5^{e}
P1T6	16.7^{b}	16.5^{b}	15.7^{c}	16.4^{d}	14.9^{d}	14.3^{c}	14.4^{c}	14.8^{b}	14.8^{b}
P1T7	17.5^{a}	17.4^{a}	17.5^{a}	17.4^{b}	16.0^{b}	15.4^{a}	15.5^{a}	15.6^{a}	15.7^{a}
P2T1	10.2^{e}	10.3^{f}	10.3^{fg}	10.5^{g}	10.5^{g}	10.5^{f}	10.7^{g}	10.8^{f}	10.8^{g}
P2T2	10.1^{e}	10.2^{f}	10.2^{g}	10.2^{h}	10.2^{h}	10.2^{g}	10.3^{i}	10.6^{gh}	10.7^{gh}
P2T3	10.1^{e}	10.4^{f}	10.4^{f}	10.4^{gh}	10.4^{g}	10.4^{fg}	10.5^{ghi}	10.5^{h}	10.6^{h}
P2T4	10.1^{e}	10.3^{f}	10.3^{fg}	10.3^{gh}	10.4^{g}	10.4^{fg}	10.4^{hi}	10.6^{gh}	10.7^{gh}
P2T5	10.0^{e}	10.2^{f}	10.2^{g}	10.2^{h}	10.2^{h}	10.3^{fg}	10.4^{hi}	10.5^{h}	10.5^{i}
P2T6	10.1^{e}	10.2^{f}	10.3^{fg}	10.4^{gh}	10.5^{g}	10.5^{f}	10.6^{gh}	10.7^{fg}	10.8^{g}
P2T7	10.1^{e}	10.2^{f}	10.2^{g}	10.4^{gh}	10.4^{g}	10.5^{f}	10.7^{g}	10.7^{fg}	10.9^{f}
SEm ±	0.07	0.05	0.06	0.08	0.06	0.07	0.06	0.05	0.03
CD (0.05)	0.22	0.15	0.17	0.25	0.17	0.22	0.19	0.14	0.10

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

4.1.10 Seed infection

The results on seed infection per cent as influenced by packing material, halogen treatment and their interaction effects during the storage period are presented in Table 19.

Due to packing material (P)

The seed infection (%) varied from 9.00 to 25.57 per cent in P1 (jute bag) and it varied from 8.00 to 19.71 per cent in P2 (polyethylene bag of 400G) during the storage period. The per cent increase in seed infection over initial seed infection varied from 131.88 in P2 to 200.82 in P1.

Due to halogen treatment (T)

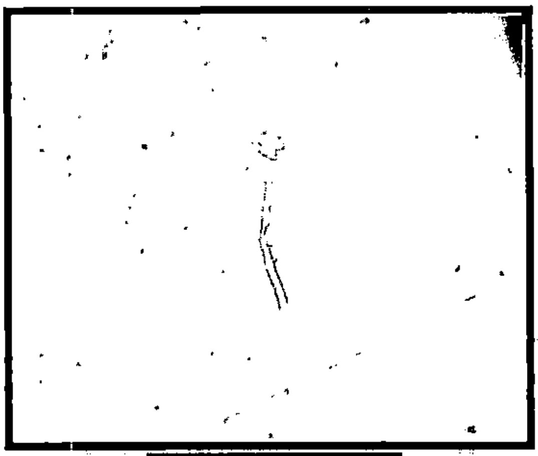
The seed infection (%) varied from 15.00 per cent in T5 to 33.00 per cent in T1 at the end of storage period. The lowest seed infection was recorded in $CaOCl_2$ + $CaCO_3$ @ 3 g each/kg seed (T5) (15.00%), followed by T3 (19.00%) which was on par with T2 (19.50%). While, the highest seed infection was recorded in T1 (control) (33.00%) at the end of storage period. The per cent increase over initial infection ranged from 76.47 in T5 to 288.24 in T1.

Due to interaction (P x T)

The lowest seed infection (%) was recorded in P2T5 (13.00%), followed by P2T2 (16.00%) on par with P1T5 (17.00%) and P2T3 (18.00%). P1T1 (control + storage in jute bag) (39.00%) recorded the highest infection followed by P1T7 (31.00%) at the end of storage period. The per cent increase varied from 62.50 in P2T5 to 333.33 in P1T1 over initial infection. Seed microflora observed were *Aspergillus* sp., *Rhizopus* sp., *Helminthosporium* sp. and *Curvularia* sp. (Plate 1).

Plate 1: Pathogens observed in rice seed storage

Aspergillus sp.



Rhizopus sp.

Helminthosporium sp.

Alternaria sp.

Table 19: Influence of packing material, halogen treatment and their interaction effect on seed infection (%) in rice (*rabi*, 2013-14) during storage

Treatments	Seed infection (%)	
	End of storage	Per cent increase of seed infection
Packing materials (P)		
P1	25.57^{a} (14.82)	200.82
P2	19.71^{b} (11.37)	131.88
SEm ±	0.26	
CD (0.05)	0.80	
Halogen treatments (T)		
T1	33.00^{a} (19.27)	288.24
T2	19.50^{de} (11.24)	129.41
T3	19.00^{e} (10.95)	123.53
T4	21.00^{d} (12.12)	147.06
T5	15.00^{f} (8.63)	76.47
T6	24.00^{c} (13.89)	182.35
T7	27.00^{b} (15.66)	217.65
SEm ±	0.55	
CD (0.05)	1.69	
Interaction (P x T)		
P1T1	39.00^{a} (22.95)	333.33
P1T2	23.00^{d} (13.30)	155.56
P1T3	20.00^{ef} (11.54)	122.22
P1T4	22.00^{de} (12.71)	144.44
P1T5	17.00^{g} (9.79)	88.89
P1T6	27.00^{c} (15.66)	200.00
P1T7	31.00^{b} (18.06)	244.44
P2T1	27.00^{c} (15.66)	237.50
P2T2	16.00^{g} (9.21)	100.00
P2T3	18.00^{fg} (10.37)	125.00
P2T4	20.00^{ef} (11.54)	150.00
P2T5	13.00^{h} (7.47)	62.50
P2T6	21.00^{de} (12.12)	162.50
P2T7	23.00^{d} (13.30)	187.50
SEm ±	0.69	
CD (0.05)	2.11	

Initial seed infection

P1- 9.00 %

P2- 8.00 %

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

4.2 Seed longevity of rice variety Jyothi (summer, 2013-14)

The result pertaining to seeds of summer 2013-14 stored over a period of eleven months is enumerated below.

4.2.1 Analysis of variance

The analysis of variance revealed that, there existed significant differences in the impact on seed qualities like germination per cent, seedling shoot and root length, seedling dry weight, seedling vigour index I and II, electrical conductivity of seed leachate, seed moisture content and seed infection per cent among the various packing material, seed halogenation treatments and their interaction during storage.

4.2.2 Seed quality before storage

The results on seed quality parameters before treatment and storage are presented in Table 20.

The seed quality parameters recorded before storage was moisture content (12.3 % and 10.0 %), germination (97.00 % and 97.50 %), seedling shoot length (20.33 cm and 20.35 cm), seedling root length (30.10 cm and 30.15 cm), seedling dry weight (20.25 mg and 20.30 mg), vigour index I (4942 and 4949), vigour index II (1985 and 1989), electrical conductivity of seed leachate (0.0200 dSm^{-1} and 0.0190 dSm^{-1}) in P1 (jute bag) and P2 (polyethylene bag of 400G), respectively.

4.2.3 Seed quality during storage

4.2.3.1 Germination (%)

The results on germination percentage as influenced by packing material, halogen treatment and their interaction effects during the storage period are presented in Table 21.

Table 20: Seed quality parameters before storage (M0) (summer 2013-14)

Packing material (P)	Moisture content (%)	Germination (%)	Seedling shoot length (cm)	Seedling root length (cm)	Seedling dry weight (mg)	Vigour index I	Vigour index II	EC (dSm^{-1})	Seed infection (%)
P1*	12.3	97.00	20.33	30.10	20.25	4942	1985	0.0200	6.00
P2**	10.0	97.50	20.35	30.15	20.30	4949	1989	0.0190	4.00

*observations were taken after drying the seeds to a moisture content of 12.3%

**observations were taken after drying the seeds to a moisture content of 10.0%

Due to packing material (P)

Germination declined progressively over the period of storage. Throughout the storage period, the germination of seeds stored in P2 was significantly superior to that stored in P1. Germination in P1 (jute bag) reduced from 97.00 to 59.77 per cent while the reduction was from 97.50 per cent to 69.11 per cent in P2 (polyethylene bag of 400G). A reduction of 29.12 per cent (P2) and 38.38 per cent (P1) in germination over initial germination was observed. The germination in P1 and P2 was above the MSCS of 80 per cent for four and eight months respectively.

Due to halogen treatment (T)

Reduction in germination was observed with increase in storage period. Seed halogenated at T5 ($CaOCl_2$ +$CaCO_3$ @ 3g each/kg of seed) was superior to other treated and untreated seeds at each month of storage. Germination per cent in T5 at the end of the storage period of eleven months was the highest (74.88%). T4 ($CaOCl_2$ @ 9 g/kg seed) with a germination of 67.44 per cent was the next best. Treatment T7 recorded the least germination (55.88%) at the end of storage period followed by T1 (59.56%) The per cent reduction varied from 22.98 per cent in T5 to 42.52 per cent in T7 over initial germination. The germination in T5 was retained above the MSCS for nine months compared to seven months in T3. However germination was above 80 per cent for six months in case of T1 (untreated).

Due to interaction (P x T)

P2T5 was superior to other treatments with respect to germination throughout the storage period except in the third month of storage. P2T5 recorded a germination of 78.63 per cent at the end of eleven months of storage. The viability in P2T5 was retained above MSCS for ten months of storage whereas it was for nine months each in case of P2T4. Untreated seeds in polyethylene bags (P2T1) retained viability above MSCS for eight months compared to 6 months in jute bags (P1T1).

Table 21: Influence of packing material, halogen treatment and their interaction effect on germination (%) during storage in rice (summer, 2013-14)

Treatments	Storage period (months)												
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	Mean	Per cent reduction of germination
Packing materials (P)													
P1	93.93^{b} (69.93)	90.54^{b} (64.88)	87.71^{b} (61.29)	83.30^{b} (56.41)	79.77^{b} (52.91)	78.14^{b} (51.39)	76.02^{b} (49.48)	72.38^{b} (46.37)	68.63^{b} (43.34)	64.57^{b} (40.22)	59.77^{b} (36.71)	77.71	38.38
P2	95.43^{a} (72.61)	94.52^{a} (70.94)	92.88^{a} (68.25)	89.86^{a} (63.97)	88.95^{a} (62.81)	85.41^{a} (58.66)	83.04^{a} (56.14)	80.41^{a} (53.52)	77.05^{a} (50.40)	73.20^{a} (47.05)	69.11^{a} (43.72)	84.53	29.12
SEm ±	0.17	0.14	0.20	0.14	0.17	0.15	0.13	0.15	0.15	0.16	0.10		
CD (0.05)	0.51	0.42	0.61	0.43	0.51	0.47	0.40	0.46	0.47	0.49	0.31		
Halogen treatments (T)													
T1	95.88^{a} (73.50)	94.00^{b} (70.05)	91.00^{b} (65.51)	87.13^{b} (60.61)	84.81^{bc} (58.01)	81.44^{c} (54.53)	78.88^{c} (52.07)	77.19^{b} (50.52)	70.75^{c} (45.03)	66.31^{d} (41.54)	59.56^{e} (36.56)	80.64	38.71
T2	95.06^{b} (71.92)	93.81^{b} (69.73)	92.13^{a} (67.12)	84.31^{c} (57.47)	81.13^{d} (54.22)	78.69^{d} (51.90)	76.56^{e} (49.96)	75.00^{c} (48.59)	72.88^{b} (46.79)	70.00^{b} (44.43)	64.00^{d} (39.79)	80.33	34.19
T3	95.06^{b} (71.92)	91.06^{c} (65.59)	91.06^{b} (65.59)	87.56^{b} (61.12)	85.19^{b} (58.42)	82.69^{b} (55.78)	81.13^{b} (54.22)	76.63^{b} (50.02)	73.44^{b} (47.26)	68.88^{bc} (43.54)	66.19^{c} (41.44)	81.73	31.93
T4	94.44^{c} (70.80)	91.06^{c} (65.59)	89.13^{c} (63.04)	84.44^{c} (57.61)	84.06^{c} (57.20)	81.75^{bc} (54.84)	78.88^{c} (52.07)	76.75^{b} (50.13)	74.06^{b} (47.78)	69.88^{b} (44.33)	67.44^{b} (42.41)	81.09	30.69
T5	96.00^{a} (73.74)	94.88^{a} (71.59)	92.63^{a} (67.87)	93.69^{a} (69.54)	92.25^{a} (67.29)	90.06^{a} (64.24)	87.88^{a} (61.50)	85.25^{a} (58.48)	82.81^{a} (55.90)	78.63^{a} (51.84)	74.88^{a} (48.49)	88.10	22.98
T6	94.31^{c} (70.58)	93.75^{b} (69.64)	90.38^{b} (64.66)	87.13^{b} (60.61)	84.75^{bc} (57.94)	82.63^{b} (55.72)	77.56^{d} (50.86)	75.25^{c} (48.81)	73.31^{b} (47.15)	68.06^{c} (42.89)	63.13^{d} (39.15)	80.95	35.12
T7	92.00^{d} (66.93)	89.13^{d} (63.04)	85.75^{d} (59.04)	81.81^{d} (54.90)	78.31^{e} (51.55)	75.19^{e} (48.76)	75.81^{e} (49.30)	68.69^{d} (43.39)	62.63^{d} (38.78)	60.44^{e} (37.19)	55.88^{f} (33.97)	75.05	42.52
SEm ±	0.35	0.29	0.43	0.30	0.35	0.33	0.28	0.32	0.33	0.34	0.22		
CD (0.05)	1.07	0.90	1.30	0.91	1.07	1.00	0.85	0.98	1.00	1.04	0.66		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

**Values in parentheses are Arc sine transformed values

Table 21: Influence of packing material, halogen treatment and their interaction effect on germination (%) during storage in rice (summer, 2013-14) (contd)

Treatments	Storage period (months)												
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	Mean	Per cent reduction of germination
Interaction (P x T)													
P1T1	95.13^{bc} (72.05)	93.25^{cde} (68.83)	88.75^{e} (62.56)	86.00^{h} (59.32)	82.88^{f} (55.97)	80.75^{gh} (53.85)	76.88^{g} (50.25)	73.88^{hi} (47.63)	68.75^{h} (43.44)	64.00^{h} (39.79)	58.75^{j} (35.98)	79.00	39.43
P1T2	94.75^{c} (71.36)	92.25^{g} (67.30)	90.38^{d} (64.66)	78.00^{j} (51.26)	74.63^{g} (48.27)	74.38^{i} (48.05)	73.00^{h} (46.89)	73.13^{ij} (46.99)	71.63^{g} (45.75)	69.00^{f} (43.63)	60.00^{hi} (36.87)	77.38	38.14
P1T3	94.88^{bc} (71.58)	88.75^{h} (62.56)	86.75^{f} (60.17)	85.00^{h} (58.21)	82.13^{f} (55.21)	81.63^{fg} (54.71)	80.38^{ef} (53.49)	74.88^{gh} (48.48)	71.63^{g} (45.75)	67.13^{g} (42.17)	63.00^{i} (39.05)	79.65	35.05
P1T4	93.25^{d} (68.83)	88.25^{h} (61.95)	86.00^{f} (59.32)	80.13^{i} (53.25)	74.50^{g} (48.16)	72.75^{j} (46.68)	71.13^{i} (45.34)	69.63^{k} (44.13)	67.00^{i} (42.07)	61.63^{i} (38.05)	59.13^{ij} (36.25)	74.85	39.04
P1T5	95.25^{bc} (72.28)	93.13^{def} (68.63)	91.13^{d} (65.68)	93.13^{b} (68.64)	90.63^{b} (64.99)	88.63^{b} (62.41)	84.88^{c} (58.08)	81.88^{c} (54.96)	78.88^{c} (52.07)	75.13^{c} (48.70)	71.13^{c} (45.34)	85.80	26.67
P1T6	93.38^{d} (69.04)	92.38^{fg} (67.49)	90.13^{d} (64.32)	85.00^{h} (58.21)	81.75^{f} (54.84)	80.00^{h} (53.13)	73.50^{h} (47.31)	71.75^{j} (45.85)	69.13^{h} (43.73)	63.13^{hi} (39.14)	56.13^{k} (34.14)	77.84	42.13
P1T7	90.88^{e} (65.33)	85.75^{i} (59.06)	80.88^{g} (53.98)	75.88^{k} (49.36)	71.88^{h} (45.95)	68.88^{k} (43.53)	72.38^{hi} (46.37)	61.50^{l} (37.95)	53.38^{j} (32.26)	52.00^{i} (31.33)	50.25^{l} (30.17)	69.42	48.20
P2T1	96.63^{a} (75.07)	94.75^{b} (71.36)	93.25^{bc} (68.83)	88.25^{fg} (61.95)	86.75^{d} (60.17)	82.13^{ef} (55.21)	80.88^{de} (53.98)	80.50^{d} (53.61)	72.75^{fg} (46.68)	68.63^{fg} (43.34)	60.38^{gh} (37.14)	82.26	38.07
P2T2	95.38^{bc} (72.51)	95.38^{b} (72.51	93.88^{b} (69.84)	90.63^{c} (64.99)	87.63^{cd} (61.20)	83.00^{de} (56.10)	80.13^{ef} (53.25)	76.88^{f} (50.24)	74.13^{ef} (47.84)	71.00^{e} (45.24)	68.00^{c} (42.84)	83.28	30.26
P2T3	95.25^{bc} (72.28)	93.38^{cd} (69.03)	95.38^{a} (72.52)	90.13^{cd} (64.32)	88.25^{c} (61.95)	83.75^{d} (56.88)	81.88^{d} (54.96)	78.38^{e} (51.61)	75.25^{e} (48.81)	70.63^{e} (44.93)	69.38^{d} (43.93)	83.79	28.84
P2T4	95.63^{b} (72.99)	93.88^{c} (69.85)	92.25^{c} (67.30)	88.75^{ef} (62.56)	93.63^{a} (69.46)	90.75^{a} (65.18)	86.63^{b} (60.03)	83.88^{b} (57.01)	81.13^{b} (54.22)	78.13^{b} (51.38)	75.75^{b} (49.24)	87.31	22.31
P2T5	96.75^{a} (75.36)	96.63^{a} (75.07)	94.13^{b} (70.26)	94.25^{a} (70.48)	93.88^{a} (69.84)	91.50^{a} (66.21)	90.88^{a} (65.33)	88.63^{a} (62.41)	86.75^{a} (60.17)	82.13^{a} (55.21)	78.63^{a} (51.84)	90.38	19.35
P2T6	95.25^{bc} (72.28)	95.13^{b} (72.05)	90.63^{d} (65.02)	89.25^{de} (63.19)	87.75^{cd} (61.34)	85.25^{c} (58.49)	81.63^{d} (54.71)	78.75^{c} (51.95)	77.50^{d} (50.81)	73.00^{d} (46.89)	70.13^{cd} (44.53)	84.02	28.07
P2T7	93.13^{d} (68.63)	92.50^{efg} (67.67)	90.63^{d} (65.00)	87.75^{g} (61.34)	84.75^{e} (57.94)	81.50^{fg} (54.59)	79.25^{f} (52.52)	75.88^{fg} (49.36)	71.88^{g} (45.95)	68.88^{f} (43.53)	61.50^{g} (37.95)	80.70	36.92
SEm ±	0.44	0.37	0.53	0.37	0.44	0.41	0.35	0.40	0.41	0.42	0.27		
CD (0.05)	1.34	1.12	1.62	1.13	1.34	1.25	1.06	1.22	1.25	1.29	0.83		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

At the end of storage period, P1T7 recorded the least germination (50.25%) followed by P1T6 (56.13 %). Treatment P1T7 retained viability above MSCS for the least period (3 months).

4.2.3.2 Seedling shoot length (cm)

The results on shoot length as influenced by packing material, halogen treatment and their interaction effects during the storage period are presented in Table 22.

Due to packing material (P)

Seedling shoot length was observed to decrease with increase in storage period. The shoot length of seeds stored in P2 was found to be maximum and significantly superior over that in P1 during each month of storage. The shoot length decreased from 20.33 to 12.84 cm in P1 (jute bag) while the reduction was from 20.35 to 13.90 cm in P2 (polyethylene bag of 400G).

Due to halogen treatment (T)

Seedling shoot length decreased over storage irrespective of the halogenation treatment. At each month of storage, T5 ($CaOCl_2$ + $CaCO_3$ @ 3 g each/kg seed) recorded the maximum shoot length and was superior to all other treatments throughout the storage period. T1, T2 and T4 were found to be the next best treatments with respect to shoot length at the end of storage while it was least the in T7 (10.29 cm). Treatment T6 recorded the next lowest shoot length (12.26 cm).

***Due to interaction* (P x T)**

P2T5 was superior to all other treatments with respect to shoot length throughout the storage period. The shoot length in P2T5 varied from 19.20 cm (M1) to 16.23 cm (M11). P1T5 (14.60 cm) was on par with P2T5 at the end of storage period. P2T1 (14.48 cm), P2T2 (14.44 cm), P2T4 (14.27 cm) and P2T6 (14.41 cm)

Table 22: Influence of packing material, halogen treatment and their interaction effect on seedling shoot length (cm) during storage in rice (summer, 2013-14)

Treatments	Storage period (months)												
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	Mean	Per cent reduction of shoot length
Packing materials (P)													
P1	15.75^{b}	14.66^{b}	14.66^{b}	13.63^{b}	13.40^{b}	13.44^{b}	13.38^{b}	13.25^{b}	13.09^{b}	12.94^{b}	12.84^{b}	13.73	36.84
P2	17.52^{a}	16.14^{a}	15.99^{a}	15.18^{a}	14.91^{a}	14.73^{a}	14.49^{a}	14.40^{a}	14.27^{a}	14.09^{a}	13.90^{a}	15.06	31.70
SEm ±	0.09	0.08	0.09	0.09	0.10	0.09	0.08	0.08	0.07	0.06	0.05		
CD (0.05)	0.27	0.25	0.28	0.27	0.30	0.29	0.23	0.23	0.22	0.17	0.16		
Halogen treatments (T)													
T1	18.02^{b}	16.54^{b}	16.78^{b}	15.10^{b}	14.86^{b}	15.00^{b}	14.60^{b}	14.52^{b}	14.27^{b}	14.16^{b}	13.97^{b}	15.26	31.32
T2	16.47^{d}	15.74^{c}	15.83^{c}	15.50^{b}	15.27^{b}	14.72^{b}	14.55^{b}	14.55^{b}	14.31^{b}	14.15^{b}	14.06^{b}	15.01	30.88
T3	15.80^{e}	14.85^{d}	15.11^{de}	14.06^{c}	13.91^{c}	13.58^{c}	13.46^{c}	13.28^{c}	13.16^{c}	12.87^{c}	12.75^{c}	13.89	37.32
T4	17.21^{c}	15.64^{c}	15.66^{cd}	15.19^{b}	14.73^{b}	15.01^{b}	14.91^{b}	14.77^{b}	14.68^{b}	14.43^{b}	14.16^{b}	15.13	30.38
T5	18.94^{a}	17.94^{a}	17.54^{a}	16.88^{a}	16.63^{a}	16.58^{a}	16.55^{a}	16.53^{a}	16.44^{a}	16.20^{a}	16.09^{a}	16.94	20.89
T6	16.36^{de}	14.84^{d}	14.56^{e}	13.13^{d}	12.97^{d}	12.99^{c}	12.98^{c}	12.70^{d}	12.52^{d}	12.32^{d}	12.26^{d}	13.42	39.72
T7	13.66^{f}	12.26^{e}	11.81^{f}	10.97^{e}	10.73^{e}	10.71^{d}	10.50^{d}	10.42^{e}	10.42^{e}	10.47^{e}	10.29^{e}	11.11	49.41
SEm ±	0.19	0.17	0.19	0.19	0.21	0.20	0.16	0.16	0.15	0.12	0.11		
CD (0.05)	0.57	0.52	0.59	0.57	0.63	0.62	0.49	0.49	0.47	0.37	0.34		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 22: Influence of packing material, halogen treatment and their interaction effect on seedling shoot length (cm) during storage in rice (summer, 2013-14) (contd)

Treatments	Storage period (months)												
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	Mean	Per cent reduction of shoot length
-	Interaction (P x T)												
P1T1	17.69^{cd}	16.67^{cd}	17.49^{ab}	14.80^{de}	14.30^{d}	14.27^{de}	13.95^{c}	13.91^{c}	13.64^{c}	13.51^{c}	13.45^{d}	14.88	33.84
P1T2	15.78^{f}	15.07^{e}	14.50^{e}	14.53^{e}	14.38^{d}	14.26^{de}	14.19^{c}	14.10^{c}	13.88^{c}	13.71^{c}	13.68^{cd}	14.37	32.71
P1T3	14.92^{g}	13.73^{f}	13.29^{f}	13.22^{f}	13.22^{e}	13.10^{f}	13.09^{d}	13.00^{d}	12.86^{d}	12.68^{d}	12.53^{f}	13.24	38.37
P1T4	16.82^{e}	14.98^{e}	14.81^{e}	14.64^{de}	14.37^{d}	14.93^{cd}	14.93^{b}	14.75^{b}	14.61^{b}	14.35^{b}	14.05^{bc}	14.84	30.89
P1T5	18.67^{ab}	17.56^{b}	18.05^{a}	16.51^{b}	16.36^{a}	16.28^{ab}	16.42^{a}	16.28^{a}	16.22^{a}	16.05^{a}	15.94^{a}	16.76	21.59
P1T6	13.44^{h}	12.49^{g}	13.07^{f}	11.04^{g}	11.00^{f}	11.05^{g}	11.00^{e}	10.61^{ef}	10.35^{ef}	10.05^{f}	10.10^{g}	11.29	50.32
P1T7	12.95^{h}	12.11^{g}	11.39^{h}	10.64^{g}	10.17^{g}	10.17^{h}	10.05^{f}	10.10^{f}	10.10^{f}	10.20^{f}	10.10^{g}	10.73	50.32
P2T1	18.34^{bc}	16.41^{d}	16.06^{d}	15.39^{cd}	15.42^{bc}	15.73^{bc}	15.25^{b}	15.12^{b}	14.89^{b}	14.80^{b}	14.48^{b}	15.63	28.85
P2T2	17.15^{de}	16.40^{d}	17.15^{bc}	16.47^{b}	16.16^{ab}	15.17^{c}	14.90^{b}	15.00^{b}	14.74^{b}	14.59^{b}	14.44^{b}	15.65	29.04
P2T3	16.68^{e}	15.97^{d}	16.93^{bc}	14.90^{de}	14.60^{cd}	14.06^{e}	13.83^{c}	13.56^{cd}	13.45^{c}	13.05^{d}	12.96^{e}	14.54	36.31
P2T4	17.60^{cd}	16.29^{d}	16.50^{cd}	15.74^{c}	15.08^{cd}	15.09^{cd}	14.89^{b}	14.79^{b}	14.75^{b}	14.50^{b}	14.27^{b}	15.41	29.88
P2T5	19.20^{a}	18.32^{a}	17.02^{bc}	17.24^{a}	16.89^{a}	16.87^{a}	16.68^{a}	16.78^{a}	16.65^{a}	16.35^{a}	16.23^{a}	17.11	20.25
P2T6	19.28^{a}	17.19^{bc}	16.05^{d}	15.21^{cde}	14.94^{cd}	14.93^{cd}	14.95^{b}	14.79^{b}	14.69^{b}	14.59^{b}	14.41^{b}	15.55	29.19
P2T7	14.36^{g}	12.40^{g}	12.23^{g}	11.30^{g}	11.28^{f}	11.25^{g}	10.95^{e}	10.74^{e}	10.74^{e}	10.73^{c}	10.48^{g}	11.50	48.50
SEm ±	0.23	0.22	0.24	0.23	0.26	0.26	0.20	0.20	0.19	0.15	0.14		
CD (0.05)	0.71	0.66	0.74	0.71	0.78	0.78	0.61	0.61	0.59	0.46	0.42		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

were the next best treatments. At the end of storage, the shoot length of untreated seeds packed in jute bag was 13.45 cm. The lowest shoot length was recorded in P1T6 (10.10 cm) and P1T7 (10.10 cm) followed by P2T7 (10.48 cm). P1T6, P1T7 and P2T7 were on par with each other.

