STORABILITY OF RICE SEED WITH VARIED MOISTURE CONTENT IN EARTHEN POT OF DIFFERENT FORMS

SOHELI SARKER

DEPARTMENT OF AGRONOMY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
SHER-E-BANGLA NAGAR, DHAKA-1207, BANGLADESH

DECEMBER, 2014

STORABILITY OF RICE SEED WITH VARIED MOISTURE CONTENT IN EARTHEN POTS OF DIFFERENT FORMS

BY

SOHELI SARKER

REGISTRATION No. 07-02261

A Thesis
Submitted to the faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE
IN
AGRONOMY

SEMESTER: JULY-DECEMBER, 2014

APPROVED BY

…………………………	……………………………
Prof. (Rtd.) Sadrul Anam Sarder	**Prof. Dr. A.K.M. Ruhul Amin**
Professor	**Professor**
Research Supervisor	**Co-supervisor**

……………………………….

Prof. Dr. H. M. M. Tariq Hossain
Chairman
Examination Committee

Department of Agronomy

Sher-e Bangla Agricultural University

Sher-e-Bangla Nagar

Dhaka-1207

CERTIFICATE

This is to certify that thesis entitled, "***STORABILITY OF RICE SEED WITH VARIED MOISTURE CONTENT IN EARTHEN POTS OF DIFFERENT FORMS***" submitted to the Faculty of Agriculture, Sher-e-BanglaAgricultural University, Dhaka, in partial fulfillment of the requirements for the degreeof **MASTER OF SCIENCE (MS) IN AGRONOMY**, embodies the result of apiece of *bona-fide* research work carried out by **SOHELI SARKER**, Registration no. **07-02261** under my supervision and guidance. No part of the thesis hasbeen submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of duringthe course of this investigation has duly been acknowledged.

....

Date: **Prof. (Rtd.) Dr. Sadrul Anam Sarder**

Place: Dhaka, Bangladesh

Supervisor

DEDICATED
TO
MY BELOVED FAMILY

ACKNOWLEDGEMENT

Alhamdulillahi Rabbil Al-Amin, all praises are due to the almighty ALLAH Rabbul Al-Amin for his gracious kindness and infinite mercy in all the endeavours the author to let me successfully complete the research work and the thesis leading to Master of Science.

There are a number of individuals for which I would like to recognize for their contribution to my development and success. First and foremost with a deep sense of gratitude and indebtedness, I thank my research supervisor Prof. Md. Sadrul Anam Sarder, Professor (Rtd.), Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207 for his invaluable guidance, constructive criticism, encouragement and keen interest. My experience with his has inculcated in me qualities that will always remain ingrained in my heart, mind and soul. His constructive criticism and frequent discussion inspired me to go ahead in difficult times and cope up with every little problem during my thesis.

I would also like to express my deepest sense and gratitude to my co-supervisors Prof. Dr. A.K.M. Ruhul Amin, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, for his valuable advice and encouragement during the study and preparing of the dissertation.

I avail this opportunity to express my sincere thanks and profound appreciation to the departmental Chairman Prof. Dr. Md. Fazlul Karim along with all the teachers and stuff members of the Department of Agronomy, SAU, Dhaka-1207, for their co-operation and support during the study.

I would also like to acknowledge the moral support, encouragement and cooperation from my very near ones including Sadia Masrufa, Md. Rasheduzzaman Sarker, Md. Ahsan Habib and special thanks to Md. Al-Amin, lab attendant, BSMRAU for his supportive help at their lab. I would like to thank my parents, brothers and husband for their unconditional love and support they have lent for many years. None of my success I am able to celebrate would be possible without the values they have instilled in me. Next, I would like to extend gratitude and thanks to all of my family members, relatives and friends for their blessings, continuous support and inspiration in all phases of my academic endeavors.

December, 2014 **The Author**

STORABILITY OF RICE SEED WITH VARIED MOISTURE CONTENT IN EARTHEN POT OF DIFFERENT FORMS

ABSTARACT

The experiment was conducted in the farm laboratory of the department of Agronomy, Sher-e-Bangla Agricultural University during the period from June to December, 2013. The experiment was carried out to evaluate the efficiency of different storage containers with different seed moisture content on seed quality of boro rice (BRRI dhan28) seeds. Different storage containers used in the study were C_1 = coalter coated earthen pot, C_2 = traditional earthen pot and C_3 = polythene bag contained in traditional earthen pot. Different seed moisture contents were M_1= 10% seed moisture, M_2= 12% seed moisture, M_3= 14% seed moisture and M4= 16% seed moisture. The experiment was designed in Completely Randomized consisting two factors: storage container and seed moisture content. Seed quality measuring parameter viz. seed moisture and germination percentage, seed vigour and seedling vigour were determined at 2 months interval i.e. in August, October and December. The storage container, coalter coated earthen pot (C_1) showed the highest germination, normal seedlings and vigour index followed by polythene bag in traditional earthen pot (C_3) and traditional earthen pot (C_2) where the last one showed significantly the lowest. Seed moisture percentage, electrical conductivity was the highest in traditional earthen pot but lowest in coalter coated earthen pot. Seed vigour, seedling root-shoot length were significantly affected when the rice seeds were stored in traditional earthen pot with 16% seed moisture content. The coalter coated earthen pot with irrespective of seed moisture content could produce normal seedling up to the end of the storage i.e. December, 2013 but polythene bag contained in earthen pot and traditional earthen pot could produce only