4.2.3.3 Seedling root length (cm)

The results on root length as influenced by packing material, halogen treatment and their interaction effects during the storage period are presented in Table 23.

Due to packing material (P)

Seedling root length decreased over the period of storage. The root length of seeds stored in P2 was found to be maximum and superior over that in P1 during each month of storage. Root length of seedling decreased from 30.10 to 21.47 cm in P1 (jute bag) whereas the reduction was from 30.15 to 22.55 cm in P2 (polyethylene bag of 400G).

Due to halogen treatment (T)

As in seedling shoot length, seedling root length also decreased over storage irrespective of halogen treatment. T5 was superior from all other treatments with respect to root length during storage. T6 was found to be the next best treatment with respect to root length (23.42 cm) at the end of storage.

Treatment T7 recorded the least root length (18.84 cm) at the end of storage period. However, untreated seeds (T1) recorded a root length of 21.32 cm and was on par with T4 (21.57 cm).

Table 23: Influence of packing material, halogen treatment and their interaction effect on seedling root length (cm) during storage in rice (summer, 2013-14)

Treatments	Storage period (months)												
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	Mean	Per cent reduction of root length
Packing materials (P)													
P1	24.90^{b}	24.38^{b}	23.85^{b}	22.95^{b}	22.49^{b}	22.44^{b}	22.18^{b}	21.94^{b}	21.78^{b}	21.62^{b}	21.47^{b}	22.73	28.67
P2	26.39^{a}	25.17^{a}	24.94^{a}	24.06^{a}	23.44^{a}	23.30^{a}	22.96^{a}	22.84^{a}	22.74^{a}	22.68^{a}	22.55^{a}	23.73	25.21
SEm ±	0.16	0.11	0.11	0.08	0.09	0.08	0.09	0.09	0.08	0.08	0.08		
CD (0.05)	0.48	0.33	0.34	0.24	0.29	0.25	0.29	0.29	0.23	0.23	0.23		
Halogen treatments (T)													
T1	25.80^{b}	24.78^{b}	24.70^{b}	22.46^{c}	22.27^{d}	22.12^{e}	22.03^{d}	21.88^{d}	21.69^{d}	21.50^{d}	21.32^{d}	22.78	29.24
T2	25.14^{bc}	24.04^{c}	23.79^{c}	22.88^{c}	22.74^{cd}	22.76^{cd}	22.68^{c}	22.56^{c}	22.44^{c}	22.28^{c}	22.06^{c}	23.03	26.78
T3	24.93^{bc}	24.17^{bc}	23.93^{c}	22.85^{c}	22.94^{c}	22.87^{c}	22.80^{c}	22.70^{c}	22.41^{c}	22.33^{c}	22.20^{c}	23.10	26.32
T4	24.35^{c}	23.54^{c}	23.38^{cd}	22.80^{c}	22.35^{cd}	22.26^{de}	22.05^{d}	21.88^{d}	21.75^{d}	21.69^{d}	21.57^{d}	22.51	28.41
T5	27.40^{a}	26.38^{a}	25.86^{a}	25.49^{b}	25.19^{b}	25.11^{b}	25.02^{a}	24.89^{a}	24.90^{a}	24.79^{a}	24.66^{a}	25.43	18.15
T6	27.45^{a}	26.90^{a}	26.31^{a}	26.31^{a}	25.82^{a}	25.70^{a}	24.25^{b}	23.78^{b}	23.65^{b}	23.56^{b}	23.42^{b}	25.20	22.27
T7	24.46^{c}	23.64^{c}	22.84^{d}	21.75^{d}	19.44^{e}	19.28^{f}	19.18^{e}	19.04^{e}	18.99^{e}	18.90^{e}	18.84^{e}	20.58	37.47
SEm ±	0.33	0.23	0.24	0.17	0.20	0.18	0.20	0.20	0.16	0.16	0.16		
CD (0.05)	1.02	0.69	0.72	0.52	0.62	0.54	0.60	0.62	0.48	0.49	0.48		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 23: Influence of packing material, halogen treatment and their interaction effect on seedling root length (cm) during storage in rice (summer, 2013-14) (contd)

Treatments	Storage period (months)											
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	Mean	Per cent reduction of root length
Interaction (P x T)													
P1T1	24.86^{cde}	23.88^{fgh}	23.68^{cde}	22.31^{e}	22.12^{ef}	22.05^{fg}	22.00^{de}	21.79^{fg}	21.50^{fg}	21.28^{ef}	21.12^{de}	22.42	29.83
P1T2	24.49^{cde}	23.13^{gh}	23.12^{e}	22.39^{e}	22.19^{ef}	22.26^{efg}	22.15^{de}	22.02^{fg}	21.86^{ef}	21.61^{ef}	21.37^{de}	22.42	29.00
P1T3	24.34^{de}	24.36^{def}	23.98^{cde}	22.37^{e}	22.48^{def}	22.46^{ef}	22.36^{d}	22.23^{f}	21.87^{ef}	21.77^{de}	21.67^{d}	22.72	28.01
P1T4	24.36^{de}	24.05^{efg}	23.37^{e}	22.08^{e}	21.78^{f}	21.66^{g}	21.39^{e}	21.25^{g}	21.11^{g}	21.00^{f}	20.84^{e}	22.08	30.76
P1T5	25.72^{cde}	25.24^{cd}	24.55^{c}	24.46^{c}	24.43^{b}	24.34^{c}	24.23^{b}	24.11^{bc}	24.09^{b}	23.93^{b}	23.78^{b}	24.44	21.00
P1T6	26.47^{b}	26.44^{b}	26.10^{b}	25.76^{b}	25.16^{b}	25.19^{b}	24.13^{b}	23.37^{cd}	23.21^{c}	23.00^{c}	22.84^{c}	24.70	24.12
P1T7	24.05^{e}	23.56^{fgh}	22.17^{f}	21.28^{f}	19.25^{g}	19.12^{h}	19.03^{f}	18.82^{h}	18.83^{h}	18.74^{g}	18.66^{f}	20.32	38.01
P2T1	26.73^{b}	25.68^{bc}	25.71^{b}	22.61^{e}	22.42^{ef}	22.19^{efg}	22.05^{de}	21.97^{fg}	21.88^{ef}	21.72^{e}	21.52^{d}	23.13	28.62
P2T2	25.79^{bc}	24.94^{cde}	24.45^{cd}	23.37^{d}	23.28^{cd}	23.25^{d}	23.20^{c}	23.10^{de}	23.01^{cd}	22.94^{c}	22.74^{c}	23.64	24.58
P2T3	25.51^{bcd}	23.97^{fgh}	23.87^{cde}	23.32^{d}	23.39^{c}	23.28^{d}	23.23^{c}	23.16^{de}	22.95^{cd}	22.88^{c}	22.72^{c}	23.48	24.64
P2T4	24.34^{de}	23.03^{h}	23.39^{e}	23.52^{d}	22.92^{cde}	22.85^{de}	22.71^{cd}	22.51^{ef}	22.38^{de}	22.38^{cd}	22.30^{c}	22.94	26.04
P2T5	29.08^{a}	27.52^{a}	27.17^{a}	26.51^{a}	25.95^{a}	25.87^{a}	25.81^{a}	25.67^{a}	25.70^{a}	25.65^{a}	25.53^{a}	26.41	15.32
P2T6	28.42^{a}	27.35^{a}	26.51^{ab}	26.85^{a}	26.48^{a}	26.21^{a}	24.37^{b}	24.19^{b}	24.09^{b}	24.11^{b}	23.99^{b}	25.69	20.43
P2T7	24.87^{cde}	23.72^{fgh}	23.51^{de}	22.21^{e}	19.62^{g}	19.43^{h}	19.32^{f}	19.26^{h}	19.15^{h}	19.06^{g}	19.02^{f}	20.83	36.92
SEm ±	0.42	0.28	0.29	0.21	0.25	0.22	0.25	0.26	0.20	0.20	0.20		
CD (0.05)	1.27	0.86	0.89	0.64	0.77	0.67	0.75	0.78	0.60	0.61	0.60		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Due to interaction (P x T)

Maximum root length of 25.53 cm was recorded in P2T5 followed by P2T6 (23.99 cm) which was on par with P1T5 (23.78 cm) at the end of storage period. The lowest root length was recorded in P1T7 (18.66 cm) which was found to be on par with P2T7 (19.02 cm) at the end of storage period. The untreated seeds stored in jute (P1T1) and polyethylene bag (P2T1) recorded a root length of 21.12 and 21.52 cm, respectively. P1T1 and P2T2 were on par with each other.

4.2.3.4 Seedling dry weight (mg)

The results on seedling dry weight as influenced by packing material, halogen treatment and their interaction effects during the storage period are presented in Table 24.

Due to packing material (P)

Seedling dry weight was observed to decrease with increase in storage period. The dry weight of seedlings from seeds stored in P2 was found to be maximum and significantly superior over that in P1 during each month of storage. The dry weight decreased from 20.25 to 14.79 mg in P1 (jute bag) while the reduction was from 20.30 to 16.64 mg in P2 (polyethylene bag of 400G).

Due to halogen treatment (T)

Seedling dry weight decreased over storage irrespective of the halogenation treatment. At each month of storage, T5 ($CaOCl_2$ + $CaCO_3$ @ 3 g each/kg seed) recorded the maximum seedling dry weight and was superior to all other treatments throughout the storage period. T6 was found to be the next best treatment with respect to seedling dry weight at the end of storage while it was the least in T1 (15.15 mg), T2 (15.48 mg), T3 (15.13 mg), T4 (15.10 mg) and T7 (15.43 mg). Treatments T1, T2, T3, T4 and T7 were on par with each other at the end of storage period.

Table 24: Influence of packing material, halogen treatment and their interaction effect on seedling dry weight (mg) during storage in rice (summer, 2013-14)

Treatments	Storage period (months)												
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	Mean	Per cent reduction of dry weight
Packing materials (P)													
P1	17.39^{b}	17.15^{b}	16.47^{b}	16.55^{b}	16.11^{b}	15.84^{b}	15.59^{b}	15.36^{b}	15.21^{b}	15.06^{b}	14.79^{b}	15.96	26.96
P2	19.09^{a}	18.46^{a}	18.57^{a}	18.59^{a}	18.10^{a}	17.76^{a}	17.37^{a}	16.98^{a}	16.89^{a}	16.80^{a}	16.64^{a}	17.75	18.03
SEm ±	0.10	0.18	0.05	0.09	0.11	0.09	0.09	0.08	0.09	0.09	0.08		
CD (0.05)	0.30	0.56	0.14	0.28	0.35	0.27	0.29	0.24	0.28	0.26	0.23		
Halogen treatments (T)													
T1	17.23^{d}	16.88^{c}	17.30^{c}	16.93^{c}	16.83^{c}	16.58^{c}	16.20^{b}	15.88^{cd}	15.73^{c}	15.35^{c}	15.15^{c}	16.37	25.30
T2	18.33^{bc}	17.48^{bc}	17.53^{c}	17.28^{c}	16.35^{c}	16.20^{c}	15.85^{b}	15.63^{cd}	15.60^{c}	15.68^{c}	15.48^{c}	16.49	23.67
T3	18.63^{b}	17.63^{bc}	16.85^{d}	16.73^{c}	16.38^{c}	16.13^{c}	15.78^{b}	15.40^{d}	15.30^{c}	15.25^{c}	15.13^{c}	16.29	25.39
T4	16.48^{e}	16.80^{c}	15.35^{e}	17.00^{c}	16.40^{c}	16.18^{c}	15.80^{b}	15.40^{d}	15.33^{c}	15.40^{c}	15.10^{c}	15.93	25.54
T5	19.78^{a}	19.75^{a}	19.25^{a}	19.30^{a}	18.80^{a}	18.25^{a}	17.95^{a}	17.68^{a}	17.60^{a}	17.55^{a}	17.55^{a}	18.50	13.46
T6	19.33^{a}	18.63^{ab}	18.80^{b}	18.55^{b}	18.03^{b}	17.63^{b}	17.40^{b}	17.05^{b}	16.93^{b}	16.73^{b}	16.18^{b}	17.75	20.22
T7	17.93^{c}	17.50^{bc}	17.58^{c}	17.23^{c}	16.98^{c}	16.65^{c}	16.40^{b}	16.15^{c}	15.85^{c}	15.58^{c}	15.43^{c}	16.66	23.92
SEm ±	0.21	0.39	0.09	0.20	0.24	0.19	0.20	0.17	0.19	0.18	0.16		
CD (0.05)	0.64	1.19	0.29	0.60	0.74	0.57	0.61	0.52	0.59	0.55	0.49		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 24: Influence of packing material, halogen treatment and their interaction effect on seedling dry weight (mg) during storage in rice (summer, 2013-14) (contd)

Treatments	Storage period (months)												
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	Mean	Per cent reduction of dry weight
Interaction (P x T)													
P1T1	15.10^{g}	15.35^{f}	15.85^{e}	15.55^{d}	15.95^{d}	15.65^{e}	15.20^{d}	15.00^{ef}	14.80^{e}	14.60^{de}	14.40^{fg}	15.22	28.89
P1T2	17.95^{def}	17.15^{cde}	16.60^{d}	16.60^{c}	15.30^{d}	15.35^{e}	15.15^{d}	15.00^{ef}	15.05^{e}	15.10^{d}	14.90^{ef}	15.83	26.42
P1T3	17.95^{def}	16.85^{cdef}	15.40^{f}	15.70^{d}	15.25^{d}	15.00^{e}	14.65^{de}	14.40^{f}	14.35^{ef}	14.35^{ef}	14.25^{gh}	15.29	29.63
P1T4	15.20^{g}	15.85^{ef}	14.05^{g}	14.65^{e}	14.10^{e}	14.10^{f}	13.95^{e}	13.75^{g}	13.65^{f}	13.80^{f}	13.65^{h}	14.25	32.59
P1T5	19.55^{abc}	19.80^{a}	18.80^{b}	19.45^{a}	18.75^{a}	17.90^{abc}	17.70^{ab}	17.35^{b}	17.25^{ab}	17.05^{b}	17.00^{b}	18.24	16.05
P1T6	18.45^{de}	18.40^{abc}	18.20^{c}	17.70^{b}	17.40^{c}	17.20^{cd}	17.05^{bc}	16.75^{bcd}	16.70^{bcd}	16.40^{bc}	15.35^{de}	17.24	24.20
P1T7	17.50^{f}	16.65^{def}	16.40^{d}	16.20^{cd}	16.05^{d}	15.65^{e}	15.45^{d}	15.25^{e}	14.65^{e}	14.15^{ef}	14.00^{gh}	15.63	30.86
P2T1	19.35^{abc}	18.40^{abc}	18.75^{b}	18.30^{b}	17.70^{bc}	17.50^{bcd}	17.20^{bc}	16.75^{bcd}	16.65^{bcd}	16.10^{c}	15.90^{cd}	17.51	21.67
P2T2	18.70^{cd}	17.80^{bcd}	18.45^{bc}	17.95^{b}	17.40^{c}	17.05^{d}	16.55^{c}	16.25^{d}	16.15^{d}	16.25^{c}	16.05^{c}	17.15	20.94
P2T3	19.30^{bc}	18.40^{abc}	18.30^{c}	17.75^{b}	17.50^{c}	17.25^{cd}	16.90^{bc}	16.40^{cd}	16.25^{cd}	16.15^{c}	16.00^{c}	17.29	21.18
P2T4	17.75^{ef}	17.75^{bcd}	16.65^{d}	19.35^{a}	18.70^{ab}	18.25^{ab}	17.65^{ab}	17.05^{bc}	17.00^{bc}	17.00^{b}	16.55^{bc}	17.61	18.47
P2T5	20.00^{ab}	19.70^{a}	19.70^{a}	19.15^{a}	18.85^{a}	18.60^{a}	18.20^{a}	18.00^{a}	17.95^{a}	18.05^{a}	18.10^{a}	18.75	10.84
P2T6	20.20^{a}	18.85^{ab}	19.40^{a}	19.40^{a}	18.65^{ab}	18.05^{ab}	17.75^{ab}	17.35^{b}	17.15^{b}	17.05^{b}	17.00^{b}	18.26	16.26
P2T7	18.35^{def}	18.35^{abc}	18.75^{b}	18.25^{b}	17.90^{abc}	17.65^{bcd}	17.35^{bc}	17.05^{bc}	17.05^{bc}	17.00^{b}	16.85^{b}	17.69	17.00
SEm ±	0.26	0.48	0.11	0.25	0.30	0.24	0.25	0.21	0.24	0.23	0.20		
CD (0.05)	0.79	1.48	0.35	0.75	0.93	0.72	0.76	0.64	0.74	0.69	0.61		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Due to interaction (P x T)

P2T5 was superior to all other treatments with respect to seedling dry weight throughout the storage period. The seedling dry weight in P2T5 varied from 20.00 mg (M1) to 18.10 mg (M11). P1T5 (17.00 mg), P2T6 (17.00 mg), P2T7 (16.85 mg) and P2T4 (16.55 mg) were the next best treatments. At the end of storage, the seedling dry weight of untreated seeds packed in jute bag was 14.40 mg and that in polyethylene bag (400G) was 15.90 mg. The lowest seedling dry weight was recorded in P1T4 (13.65 mg), P1T7 (14.00 mg) and P1T3 (14.25 mg). P1T4, P1T7 and P1T3 were on par with each other.

4.2.3.5 Vigour index I

The results on seedling vigour index I as influenced by packing material, halogen treatment and their interaction effects during the storage period are presented in Table 25.

Due to packing material (P)

Seedling vigour index I was observed to decrease with increase in storage period. The seedling vigour index I of seeds stored in P2 was found to be maximum and significantly superior over that in P1 during each month of storage. The seedling vigour index I decreased from 4942 to 2037 in P1 (jute bag) while the reduction was from 4949 to 2523 mg in P2 (polyethylene bag of 400G).

Due to halogen treatment (T)

Seedling vigour index I decreased over storage irrespective of the halogenation treatment. At each month of storage, T5 ($CaOCl_2$ + $CaCO_3$ @ 3 g each/kg seed) recorded the maximum seedling vigour index I and was superior to all other treatments throughout the storage period. T4, T3 and T6 were found to be the next best treatments with respect to seedling vigour index I at the end of storage. T4,

Table 25: Influence of packing material, halogen treatment and their interaction effect on vigour index I during storage in rice (summer, 2013-14)

Treatments	Storage period (months)											
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	Mean	Per cent reduction of VI I
Packing materials (P)													
P1	3824^{b}	3550^{b}	3385^{b}	3030^{b}	2854^{b}	2805^{b}	2652^{b}	2576^{b}	2401^{b}	2229^{b}	2037^{b}	2849	58.78
P2	4203^{a}	3887^{a}	3804^{a}	3524^{a}	3435^{a}	3238^{a}	3114^{a}	2956^{a}	2867^{a}	2721^{a}	2523^{a}	3297	49.02
SEm ±	28	27	21	18	23	18	18	21	23	14	19		
CD (0.05)	84	81	64	56	69	54	56	64	71	43	58		
Halogen treatments (T)													
T1	4164^{b}	3844^{b}	3733^{b}	3231^{c}	3158^{b}	3007^{c}	2858^{b}	2767^{b}	2519^{c}	2320^{d}	2014^{c}	3056	59.28
T2	3954^{c}	3742^{b}	3648^{b}	3269^{bc}	3125^{b}	2963^{c}	2833^{b}	2785^{b}	2683^{b}	2552^{b}	2316^{b}	3079	53.17
T3	3910^{c}	3552^{c}	3598^{bc}	3250^{bc}	3136^{b}	3027^{c}	2937^{b}	2734^{b}	2634^{bc}	2465^{bc}	2310^{b}	3050	53.30
T4	3949^{c}	3565^{c}	3476^{c}	3197^{c}	3160^{b}	3062^{c}	2888^{b}	2790^{b}	2702^{b}	2499^{bc}	2365^{b}	3059	52.18
T5	4448^{a}	4212^{a}	4080^{a}	3941^{a}	3849^{a}	3753^{a}	3702^{a}	3564^{a}	3394^{a}	3244^{a}	3017^{a}	3746	39.00
T6	4165^{b}	3884^{b}	3678^{b}	3365^{b}	3196^{b}	3178^{b}	2912^{b}	2744^{b}	2653^{bc}	2451^{c}	2305^{b}	3139	53.40
T7	3509^{d}	3232^{d}	2950^{d}	2688^{d}	2387^{c}	2162^{d}	2053^{c}	1979^{c}	1858^{d}	1796^{e}	1634^{d}	2386	66.96
SEm ±	58	56	44	39	48	38	39	45	49	29	40		
CD (0.05)	177	172	135	118	146	115	119	136	149	90	123		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 25: Influence of packing material, halogen treatment and their interaction effect on vigour index I during storage in rice (summer, 2013-14) (contd)

Treatments	Storage period (months)												
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	Mean	Per cent reduction of VI I
Interaction (P x T)													
P1T1	4001^{def}	3730^{c}	3623^{d}	3117^{e}	2986^{e}	2905^{d}	2732^{fg}	2642^{ef}	2389^{fgh}	2156^{h}	1867^{e}	2923	62.22
P1T2	3785^{fg}	3514^{cde}	3385^{ef}	2953^{f}	2779^{fg}	2776^{de}	2617^{gh}	2673^{ef}	2573^{def}	2401^{fg}	2103^{d}	2869	57.45
P1T3	3769^{fg}	3430^{de}	3279^{f}	3061^{ef}	2928^{ef}	2917^{d}	2836^{ef}	2677^{ef}	2501^{efg}	2343^{g}	2122^{d}	2897	57.06
P1T4	3871^{efg}	3434^{de}	3282^{f}	2938^{f}	2747^{fg}	2634^{e}	2542^{h}	2521^{fg}	2358^{gh}	2121^{h}	2023^{d}	2770	59.07
P1T5	4261^{bc}	4023^{b}	3919^{b}	3769^{b}	3671^{b}	3574^{b}	3495^{b}	3393^{b}	3144^{b}	2959^{b}	2860^{b}	3552	42.13
P1T6	3750^{g}	3582^{cd}	3525^{de}	2944^{f}	2748^{fg}	2899^{d}	2599^{gh}	2447^{gh}	2282^{hi}	2115^{h}	1845^{e}	2794	62.67
P1T7	3332^{h}	3139^{i}	2684^{g}	2426^{g}	2118^{h}	1932^{g}	1745^{j}	1678^{i}	1563^{j}	1505^{i}	1439^{f}	2142	70.88
P2T1	4326^{b}	3957^{b}	3842^{bc}	3344^{d}	3330^{d}	3109^{c}	2984^{de}	2892^{cd}	2648^{cde}	2484^{ef}	2160^{d}	3189	56.35
P2T2	4122^{bcd}	3969^{b}	3910^{b}	3585^{c}	3470^{cd}	3149^{c}	3048^{d}	2896^{cd}	2793^{c}	2702^{d}	2528^{c}	3288	48.92
P2T3	4050^{cde}	3674^{c}	3916^{b}	3438^{cd}	3343^{d}	3137^{c}	3038^{d}	2791^{de}	2766^{cd}	2587^{e}	2497^{c}	3203	49.55
P2T4	4026^{cde}	3696^{c}	3670^{cd}	3455^{cd}	3573^{bc}	3490^{b}	3233^{c}	3059^{c}	3045^{b}	2877^{bc}	2707^{b}	3348	45.30
P2T5	4635^{a}	4401^{a}	4241^{a}	4112^{a}	4027^{a}	3932^{a}	3908^{a}	3735^{a}	3643^{a}	3528^{a}	3174^{a}	3940	35.87
P2T6	4579^{a}	4186^{b}	3830^{bc}	3785^{b}	3644^{bc}	3456^{b}	3224^{c}	3040^{c}	3024^{b}	2786^{cd}	2764^{b}	3483	44.15
P2T7	3686^{g}	3324^{ef}	3216^{f}	2949^{f}	2656^{g}	2392^{f}	2361^{i}	2280^{h}	2152^{i}	2086^{h}	1828^{e}	2630	63.06
SEm ±	72	70	55	48	60	47	49	55	61	37	50		
CD (0.05)	221	214	169	148	183	143	149	169	187	113	153		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

T3 and T6 were on par with each other. The least seedling vigour index I was recorded in T7 (1634). The untreated seeds recorded the second least seedling vigour index I (2014).

Due to interaction (P x T)

P2T5 was superior to all other treatments with respect to seedling vigour index I throughout the storage period. The seedling vigour index I in P2T5 varied from 4635 (M1) to 3174 (M11). P1T5 (2860), P2T6 (2764) and P2T4 (2707) were the next best treatments. P1T5, P2T6 and P2T4 were on par with each other. The lowest seedling vigour index I was recorded in P1T7 (1439). At the end of storage, the seedling vigour index I of untreated seeds packed in jute bag was 1867 and that in polyethylene bag (400G) was 2160.

4.2.3.6 Vigour index II

The results on seedling vigour index II as influenced by packing material, halogen treatment and their interaction effects during the storage period are presented in Table 26.

Due to packing material (P)

Seedling vigour index II was observed to decrease with increase in storage period. The seedling vigour index II of seeds stored in P2 was found to be maximum and significantly superior over that in P1 during each month of storage. The seedling vigour index II decreased from 1985 to 876 in P1 (jute bag) while the reduction was from 1989 to 1148 mg in P2 (polyethylene bag of 400G).

Table 26: Influence of packing material, halogen treatment and their interaction effect on vigour index II during storage in rice (summer, 2013-14)

Treatments	Storage period (months)												
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	Mean	Per cent reduction of VI II
Packing materials (P)													
P1	1635^{b}	1560^{b}	1448^{b}	1371^{b}	1280^{b}	1236^{b}	1158^{b}	1118^{b}	1043^{b}	969^{b}	876^{b}	1245	55.87
P2	1828^{a}	1736^{a}	1725^{a}	1669^{a}	1620^{a}	1509^{a}	1441^{a}	1346^{a}	1305^{a}	1241^{a}	1148^{a}	1506	42.28
SEm ±	14	20	8	12	15	12	15	11	11	10	10		
CD (0.05)	43	61	24	37	45	37	45	35	35	31	32		
Halogen treatments (T)													
T1	1639^{d}	1571^{c}	1560^{d}	1459^{c}	1434^{bc}	1344^{c}	1266^{bc}	1209^{bc}	1103^{c}	1001^{d}	866^{c}	1314	56.42
T2	1742^{bc}	1644^{bc}	1615^{c}	1472^{c}	1347^{c}	1283^{cd}	1208^{cd}	1173^{c}	1140^{c}	1099^{bc}	993^{b}	1338	50.03
T3	1788^{c}	1605^{bc}	1556^{d}	1475^{c}	1396^{bc}	1340^{c}	1279^{bc}	1171^{c}	1134^{c}	1070^{c}	1002^{b}	1347	49.57
T4	1567^{bc}	1532^{c}	1371^{f}	1438^{c}	1415^{bc}	1347^{c}	1249^{c}	1181^{c}	1148^{c}	1078^{bc}	1008^{b}	1303	49.27
T5	1899^{a}	1877^{a}	1811^{a}	1795^{a}	1730^{a}	1644^{a}	1599^{a}	1521^{a}	1445^{a}	1390^{a}	1300^{a}	1637	34.57
T6	1837^{b}	1733^{b}	1692^{b}	1581^{b}	1482^{b}	1446^{b}	1359^{b}	1280^{b}	1237^{b}	1139^{b}	1042^{b}	1439	47.56
T7	1650^{d}	1577^{c}	1500^{e}	1419^{c}	1348^{c}	1205^{d}	1141^{d}	1090^{d}	1010^{d}	963^{d}	873^{c}	1252	56.06
SEm ±	29	42	16	26	31	26	31	24	25	22	23		
CD (0.05)	90	129	50	78	95	78	95	74	75	66	69		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 26: Influence of packing material, halogen treatment and their interaction effect on vigour index II during storage in rice (summer, 2013-14) (contd)

Treatments	Storage period (months)												
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	Mean	Per cent reduction of VI II
Interaction (P x T)													
P1T1	1419^{e}	1412^{fg}	1395^{f}	1306de	1309^{d}	1252^{e}	1155^{ef}	1111^{f}	1007^{e}	906^{hi}	778^{fg}	1186	60.81
P1T2	1688^{c}	1578^{def}	1495^{e}	1328^{cde}	1163^{ef}	1167^{e}	1091^{fg}	1110^{f}	1084de	1027^{fg}	894de	1239	54.96
P1T3	1723^{c}	1517^{efg}	1355^{fg}	1351^{cd}	1251de	1231^{e}	1172^{ef}	1095^{f}	1033^{e}	976^{gh}	884de	1235	55.47
P1T4	1429^{e}	1395^{g}	1209^{h}	1172^{f}	1072^{f}	1015^{f}	978^{gh}	963^{g}	902^{f}	828^{i}	791^{f}	1069	60.15
P1T5	1877^{ab}	1862^{ab}	1730^{bc}	1790^{a}	1688^{ab}	1576^{b}	1523^{b}	1458^{b}	1346^{b}	1262^{bc}	1224^{b}	1576	38.34
P1T6	1734^{c}	1693^{bcde}	1638^{d}	1416^{c}	1323^{d}	1376^{d}	1262de	1206^{e}	1136^{cd}	1050^{fg}	860^{ef}	1336	56.68
P1T7	1575^{d}	1465^{fg}	1312^{g}	1231^{ef}	1156^{ef}	1033^{f}	927^{h}	884^{g}	791^{g}	736^{j}	700^{g}	1074	64.74
P2T1	1858^{ab}	1730^{abcd}	1725^{bc}	1611^{b}	1558^{c}	1436^{cd}	1376^{cd}	1307^{cde}	1199^{c}	1095^{ef}	954^{d}	1441	52.04
P2T2	1795^{bc}	1709^{bcd}	1735^{bc}	1616^{b}	1531^{c}	1398^{d}	1324^{d}	1235^{e}	1195^{c}	1170de	1092^{c}	1436	45.10
P2T3	1853^{ab}	1693^{bcde}	1757^{b}	1598^{b}	1540^{c}	1449^{cd}	1386^{cd}	1247^{e}	1235^{c}	1163de	1120^{c}	1458	43.69
P2T4	1704^{c}	1669^{cde}	1532^{e}	1703^{ab}	1757^{ab}	1679^{a}	1519^{b}	1398^{bc}	1394^{b}	1327^{b}	1225^{b}	1537	38.41
P2T5	1920^{a}	1892^{a}	1891^{a}	1800^{a}	1772^{a}	1711^{a}	1675^{a}	1584^{a}	1544^{a}	1517^{a}	1376^{a}	1698	30.82
P2T6	1939^{a}	1772^{abc}	1746^{bc}	1746^{a}	1641^{bc}	1516^{bc}	1456^{bc}	1353^{cd}	1338^{b}	1228^{cd}	1224^{b}	1542	38.46
P2T7	1725^{c}	1688^{bcde}	1687^{cd}	1606^{b}	1540^{c}	1377^{d}	1354^{cd}	1296de	1228^{c}	1190^{cd}	1045^{c}	1431	47.46
SEm ±	37	53	21	32	39	32	39	30	30	27	28		
CD (0.05)	113	161	63	97	119	98	119	93	93	82	86		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Due to halogen treatment (T)

Seedling vigour index II decreased over storage irrespective of the halogenation treatment. At each month of storage, T5 ($CaOCl_2$ + $CaCO_3$ @ 3 g each/kg seed) recorded the maximum seedling vigour index I and was superior to all other treatments throughout the storage period (1899 to 1300). T6 (1042), T4 (1008), T3 (1002) and T2 (993) were found to be the next best treatments with respect to seedling vigour index II at the end of storage. T6, T4, T3 and T2 were on par with each other. The least seedling vigour index II was recorded in T7 (873) which was on par with T1 (866).

Due to interaction (P x T)

P2T5 was superior to all other treatments with respect to seedling vigour index II throughout the storage period. The seedling vigour index II in P2T5 varied from 1920 (M1) to 1376 (M11). P2T4 (1225), P2T6 (1224) and P1T5 (1224) were the next best treatments. P1T5, P2T6 and P2T4 were on par with each other. The lowest seedling vigour index II was recorded in P1T7 (700) which was on par with P1T1 (778). At the end of storage, the seedling vigour index II of untreated seeds packed in polyethylene bag was 954.

4.2.3.7 Electrical conductivity of seed leachate (dSm^{-1})

The results on electrical conductivity as influenced by packing material, halogen treatment and their interaction effects during the storage period are presented in Table 27.

Due to packing material (P)

The electrical conductivity of seed leachate was observed to increase with increase in storage period. The electrical conductivity of seed leachate of seeds stored in P2 was found to be minimum and significantly superior over that in P1 during each

Table 27: Influence of packing material, halogen treatment and their interaction effect on electrical conductivity of seed leachate (dSm^{-1}) during storage in rice (summer, 2013-14)

Treatments	Storage period (months)											
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	Mean	Per cent increase of EC
Packing materials (P)													
P1	0.0394^{a}	0.0402^{a}	0.0441^{a}	0.0475^{a}	0.0491^{a}	0.0515^{a}	0.0558^{a}	0.0585^{a}	0.0607^{a}	0.0627^{a}	0.0690^{a}	0.0526	245.00
P2	0.0352^{b}	0.0369^{b}	0.0398^{b}	0.0418^{b}	0.0446^{b}	0.0465^{b}	0.0493^{b}	0.0510^{b}	0.0531^{b}	0.0552^{b}	0.0570^{b}	0.0464	200.00
SEm ±	0.0003	0.0002	0.0004	0.0003	0.0002	0.0003	0.0002	0.0002	0.0003	0.0002	0.0006		
CD (0.05)	0.0008	0.0007	0.0013	0.0009	0.0007	0.0008	0.0007	0.0007	0.0008	0.0007	0.0018		
Halogen treatments (T)													
T1	0.0256^{f}	0.0262^{d}	0.0297^{d}	0.0355^{d}	0.0353^{e}	0.0352^{e}	0.0380^{e}	0.0401^{e}	0.0407^{e}	0.0436^{e}	0.0456^{e}	0.0360	128.00
T2	0.0275^{e}	0.0272^{d}	0.0298^{d}	0.0326^{e}	0.0335^{f}	0.0343^{e}	0.0353^{f}	0.0363^{f}	0.0372^{f}	0.0395^{f}	0.0406^{f}	0.0340	103.00
T3	0.0330^{d}	0.0359^{c}	0.0385^{c}	0.0398^{c}	0.0411^{d}	0.0422^{d}	0.0436^{d}	0.0449^{d}	0.0472^{d}	0.0487^{d}	0.0511^{d}	0.0424	155.50
T4	0.0514^{b}	0.0516^{b}	0.0540^{b}	0.0558^{b}	0.0570^{c}	0.0593^{c}	0.0609^{c}	0.0625^{c}	0.0643^{c}	0.0664^{c}	0.0674^{c}	0.0591	237.00
T5	0.0213^{g}	0.0240^{e}	0.0257^{e}	0.0265^{f}	0.0278^{g}	0.0295^{f}	0.0310^{g}	0.0334^{g}	0.0347^{g}	0.0361^{g}	0.0369^{f}	0.0297	84.50
T6	0.0487^{c}	0.0516^{b}	0.0540^{b}	0.0558^{b}	0.0636^{b}	0.0686^{b}	0.0769^{b}	0.0793^{b}	0.0828^{b}	0.0843^{b}	0.0893^{b}	0.0686	346.50
T7	0.0536^{a}	0.0533^{a}	0.0622^{a}	0.0664^{a}	0.0698^{a}	0.0741^{a}	0.0823^{a}	0.0866^{a}	0.0913^{a}	0.0941^{a}	0.1101^{a}	0.0767	450.50
SEm ±	0.0006	0.0005	0.0009	0.0007	0.0005	0.0006	0.0005	0.0005	0.0006	0.0005	0.0012		
CD (0.05)	0.0017	0.0015	0.0027	0.0020	0.0015	0.0017	0.0015	0.0015	0.0017	0.0015	0.0038		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 27: Influence of packing material, halogen treatment and their interaction effect on electrical conductivity of seed leachate (dSm^{-1}) during storage in rice (summer, 2013-14) (contd)

Treatments	Storage period (months)											
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	Mean	Per cent increase of EC
Interaction (P x T)												
P1T1	0.0258^{g}	0.0273^{fg}	0.0309^{ef}	0.0365^{f}	0.0355^{h}	0.0354^{g}	0.0390^{g}	0.0417^{h}	0:0428^{i}	0.0471^{h}	0.0496^{g}	0.0374	148.00
P1T2	0.0286^{ef}	0.0279^{ef}	0.0309^{ef}	0.0342^{f}	0.0354^{a}	0.0366^{g}	0.0379^{g}	0.0384^{i}	0.0391^{j}	0.0406^{j}	0.0418^{hi}	0.0356	109.00
P1T3	0.0354^{d}	0.0395^{d}	0.0439^{d}	0.0461^{e}	0.0471^{g}	0.0481^{f}	0.0495^{f}	0.0506^{g}	0.0518^{h}	0.0534^{g}	0.0562^{f}	0.0474	181.00
P1T4	0.0566^{a}	0.0530^{a}	0.0563^{b}	0.0595^{c}	0.0606^{e}	0.0627^{d}	0.0645^{d}	0.0660^{e}	0.0669^{f}	0.0690^{e}	0.0701^{c}	0.0623	250.50
P1T5	0.0216^{h}	0.0247^{h}	0.0266^{g}	0.0274^{h}	0.0288^{j}	0.0306^{hi}	0.0327^{h}	0.0352^{j}	0.0364^{k}	0.0374^{k}	0.0383^{ij}	0.0309	91.50
P1T6	0.0511^{b}	0.0530^{b}	0.0563^{b}	0.0595^{c}	0.0645^{d}	0.0709^{b}	0.0830^{a}	0.0868^{b}	0.0919^{c}	0.0935^{b}	0.0986^{b}	0.0736	393.00
P1T7	0.0564^{a}	0.0558^{a}	0.0637^{a}	0.0692^{a}	0.0717^{b}	0.0766^{a}	0.0842^{a}	0.0908^{a}	0.0960^{b}	0.0978^{a}	0.1285^{a}	0.0810	542.50
P2T1	0.0253^{g}	0.0251^{g}	0.0286^{fg}	0.0345^{f}	0.0351^{h}	0.0350^{g}	0.0369^{g}	0.0385^{i}	0.0387^{a}	0.0401^{j}	0.0416^{hi}	0.0345	118.95
P2T2	0.0265^{fg}	0.0266^{fg}	0.0287^{fg}	0.0310^{g}	0.0316^{i}	0.0320^{h}	0.0326^{h}	0.0341^{j}	0.0353^{kl}	0.0384^{jk}	0:0394^{ij}	0.0324	107.37
P2T3	0.0307^{e}	0.0323^{e}	0.0330^{e}	0.0336^{fg}	0.0351^{h}	0.0363^{g}	0.0378^{g}	0.0391^{k}	0.0427^{i}	0.0440^{i}	0.0461^{gh}	0.0373	142.63
P2T4	0.0462^{c}	0.0502^{c}	0.0517^{c}	0.0522^{d}	0.0535^{f}	0.0560^{e}	0.0574^{e}	0.0591^{f}	0.0616^{g}	0.0638^{f}	0.0648^{e}	0.0560	241.05
P2T5	0.0210^{h}	0.0234^{h}	0.0247^{g}	0.0256^{h}	0.0268^{j}	0.0284^{i}	0.0294^{i}	0.0316^{k}	0.0330^{l}	0.0349^{l}	0.0355^{j}	0.0286	86.84
P2T6	0.0462^{c}	0.0502^{c}	0.0517^{c}	0.0522^{d}	0.0627^{de}	0.0664^{c}	0.0708^{c}	0.0719^{d}	0.0737^{c}	0.0750^{d}	0.0800^{d}	0.0637	321.05
P2T7	0.0507^{b}	0.0509^{b}	0.0607^{a}	0.0636^{b}	0.0679^{c}	0.0716^{b}	0.0804^{b}	0.0825^{c}	0.0866^{d}	0.0905^{c}	0.0916^{c}	0.0725	382.11
SEm ±	0.0008	0.0007	0.0013	0.0009	0.0007	0.0008	0.0007	0.0007	0.0008	0.0007	0.0018		
CD (0.05)	0.0024	0.0022	0.0039	0.0028	0.0022	0.0024	0.0022	0.0022	0.0024	0.0022	0.0054		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

month of storage. The electrical conductivity of seed leachate increased from 0.0200 dSm^{-1} to 0.0690 dSm^{-1} in P1 (jute bag) while the increase was from 0.0190 dSm^{-1} to 0.0570 dSm^{-1} in P2 (polyethylene bag of 400G).

Due to halogen treatment (T)

Electrical conductivity of seed leachate increased over storage irrespective of the halogenation treatment. At each month of storage, T5 ($CaOCl_2$ + $CaCO_3$ @ 3 g each/kg seed) recorded the minimum electrical conductivity of seed leachate and was superior to all other treatments throughout the storage period (0.0213 to 0.0369 dSm^{-1}). T2 (0.0406 dSm^{-1}) was found to be the next best treatment with respect to electrical conductivity of seed leachate at the end of storage. T5 and T2 were on par with each other. The highest electrical conductivity of seed leachate was recorded in T7 (0.1101 dSm^{-1}) followed by T6 (0.0893 dSm^{-1}).

Due to interaction (P x T)

P2T5 was superior to all other treatments with respect to electrical conductivity of seed leachate throughout the storage period. The electrical conductivity of seed leachate in P2T5 varied from 0.0210 dSm^{-1} (M1) to 0.0355 dSm^{-1} (M11). P1T5 (0.0383 dSm^{-1}) and P2T2 (0.0394 dSm^{-1}) were the next best treatments. P1T5, P2T2 and P2T5 were on par with each other. The highest electrical conductivity of seed leachate was recorded in P1T7 (0.1285 dSm^{-1}) followed by P1T6 (0.0986 dSm^{-1}). At the end of storage, the electrical conductivity of seed leachate of untreated seeds packed in jute bag (P1T1) was 0.0496 dSm^{-1}.

4.2.3.8 Moisture content

The results on seed moisture content as influenced by packing material, halogen treatment and their interaction effects during the storage period are presented in Table 28.

Table 28: Influence of packing material, halogen treatment and their interaction effect on moisture content (%) during storage in rice (summer, 2013-14)

Treatments	Moisture content (%)											
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	Mean	Per cent increase of MC
Packing materials (P)													
P1	13.0^{a}	13.5^{a}	14.8^{a}	14.9^{a}	15.0^{a}	15.0^{a}	15.0^{a}	14.9^{a}	14.9^{a}	16.6^{a}	16.5^{a}	14.9	34.15
P2	10.0^{b}	10.1^{b}	10.2^{b}	10.4^{b}	10.4^{b}	10.5^{b}	10.5^{b}	10.6^{b}	10.6^{b}	10.7^{b}	10.7^{b}	10.4	7.00
SEm ±	0.02	0.02	0.03	0.06	0.02	0.02	0.02	0.03	0.02	0.04	0.04		
CD (0.05)	0.05	0.07	0.08	0.18	0.07	0.05	0.05	0.08	0.07	0.12	0.11		
Halogen treatments (T)													
T1	11.4^{b}	11.7^{b}	12.2^{d}	12.3^{c}	12.5^{c}	12.6^{c}	12.6^{c}	12.5^{c}	12.5^{c}	13.9^{bc}	14.0^{b}	12.6	25.00
T2	11.3^{bc}	11.7^{b}	12.2^{d}	12.2^{c}	12.3^{d}	12.4^{c}	12.4^{e}	12.4^{c}	12.4^{c}	13.1^{e}	13.1^{d}	12.3	16.96
T3	11.3^{bc}	11.5^{c}	12.4^{c}	12.3^{c}	12.5^{c}	12.5^{d}	12.5^{d}	12.5^{c}	12.5^{c}	14.0^{b}	13.8^{b}	12.5	23.21
T4	11.3^{bc}	11.7^{b}	12.7^{b}	12.9^{b}	13.0^{b}	13.1^{b}	13.1^{b}	13.0^{b}	13.1^{b}	13.6^{d}	13.5^{c}	12.8	20.54
T5	11.2^{c}	11.4^{c}	12.3^{cd}	12.4^{c}	12.4^{cd}	12.4^{e}	12.4^{e}	12.5^{c}	12.5^{c}	12.8^{f}	12.8^{e}	12.3	14.29
T6	12.1^{a}	12.4^{a}	12.9^{a}	13.0^{b}	13.1^{ab}	13.1^{b}	13.1^{b}	13.1^{ab}	13.2^{ab}	13.7^{cd}	13.9^{c}	13.1	24.11
T7	12.1^{a}	12.4^{a}	13.0^{a}	13.6^{a}	13.2^{a}	13.2^{a}	13.2^{a}	13.3^{a}	13.3^{a}	14.6^{a}	14.5^{a}	13.3	29.46
SEm ±	0.04	0.05	0.05	0.12	0.05	0.03	0.03	0.05	0.05	0.08	0.08		
CD (0.05)	0.11	0.15	0.16	0.38	0.14	0.09	0.09	0.16	0.15	0.24	0.23		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 28: Influence of packing material, halogen treatment and their interaction effect on moisture content (%) during storage in rice (summer, 2013-14) (contd)

Treatments	Moisture content (%)											
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	Mean	Per cent increase of MC
Interaction (P x T)													
P1T1	12.9^{b}	13.3^{c}	14.3^{cd}	14.5^{b}	14.6^{c}	14.8^{c}	14.8^{c}	14.5^{c}	14.5^{c}	17.2^{b}	17.2^{b}	14.8	39.84
P1T2	12.5^{cd}	13.2^{c}	14.2^{d}	14.2^{b}	14.3^{d}	14.3^{e}	14.3^{e}	14.2^{d}	14.2^{d}	15.6^{d}	15.5^{e}	14.2	26.02
P1T3	12.6^{c}	12.9^{d}	14.5^{c}	14.4^{b}	14.6^{c}	14.6^{d}	14.6^{d}	14.4^{cd}	14.4^{c}	17.4^{b}	17.0^{b}	14.7	38.21
P1T4	12.6^{c}	13.3^{c}	15.2^{b}	15.4^{a}	15.6^{b}	15.6^{b}	15.6^{b}	15.4^{b}	15.4^{b}	16.5^{c}	16.2^{d}	15.2	31.71
P1T5	12.4^{d}	12.8^{d}	14.4^{cd}	14.5^{b}	14.5^{c}	14.4^{e}	14.4^{e}	14.5^{c}	14.5^{c}	15.0^{e}	15.0^{f}	14.2	21.95
P1T6	14.1^{a}	14.7^{a}	15.5^{a}	15.8^{a}	15.9^{a}	15.9^{a}	15.9^{a}	15.8^{a}	15.8^{a}	16.6^{c}	16.9^{c}	15.7	37.40
P1T7	14.2^{a}	14.5^{b}	15.6^{a}	15.8^{a}	15.8^{a}	15.8^{a}	15.8^{a}	15.8^{a}	15.8^{a}	18.3^{a}	18.1^{a}	16.0	47.15
P2T1	10.0^{e}	10.1^{e}	10.2^{e}	10.2^{c}	10.4^{e}	10.4^{g}	10.5^{gh}	10.6^{ef}	10.6^{ef}	10.7^{f}	10.7^{g}	10.4	7.00
P2T2	10.1^{e}	10.2^{e}	10.2^{e}	10.3^{c}	10.4^{e}	10.5^{g}	10.5^{gh}	10.6^{ef}	10.6^{ef}	10.7^{f}	10.7^{g}	10.4	7.00
P2T3	10.0^{e}	10.1^{e}	10.3^{e}	10.2^{c}	10.4^{e}	10.5^{g}	10.5^{gh}	10.5^{f}	10.6^{ef}	10.6^{f}	10.7^{g}	10.4	7.00
P2T4	10.1^{e}	10.2^{e}	10.3^{e}	10.4^{c}	10.5^{e}	10.5^{g}	10.6^{fg}	10.7^{ef}	10.7^{ef}	10.7^{f}	10.8^{g}	10.5	8.00
P2T5	10.0^{e}	10.1^{c}	10.2^{c}	10.3^{c}	10.3^{e}	10.4^{g}	10.5^{gh}	10.5^{f}	10.5^{f}	10.6^{f}	10.6^{g}	10.4	6.00
P2T6	10.1^{e}	10.2^{e}	10.3^{e}	10.3^{c}	10.4^{e}	10.4^{g}	10.4^{h}	10.5^{f}	10.6^{ef}	10.8^{f}	10.9^{g}	10.4	9.00
P2T7	10.1^{e}	10.3^{c}	10.4^{e}	10.4^{c}	10.5^{e}	10.7^{f}	10.7^{f}	10.8^{e}	10.8^{e}	10.9^{f}	10.9^{g}	10.6	9.00
SEm ±	0.05	0.06	0.07	0.08	0.06	0.04	0.04	0.07	0.06	0.10	0.09		
CD (0.05)	0.14	0.19	0.21	0.23	0.18	0.12	0.12	0.21	0.19	0.31	0.28		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Due to packing material (P)

The moisture content of seed was observed to increase with increase in storage period. The moisture content of seeds stored in P2 was found to be minimum and significantly superior over that in P1 during each month of storage. The seed moisture content increased from 12.3 to 16.5 per cent in P1 (jute bag) while the increase was from 10.0 to 10.7 per cent in P2 (polyethylene bag of 400G).

Due to halogen treatment (T)

Seed moisture content increased during storage irrespective of the halogenation treatment. At each month of storage, T5 ($CaOCl_2$ + $CaCO_3$ @ 3 g each/kg seed) recorded the minimum seed moisture content and was superior to all other treatments throughout the storage period (11.2 to 12.8%). T2 (13.1%) was found to be the next best treatment with respect to seed moisture content at the end of storage. The highest seed moisture content was recorded in T7 (14.5%).

Due to interaction (P x T)

P2T5 was superior to all other treatments with respect to seed moisture content throughout the storage period. The moisture content of seed in P2T5 varied from 10.0 per cent (M1) to 10.6 per cent (M11). All the treatment combinations involving polyethylene bag maintained the moisture content throughout the storage period. The highest seed moisture content was recorded in P1T7 (18.1%).

4.2.3.9 Seed infection

The results on seed infection as influenced by packing material, halogen treatment and their interaction effects during the storage period are presented in Table 29.

Table 29: Influence of packing material, halogen treatment and their interaction effect on seed infection (%) during storage in rice (summer, 2013-14)

Treatments	Seed infection (%)	
	End of storage	Per cent increase of seed infection
Packing materials (P)		
P1	24.71^{a} (14.31)	394.20
P2	18.57^{b} (10.70)	271.40
SEm ±	0.24	
CD (0.05)	0.73	
Halogen treatments (T)		
T1	30.00^{a} (17.46)	500.00
T2	17.00^{e} (9.79)	240.00
T3	19.50^{d} (11.24)	290.00
T4	21.00^{d} (12.12)	320.00
T5	13.50^{f} (7.76)	170.00
T6	24.00^{c} (13.89)	380.00
T7	26.50^{b} (15.37)	430.00
SEm ±	0.51	
CD (0.05)	1.55	
Interaction (PxT)		
P1T1	36.00^{a} (21.10)	500.00
P1T2	20.00^{ef} (11.54)	233.33
P1T3	21.00^{e} (12.12)	250.00
P1T4	22.00^{e} (12.71)	266.67
P1T5	15.00^{g} (8.63)	150.00
P1T6	28.00^{c} (16.26)	366.67
P1T7	31.00^{b} (18.06)	416.67
P2T1	24.00^{d} (13.89)	500.00
P2T2	14.00^{g} (8.05)	250.00
P2T3	18.00^{f} (10.37)	350.00
P2T4	20.00^{ef} (11.54)	400.00
P2T5	12.00^{h} (6.89)	200.00
P2T6	20.00^{ef} (11.54)	400.00
P2T7	22.00^{e} (12.71)	450.00
SEm ±	0.64	
CD (0.05)	1.94	

Initial seed infection

P1- 6.00 %

P2- 4.00 %

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Due to packing material (P)

The seed infection (%) varied from 6.00 per cent to 24.71 per cent in P1 (jute bag) and from 4.00 to 18.57 per cent in P2 (polyethylene bag of 400G) during storage. The per cent increase in seed infection over initial infection ranged from 271.40 in P2 to 394.20 in P1.

Due to halogen treatment (T)

The seed infection (%) varied from 13.50 per cent in T5 to 30.00 per cent in T1 at the end of storage period. The lowest seed infection was recorded in $CaOCl_2$ + $CaCO_3$ @ 3 g each/kg seed (T5) (13.50%), followed by T2 (17.00%) and highest seed infection (%) was recorded in T1 (control) (30.00 %) at the end of storage period. The per cent increase over initial infection varied from 170.00 in T5 to 500.00 in T1.

Due to interaction (P x T)

The lowest seed infection was recorded in P2T5 (12.00%), followed by P2T2 (14.00%) on par with P1T5 (15.00%). Untreated seeds stored in jute bags (P1T1) recorded the highest infection (36.00%) at the end of storage period. The per cent increase varied from 150.00 in P1T5 to 500.00 in P1T1 over initial infection. Seed microflora observed were *Aspergillus* sp. and *Rhizopus* sp.

4.3 Seed longevity of rice variety Jyothi (*kharif* 2014)

The result pertaining to seeds of *kharif* 2014 stored over a period of seven months is enumerated below.

4.3.1 Analysis of variance

The analysis of variance revealed that, there existed significant differences in the impact on seed qualities like germination per cent, seedling shoot

Table 30: Seed quality parameters before storage (M0) (*kharif* 2014)

Packing material (P)	Moisture content (%)	Germination (%)	Seedling shoot length (cm)	Seedling root length (cm)	Seedling dry weight (mg)	Vigour index I	Vigour index II	EC (dSm^{-1})	Seed infection (%)
P1*	12.3	98.25	20.13	30.00	20.00	4925	1965	0.0230	5.00
P2**	10.0	98.50	20.15	30.05	20.15	4945	1985	0.0218	5.00

*observations were taken after drying the seeds to a moisture content of 12.3%

**observations were taken after drying the seeds to a moisture content of 10.0%

and root length, seedling dry weight, seedling vigour index I and II, electrical conductivity of seed leachate, seed moisture content and seed infection per cent among the various packing material, seed halogenation treatments and their interaction during storage.

4.3.2 Seed quality before storage

The results on seed quality parameters before treatment and storage are presented in Table 30.

The seed quality parameters recorded before storage was moisture content (12.3 % and 10.0 %), germination (98.25 % and 98.50 %), seedling shoot length (20.13 cm and 20.15 cm), seedling root length (30.00 cm and 30.05 cm), seedling dry weight (20.00 mg and 20.15 mg), vigour index I (4925 and 4945), vigour index II (1965 and 1985), electrical conductivity of seed leachate (0.0230 dSm^{-1} and 0.0218 dSm^{-1}) in P1 (jute bag) and P2 (polyethylene bag of 400G), respectively.

4.3.3 Seed quality during storage

4.3.3.1 Germination (%)

The results on germination percentage as influenced by seed quality, seed priming and their interaction effects during five months of storage period are presented in Table 31.

Due to packing material (P)

Germination declined progressively over the period of storage. Throughout the storage period, the germination of seeds stored in P2 was significantly superior to that stored in P1 except 3rd and 4th month. Germination in P1 (jute bag) reduced from 98.25 to 83.81 per cent while the reduction was from 98.50 per cent to 86.94 per cent in P2 (polyethylene bag of 400G). A reduction of 11.78 per cent (P2) and 14.71 per

Table 31: Influence of packing material, halogen treatment and their interaction effect on germination (%) during storage in rice (*kharif*, 2014)

Treatments	Storage period (months)								
	M1	M2	M3	M4	M5	M6	M7	Mean	Per cent reduction of germination
Packing materials (P)									
P1	93.06[b] (68.52)	91.54[b] (66.26)	91.11 (65.66)	90.57 (64.92)	89.09[b] (62.99)	87.45[b] (60.98)	83.81[b] (56.94)	89.51	14.71
P2	95.07[a] (71.94)	93.23[a] (68.80)	91.82 (66.67)	91.00 (65.51)	90.50[a] (64.83)	89.18[a] (63.10)	86.94[a] (60.39)	91.10	11.78
SEm ±	0.70	0.56	0.41	0.51	0.52	0.49	0.53		
CD (0.05)	2.13	1.70	NS	NS	1.59	1.51	1.63		
Halogen treatments (T)									
T1	96.00[ab] (73.74)	93.94[b] (69.95)	94.07[b] (70.16)	94.07[ab] (70.16)	93.50[ab] (69.23)	92.25[ab] (67.29)	88.07[b] (61.73)	93.13	10.48
T2	92.57[cd] (67.77)	92.69[bc] (67.96)	92.19[c] (67.21)	91.57[c] (66.30)	91.76[c] (66.58)	90.25[b] (64.49)	87.38[bc] (60.90)	91.20	11.18
T3	94.94[bc] (71.70)	93.19[b] (68.73)	92.57[bc] (67.77)	92.38[bc] (67.48)	91.44[bc] (66.12)	90.25[b] (64.49)	88.57[b] (62.34)	91.91	9.97
T4	94.07[bc] (70.16)	91.51[bcd] (66.21)	90.82[c] (65.25)	90.07[c] (64.24)	89.13[c] (63.04)	87.07[c] (60.54)	84.38[c] (57.54)	89.58	14.23
T5	97.32[a] (76.69)	96.38[a] (74.54)	96.32[a] (74.40)	94.82[a] (71.47)	94.19[a] (70.37)	93.19[a] (68.73)	91.94[a] (66.84)	94.88	6.55
T6	93.13[cd] (68.64)	90.26[cd] (64.50)	87.88[d] (61.50)	87.01[d] (60.46)	85.07[d] (58.29)	83.32[d] (56.43)	79.82[d] (52.96)	86.64	18.87
T7	90.44[d] (64.74)	88.75[d] (62.56)	86.44[d] (59.81)	85.63[d] (58.90)	83.50[d] (56.62)	81.88[d] (54.96)	77.49[d] (50.80)	84.88	21.23
SEm ±	1.48	1.18	0.87	1.08	1.10	1.05	1.13		
CD (0.05)	4.51	3.61	2.65	3.31	3.37	3.20	3.45		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability
**Values in parentheses are Arc sine transformed values

Table 31: Influence of packing material, halogen treatment and their interaction effect on germination (%) during storage in rice (*kharif*, 2014) (contd)

Treatments	Storage period (months)								
	M1	M2	M3	M4	M5	M6	M7	Mean	Per cent reduction of germination
				Interaction (P x T)					
P1T1	94.50^{cd} (70.91)	94.38^{bc} (70.70)	94.25^{bc} (70.48)	93.75^{abc} (69.64)	93.25^{ab} (68.83)	91.25^{abcd} (65.85)	86.00^{cde} (59.32)	92.48	12.47
P1T2	92.13^{de} (67.12)	92.38^{cd} (67.49)	92.38^{cde} (67.49)	92.13^{bcd} (67.12)	91.38^{bcd} (66.04)	89.00^{de} (62.87)	85.50^{de} (58.76)	90.70	12.98
P1T3	95.00^{bcd} (71.81)	92.63^{cd} (67.87)	92.38^{cde} (67.49)	92.50^{bcd} (67.67)	91.00^{bcd} (65.51)	89.75^{cd} (63.83)	87.38^{bcd} (60.90)	91.52	11.06
P1T4	92.00^{de} (66.93)	90.38^{de} (64.66)	90.00^{ef} (64.16)	90.00^{de} (64.16)	88.50^{def} (62.25)	85.63^{ef} (58.90)	83.00^{ef} (56.10)	88.50	15.52
P1T5	96.38^{abc} (74.54)	95.88^{ab} (73.50)	96.00^{ab} (73.74)	94.25^{ab} (70.48)	93.75^{ab} (69.64)	92.63^{abc} (67.87)	90.88^{ab} (65.34)	94.25	7.50
P1T6	92.38^{de} (67.49)	88.13^{e} (61.80)	86.88^{g} (60.32)	86.38^{f} (59.75)	83.75^{gh} (56.88)	82.88^{fg} (55.98)	78.00^{ghi} (51.26)	85.49	20.61
P1T7	89.00^{e} (62.87)	87.00^{e} (60.46)	85.88^{g} (59.18)	85.00^{f} (58.21)	82.00^{h} (55.08)	81.00^{g} (54.10)	75.88^{h} (49.36)	83.68	22.77
P2T1	97.50^{ab} (77.16)	93.50^{bcd} (69.23)	93.88^{cd} (69.85)	94.38^{ab} (70.70)	93.75^{ab} (69.64)	93.25^{ab} (68.83)	90.13^{ab} (64.33)	93.77	8.50
P2T2	93.00^{cde} (68.43)	93.00^{bcd} (68.43)	92.00^{cde} (66.93)	91.00^{cde} (65.51)	92.13^{abc} (67.12)	91.50^{abcd} (66.21)	89.25^{bcd} (63.19)	91.70	9.39
P2T3	94.88^{bcd} (71.59)	93.75^{bcd} (69.64)	92.75^{cd} (68.05)	92.25^{bcd} (67.29)	91.88^{abcd} (66.75)	90.75^{bcd} (65.16)	89.75^{abc} (63.83)	92.29	8.88
P2T4	96.13^{abc} (74.01)	92.63^{cd} (67.87)	91.63^{de} (66.39)	90.13^{de} (64.33)	89.75^{cde} (63.83)	88.50^{de} (62.25)	85.75^{de} (59.04)	90.65	12.94
P2T5	98.25^{a} (79.27)	96.88^{a} (75.65)	96.63^{a} (75.08)	95.38^{a} (72.52)	94.63^{a} (71.14)	93.75^{a} (69.64)	93.00^{a} (68.43)	95.50	5.58
P2T6	93.88^{cd} (69.85)	92.38^{cd} (67.49)	88.88^{fg} (62.72)	87.63^{ef} (61.20)	86.38^{efg} (59.75)	83.75^{fg} (56.88)	81.63^{efg} (54.72)	87.79	17.13
P2T7	91.88^{de} (66.75)	90.50^{de} (64.82)	87.00^{g} (60.46)	86.25^{f} (59.60)	85.00^{fgh} (58.21)	82.75^{fg} (55.84)	79.10^{fgh} (52.28)	86.07	19.70
SEm ±	1.84	1.47	1.08	1.36	1.38	1.31	1.41		
CD (0.05)	3.25	3.00	2.23	2.67	2.67	2.59	2.70		

cent (P1) in germination over initial germination was observed. The germination in P1 and P2 was above the MSCS of 80 per cent at the end of seven months of storage.

Due to halogen treatment (T)

Reduction in germination was observed with increase in storage period. Seed halogenated at T5 ($CaOCl_2$ +$CaCO_3$@ 3g each/kg of seed) was superior to other treated and untreated seeds at each month of storage. Germination per cent in T5 at the end of the storage period of seven months was the highest (91.94%). T1 (88.07%), T2 (87.38%) and T3 (88.57%) were the next best which were on par with each other. Treatment T7 recorded the least germination (77.49%) which was on par with T6 (79.82%) The per cent reduction varied from 6.55 in T5 to 21.23 in T7 over initial germination. All the treatments retained above the MSCS for seven months except T6 and T7.

Due to interaction (P x T)

P2T5 was superior to other treatments with respect to germination throughout the storage period. P2T5 recorded a germination of 93.00 per cent at the end of seven months of storage. At the end of storage period, P1T7 recorded the least germination (75.88%) which was on par with P1T6 (78.00%) and P1T7 (79.10%).Treatment P1T6, P1T7 and P2T7 retained viability above MSCS for the least period (6 months). The viability in other treatment combinations was retained above MSCS at the end of seven months of storage.

4.3.3.2 Seedling shoot length (cm)

The results on shoot length as influenced by packing material, halogen treatment and their interaction effects during the storage period are presented in Table 32.

Due to packing material (P)

Seedling shoot length was observed to decrease with increase in storage period. The shoot length of seeds stored in P2 was found to be maximum and significantly superior over that in P1 during each month of storage. The shoot length decreased from 20.13 to 13.24 cm in P1 (jute bag) while the reduction was from 20.15 to 14.52 cm in P2 (polyethylene bag of 400G).

Due to halogen treatment (T)

Seedling shoot length decreased over storage irrespective of the halogenation treatment. At each month of storage, T5 ($CaOCl_2$ + $CaCO_3$ @ 3 g each/kg seed) recorded the maximum shoot length and was superior to all other treatments throughout the storage period. T1 was found to be the next best treatment with respect to shoot length (15.43 cm) at the end of storage while it was least the in T7 (10.53 cm). Treatment T6 recorded the next lowest shoot length (12.50 cm).

Due to interaction (P x T)

P2T5 was superior to all other treatments with respect to shoot length throughout the storage period. The shoot length in P2T5 varied from 19.35 cm (M1) to 17.27 cm (M7). P1T5 (16.23 cm) and P2T1 (15.93 cm) were the next best treatments. P1T5 and P2T1 were on par with each other. At the end of storage, the shoot length of untreated seeds packed in jute bag was 14.93 cm. The lowest shoot length was recorded in P1T7 (10.05 cm) followed by P1T6 (11.00 cm) and P2T7 (11.01 cm) which was on par with each other.

Table 32: Influence of packing material, halogen treatment and their interaction effect on seedling shoot length (cm) during storage in rice (*kharif*, 2014)

Treatments	Storage period (months)								
	M1	M2	M3	M4	M5	M6	M7	Mean	Per cent reduction of shoot length
Packing materials (P)									
P1	15.85^{b}	14.70^{b}	14.24^{b}	13.74^{b}	13.48^{b}	13.37^{b}	13.24^{b}	14.09	34.23
P2	17.14^{a}	16.24^{a}	15.99^{a}	15.37^{a}	15.04^{a}	14.72^{a}	14.52^{a}	15.57	27.94
SEm ±	0.06	0.08	0.08	0.08	0.08	0.05	0.07		
CD (0.05)	0.18	0.23	0.24	0.25	0.23	0.16	0.22		
Halogen treatments (T)									
T1	17.94^{b}	16.57^{b}	15.88^{b}	15.59^{b}	15.47^{b}	15.38^{b}	15.43^{b}	16.04	23.39
T2	16.33^{d}	16.03^{c}	15.84^{b}	15.63^{b}	15.29^{b}	14.71^{c}	14.51^{c}	15.48	27.95
T3	15.85^{e}	14.89^{d}	15.05^{c}	14.08^{c}	13.93^{d}	13.46^{d}	13.37^{d}	14.38	33.61
T4	17.03^{c}	15.67^{c}	15.66^{b}	15.13^{b}	14.72^{c}	14.67^{c}	14.09^{c}	15.28	30.04
T5	19.01^{a}	17.84^{a}	17.34^{a}	17.13^{a}	16.81^{a}	16.83^{a}	16.75^{a}	17.39	16.83
T6	15.44^{f}	14.42^{d}	14.26^{d}	13.38^{d}	12.92^{e}	12.56^{e}	12.50^{e}	13.64	37.93
T7	13.88^{g}	12.91^{e}	11.81^{e}	10.97^{e}	10.68^{f}	10.73^{f}	10.53^{f}	11.64	47.72
SEm ±	0.13	0.16	0.16	0.18	0.16	0.11	0.15		
CD (0.05)	0.39	0.50	0.50	0.54	0.49	0.33	0.47		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 32: Influence of packing material, halogen treatment and their interaction effect on seedling shoot length (cm) during storage in rice (*kharif*, 2014) (contd)

Treatments	Storage period (months)								
	M1	M2	M3	M4	M5	M6	M7	Mean	Per cent reduction of shoot length
Interaction (P x T)									
P1T1	17.70^{cd}	16.63^{cd}	15.39^{de}	15.05^{de}	14.94^{c}	14.90^{d}	14.93^{c}	15.65	25.83
P1T2	15.60^{g}	15.00^{e}	14.54^{f}	14.63^{e}	14.46^{c}	14.23^{e}	14.23^{de}	14.67	29.31
P1T3	15.07^{h}	13.74^{f}	13.38^{g}	13.22^{f}	13.12^{d}	12.91^{f}	12.83^{g}	13.47	36.26
P1T4	16.92^{ef}	14.93^{e}	14.81^{ef}	14.58^{e}	14.42^{c}	14.40^{e}	13.43^{f}	14.78	33.28
P1T5	18.67^{b}	17.50^{b}	17.15^{ab}	16.51^{b}	16.18^{b}	16.28^{b}	16.23^{b}	16.93	19.37
P1T6	13.59^{j}	12.51^{h}	13.02^{g}	11.54^{g}	11.04^{e}	10.68^{h}	11.00^{h}	11.91	45.36
P1T7	13.38^{j}	12.61^{gh}	11.39^{i}	10.64^{h}	10.17^{f}	10.20^{i}	10.05^{i}	11.21	50.07
P2T1	18.18^{c}	16.50^{cd}	16.36^{c}	16.13^{bc}	16.00^{b}	15.85^{c}	15.93^{b}	16.42	20.94
P2T2	17.06^{ef}	17.06^{bc}	17.14^{ab}	16.63^{b}	16.12^{b}	15.18^{d}	14.79^{cd}	16.28	26.60
P2T3	16.62^{f}	16.03^{d}	16.72^{bc}	14.93^{e}	14.74^{c}	14.00^{e}	13.91^{ef}	15.28	30.97
P2T4	17.14^{ef}	16.40^{cd}	16.50^{bc}	15.67^{cd}	15.01^{c}	14.94^{d}	14.74^{cd}	15.77	26.85
P2T5	19.35^{a}	18.17^{a}	17.52^{a}	17.74^{a}	17.44^{a}	17.38^{a}	17.27^{a}	17.84	14.29
P2T6	17.28^{de}	16.33^{d}	15.49^{d}	15.21^{de}	14.79^{c}	14.44^{e}	14.00^{ef}	15.36	30.52
P2T7	14.38^{i}	13.20^{fg}	12.23^{h}	11.30^{gh}	11.18^{e}	11.25^{g}	11.01^{h}	12.08	45.36
SEm ±	0.16	0.20	0.20	0.22	0.20	0.13	0.19		
CD (0.05)	0.49	0.62	0.62	0.67	0.61	0.41	0.59		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

4.3.3.3 Seedling root length (cm)

The results on root length as influenced by packing material, halogen treatment and their interaction effects during the storage period are presented in Table 33.

Due to packing material (P)

Seedling root length decreased over the period of storage. The root length of seeds stored in P2 was found to be maximum and superior over that in P1 during each month of storage. Root length of seedling decreased from 30.00 to 22.60 cm in P1 (jute bag) whereas the reduction was from 30.05 to 23.69 cm in P2 (polyethylene bag of 400G).

Due to halogen treatment (T)

As in seedling shoot length, seedling root length also decreased over storage irrespective of halogen treatment. Treatment T1 recorded the highest root length (25.81 cm) at the end of seven months storage. T5 was found to be the next best treatment with respect to root length (25.12 cm) at the end of storage. Treatment T7 recorded the least root length (19.29 cm) at the end of storage period.

Due to interaction (P x T)

Maximum root length of 26.66 cm was recorded in P2T1 followed by P2T5 (25.99 cm) at the end of storage period. The lowest root length was recorded in P1T7 (19.10 cm) which was found to be on par with P2T7 (19.47 cm) at the end of storage period. The untreated seeds stored in jute (P1T1) recorded a root length of 24.95 cm.

Table 33: Influence of packing material, halogen treatment and their interaction effect on seedling root length (cm) during storage in rice (*kharif*, 2014)

Treatments	Storage period (months)								
	M1	M2	M3	M4	M5	M6	M7	Mean	Per cent reduction of root length
Packing materials (P)									
P1	25.09[b]	24.77[b]	24.05[b]	23.29[b]	22.71[b]	22.88[b]	22.60[b]	23.63	24.67
P2	26.58[a]	25.43[a]	25.16[a]	24.43[a]	23.97[a]	23.90[a]	23.69[a]	24.74	21.16
SEm ±	0.08	0.06	0:06	0.05	0.07	0.06	0.06		
CD (0.05)	0.25	0.19	0.18	0.16	0.20	0.17	0.18		
Halogen treatments (T)									
T1	27.05[b]	26.62[a]	26.30[a]	25.49[a]	25.65[a]	25.67[ab]	25.81[a]	26.08	14.05
T2	25.12[c]	23.98[c]	23.82[c]	22.85[b]	22.75[c]	22.65[c]	22.71[d]	23.41	24.38
T3	24.96[c]	24.64[b]	23.58[c]	22.88[b]	22.70[c]	22.59[cd]	22.72[d]	23.44	24.34
T4	24.37[d]	23.67[c]	23.56[c]	22.88[b]	22.39[c]	22.27[d]	21.98[e]	23.02	26.81
T5	27.33[ab]	26.75[a]	26.26[a]	25.75[a]	25.31[ab]	25.34[b]	25.12[b]	25.98	16.35
T6	27.75[a]	26.35[a]	25.86[b]	25.46[a]	25.15[b]	25.88[a]	24.41[c]	25.84	18.71
T7	24.27[d]	23.69[c]	22.88[d]	21.70[c]	19.44[d]	19.35[e]	19.29[f]	21.52	35.76
SEm ±	0.18	0.13	0.12	0.11	0.14	0.11	0.12		
CD (0.05)	0.54	0.40	0.38	0.34	0.43	0.35	0.37		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 33: Influence of packing material, halogen treatment and their interaction effect on seedling root length (cm) during storage in rice (*kharif*, 2014) (contd)

Treatments	Storage period (months)								
	M1	M2	M3	M4	M5	M6	M7	Mean	Per cent reduction of root length
				Interaction (P x T)					
P1T1	26.36^{g}	26.33^{c}	25.78^{c}	25.36^{c}	25.12^{b}	25.14^{b}	24.95^{c}	25.58	16.83
P1T2	24.53^{e}	23.12^{h}	23.14^{h}	22.32^{f}	22.23^{e}	22.21^{e}	22.16^{h}	22.82	26.13
P1T3	24.33^{ef}	24.41^{de}	23.23^{h}	22.34^{f}	22.20^{e}	22.06^{ef}	22.31^{gh}	22.98	25.63
P1T4	24.42^{ef}	24.20^{ef}	23.32^{gh}	22.14^{f}	21.81^{e}	21.68^{f}	21.30^{i}	22.70	29.00
P1T5	25.78^{d}	25.84^{c}	25.26^{d}	24.79^{d}	24.39^{c}	24.29^{c}	24.25^{de}	24.94	19.17
P1T6	26.47^{c}	25.85^{c}	25.20^{d}	24.76^{d}	23.96^{c}	25.54^{b}	24.13^{e}	25.13	19.57
P1T7	23.75^{f}	23.61^{gh}	22.40^{i}	21.29^{g}	19.25^{f}	19.22^{g}	19.10^{j}	21.23	36.33
P2T1	27.73^{b}	26.90^{b}	26.81^{ab}	25.61^{c}	26.17^{a}	26.19^{a}	26.66^{a}	26.58	11.28
P2T2	25.71^{d}	24.84^{d}	24.50^{e}	23.37^{e}	23.27^{d}	23.08^{d}	23.26^{f}	24.00	22.60
P2T3	25.59^{d}	24.87^{d}	23.92^{f}	23.41^{e}	23.19^{d}	23.11^{d}	23.13^{f}	23.89	23.03
P2T4	24.31^{ef}	23.14^{h}	23.80^{fg}	23.62^{e}	22.97^{d}	22.85^{d}	22.66^{g}	23.34	24.59
P2T5	28.88^{a}	27.65^{a}	27.25^{a}	26.70^{a}	26.22^{a}	26.38^{a}	25.99^{b}	27.01	13.51
P2T6	29.03^{a}	26.85^{b}	26.51^{b}	26.16^{b}	26.33^{a}	26.21^{a}	24.69^{cd}	26.54	17.84
P2T7	24.78^{e}	23.77^{fg}	23.36^{gh}	22.11^{f}	19.62^{f}	19.47^{g}	19.47^{j}	21.80	35.21
SEm ±	0.22	0.16	0.16	0.14	0.17	0.14	0.15		
CD (0.05)	0.67	0.50	0.48	0.42	0.53	0.44	0.46		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

4.3.3.4 Seedling dry weight (mg)

The results on seedling dry weight as influenced by packing material, halogen treatment and their interaction effects during the storage period are presented in Table 34.

Due to packing material (P)

Seedling dry weight was observed to decrease with increase in storage period. The dry weight of seedlings from seeds stored in P2 was found to be maximum and significantly superior over that in P1 during each month of storage. The dry weight decreased from 20.00 to 15.28 mg in P1 (jute bag) while the reduction was from 20.15 to 17.34 mg in P2 (polyethylene bag of 400G).

Due to halogen treatment (T)

Seedling dry weight decreased over storage irrespective of the halogenation treatment. At each month of storage, T5 ($CaOCl_2$ + $CaCO_3$ @ 3 g each/kg seed) recorded the maximum seedling dry weight and was superior to all other treatments throughout the storage period. T6 was found to be the next best treatment with respect to seedling dry weight (16.75 mg) at the end of storage while it was the least in T1 (16.10 mg), T2 (15.88 mg), T3 (15.73 mg) and T4 (15.78 mg). Treatments T1, T2, T3 and T4 were on par with each other at the end of storage period.

Due to interaction (P x T)

P2T5 was superior to all other treatments with respect to seedling dry weight throughout the storage period. The seedling dry weight in P2T5 varied from 19.90 mg (M1) to 18.20 mg (M11). P1T6 (17.75 mg) was the next best treatment which was on par with P2T5. The lowest seedling dry weight was recorded in P1T4 (13.95 mg). At the end of storage, the seedling dry weight of untreated seeds packed in jute bag was 15.15 mg and that in polyethylene bag (400G) was 17.05 mg.

Table 34: Influence of packing material, halogen treatment and their interaction effect on seedling dry weight (mg) during storage in rice (*kharif*, 2014)

Treatments	Storage period (months)								
	M1	M2	M3	M4	M5	M6	M7	Mean	Per cent reduction of dry weight
Packing materials (P)									
P1	17.33[b]	17.01[b]	16.36[b]	16.20[b]	15.79[b]	15.69[b]	15.28[b]	16.24	23.60
P2	18.94[a]	18.27[a]	18.16[a]	18.59[a]	18.13[a]	17.79[a]	17.34[a]	18.17	13.95
SEm ±	0.10	0.06	0.09	0.07	0.07	0.05	0.06		
CD (0.05)	0.32	0.17	0.29	0.20	0.20	0.14	0.18		
Halogen treatments (T)									
T1	17.90[c]	17.10[d]	17.03[c]	16.75[d]	16.45[c]	16.40[cd]	16.10[cd]	16.82	19.82
T2	18.40[bc]	17.75[c]	17.40[c]	17.25[c]	16.43[c]	16.25[de]	15.88[cd]	17.05	20.92
T3	18.60[bc]	17.60[c]	16.88[c]	16.63[d]	16.38[c]	16.08[e]	15.73[d]	16.84	21.66
T4	16.55[d]	16.95[d]	15.95[d]	17.03[cd]	16.65[c]	16.43[cd]	15.78[cd]	16.48	21.41
T5	19.73[a]	19.75[a]	19.30[a]	19.30[a]	18.90[a]	18.30[a]	17.75[a]	19.00	11.60
T6	19.00[b]	18.30[b]	18.38[b]	17.98[b]	17.60[b]	17.13[b]	16.75[b]	17.88	16.58
T7	16.75[d]	16.03[e]	15.93[d]	16.83[cd]	16.33[c]	16.60[c]	16.18[c]	16.38	19.42
SEm ±	0.22	0.12	0.20	0.14	0.14	0.09	0.13		
CD (0.05)	0.68	0.36	0.61	0.42	0.42	0.29	0.39		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 34: Influence of packing material, halogen treatment and their interaction effect on seedling dry weight (mg) during storage in rice (*kharif*, 2014) (contd)

Treatments	Storage period (months)								
	M1	M2	M3	M4	M5	M6	M7	Mean	Per cent reduction of dry weight
Interaction (P x T)									
P1T1	16.45^{de}	15.75^{h}	15.35^{g}	15.20^{d}	15.00^{de}	15.15^{hi}	15.15^{g}	15.44	24.25
P1T2	17.95^{c}	17.20^{f}	16.60^{de}	16.60^{c}	15.30^{d}	15.35^{gh}	15.15^{g}	16.31	24.25
P1T3	17.95^{c}	16.90^{fg}	15.50^{fg}	15.35^{d}	15.15^{de}	14.95^{ij}	14.50^{h}	15.76	27.50
P1T4	15.20^{f}	15.95^{h}	15.25^{g}	14.80^{d}	14.70^{e}	14.60^{j}	13.95^{i}	14.92	30.25
P1T5	19.55^{ab}	19.90^{a}	18.90^{bc}	19.40^{a}	19.00^{a}	17.90^{bc}	17.30^{bcd}	18.85	13.50
P1T6	17.95^{c}	17.75^{e}	17.35^{d}	16.70^{c}	16.55^{c}	16.20^{f}	15.75^{f}	16.89	21.25
P1T7	16.25^{c}	15.60^{h}	15.60^{fg}	15.35^{d}	14.85^{de}	15.65^{g}	15.15^{g}	15.49	24.25
P2T1	19.35^{ab}	18.45^{bc}	18.70^{bc}	18.30^{b}	17.90^{b}	17.65^{c}	17.05^{de}	18.20	15.38
P2T2	18.85^{b}	18.30^{cd}	18.20^{c}	17.90^{b}	17.55^{b}	17.15^{e}	16.60^{e}	17.79	17.62
P2T3	19.25^{ab}	18.30^{cd}	18.25^{c}	17.90^{b}	17.60^{b}	17.20^{de}	16.95^{de}	17.92	15.88
P2T4	17.90^{c}	17.95^{de}	16.65^{de}	19.25^{a}	18.60^{a}	18.25^{b}	17.60^{bc}	18.03	12.66
P2T5	19.90^{a}	19.60^{a}	19.70^{a}	19.20^{a}	18.80^{a}	18.70^{a}	18.20^{a}	19.16	9.68
P2T6	20.05^{a}	18.85^{b}	19.40^{ab}	19.25^{a}	18.65^{a}	18.05^{b}	17.75^{ab}	18.86	11.91
P2T7	17.25^{cd}	16.45^{g}	16.25^{ef}	18.30^{b}	17.80^{b}	17.55^{cd}	17.20^{cd}	17.26	14.64
SEm ±	0.28	0.15	0.25	0.17	0.17	0.12	0.16		
CD (0.05)	0.85	0.45	0.76	0.53	0.52	0.37	0.48		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

4.3.3.5 Vigour index I

The results on seedling vigour index I as influenced by packing material, halogen treatment and their interaction effects during the storage period are presented in Table 35.

Due to packing material (P)

Seedling vigour index I was observed to decrease with increase in storage period. The seedling vigour index I of seeds stored in P2 was found to be maximum and significantly superior over that in P1 during each month of storage. The seedling vigour index I decreased from 4925 to 2983 in P1 (jute bag) while the reduction was from 4945 to 3301 mg in P2 (polyethylene bag of 400G).

Due to halogen treatment (T)

Seedling vigour index I decreased over storage irrespective of the halogenation treatment. At each month of storage, T5 ($CaOCl_2$ + $CaCO_3$ @ 3 g each/kg seed) recorded the maximum seedling vigour index I and was superior to all other treatments throughout the storage period (4497 to 3812). T1 was found to be the next best treatment with respect to seedling vigour index I (3632) at the end of storage. The least seedling vigour index I was recorded in T7 (2297).

Due to interaction (P x T)

P2T5 was superior to all other treatments with respect to seedling vigour index I throughout the storage period. The seedling vigour index I in P2T5 varied from 4727 (M1) to 3980 (M7) which was on par with P2T1 (3834). P1T5 (3643) was the next best treatment. The lowest seedling vigour index I was recorded in P1T7 (2216). At the end of storage, the seedling vigour index I of untreated seeds packed in jute bag was 3430.

Table 35: Influence of packing material, halogen treatment and their interaction effect on vigour index I during storage in rice (*kharif*, 2014)

Treatments	Storage period (months)								
	M1	M2	M3	M4	M5	M6	M7	Mean	Per cent reduction of VI I
Packing materials (P)									
P1	3794[b]	3604[b]	3485[b]	3381[b]	3228[b]	3130[b]	2983[b]	3372	39.43
P2	4176[a]	3898[a]	3771[a]	3647[a]	3563[a]	3443[a]	3301[a]	3686	33.25
SEm ±	26	24	9	23	22	22	18		
CD (0.05)	79	74	27	70	66	68	56		
Halogen treatments (T)									
T1	4321[b]	4102[b]	3966[b]	3903[b]	3825[a]	3736[b]	3632[b]	3926	26.40
T2	3856[c]	3723[c]	3649[c]	3540[c]	3500[b]	3363[c]	3202[c]	3548	35.12
T3	3878[c]	3678[c]	3554[c]	3435[c]	3372[bc]	3244[cd]	3177[c]	3477	35.62
T4	3892[c]	3580[c]	3530[c]	3421[c]	3303[c]	3179[d]	2960[d]	3409	40.02
T5	4497[a]	4280[a]	4185[a]	4075[a]	3959[a]	3923[a]	3812[a]	4104	22.76
T6	4019[c]	3674[c]	3530[c]	3418[c]	3280[c]	3156[d]	2917[c]	3428	40.89
T7	3435[d]	3222[d]	2983[d]	2809[d]	2530[d]	2408[e]	2297[e]	2812	53.45
SEm ±	55	51	41	49	46	47	39		
CD (0.05)	167	156	125	149	141	144	119		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 35: Influence of packing material, halogen treatment and their interaction effect on vigour index I during storage in rice (*kharif*, 2014) (contd)

Treatments	Storage period (months)								
	M1	M2	M3	M4	M5	M6	M7	Mean	Per cent reduction of VI I
Interaction (P x T)									
P1T1	4142^{cde}	4037^{bc}	3787^{cd}	3799^{cd}	3685^{cd}	3604^{cd}	3430^{c}	3783	30.36
P1T2	3692^{g}	3507^{de}	3466^{e}	3399^{fg}	3375^{f}	3206^{fg}	3056^{d}	3386	37.95
P1T3	3703^{g}	3510^{de}	3368^{e}	3342^{fgh}	3179^{g}	3147^{fg}	3021^{d}	3324	38.66
P1T4	3803^{fg}	3522^{de}	3432^{e}	3304^{gh}	3188^{g}	3031^{gh}	2778^{e}	3294	43.59
P1T5	4267^{cd}	4161^{b}	4071^{b}	3883^{bc}	3813^{bc}	3732^{bc}	3643^{b}	3939	26.03
P1T6	3685^{g}	3375^{e}	3364^{e}	3194^{h}	2940^{h}	2897^{h}	2739^{e}	3171	44.39
P1T7	3267^{h}	3116^{f}	2905^{g}	2745^{i}	2413^{j}	2295^{j}	2216^{g}	2708	55.01
P2T1	4499^{b}	4166^{b}	4144^{ab}	4006^{b}	3964^{ab}	3867^{b}	3834^{a}	4069	22.47
P2T2	4020^{ef}	3938^{c}	3831^{c}	3680^{de}	3624^{d}	3520^{de}	3348^{c}	3709	32.30
P2T3	4052^{de}	3845^{c}	3739^{cd}	3527^{ef}	3564^{de}	3340^{ef}	3333^{c}	3629	32.60
P2T4	3980^{ef}	3637^{d}	3628^{d}	3537^{ef}	3418^{ef}	3326^{ef}	3141^{d}	3524	36.48
P2T5	4727^{a}	4398^{a}	4298^{a}	4266^{a}	4104^{a}	4114^{a}	3980^{a}	4270	19.51
P2T6	4353^{bc}	3973^{bc}	3696^{cd}	3641^{de}	3619^{d}	3415^{e}	3095^{d}	3685	37.41
P2T7	3603^{g}	3328^{e}	3061^{f}	2873^{i}	2647^{i}	2520^{i}	2378^{f}	2916	51.91
SEm ±	68	64	51	61	58	59	49		
CD (0.05)	209	195	156	186	176	180	149		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

4.3.3.6 Vigour index II

The results on seedling vigour index II as influenced by packing material, halogen treatment and their interaction effects during the storage period are presented in Table 36.

Due to packing material (P)

Seedling vigour index II was observed to decrease with increase in storage period. The seedling vigour index II of seeds stored in P2 was found to be maximum and significantly superior over that in P1 during each month of storage. The seedling vigour index II decreased from 1965 to 1268 in P1 (jute bag) while the reduction was from 1985 to 1491 mg in P2 (polyethylene bag of 400G).

Due to halogen treatment (T)

Seedling vigour index II decreased over storage irrespective of the halogenation treatment. At each month of storage, T5 ($CaOCl_2$ + $CaCO_3$ @ 3 g each/kg seed) recorded the maximum seedling vigour index I and was superior to all other treatments throughout the storage period (1914 to 1616). T1 (1419), T2 (1367) and T3 (1387) were found to be the next best treatments with respect to seedling vigour index II at the end of storage. T1, T2 and T3 were on par with each other. The least seedling vigour index II was recorded in T7 (1247).

Due to interaction (P x T)

P2T5 was superior to all other treatments with respect to seedling vigour index II throughout the storage period. The seedling vigour index II in P2T5 varied from 1951 (M1) to 1675 (M7). P1T5 (1557), P2T1 (1535) and P2T3 (1526) were the next best treatments. P1T5, P2T1 and P2T3 were on par with each other. The lowest seedling vigour index II was recorded in P1T4 (1116) which was found to be on par

Table 36: Influence of packing material, halogen treatment and their interaction effect on vigour index II during storage in rice (*kharif*, 2014)

Treatments	Storage period (months)								
	M1	M2	M3	M4	M5	M6	M7	Mean	Per cent reduction of VI II
Packing materials (P)									
P1	1606[b]	1553[b]	1489[b]	1478[b]	1406[b]	1350[b]	1268[b]	1450	35.47
P2	1808[a]	1709[a]	1663[a]	1699[a]	1653[a]	1581[a]	1491[a]	1658	24.89
SEm ±	15	11	13	12	13	9	9		
CD (0.05)	45	33	40	38	40	29	26		
Halogen treatments (T)									
T1	1721[b]	1626[b]	1604[b]	1593[b]	1532[b]	1494[b]	1419[b]	1570	28.15
T2	1712[b]	1652[b]	1601[b]	1587[b]	1512[b]	1465[bc]	1367[bc]	1557	30.78
T3	1768[b]	1638[b]	1553[b]	1545[b]	1510[b]	1448[bc]	1387[b]	1550	29.77
T4	1559[c]	1544[c]	1436[c]	1533[b]	1484[b]	1416[c]	1298[de]	1467	34.28
T5	1914[a]	1897[a]	1853[a]	1834[a]	1778[a]	1703[a]	1616[a]	1799	18.18
T6	1769[b]	1649[b]	1617[b]	1582[b]	1516[b]	1406[c]	1325[cd]	1552	32.91
T7	1509[c]	1412[d]	1370[c]	1447[c]	1375[c]	1330[d]	1247[e]	1384	36.86
SEm ±	31	23	28	26	28	20	18		
CD (0.05)	95	70	85	80	86	61	55		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 36: Influence of packing material, halogen treatment and their interaction effect on vigour index II during storage in rice (*kharif*, 2014) (contd)

Treatments	Storage period (months)								
	M1	M2	M3	M4	M5	M6	M7	Mean	Per cent reduction of VI II
Interaction (P x T)									
P1T1	1546^{ef}	1481^{fg}	1412^{def}	1429^{gh}	1380^{e}	1364^{ef}	1303^{fg}	1416	33.69
P1T2	1651^{cde}	1583^{de}	1527^{d}	1527^{fg}	1408^{e}	1351^{f}	1273^{fgh}	1474	35.22
P1T3	1688^{cd}	1555^{ef}	1426^{def}	1443^{g}	1364^{e}	1346^{f}	1247^{gh}	1438	36.54
P1T4	1399^{g}	1436^{g}	1374^{f}	1333^{hi}	1294^{ef}	1226^{g}	1116^{i}	1311	43.21
P1T5	1877^{ab}	1911^{a}	1815^{ab}	1824^{ab}	1787^{a}	1647^{b}	1557^{b}	1774	20.76
P1T6	1652^{cde}	1562^{def}	1527^{d}	1470^{fg}	1391^{c}	1296^{fg}	1229^{h}	1447	37.46
P1T7	1430^{fg}	1342^{h}	1342^{f}	1320^{i}	1218^{f}	1221^{g}	1152^{i}	1289	41.37
P2T1	1896^{ab}	1771^{b}	1795^{ab}	1757^{abc}	1683^{abc}	1624^{bc}	1535^{bc}	1723	22.67
P2T2	1772^{bc}	1721^{bc}	1675^{c}	1647^{de}	1615^{cd}	1578^{bcd}	1461^{de}	1638	26.40
P2T3	1848^{ab}	1721^{bc}	1679^{c}	1647^{de}	1655^{bc}	1549^{cd}	1526^{bcd}	1661	23.12
P2T4	1719^{c}	1652^{cd}	1498^{de}	1732^{bcd}	1674^{abc}	1606^{bc}	1479^{cde}	1623	25.49
P2T5	1951^{a}	1882^{a}	1891^{a}	1844^{a}	1768^{ab}	1758^{a}	1675^{a}	1824	15.62
P2T6	1885^{ab}	1735^{bc}	1707^{bc}	1694^{cd}	1641^{cd}	1516^{d}	1420^{c}	1657	28.46
P2T7	1587^{de}	1481^{fg}	1398^{ef}	1574^{ef}	1532^{d}	1439^{e}	1342^{f}	1479	32.39
SEm ±	39	29	35	33	35	25	28		
CD (0.05)	118	88	107	100	107	77	86		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

with P1T7 (1152). At the end of storage, the seedling vigour index II of untreated seeds packed in jute bag (P1T1) was 1303.

4.3.3.7 Electrical conductivity of seed leachate (dSm^{-1})

The results on electrical conductivity as influenced by packing material, halogen treatment and their interaction effects during the storage period are presented in Table 37.

Due to packing material (P)

The electrical conductivity of seed leachate was observed to increase with increase in storage period. The electrical conductivity of seed leachate of seeds stored in P2 was found to be minimum and significantly superior over that in P1 during each month of storage. The electrical conductivity of seed leachate increased from 0.0230 dSm^{-1} to 0.0470 dSm^{-1} in P1 (jute bag) while the increase was from 0.0218 dSm^{-1} to 0.0425 dSm^{-1} in P2 (polyethylene bag of 400G).

Due to halogen treatment (T)

Electrical conductivity of seed leachate increased over storage irrespective of the halogenation treatment. At each month of storage, T5 ($CaOCl_2$ + $CaCO_3$ @ 3 g each/kg seed) recorded the minimum electrical conductivity of seed leachate and was superior to all other treatments throughout the storage period (0.0280 to 0.0351 dSm^{-1}). T1 (0.0373 dSm^{-1}) was found to be the next best treatment with respect to electrical conductivity of seed leachate at the end of storage. The highest electrical conductivity of seed leachate was recorded in T7 (0.0546 dSm^{-1}) followed by T6 (0.0526 dSm^{-1}).

Table 37: Influence of packing material, halogen treatment and their interaction effect on electrical conductivity of seed leachate (dSm^{-1}) during storage in rice (*kharif*, 2014)

Treatments	Storage period (months)								
	M1	M2	M3	M4	M5	M6	M7	Mean	Per cent increase of EC
Packing materials (P)									
P1	0.0369[a]	0.0389[a]	0.0399[a]	0.0423[a]	0.0439[a]	0.0455[a]	0.0470[a]	0.0421	104.35
P2	0.0339[b]	0.0352[b]	0.0369[b]	0.0388[b]	0.0400[b]	0.0413[b]	0.0425[b]	0.0384	94.95
SEm ±	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002		
CD (0.05)	0.0006	0.0004	0.0003	0.0004	0.0004	0.0004	0.0005		
Halogen treatments (T)									
T1	0.0270[d]	0.0297[e]	0.0314[f]	0.0333[f]	0.0350[f]	0.0363[e]	0.0373[f]	0.0329	66.52
T2	0.0335[c]	0.0343[d]	0.0360[e]	0.0381[e]	0.0401[e]	0.0410[d]	0.0414[e]	0.0378	84.82
T3	0.0339[c]	0.0358[c]	0.0379[d]	0.0397[d]	0.0409[d]	0.0419[d]	0.0435[d]	0.0391	94.20
T4	0.0404[b]	0.0410[b]	0.0419[c]	0.0443[c]	0.0452[c]	0.0474[c]	0.0490[c]	0.0442	118.75
T5	0.0280[d]	0.0291[e]	0.0299[g]	0.0314[g]	0.0329[g]	0.0344[f]	0.0351[g]	0.0315	56.70
T6	0.0417[b]	0.0447[a]	0.0451[b]	0.0474[b]	0.0493[b]	0.0504[b]	0.0526[b]	0.0473	134.82
T7	0.0438[a]	0.0449[a]	0.0465[a]	0.0495[a]	0.0507[a]	0.0525[a]	0.0546[a]	0.0489	143.75
SEm ±	0.0004	0.0003	0.0003	0.0003	0.0003	0.0003	0.0004		
CD (0.05)	0.0013	0.0008	0.0008	0.0009	0.0008	0.0009	0.0011		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 37: Influence of packing material, halogen treatment and their interaction effect on electrical conductivity of seed leachate (dSm^{-1}) during storage in rice (*kharif*, 2014) (contd)

Treatments	Storage period (months)								
	M1	M2	M3	M4	M5	M6	M7	Mean	Per cent increase of EC
Interaction (P x T)									
P1T1	0.0280^{g}	0.0315^{f}	0.0327^{h}	0.0350^{i}	0.0369^{i}	0.0385^{h}	0.0396^{g}	0.0346	72.17
P1T2	0.0354^{e}	0.0364^{d}	0.0372^{f}	0.0393^{g}	0.0417^{f}	0.0424^{f}	0.0428^{f}	0.0393	86.09
P1T3	0.0361^{e}	0.0371^{d}	0.0390^{e}	0.0410^{f}	0.0420^{f}	0.0432^{f}	0.0453^{e}	0.0405	96.96
P1T4	0.0417^{bc}	0.0425^{b}	0.0429^{c}	0.0458^{cd}	0.0469^{cd}	0.0500^{c}	0.0517^{c}	0.0459	124.78
P1T5	0.0286^{g}	0.0305^{g}	0.0312^{i}	0.0328^{j}	0.0344^{j}	0.0360^{i}	0.0367^{h}	0.0329	59.57
P1T6	0.0427^{b}	0.0467^{a}	0.0470^{b}	0.0500^{b}	0.0521^{b}	0.0535^{b}	0.0556^{b}	0.0497	141.74
P1T7	0.0458^{a}	0.0476^{a}	0.0490^{a}	0.0520^{a}	0.0534^{a}	0.0548^{a}	0.0572^{a}	0.0514	148.70
P2T1	0.0259^{h}	0.0279^{h}	0.0300^{j}	0.0316^{j}	0.0330^{k}	0.0341^{j}	0.0349^{i}	0.0311	60.09
P2T2	0.0315^{f}	0.0322^{f}	0.0348^{g}	0.0369^{h}	0.0385^{h}	0.0395^{gh}	0.0400^{g}	0.0362	83.49
P2T3	0.0316^{f}	0.0344^{e}	0.0367^{f}	0.0383^{g}	0.0397^{g}	0.0406^{g}	0.0416^{f}	0.0376	90.83
P2T4	0.0390^{d}	0.0395^{c}	0.0409^{d}	0.0427^{e}	0.0434^{e}	0.0447^{e}	0.0463^{e}	0.0424	112.39
P2T5	0.0273^{gh}	0.0276^{h}	0.0286^{k}	0.0300^{k}	0.0313^{l}	0.0328^{k}	0.0335^{i}	0.0302	53.67
P2T6	0.0406^{cd}	0.0426^{b}	0.0432^{c}	0.0448^{d}	0.0464^{d}	0.0473^{d}	0.0495^{d}	0.0449	127.06
P2T7	0.0417^{bc}	0.0421^{b}	0.0439^{c}	0.0470^{c}	0.0479^{c}	0.0501^{c}	0.0520^{c}	0.0464	138.53
SEm ±	0.0006	0.0003	0.0004	0.0004	0.0004	0.0004	0.0005		
CD (0.05)	0.0019	0.0010	0.0011	0.0013	0.0011	0.0012	0.0015		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Due to interaction (P x T)

P2T5 was superior to all other treatments with respect to electrical conductivity of seed leachate throughout the storage period. The electrical conductivity of seed leachate in P2T5 varied from 0.0273 dSm^{-1} (M1) to 0.0335 dSm^{-1} (M7). P2T1 (0.0349 dSm^{-1}) was the next best treatment which was on par with P2T5. The highest electrical conductivity of seed leachate was recorded in P1T7 (0.0572 dSm^{-1}) followed by P1T6 (0.0556 dSm^{-1}). At the end of storage, the electrical conductivity of seed leachate of untreated seeds packed in jute bag (P1T1) was 0.0396 dSm^{-1}.

4.3.3.8 Moisture content

The results on seed moisture content as influenced by packing material, halogen treatment and their interaction effects during the storage period are presented in Table 38.

Due to packing material (P)

The moisture content of seed was observed to increase with increase in storage period. The moisture content of seeds stored in P2 was found to be minimum and significantly superior over that in P1 during each month of storage. The seed moisture content increased from 12.3 to 13.9 per cent in P1 (jute bag) while the increase was from 10.0 to 10.6 per cent in P2 (polyethylene bag of 400G).

Due to halogen treatment (T)

Seed moisture content increased over storage irrespective of the halogenation treatment. At each month of storage, T5 ($CaOCl_2$ + $CaCO_3$ @ 3 g each/kg seed) recorded the minimum seed moisture content and was superior to all other treatments throughout the storage period (11.1%). T2 (11.1%) was found to be the next best

Table 38: Influence of packing material, halogen treatment and their interaction effect on moisture content (%) during storage in rice (*kharif*, 2014)

Treatments	Moisture content (%)								
	M1	M2	M3	M4	M5	M6	M7	Mean	Per cent increase of MC
Packing materials (P)									
P1	12.8^{a}	12.8^{a}	13.0^{a}	13.5^{a}	13.6^{a}	13.8^{a}	13.9^{a}	13.3	13.01
P2	10.0^{b}	10.2^{b}	10.3^{b}	10.4^{b}	10.4^{b}	10.5^{b}	10.6^{b}	10.3	6.00
SEm ±	0.03	0.03	0.02	0.02	0.02	0.02	0.02		
CD (0.05)	0.10	0.09	0.05	0.07	0.06	0.05	0.05		
Halogen treatments (T)									
T1	11.3^{bc}	11.3^{bc}	11.6^{c}	11.9^{b}	11.9^{bc}	12.1^{b}	11.3^{d}	11.6	1.35
T2	11.1^{c}	11.2^{c}	11.4^{de}	11.8^{b}	11.8^{c}	11.9^{cd}	11.1^{f}	11.5	-0.45
T3	11.2^{bc}	11.3^{bc}	11.5^{cd}	11.6^{c}	11.8^{c}	11.8^{d}	11.2^{e}	11.5	0.45
T4	11.4^{b}	11.4^{b}	11.4^{de}	11.8^{b}	12.0^{b}	12.0^{bc}	11.4^{c}	11.6	2.24
T5	11.1^{c}	11.2^{c}	11.3^{e}	11.5^{c}	11.6^{d}	11.6^{e}	11.1^{f}	11.3	-0.45
T6	11.8^{a}	11.9^{a}	12.2^{b}	12.5^{a}	12.6^{a}	12.7^{a}	11.8^{b}	12.2	5.83
T7	12.0^{a}	12.0^{a}	12.3^{a}	12.5^{a}	12.5^{a}	12.8^{a}	12.0^{a}	12.3	7.62
SEm ±	0.07	0.06	0.04	0.05	0.04	0.04	0.03		
CD (0.05)	0.20	0.19	0.11	0.15	0.12	0.11	0.09		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 38: Influence of packing material, halogen treatment and their interaction effect on moisture content (%) during storage in rice (*kharif*, 2014) (contd)

Treatments	Moisture content (%)								
	M1	M2	M3	M4	M5	M6	M7	Mean	Per cent increase of MC
Interaction (P x T)									
P1T1	12.5^{bc}	12.4^{bc}	12.9^{b}	13.3^{c}	13.4^{d}	13.8^{c}	13.9^{c}	13.2	13.01
P1T2	12.3^{c}	12.3^{c}	12.5^{cd}	13.2^{c}	13.3^{d}	13.3^{e}	13.4^{e}	12.9	8.94
P1T3	12.4^{c}	12.4^{bc}	12.6^{c}	12.9^{d}	13.3^{d}	13.3^{c}	13.4^{c}	12.9	8.94
P1T4	12.7^{b}	12.6^{b}	12.6^{c}	13.3^{c}	13.6^{c}	13.6^{d}	13.6^{d}	13.1	10.57
P1T5	12.3^{c}	12.3^{c}	12.4^{d}	12.8^{d}	12.8^{e}	12.8^{f}	12.9^{f}	12.6	4.88
P1T6	13.6^{a}	13.7^{a}	14.1^{a}	14.7^{a}	14.7^{a}	14.8^{b}	15.0^{b}	14.4	21.95
P1T7	13.8^{a}	13.9^{a}	14.2^{a}	14.5^{b}	14.5^{b}	15.0^{a}	15.2^{a}	14.4	23.58
P2T1	10.1^{d}	10.3^{d}	10.3^{ef}	10.4^{e}	10.5^{f}	10.5^{hi}	10.6^{hi}	10.4	6.00
P2T2	10.0^{d}	10.1^{d}	10.3^{ef}	10.4^{e}	10.4^{f}	10.5^{hi}	10.5^{i}	10.3	5.00
P2T3	10.1^{d}	10.2^{d}	10.3^{ef}	10.4^{e}	10.4^{f}	10.4^{i}	10.6^{hi}	10.3	6.00
P2T4	10.1^{d}	10.2^{d}	10.2^{f}	10.3^{c}	10.4^{f}	10.4^{i}	10.7^{h}	10.3	7.00
P2T5	10.0^{d}	10.2^{d}	10.3^{ef}	10.3^{c}	10.4^{f}	10.4^{i}	10.5^{i}	10.3	5.00
P2T6	10.1^{d}	10.2^{d}	10.3^{ef}	10.4^{e}	10.5^{f}	10.6^{gh}	10.7^{h}	10.4	7.00
P2T7	10.1^{d}	10.2^{d}	10.4^{e}	10.5^{c}	10.5^{f}	10.7^{g}	10.9^{g}	10.5	9.00
SEm ±	0.09	0.08	0.05	0.06	0.05	0.05	0.04		
CD (0.05)	0.26	0.24	0.14	0.19	0.15	0.14	0.12		

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

treatment with respect to seed moisture content at the end of storage. The highest seed moisture content was recorded in T7 (12.0%).

Due to interaction (P x T)

P2T5 was superior to all other treatments with respect to seed moisture content throughout the storage period. The moisture content of seed in P2T5 varied from 10.0 per cent (M1) to 10.5 per cent (M11). All the treatment combinations involving polyethylene bag maintained the moisture content throughout the storage period. The highest seed moisture content was recorded in P1T7 (15.2%).

4.3.3.9 Seed microflora

The results on seed microflora as influenced by packing material, halogen treatment and their interaction effects during the storage period are presented in Table 39.

Due to packing material (P)

The seed infection (%) varied from 5.00 to 18.14 per cent in P1 (jute bag) and from 5.00 to 15.29 per cent in P2 (polyethylene bag of 400G) during the storage period of seven months. The per cent increase in seed infection over initial infection ranged from 205.80 in P2 to 262.80 in P1.

Due to halogen treatment (T)

The seed infection (%) varied from 11.00 per cent in T5 to 22.00 per cent in T1 at the end of storage period. The lowest seed infection (%) was recorded in T5 (11.00%), followed by T2 (12.50%). The untreated seeds (T1) recorded the highest seed infection (22.00 %) at the end of storage period. The per cent increase over initial infection varied from 120.00 in T5 to 340.00 in T1.

Due to interaction (P x T)

The lowest seed infection (%) was recorded in P2T5 (10.00%) on par with P2T2 (11.00%) on par with P1T5 (12.00%). Untreated seeds stored in jute bags (P1T1) recorded the highest infection (24.00%) at the end of storage period. The per cent increase ranged from 100.00 in P2T5 to 380.00 in P1T1 over initial infection. Seed microflora observed were *Aspergillus* sp. and *Rhizopus* sp.

Table 39: Influence of packing material, halogen treatment and their interaction effect on seed infection (%) during storage in rice (*kharif*, 2014)

Treatments	Seed infection (%)	
	End of storage	Per cent increase of seed infection
Packing materials (P)		
P1	18.14^{a} (10.45)	262.80
P2	15.29^{b} (8.80)	205.80
SEm ±	0.14	
CD (0.05)	0.44	
Halogen treatments (T)		
T1	22.00^{a} (12.71)	340.00
T2	12.50^{f} (7.18)	150.00
T3	16.00^{e} (9.21)	220.00
T4	17.50^{d} (10.08)	250.00
T5	11.00^{g} (6.32)	120.00
T6	18.50^{c} (10.66)	270.00
T7	19.50^{b} (11.24)	290.00
SEm ±	0.30	
CD (0.05)	0.93	
Interaction (P x T)		
P1T1	24.00^{a} (13.89)	380.00
P1T2	14.00^{e} (8.05)	180.00
P1T3	17.00^{d} (9.79)	240.00
P1T4	18.00^{d} (10.37)	260.00
P1T5	12.00^{f} (6.89)	140.00
P1T6	20.00^{c} (11.54)	300.00
P1T7	22.00^{b} (12.71)	340.00
P2T1	20.00^{c} (11.54)	300.00
P2T2	11.00^{fg} (6.32)	120.00
P2T3	15.00^{e} (8.63)	200.00
P2T4	17.00^{d} (9.79)	240.00
P2T5	10.00^{g} (5.74)	100.00
P2T6	17.00^{d} (9.79)	240.00
P2T7	17.00^{d} (9.79)	240.00
SEm ±	0.38	
CD (0.05)	1.16	

Initial seed infection

P1- 5.00 %

P2- 5.00 %

*Means in each column with atleast one letter common are not significantly different at 5% level of probability

Discussion

5. DISCUSSION

Establishment of seedling in the soil is important and foremost for better crop production. This depends largely on the germination and vigour potential of seeds used for sowing. In the normal course, seeds start to deteriorate soon after attaining the physiological maturity. The rate of deterioration however differs from one kind to another and is influenced by a number of factors that include the seed and the environmental conditions.

Procedures that will go along with the routine post-harvest operation of seeds to increase seed qualities and longevity would be most welcome and acceptable. One such approach is the halogenation of fresh seeds to counteract the effect of free radical production and to improve the storage potential of seeds. Halogens act as free radical quenchers and scavengers, thus reducing the lipid peroxidation and making the seeds less susceptible to seed deterioration. It is imperative that the optimum dose of halogen be worked out to confer best results. Apart from halogenation, seed preservation under controlled environmental condition is another advocated approach to prolong seed longevity under high humid conditions prevailing in Kerala. However, this option is costly and not feasible. An alternative suggested is the judicious choice of packaging materials.

Keeping all these in view, an attempt was made to ascertain the storage potential of rice (variety Jyothi) seeds under ambient storage conditions of storage on packing in jute bags or polyethylene bags after exposure to different doss of halogen calcium oxychloride. The outcome of the study is discussed hereunder.

5.1. Seed quality and longevity of rice variety Jyothi as influenced by packing material

The results revealed that seed quality and longevity during storage were significantly influenced by the packing material throughout the storage period.

5.1.1 Influence of packing material on storability of rice seeds (*rabi* 2013-2014)

Seeds stored in polyethylene bags (400G) were superior in germination (Fig. 2), seedling shoot length, seedling root length, seedling dry weight, seed vigour index I and II at the end of storage period of fifteen months compared to the seed stored in jute bag. The electrical conductivity of seed leachate, moisture content and seed infection per cent of seeds in polyethylene bags (400G) was the least indicating lower seed deterioration of these over that stored in jute bags. Seeds stored in polyethylene bags retained viability above MSCS for eleven months of storage compared to eight months in the case of jute bags. The results thus indicated that storing seeds of *rabi* 2013-14 in polyethylene bags (400G) is beneficial in prolonging seed longevity as well as in maintaining higher seed quality parameters during storage.

5.1.2 Influence of packing material on storability of rice seeds (summer, 2013-14)

Seeds of summer 2013-14, stored in polyethylene bags (400G) were superior in germination (Fig. 3) and other seed quality parameters like seedling shoot length, seedling root length, seedling dry weight, seed vigour index I and II at the end of storage period of eleven months compared to the seed stored in jute bag. The electrical conductivity of seed leachate, moisture content and seed infection per cent of seeds in polyethylene bags (400G) was less indicating lower seed deterioration of these over that stored in jute bags. Seeds stored in polyethylene bags retained viability above MSCS for eight months of storage compared to four months in the case of jute bags. Therefore, storing seeds of summer 2013-14 seeds in polyethylene

Fig. 2: Influence of packing material on germination (%) during storage in rice (*rabi* 2013-14)

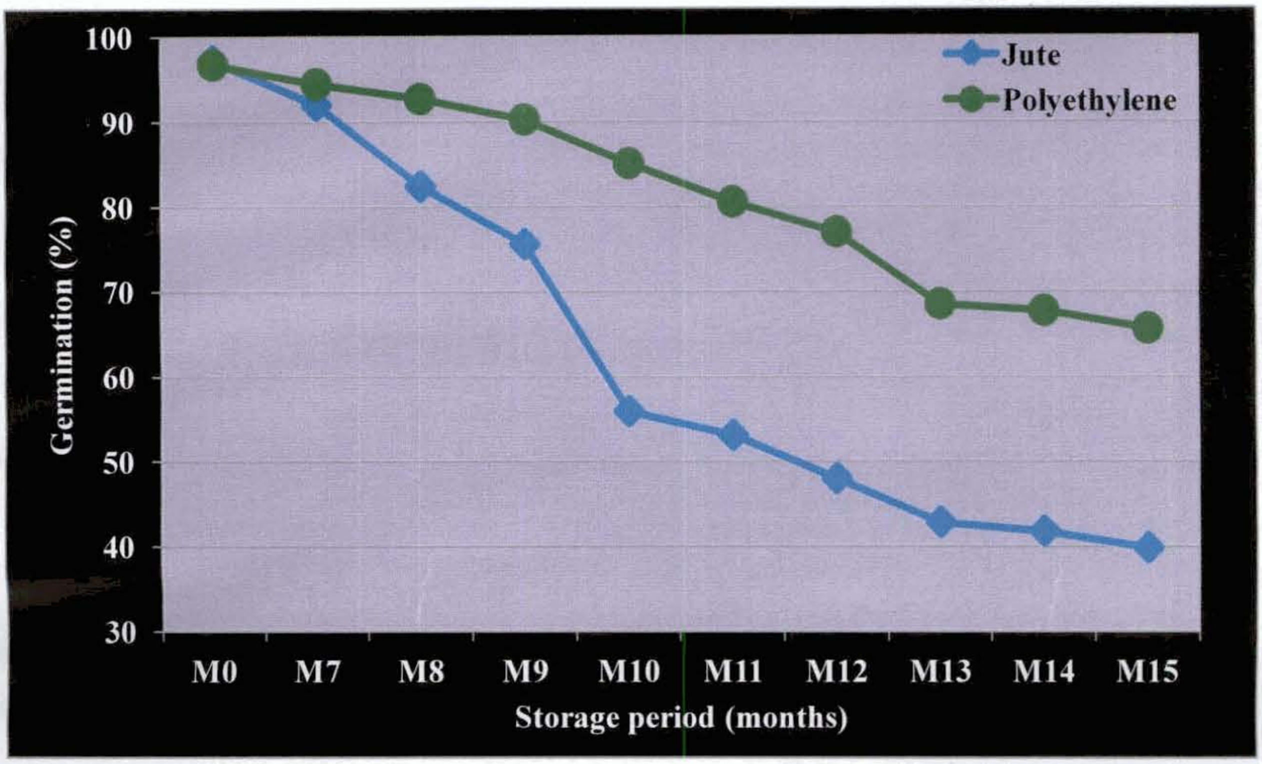


Fig. 3: Influence of packing material on germination (%) during storage in rice (summer 2013-14)

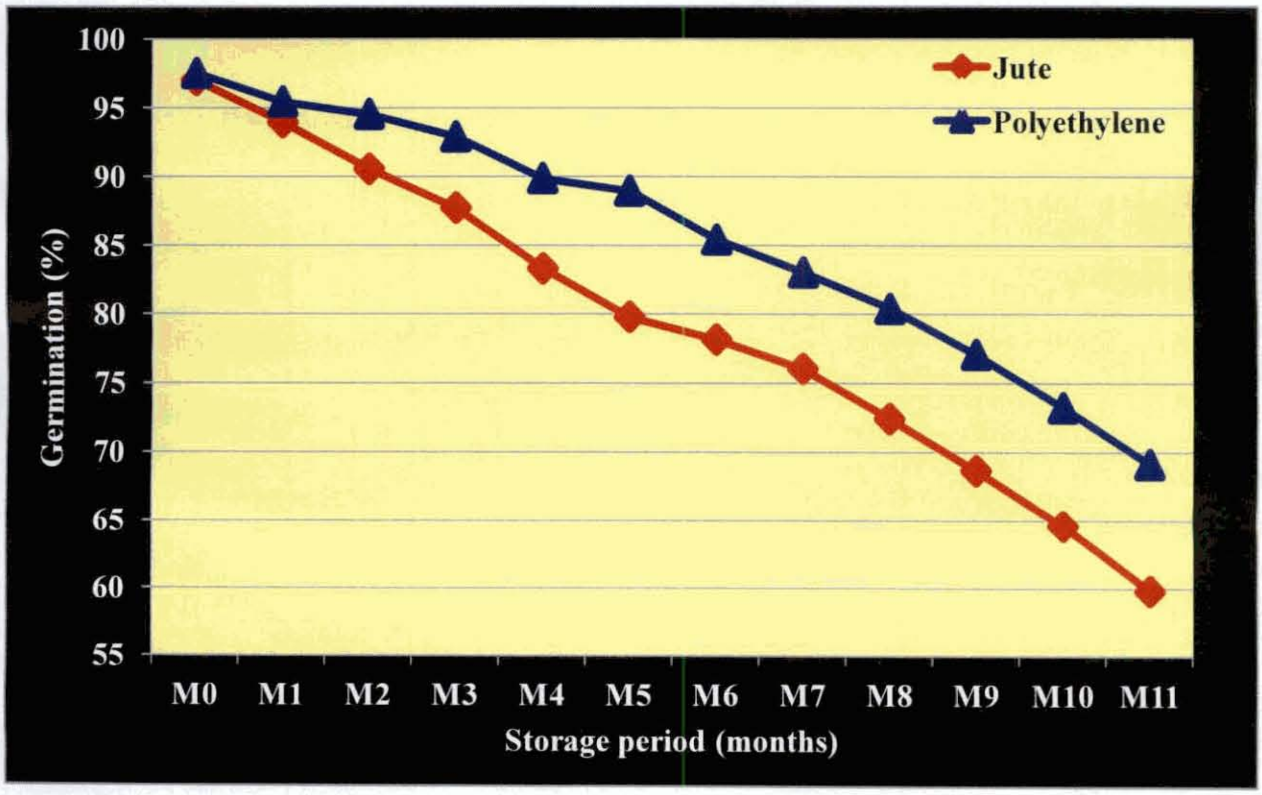
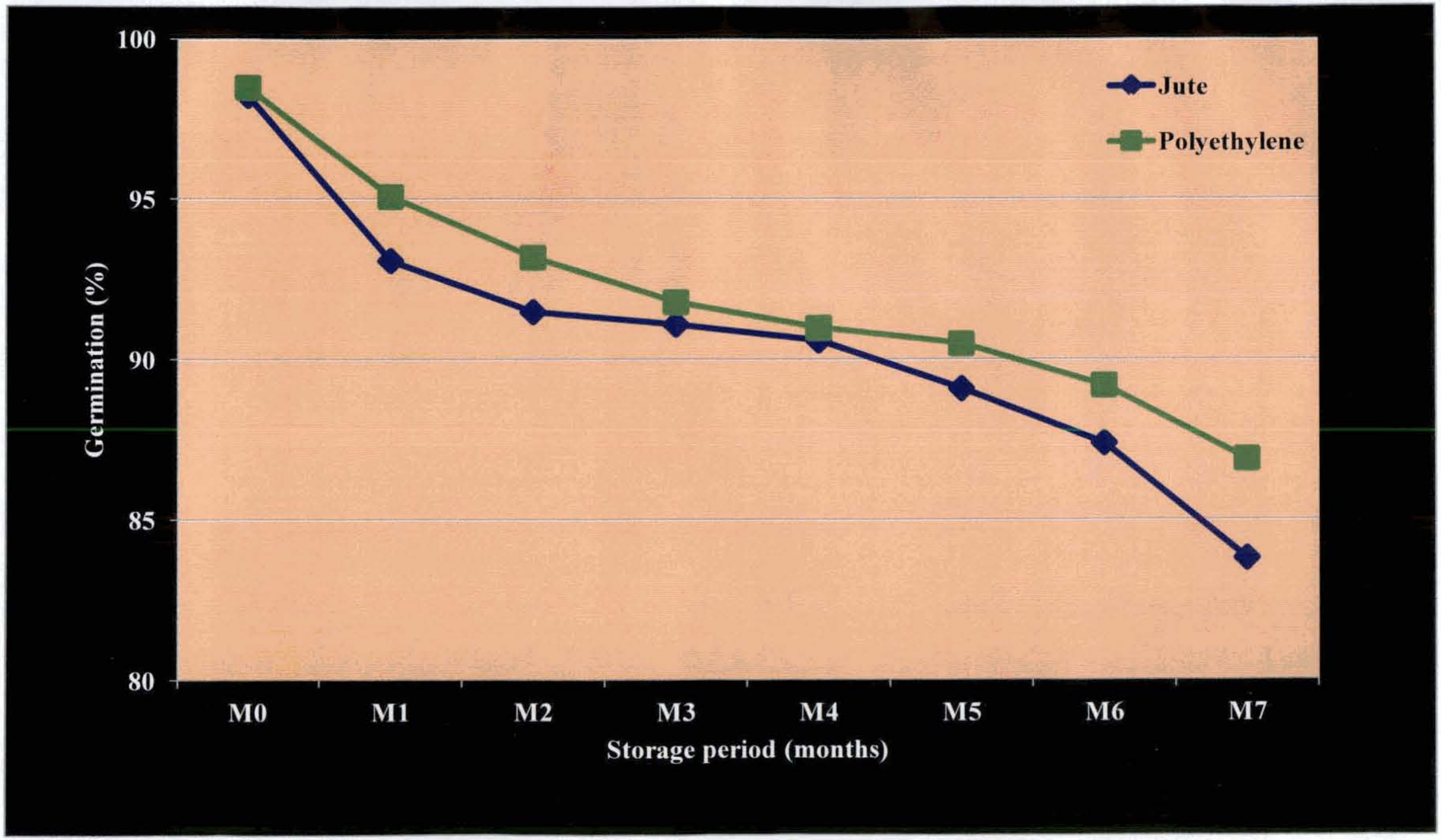


Fig. 4: Influence of packing material on germination (%) during storage in rice (*kharif*, 2014)



bags (400G) was found advantageous for prolonging seed longevity as well as in maintaining higher seed quality parameters during storage.

5.1.3 Influence of packing material on storability of rice seeds (*kharif*, 2014)

Seeds of *kharif* 2014, stored in polyethylene bags (400G) were superior in germination (Fig. 4) and other seed quality parameters like seedling shoot length, seedling root length, seedling dry weight, seed vigour index I and II at the end of storage period of eleven months compared to the seed stored in jute bag. The electrical conductivity of seed leachate, moisture content and seed infection per cent of seeds in polyethylene bags (400G) was less indicating lower seed deterioration of these over that stored in jute bags. Although seeds stored in both polyethylene bags and jute bags retained viability above MSCS for seven months of storage, the seed quality parameters in the former was higher throughout storage. Hence, it can be concluded that storing seeds of *kharif* 2014 in polyethylene bags (400G) is beneficial compared to storing seeds in jute bags.

Irrespective of the season of seed production, it can be summarized that compared to jute bags, storing seeds in polyethylene bags (400G) is more beneficial in prolonging the seed longevity and maintaining higher seed quality parameters during storage.

Similar to the study, the advantage of storing seeds in moisture impervious containers *viz.*, polyethylene bags or aluminium pouches over various moisture pervious containers *viz.*, cloth bags or jute/gunny bags and mud-pot in maintaining higher quality and prolonging viability of stored seeds have been reported by several workers (Baskin and Delouche ,1970; Nagarajan and Karivaratharaju ,1976; Doijode, 1985; Marlene and Mumford, 1986; Siddalingappa,1991; Angamuthu,1996;

Biradarpatil, 1999; Tammanagouda, 2002; Roopa, 2004; Raikar *et al.,* 2011; Parisa, 2013; Narayanan and Prakash, 2014).

The findings of the study with respect to root length, shoot length and dry matter production at the end of storage is in consonance with that of Biradarpatil (1999) in rice, Biradar (2001) and Tammanagouda (2002) in greengram, Madinur (2007) in drumstick and Udabbal (2012) in sunflower.

As observed by Biradarpatil (1999) in rice, Madinur (2007) in drumstick, Shashibhaskar (2008) in tomato, Hemashree and Kurdikeri (2011) in cotton, Raikar *et al.* (2011) in rice and Vinodkumar (2012) in pigeon pea, the superiority of polyethylene bags over moisture pervious containers *viz.*, cloth bags and jute bags in maintenance of seed vigour during storage is evident in the study.

There was steep increase in electrical conductivity value of seed leachate with advance in storage period. According to Nagarajan and Karivaratharaju (1976), Krishnaveni and Ramaswamy (1985), Bharathi (1991), Nagaveni (2005), Satishkumar (2005) and Hemashree and Kurdikeri (2011), seeds stored in polythene bags recorded significantly lower EC values especially during later stages of seed storage, indicating better seed quality with polythene bags as compared to cloth bags. This could be due to increased membrane permeability during seed ageing as opined by Malarkodi and Dharmalingam (1999) in bajra, Dharmalingam *et al.* (2000) in pulses and Raikar *et al.* (2011) in scented rice.

Pathologists opined that loss of viability and vigour of stored seeds is mainly due to storage fungi (Roberts, 1972). Results indicated that the activity of storage fungi was relatively lower in seed stored in polyethylene bag (400G) compared to that in jute bag at the end of storage period. This might be due to the lower moisture recorded in polyethylene bags owing to its impervious nature. Similar results were reported by Roopa (2006) in muskmelon and Geetha and Krishnasamy (2012) in *Cenchrus glaucus*. Christensen and Kaufman (1969) reported that fungi not only cause qualitative and quantitative loss of seed, but also increase the moisture content of the seeds in storage, bring biochemical changes leading to decreased membrane integrity, decrease food reserves in seed and cause rapid death of seeds within a short period of time.

It was obvious that storing seeds in polyethylene bags (400G) prolonged the seed longevity (germination > 80%) by three to four months compared to jute bags in *rabi* and summer 2013-14. Raikar *et al.* (2011) attributed the reason for such differential response between cloth bag/ jute bag and polythene bag, to maintenance of optimum seed moisture content in polythene bags as observed in the study. According to them, polythene bags are impervious to the exchange of water vapour from the atmosphere while the cloth bag contains minute pores through which there is possibility of gain or loss of seed moisture content leading to faster deterioration in the quality as compared to polythene bags.

Increase in moisture content leads to a greater metabolic activity thereby increasing respiration rate. This in turn leads to more utilization of food reserves (Meena *et al.*, 1998). Similar results have been supported by Reddy (1985), Kesavan (1986), Chhabra and Verma (1993), Malabasari (2003) and Shivayogi (2003) in cotton, Uppar (1998) in wheat, Sushma (2003) and Malimath and Merwade (2007) in garden pea, Pushpalatha (2008) in okra, Pal and Basu (1988), Indira (1998) and Raikar *et al.* (2011) in paddy.

Considering all the above, it can be concluded that storing the rice seed in polythene bag (400G) is advisable to maintain the quality of seed for longer period.

5.2 Seed quality and longevity of rice variety Jyothi as influenced by halogen treatment

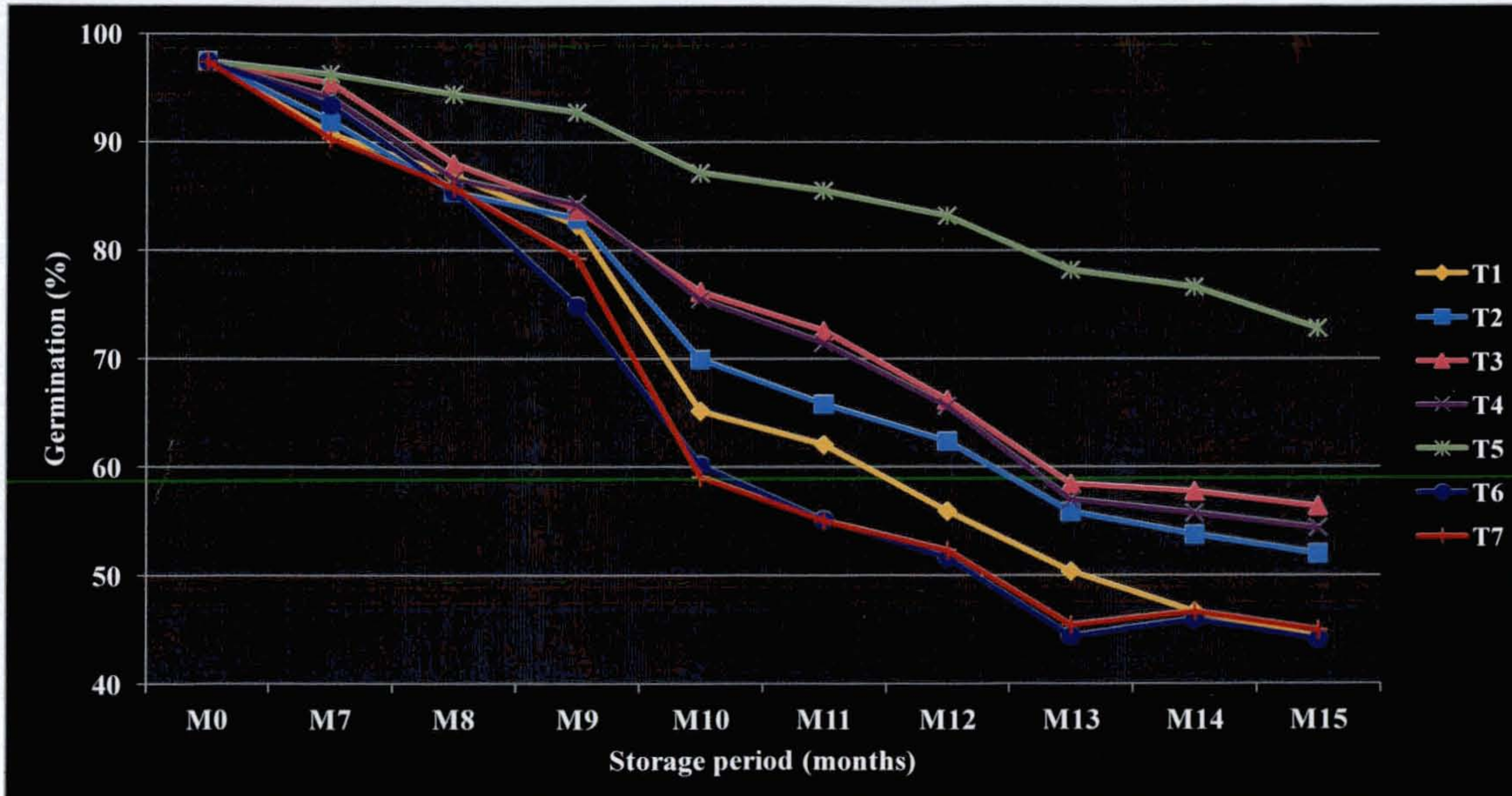
The results revealed that seed quality and longevity during storage were found to be significantly influenced by halogenation treatment throughout the storage period in all three seasons (*rabi* 2013-14, summer 2013-14 and *kharif* 2014).

5.2.1 Influence of halogen treatment on storability of rice seed (rabi 2013-14)

Irrespective of the packing material, the germination and other seed quality parameters of halogenated rice seeds of *rabi* season (2013-2014), declined with increase in the storage period irrespective of halogen dose at which it was treated.

Among the various halogen doses, seed treatment with calcium oxychloride through carrier calcium carbonate @ 3 g each/kg seed (T5) was found to maintain significantly higher germination followed by T3 ($CaOCl_2$ @ 6 g/kg seed) at the end of fifteen months of storage (Fig. 5). Apart from germination, T5 recorded higher seed quality parameters like seedling shoot length, seedling root length, seedling dry weight and seeding vigour index I and II at the end of 15 months of storage. Treatment T5 also exhibited lower electrical conductivity of seed leachate, moisture content and seed infection per cent at the end of 15 months of storage. The viability in T5 was retained above MSCS for a period of twelve months compared to nine months in untreated seeds (T1) (Fig. 3). T3 ($CaOCl_2$ @ 6 g/kg seed) and T4 ($CaOCl_2$ @ 9g /kg seed) exhibited lower seed deterioration next to T5 (nine months each). In contrast, seeds halogenated as per treatment T7 ($CaOCl_2$ + $CaCO_3$ @ 9g each /kg seed) and T6 ($CaOCl_2$ + $CaCO_3$ @ 6g each /kg seed) retained viability above 80 per cent for eight months only.

Fig. 5: Influence of halogen treatment on germination (%) during storage in rice (*rabi* 2013-14)



5.2.2 Influence of halogen treatment on storability of rice seed (summer 2013-14)

As in *rabi* 2013-14, the storage potential and qualities of rice seeds pertaining to summer season (2013-14) declined with increase in the storage period irrespective of halogen dose at which it was treated.

Among the seed treatments, irrespective of the packing material, the halogenation treatment T5 (calcium oxychloride through calcium carbonate @ 3 g each/kg seed) maintained higher germination (Fig. 6) and seed quality parameters *viz.,* seedling shoot length, seedling root length, seedling dry weight and seeding vigour index I and II during storage. Treatment T5 recorded lower electrical conductivity of seed leachate, moisture content and seed infection per cent at the end of storage. It was also observed that, germination above MSCS was retained for nine months in T5 followed by seven months in case of T3 ($CaOCl_2$ @ 6 g/kg seed) compared to six months each in case of T4, T6 and untreated seeds (T1) (Fig. 1). Seeds halogenated as per treatment T7 ($CaOCl_2$ + $CaCO_3$ @ 9g each /kg seed) retained viability above 80 per cent for four months only.

5.2.3 Influence of halogen treatment on storability of rice seed (*kharif* 2014)

As in *rabi* and summer 2013-14, seeds halogenated at T5 (calcium oxychloride through calcium carbonate @ 3 g each/kg seed) maintained significantly higher germination (Fig. 7) and seed quality parameters like seedling shoot length, seedling root length, seedling dry weight and seeding vigour index I and II compared to other halogenation doses. Treatment T5 had also recorded lower electrical conductivity of seed leachate, moisture content and seed infection during storage and retained viability above MSCS at the end of seven months of storage. It was observed that the viability was maintained above MSCS in T6 and T7 for six months only while in all other treatments, the viability was above 80 per cent throughout storage period of 7 months. Hence, in *kharif* 2014, although it cannot be concluded

Fig. 6: Influence of halogen treatment on germination (%) during storage in rice (summer 2013-14)

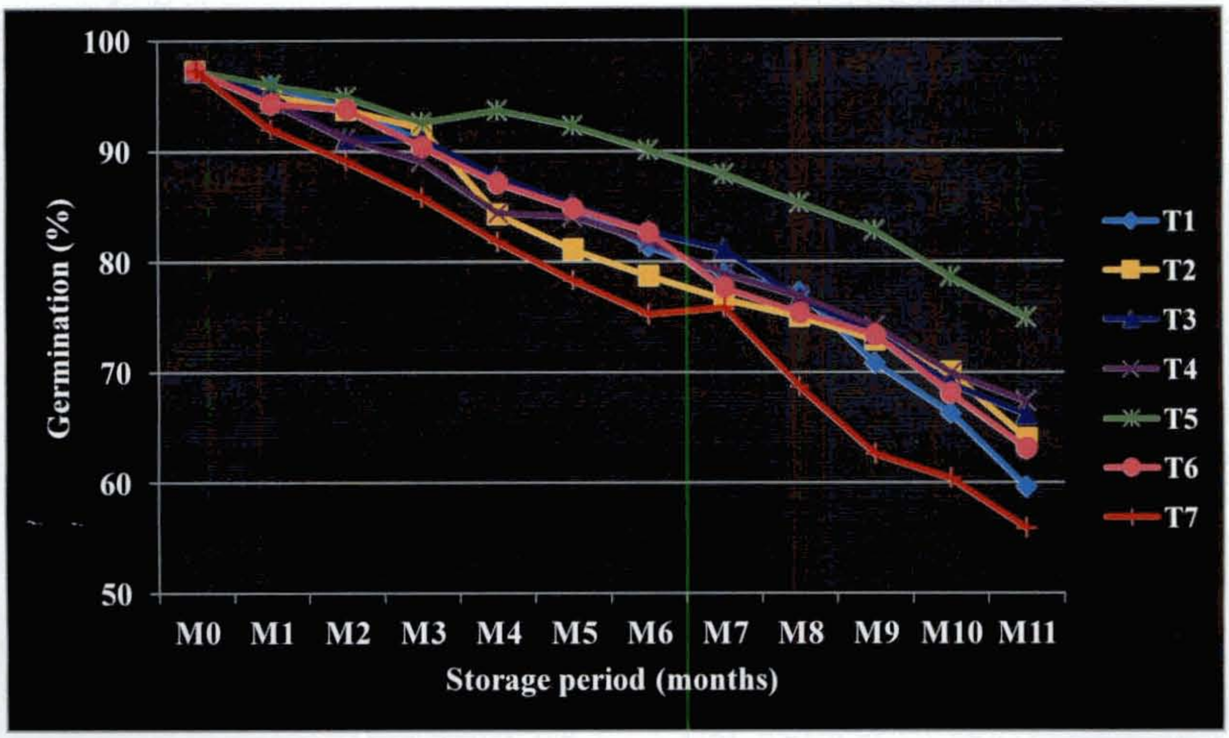
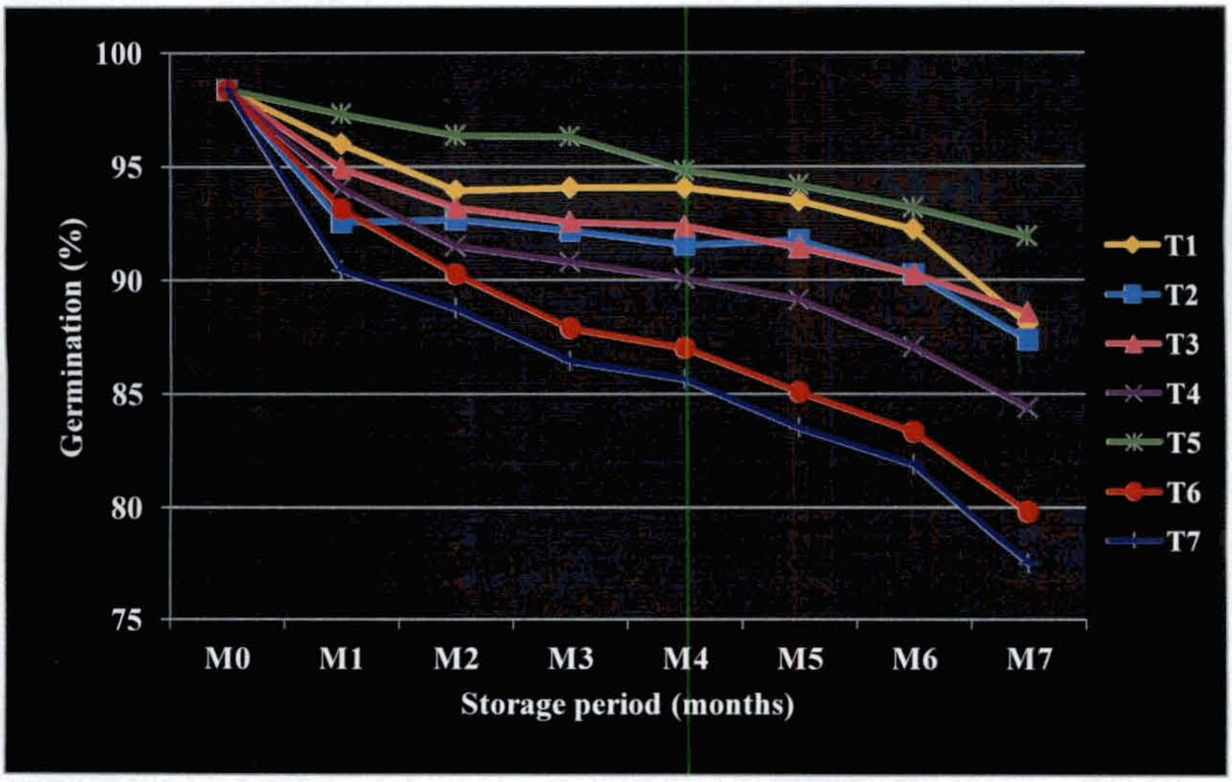


Fig. 7: Influence of halogen treatment on germination (%) during storage in rice (*kharif*, 2014)



that T5 prolonged seed longevity in comparison to other halogen doses, it clearly points out that seeds treated at T5 were significantly superior in seed qualities especially, seedling vigour indices.

According to Shaban (2013), high initial germination provides no assurance that the lot will store as well as another lot of the same kind with the same or even lower germination. Seed vigour declines first as seed deteriorates, followed by loss of germination and viability. Considering that T5 retained higher seedling vigour indices during storage as well as at the end in all three seasons, it can be concluded that seeds treated with the halogenation dose of T5 was superior in maintaining the germination and other seed quality parameters in all the three seasons. Beneficial effects of halogenation with $CaOCl_2$ through $CaCO_3$ @ 3g each/kg seed were also reported by Mandal and Basu (1986) in wheat, Maheshwari (1996) in soybean, Suneeta (2000) and Vyakaranahal *et al.* (2000) in sunflower, Sandyarani (2002) in cotton and Dharmalingam *et al.* (2000) in pulses. However, Raikar *et al.* (2011) had reported that the scented rice seeds treated with halogen calcium oxychloride at a higher concentration (5 g/kg seed) recorded higher seedling shoot and root length and dry matter production.

Several workers have attributed the reason behind seed deterioration during storage to lipid peroxidation and free radical production (Tappel, 1973; Pammenter *et al.* 1974; Wilson and McDonald, 1986; Basu, 1993; Jyoti and Malik, 2013; Shaban, 2013). The destructive element, the oxygenated fatty acids may be produced through auto oxidation or enzymatically. During auto oxidation, fatty acid hydrocarbon chains spontaneously oxidize producing reactive free radical intermediaries known as hydro peroxides. The rate of this reaction is greatly enhanced by the class of enzymes called lipoxygenases (LOXs).

The beneficial influence of halogen calcium oxychloride on germination throughout the storage period can be attributed to its antioxidant property resulting in decreased lipids auto oxidation and prevention of production of secondary cytotoxic aldehydes and free radicals. The chlorine molecules of calcium oxychloride bind lipid molecules at double bonds and prevent further oxidation of lipids (Basu, 1993). According to Dharmalingam (1995), halogenation not only maintains the seed viability, but also protects the seed from various external and internal deterioration factors and dry dressing of fresh seeds with halogens has conferred beneficial effects in several crops by lowering lipid peroxidation, thereby prolonging the viability and vigour of seeds in storage.

In the present study, seedling shoot and root length and dry matter production varied significantly during the storage period. The higher shoot and root length and dry matter production were recorded in seeds treated with T5 (calcium oxychloride through calcium carbonate @ 3 g each/kg seed) followed by T3 (calcium oxychloride @ 6 g /kg seed) and T4 (calcium oxychloride @ 9 g /kg seed) at the beginning and end of storage period respectively compared to control. Similar to the study, Raikar *et al.* (2011) had reported the advantage of halogenation with calcium oxychloride in obtaining higher seedling shoot length, root length and dry matter production during storage.

Increase in seedling shoot length, root length and dry matter production during storage in T5 was reflected in higher seed vigour I and II (Fig. 5 and Fig. 8) followed by T3 and T4 respectively. Higher seedling vigour on treatment with halogen calcium oxychloride has been reported in several crops (Rathinavel and Dharmalingam, 2001; Vimala *et al.,* 2002; Hunje *et al.*, 2007; Hemashree and Kurdikeri, 2011; Adebisi and Ayodele, 2013; Lone, 2014).

Among various halogenation doses, the lowest electrical conductivity of seed leachate was recorded in seeds treated with T5. Generally, electrical conductivity of seed leachate is negatively correlated with the seed viability and vigour. As seed ages, the cell membrane and cell organelle become leaky on account of decrease in phospholipids content due to either enzymatic or non enzymatic lipid auto oxidation or due to fungi and insect activity (Ching and Schoolcraft, 1968; Koostra and Harrington, 1969; Pammenter *et al.*, 1974). Ghasseemi *et al.* (2010) and Jyothi and Malik (2013) also argued that lipid peroxidation not only destroys lipids but can damage the cell membrane and other cellular components which in turn leads to leaching loss and seed deterioration.

The lowest electrical conductivity of seed leachate in T5 may be due to the antioxidant effect of calcium oxychloride. Antioxidants can inhibit lipid peroxidation by reducing the level of active oxygen species such as superoxide radicals, hydrogen peroxide and hydroxyl radical by blocking the propagation of free radical chain reactions (Basu and Rudrapal, 1979; Dahuja and Lodha, 2014). The differential EC values recorded among the seed treatments indicated that the nature and extent of membrane protection offered may not be same for all the treatments, thus resulting in difference in EC values (Kurdikeri, 1991).

The fluctuations in seed moisture content and seed infection were the least throughout the storage study in T5 compared to the other treatments. The storage potential of seed is mainly affected by seed moisture content during storage. Generally, at higher seed moisture content seed deterioration occurs more rapidly owing to more invasion of fungi, increased activity of storage pest and higher metabolic and enzymatic activity (Roberts, 1972; Christensen and Kaufman, 1969; Chitra, 1995). This may also be a factor for prolonged longevity of halogenated seeds compared to untreated seeds as evident in the study. It has been observed that the viability in T5 was retained above MSCS for a period of twelve months compared to nine months in untreated seeds (T1) during *rabi* 2013-14 while during summer 2013-14, germination above MSCS was retained for nine months in T5 against six months each in T1, T4 and T6. Considering retention of viability, over both the seasons the next promising seed halogenation doses were T3 and T4. These treatments also exhibited higher seedling vigour indices next to T5.

Further, seeds halogenated at a higher dose of $CaOCl_2$ + $CaCO_3$ @ 9g each /kg seed (T7) lost viability even before untreated seeds (eight months and four months respectively in *rabi* 2013-14 and summer 2013-14). This indicated that, halogenation at higher doses like T7 was detrimental to seed quality and viability. According to Dahuja and Lodha (2014), some antioxidants may be toxic and thus could mask any promotive effect in enhancing seed longevity.

5.3 Seed quality and longevity of rice variety Jyothi as influenced by interaction of packing material and halogen treatment

The results revealed that seed quality and longevity during storage were found to be significantly influenced by the interaction effects of packing material and halogenation treatment throughout the storage period during *rabi* 2013-14, summer 2013-14 and *kharif* 2014.

5.3.1 Influence of interaction of packing and halogen treatment on storability of rice seed (*rabi* 2013-14)

In *rabi* 2013-2014, seeds treated with $CaOCl_2$ through carrier $CaCO_3$ @ 3 g each/kg seed and stored in polyethylene bags (400G) (P2T5) recorded significantly higher germination per cent (Fig. 8) from 6^{th} month of storage. P2T5 was also superior to other treatment combinations with respect to other seed quality parameters like seedling shoot and root length (Plate 2), seedling dry weight and seeding vigour

Fig. 8: Interaction effect of packing material and halogen treatment on germination (%) during storage in rice (*rabi* 2013-14)

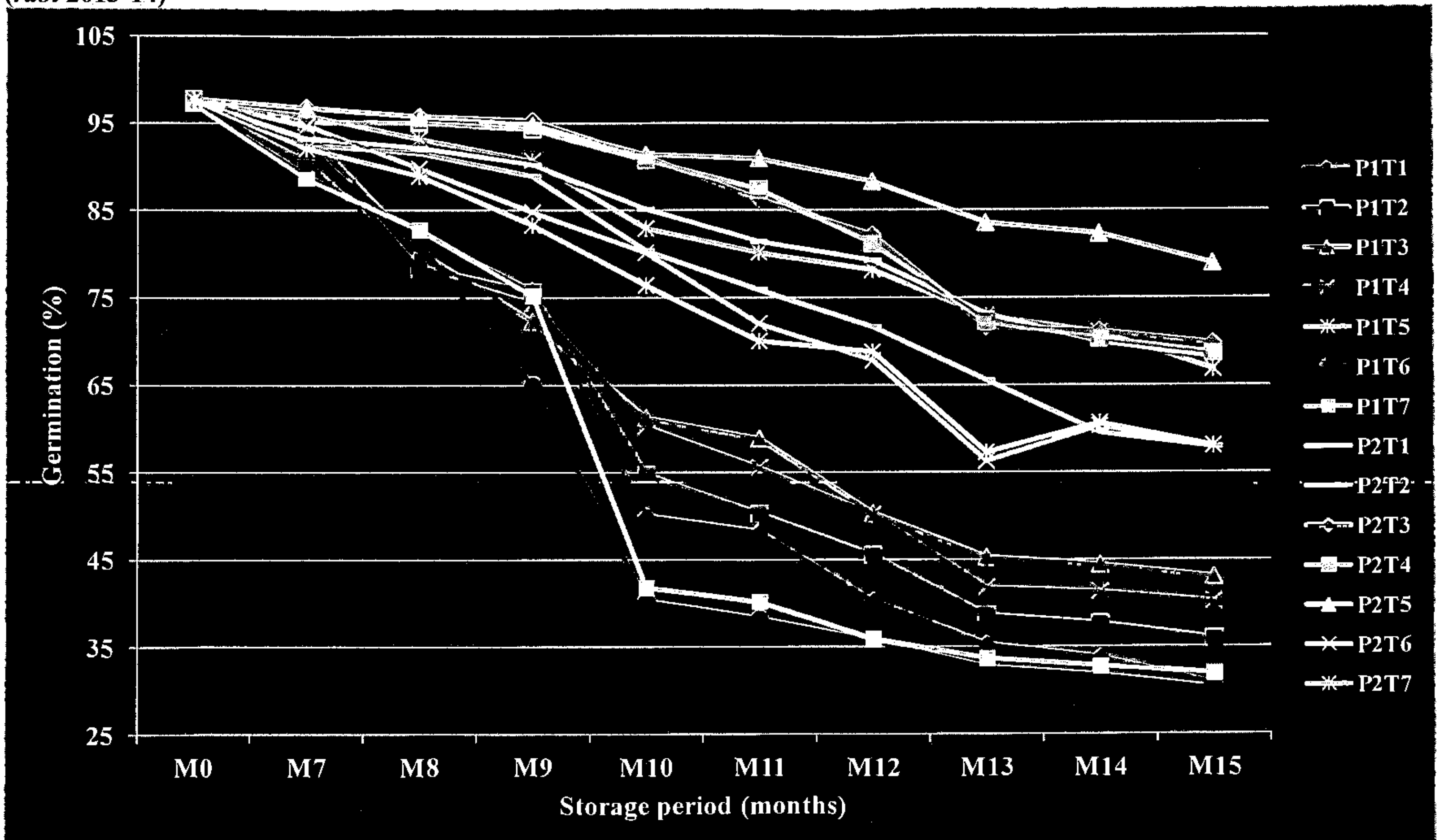
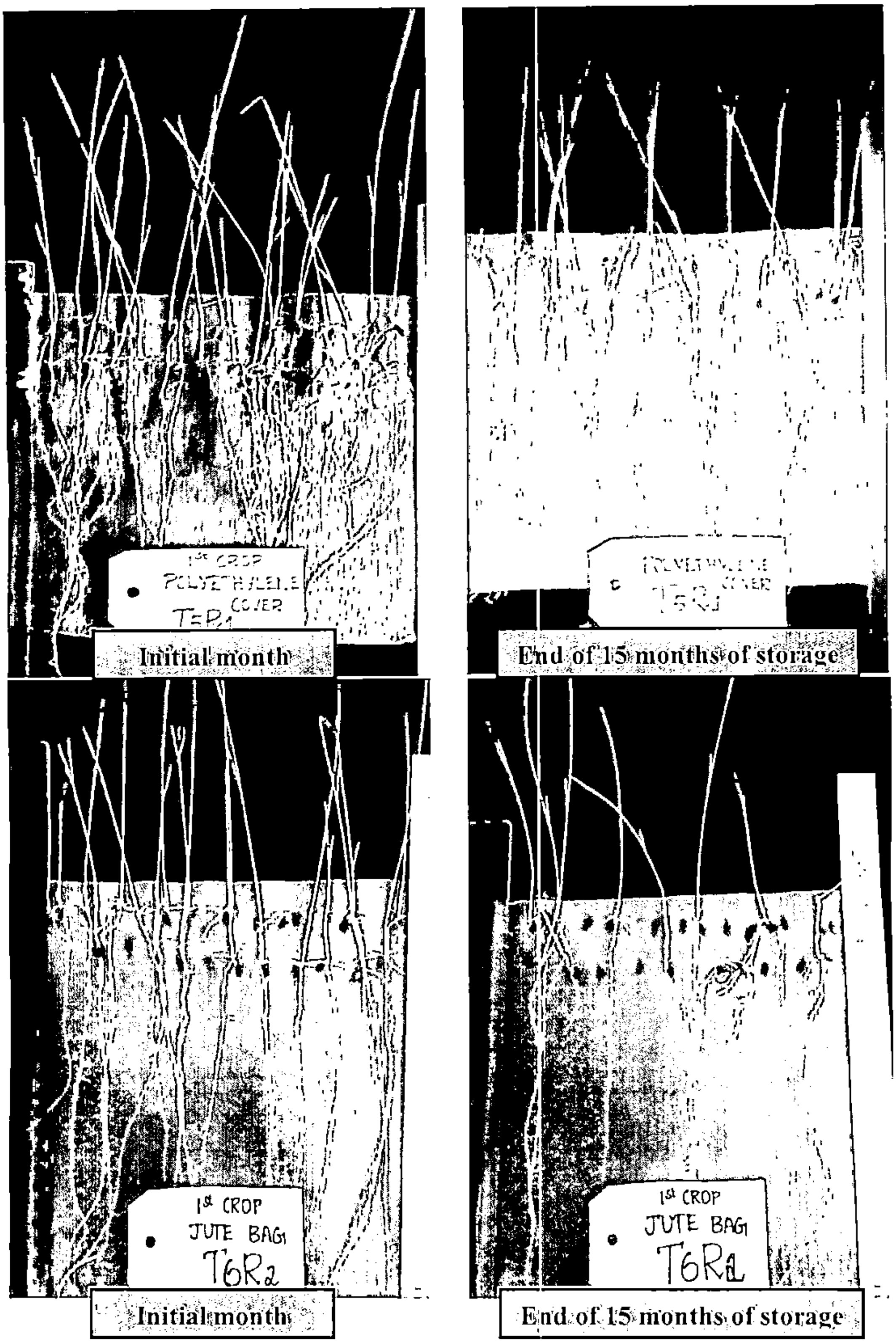


Plate 2: Seedlings of rice (*rabi*, 2013-14)



index I and II at the end of storage. P2T3 ($CaOCl_2$ @ 6 g /kg seed and stored in polyethylene bags of 400G) was the next best combination with respect to germination at the end of storage period. P2T5 had also recorded lower electrical conductivity of seed leachate, moisture content and seed infection per cent. Seeds in P2T5 retained germination above MSCS for fourteen months of storage compared to eight and ten months in untreated seeds stored in jute (P1T1) and polyethylene bag (P2T1) respectively. Viability in P2T3 and P2T4 ($CaOCl_2$ @ 9 g /kg seed and stored in polyethylene bags of 400G) was retained above 80 per cent for twelve months each whereas in P1T5, it was for 14 months.

5.3.2 Influence of interaction of packing and halogen treatment on storability of rice seed (summer 2013-14)

As in *rabi* 2013-14, during summer 2013-14 also, treatment combination P2T5 recorded significantly higher germination per cent throughout the storage period (Fig. 9). P2T5 followed by P2T3 ($CaOCl_2$ @ 6 g /kg seed and stored in polyethylene bags of 400G) and P1T5 ($CaCO_3$ + $CaOCl_2$ @ 6 g /kg seed and stored in jute bags) was superior to other treatment combinations with respect to other seed quality parameters like seedling shoot and root length, seedling dry weight and seeding vigour index I and II at the end of storage period. P2T5 recorded lower electrical conductivity of seed leachate, moisture content and seed infection per cent throughout the storage period. It retained germination above MSCS for ten months after storage compared to six and eight months in untreated seeds stored in jute (P1T1) and polyethylene bag respectively (P1T2). P2T4 was the next best treatment combination in retaining viability above 80 per cent for nine months.

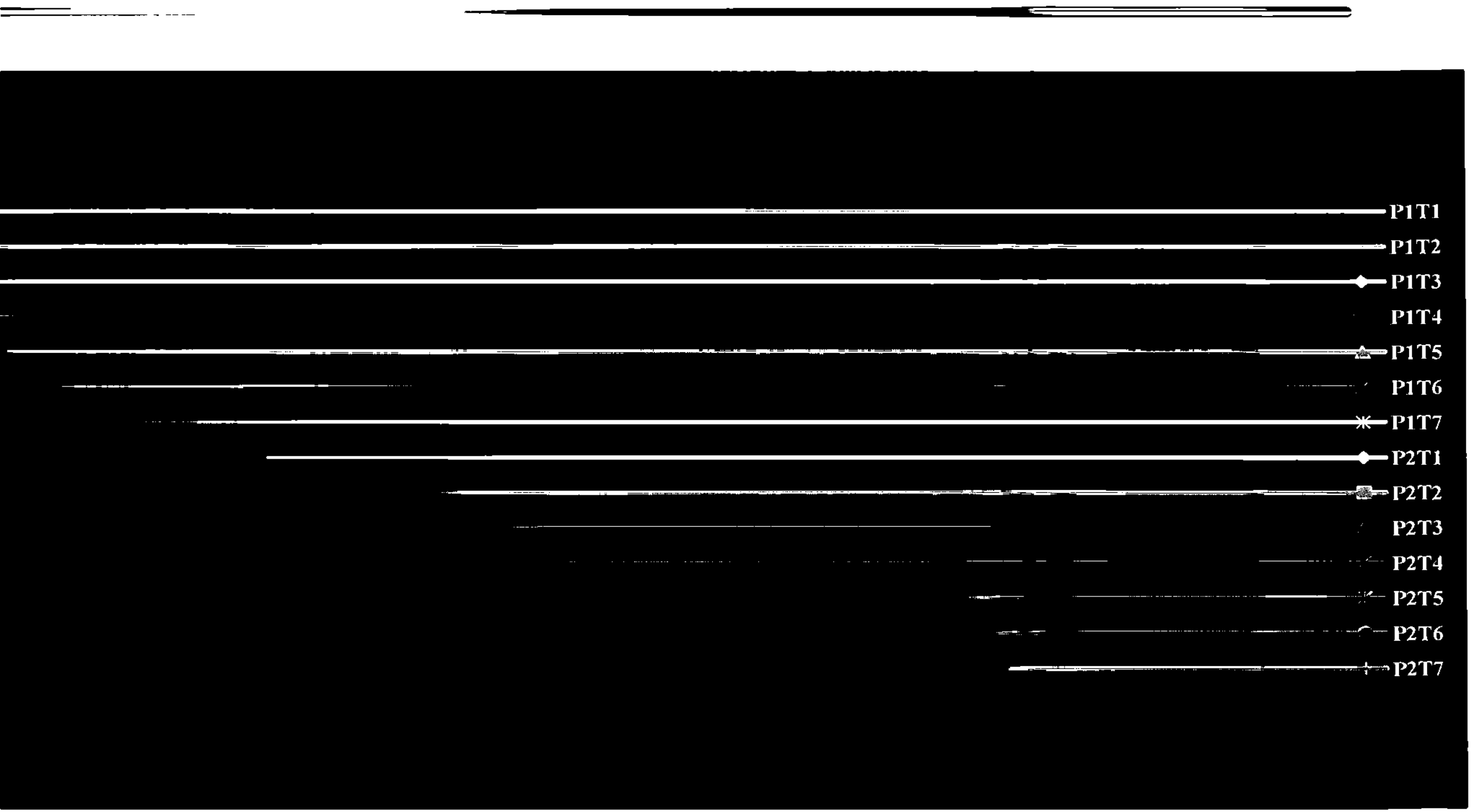
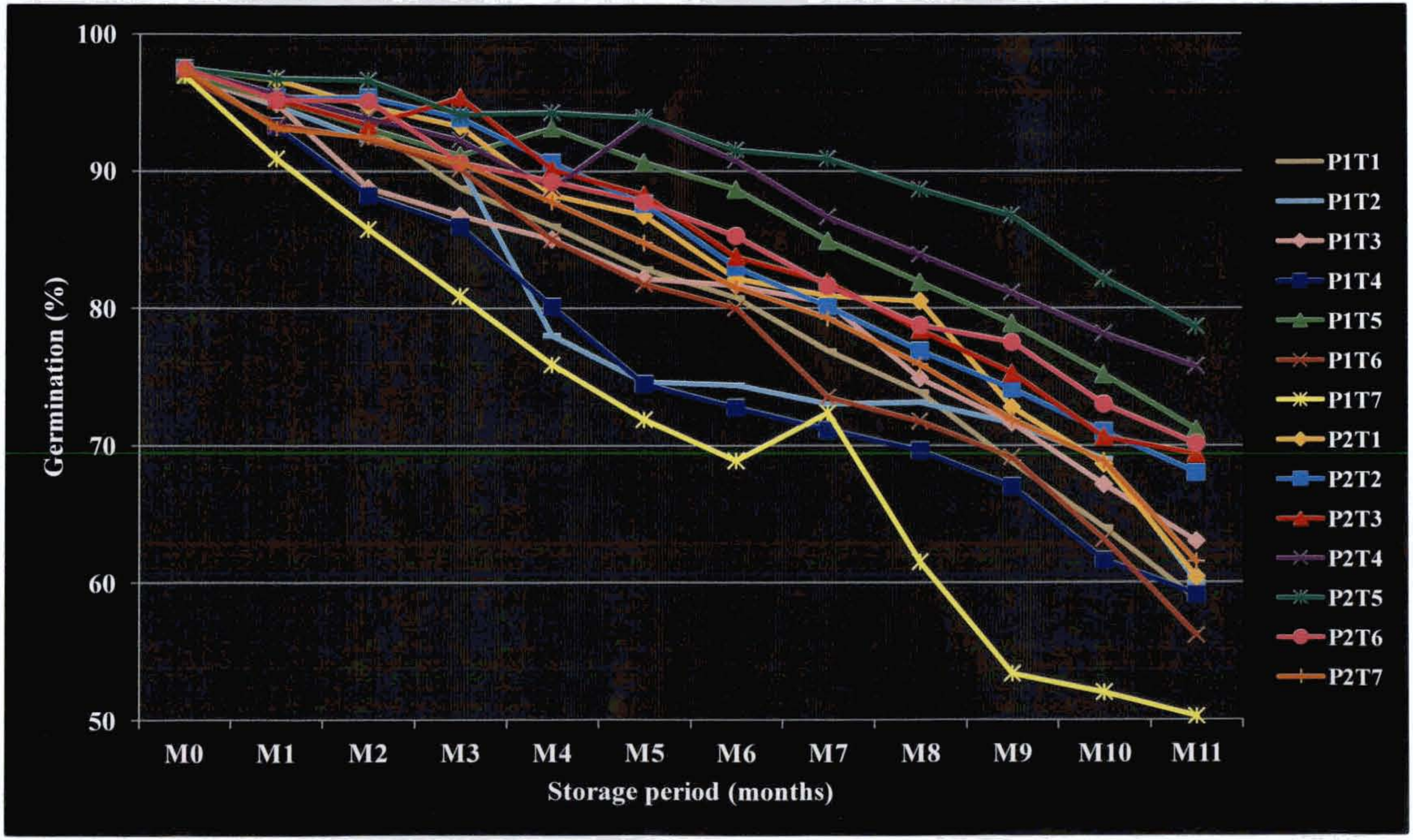

P1T1
P1T2
P1T3
P1T4
P1T5
P1T6
P1T7
P2T1
P2T2
P2T3
P2T4
P2T5
P2T6
P2T7

Fig. 9: Interaction effect of packing material and halogen treatment on germination (%) during storage in rice (summer 2013-14)



5.3.3 Influence of interaction of packing and halogen treatment on storability of rice seed (*kharif* 2014)

The storage studies with seeds of *kharif* 2014 also indicated that among the combination of packing materials and halogen treatments, P2T5 recorded higher seed quality parameters *viz.,* germination (Fig. 10), seedling shoot length (Plate 3), seedling dry weight and seeding vigour index I and II throughout the storage period. P2T5 had also recorded lower electrical conductivity of seed leachate, moisture content and seed infection per cent throughout the storage period. Germination in all treatments was retained above MSCS at the end of storage period except for P1T6, P1T7 and P2T7.

Considering that the seed quality parameters were the highest in P2T5, in seeds of all the three seasons (*rabi* and summer 2013-14, and *kharif* 2014), coupled with the fact that it resulted in retention of viability above 80 per cent for a longer period, P2T5 can be adjudged the best treatment combination (Fig. 11). Untreated seeds packed in jute bag (P1T1) had retained viability above MSCS for eight months and six months respectively in *rabi* and summer 2013-14 (Fig. 12). Among the combinations P2T3, P1T5, P2T4 and P2T1 showed promising results in different seasons. P1T5 however was consistent in all three seasons indicating that halogenation with calcium oxychloride through carrier calcium carbonate and packing in jute bags was also a viable option for prolonging seed longevity.

The advantage of combination of halogenation and polyethylene bag was also reported by Uppar (1998) in wheat, Malarkodi and Dharmalingam (1999) in bajra, Arati (2000) in chickpea, Joeraj (2000) in sunflower hybrid, Sandyarani (2002) in cotton, Madinur (2007) in drumstick, Sangamnathrao (2009) in maize, Vadgave

Fig. 10: Interaction effect of packing material and halogen treatment on germination (%) during storage in rice (*kharif* 2014)

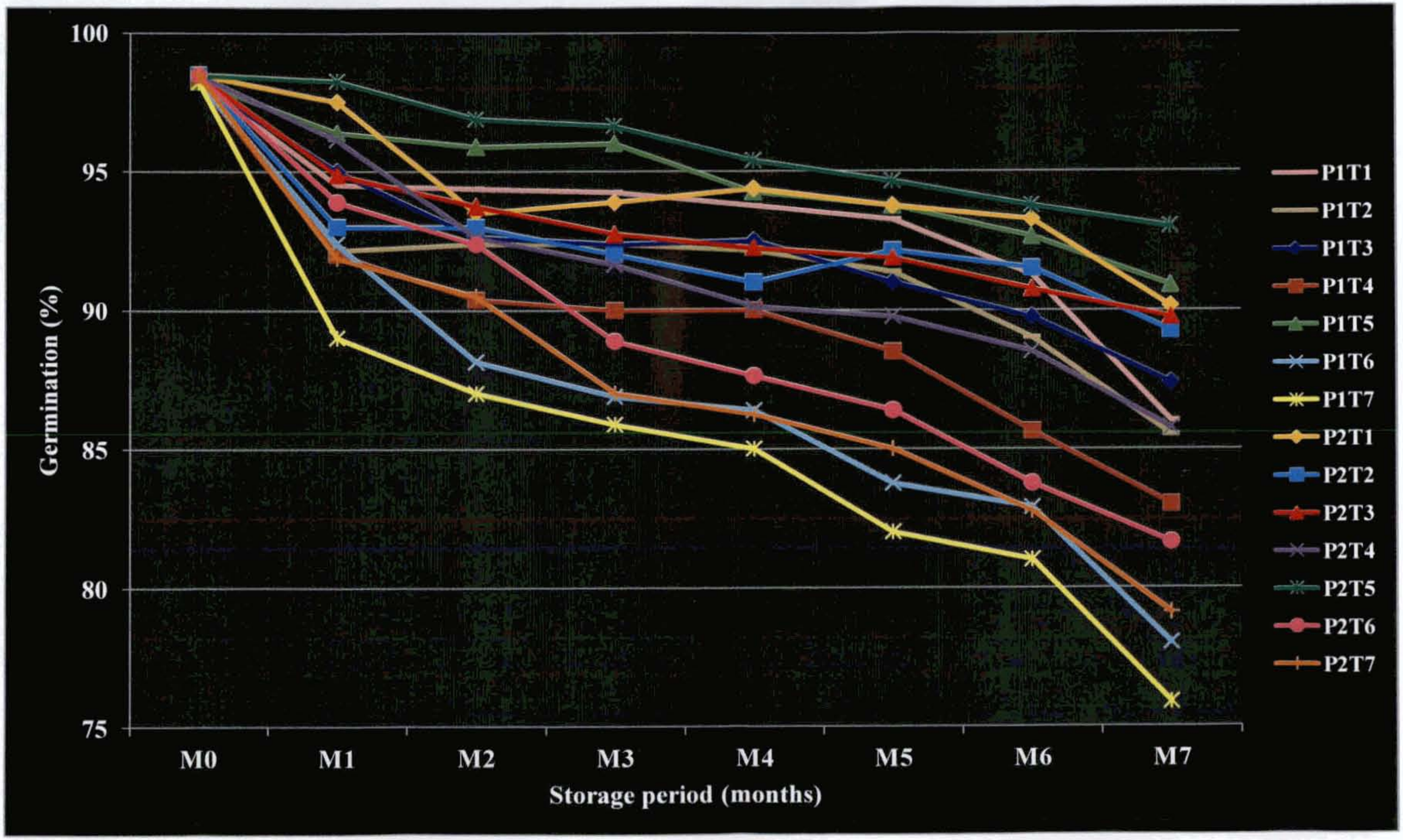


Fig. 11: Trend in germination in treatment combination P2T5 over three seasons (*rabi* 2013-14, summer 2013-14 and *kharif* 2014)

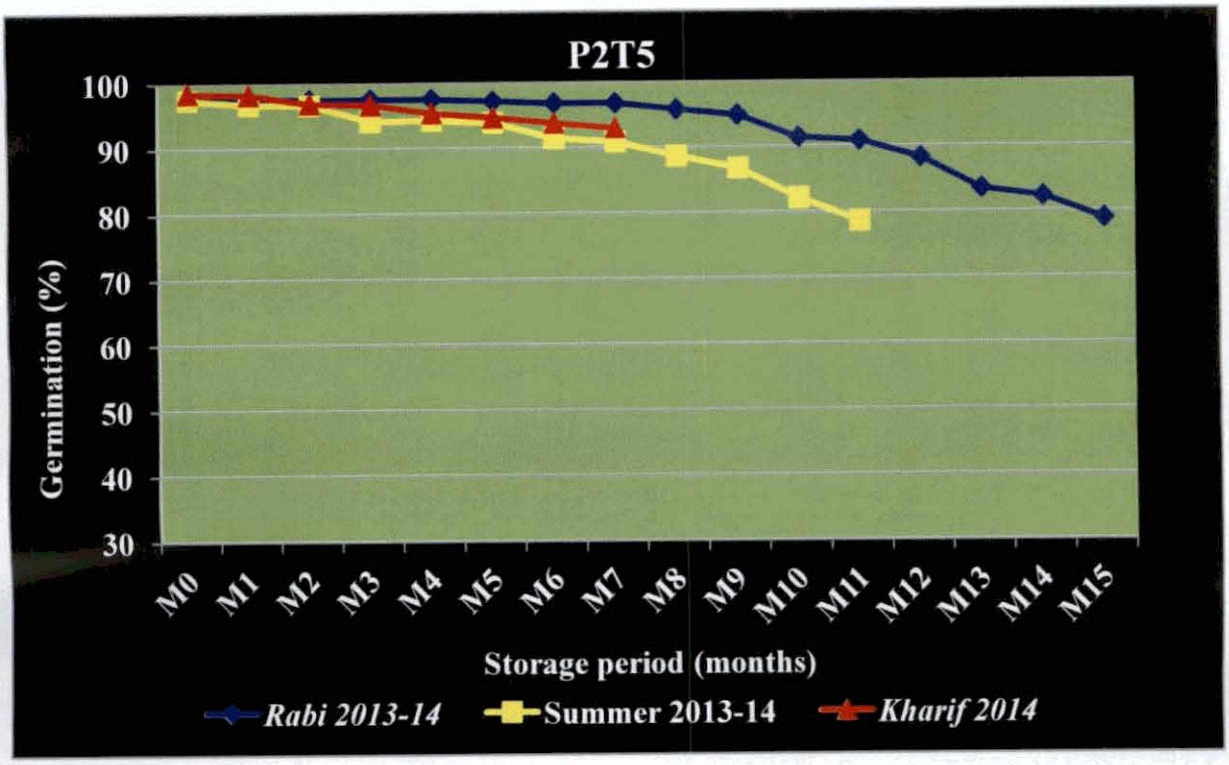


Fig. 12: Trend in germination in treatment combination P1T1 over three seasons (*rabi* 2013-14, summer 2013-14 and *kharif* 2014)

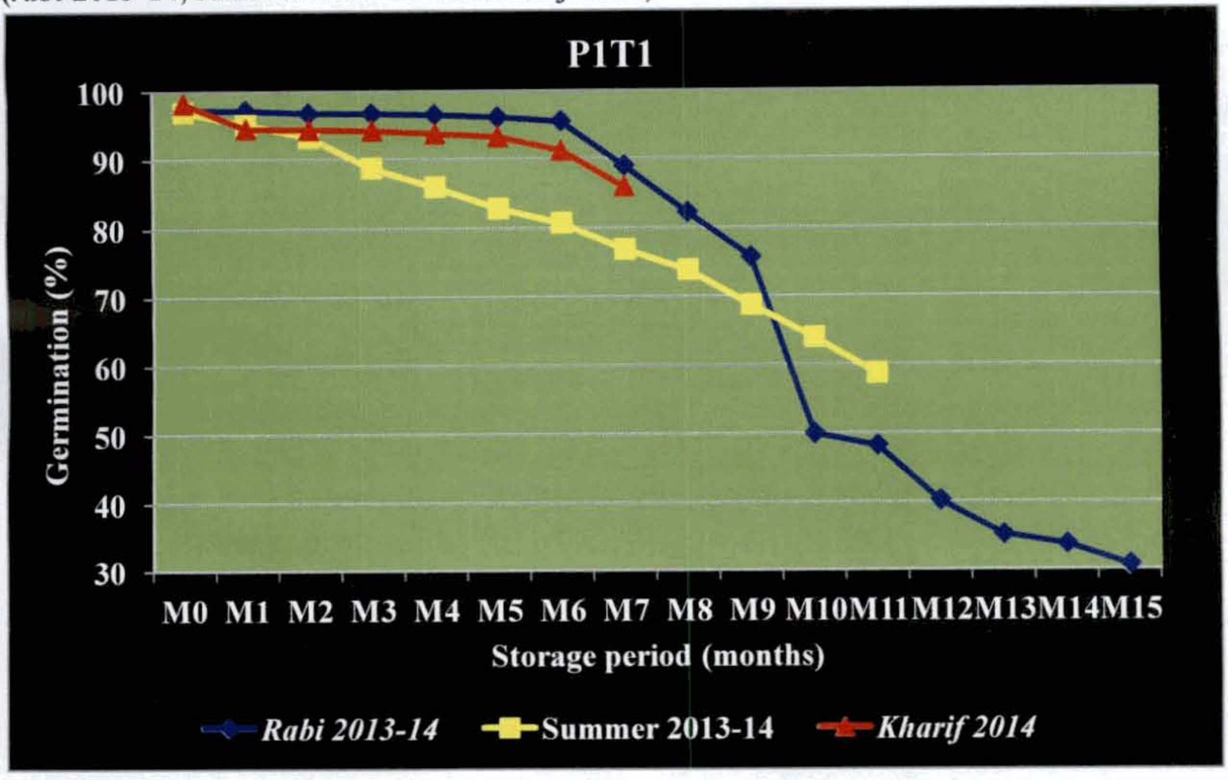
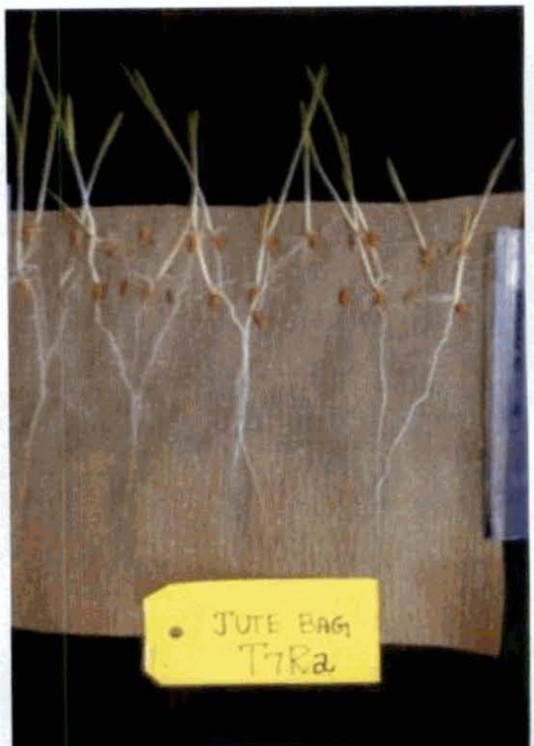


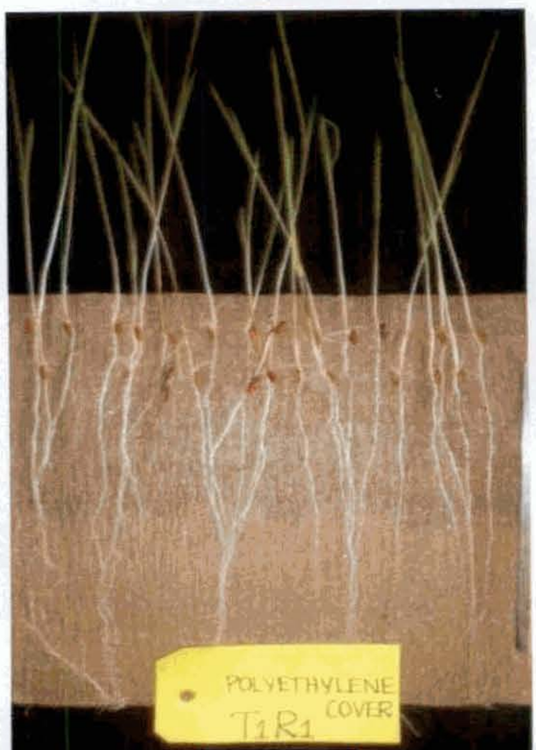
Plate 3: Seedlings of rice at the end of 7 months of storage (*kharif*, 2014)

P2T5



P1T7

P1T1



P2T1

(2010) in green gram, Hemashree and Kurdikeri (2011) in Bt cotton, Geetha and Krishnasamy (2012) in *Cenchrus*, Narayanan and Prakash (2014) in groundnut.

The findings of the study with respect to root length, shoot length and dry matter production at the end of storage were in conformity with Punitha (1996) in vegetables and Anjalidevi (1998) in cotton.

Generally, seed quality is inversely related to seed leachate values; higher the EC, lower is the seed quality. As substantiated earlier, the lower electrical conductivity of seed leachate recorded in P2T5 may be due to the antioxidant effect of halogen calcium oxychloride which prevents the loss in integrity of the plasma membrane in aged seeds. P1T7 recorded the highest electrical conductivity throughout the storage period, which showed that the seed stored under that particular treatment combination is deteriorating at a faster rate as reflected in its early loss of viability. The proportional increase in the extent of leakage of cytoplasmic components to external medium with ageing has been confirmed by Simon (1976) and Dahuja and Lodha (2014).

Temperature, relative humidity and seed moisture are the key factors that determine longevity of seed. The interaction of high temperature during storage and high moisture content in seeds may cause seed deterioration synergistically (Dahuja and Lodha, 2014). Higher seed longevity in P2T5 may be attributed to the low moisture fluctuations in polyethylene bags owing to impervious nature and preventive role of chlorine in peroxidative and free radical productions. Membrane integrity was found to be maintained with $CaOCl_2$ treated seeds and stored in polythene bag as evident with decreased EC values compared to seeds treated and stored in jute bags (Ravichandran and Dharmalingam, 1994 in rice; Arati, 2000 in chickpea; Vidyadhar and Gopalsingh, 2000 in maize). Although stored in jute bags, seeds halogenated with T5 (P1T5) also proved beneficial in reducing the rate of seed deterioration. This may be attributed to the antioxidant effect of the halogen.

The lower moisture content coupled with halogenation in P2T5 is also likely to have reduced the microflora growth thereby reducing seed deterioration compared to P1T5 and untreated seeds. Christensen and Kaufman (1969) reported that fungi not only cause qualitative and quantitative loss of seed, but also increase the moisture content of the seeds in storage, bringing biochemical changes leading to decreased membrane integrity, decreased food reserves in seed and causes rapid death of seeds within a shortest period of time. Antimicrobial activity of halogens has been reported by Pryor and Lasswell (1975). Chitra (1995) had reported antimicrobial property of calcium oxychloride.

In addition to the fungal infection, Jyoti and Malik (2013) proposed that with increase in seed moisture content, hydrolysis of phospholipids hastens the release of glycerol and fatty acids. The accumulation of free fatty acids results in a decline in cellular pH which is detrimental to normal cellular metabolism.

Further, seed moisture content is a function of relative humidity and it fluctuates concomitantly with the changes in atmospheric relative humidity and temperature due to the hygroscopic nature of seed (Anderson and Baker, 1983). According to them, higher the RH, the higher the seed moisture and faster the rate of deterioration particularly at moisture contents above twelve per cent. In the present study also, fluctuation in seed moisture content in halogen treatment was noticed in all the storage months.

Considering the above facts and the results obtained it can be summarized that, to maintain higher seed quality and prolong viability during storage under high hot humid conditions prevailing in Kerala, it is best advisable to store rice seeds in moisture vapour proof polyethylene bags (400G) at ten per cent moisture after treating with halogen calcium oxychloride along with carrier calcium carbonate @ 3g each/ kg of seed *i.e.,* P2T5. Results also indicated that, storing seeds at thirteen per cent moisture in jute bags after halogenating the seeds at the same halogen dose (T5) was also beneficial although to a lesser extent compared to P2T5. This has far reaching implications since, it can be easily practised by farming community as lowering of seed moisture to ten per cent is not essential as required in P2T5.

To conclude, P1T5 is a practical and viable approach that can be practised by farmers while P2T5 is the most beneficial approach that can be embraced by organized seed sector in the state with far reaching effects.

FUTURE LINE OF WORK

Seed storability is a crucial issue under the hot humid conditions prevailing in Kerala. Easy and farmer friendly approaches need to be devised to improve qualities and longevity during storage. Efforts should be directed in the following aspects in future:

1) Studies to confirm the superiority of storing seeds in polyethylene bags (400G), seed treatment with halogen calcium oxychloride along with carrier calcium carbonate @ 3g each/ kg of seed and their interactive effect (P2T5) on prolonging seed longevity need to be undertaken with seeds produced in *kharif* season.

2) Since there is possibility of wear and tear of polyethylene bags (400G) during handling and stacking of seed bags effect of storage in sturdy packing materials like polylined jute bags need to be evaluated.

3) Owing to monsoon, reduction of seed moisture to 10 per cent before packing in polyethylene bags (400G) may be delayed in seed of *kharif* and summer crop. Hence, the impact on seed longevity and qualities on delayed packing may be assessed.

4) With the present impetus on organic farming, the possibility of prolonging seed longevity through use of botanicals may be worked out.

5) The results may be extrapolated to other crops and the impact assessed.

Summary

6. SUMMARY

Storage study was carried at the Department of Seed Science and Technology, College of Horticulture, Kerala Agricultural University (KAU), Vellanikkara, Thrissur, with seeds of rice variety Jyothi pertaining to *rabi* 2013-14, summer 2013-14 and *kharif* 2014. The study intended to optimize the dosage and mode of application of halogen and to evaluate the efficacy of different halogen treatments and packing material on longevity of rice seeds under ambient storage conditions. The results obtained are summarized below.

The salient findings of the study are summarized below:

I. Seed quality and longevity of rice variety Jyothi as influenced by packing material

1. Irrespective of season of production, seed quality and longevity during storage were significantly influenced by the packing material throughout the storage period.

2. Irrespective of halogenation, seeds of all three seasons stored in polyethylene bags (400 G) were significantly superior to that in jute bags with respect to germination and other seed quality parameters like seedling length, seedling dry weight, vigour index I and II, electrical conductivity, seed moisture content and infection by seed microflora at the end of storage.

3. Seeds of *rabi* and summer 2013-14 stored in polyethylene bags (400 G) retained viability above minimum seed certification standards (MSCS) (80%) for eleven and eight months respectively compared to eight and four months in case of jute bags. This indicated that storing seeds in polyethylene bags (400 G) prolonged seed longevity in storage over storing them in jute bags.

4. Conclusive evidence as to superiority of polyethylene bags (400 G) over jute bags could not be obtained in seeds of *kharif* 2014 owing to short storage period (seven months).

5. Considering the superiority of seeds in polyethylene bags (400 G) over that in jute bags over three seasons with respect to maintaining seed quality parameters and the impact of polyethylene bags (400 G) in prolonging seed longevity during *rabi* and summer 2013-14, it can be concluded that, storing seeds in polyethylene bags (400 G) at 10 per cent moisture is advantageous over storing them in jute bags at 13 per cent moisture content under the hot humid conditions prevailing in Kerala.

II. Seed quality and longevity of rice variety Jyothi as influenced by halogen treatment

1. Seed quality and longevity during storage were found to be significantly influenced by halogenation treatment throughout the storage period in all three seasons.

2. Irrespective of the packing material used, seeds of all three seasons treated with $CaOCl_2$+$CaCO_3$ @ 3 g each/kg seed (T5) recorded the significantly high germination per cent, seedling shoot length, seedling dry weight and vigour index I and II.

3. T5 also recorded the least electrical conductivity, moisture content and seed infection at the end of storage indicating superiority of T5 over other halogen doses in maintaining seed qualities during storage.

4. T3 ($CaOCl_2$ @ 6 g/kg seed) that exhibited lower seed deterioration next to T5 as evident from higher seedling shoot length, root length and vigour indices, is adjudged the next best halogenation dose.

5. The viability in T5 was retained above MSCS for a period of twelve and nine months in *rabi* and summer 2013-14 respectively compared to nine and seven months in case of T3. Untreated seeds (T1) had retained viability above 80 per cent for nine and six months *rabi* and summer 2013-14 respectively.

6. Seeds halogenation as per treatment T7 ($CaOCl_2$ + $CaCO_3$ @ 9g each /kg seed) proved detrimental as the retention of viability above 80 per cent was found to be lower than in untreated seeds.

7. Again, the superiority of halogenation dose at T5 in prolonging seed longevity was not decisive in seeds of *kharif* 2014 owing to the short storage period of seven months.

8. From the estimates of other seed quality parameters observed during storage, and longer period of retention of viability above MSCS in *rabi* and summer 2013-14, it can be concluded that T5 followed by T3 were the best halogenation dose in maintaining higher seed qualities and prolonging longevity of seeds during storage.

III. Seed quality and longevity of rice variety Jyothi as influenced by interaction of packing material and halogen treatment

1. Results revealed that seed quality and longevity during storage were found to be significantly influenced by the interaction effects of packing material and halogenation treatment during storage in all three seasons.

2. Seeds treated with $CaOCl_2$+$CaCO_3$ @ 3 g each/kg seed and stored in polyethylene bags (400 G) (P2T5) showed superiority in all the seed quality parameters studied over untreated seeds packed in jute bags (P1T1) or polyethylene bags (400G) *i.e.,* P2T1 as well as other halogenated seeds at the end of storage period in all three seasons.

3. Among the various combinations of halogen doses and packing material, seeds in P2T5 retained germination above MSCS for the longest period of storage (fourteen and ten months during *rabi* and summer 2013-14 respectively), indicating its superiority in prolonging seed longevity.

4. Untreated seeds packed in jute bag (P1T1) had retained viability above MSCS for eight months and six months respectively in *rabi* and summer 2013-14 while it was for ten and eight months in case of untreated seeds packed in polyethylene bags (400 G) (P2T1).

5. Among various combinations of packing material and halogen doses P2T3 ($CaOCl_2$ @ 6g /kg seed and stored in polyethylene bag of 400G), P1T5 ($CaOCl_2$+$CaCO_3$ @ 3g each/kg seed and stored in jute bag), P2T4 ($CaOCl_2$ @ 9 g/kg seed and stored in polyethylene bag of 400G) and P2T1 (untreated seeds stored in polyethylene bag of 400G) showed promising result in different seasons.

6. Since P1T5 was consistent in all three seasons indicating that halogenation with calcium oxychloride through carrier calcium carbonate and packing in jute bags was also a viable option for prolonging seed longevity.

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HALOGENATION OF RICE SEEDS TO PROLONG STORABILITY

By

S. SUGANYA

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ABSTRACT OF THE THESIS

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ABSTRACT

An experiment on the effect of halogens and packing materials on paddy seeds was undertaken at the Department of Seed Science and Technology, College of Horticulture, Kerala Agricultural University (KAU), Vellanikkara, Thrissur with seeds of rice variety Jyothi pertaining to *rabi* 2013-14, summer 2013-14 and *kharif* 2014. The experiment aimed to standardize the optimum dose and mode of application of halogens and elucidate the impact of seed treatment with halogen and the packing material on seed quality and longevity. The experiment was conducted as completely randomized design involving two factors (packing material and halogenation dose) with two replications. Treatments comprised of a combination of a packing material either jute bag (P1) or polyethylene bag of 400G (P2) with seed halogenation (T) at different doses. Observations recorded on germination, seedling shoot and root length, seedling dry weight, seedling vigour index I and II, electrical conductivity of seed leachate, seed moisture content and seed infection were statistically analyzed and results interpreted.

Seed quality and longevity during storage were found to be significantly influenced by packing material, dose of halogen and the interaction effects of packing material and dose of halogen throughout the storage period.

Irrespective of halogenation, seeds of all the three seasons stored in polyethylene bags (400G) were significantly superior to that in jute bags with respect to germination and other seed quality parameters like seedling length, seedling dry weight, seedling vigour index I and II, electrical conductivity of seed leachate, seed moisture content and infection by seed microflora at the end of storage. Seeds of *rabi* and summer 2013-14 stored in polyethylene bags (400G) retained viability above minimum seed certification standards (MSCS) (80%) for eleven and eight months compared to eight and four months in case of jute bags respectively. Hence, results pointed out that there was definite advantage in storing seeds in polyethylene bags

(400G) over storing them in jute bags both with respect to seed qualities and prolonging seed longevity.

Seeds halogenated with calcium oxychloride ($CaOCl_2$) in combination with carrier calcium carbonate ($CaCO_3$) @ 3g each/kg of seed (T5) recorded significantly high germination, seedling shoot length, seedling dry weight and seedling vigour index I and II. It also recorded the least electrical conductivity, moisture content and seed infection at the end of storage irrespective of the packing material and season of seed production. In addition, T5 prolonged seed viability above MSCS for a period of twelve and nine months compared to nine and six months in untreated seeds (T1) in *rabi* and summer 2013-14 respectively. Results thus proved the superiority of halogenation at T5 ($CaOCl_2$+$CaCO_3$@ 3g each/kg seed) in retaining seed qualities and prolonging seed longevity during storage. T3 ($CaOCl_2$ @ 6 g/kg seed) that exhibited lower seed deterioration next to T5 retained viability above 80 per cent for nine and seven months in *rabi* and summer 2013-14 respectively, is adjudged the next best halogenation dose.

The interactive effect of packing material and seed halogenation indicated that, seed treated with $CaOCl_2$ through carrier $CaCO_3$ @ 3g each /kg of seed (T5) and stored in polyethylene bags of 400G (P2) *i.e.,* treatment combination P2T5, exhibited significantly higher seed qualities at the end of storage in all three seasons. P2T5 had also retained viability above MSCS for longer period both in *rabi* and summer 2013-14 (fourteen and ten months respectively) compared to untreated seeds packed in jute bag (P1T1) (eight months and six months respectively).

Among the various combinations, P1T5 ($CaOCl_2$+$CaCO_3$ @ 3g each/kg seed and packing in jute bag) was found consistent in all three seasons with respect to maintain seed quality parameters at the end of storage. Seeds in P1T5 had retained viability above MSCS for eleven and eight months in *rabi* and summer 2013-14 respectively, indicating its advantage over untreated seeds packed in jute bag (P1T1).

Hence, halogenation with calcium oxychloride through carrier calcium carbonate (T5) and packing in jute bags is also a viable option for prolonging seed longevity.

Considering the above, it can be concluded that, to maintain higher seed quality and prolonging viability during storage, it is best advisable to store rice seeds in moisture vapour proof polyethylene bags (400G) at ten per cent moisture after treating with halogen calcium oxychloride along with carrier calcium carbonate @ 3g each/ kg of seed *i.e.,* P2T5 followed by P1T5 ($CaOCl_2$+$CaCO_3$ @ 3g each/kg seed and packing in jute bag).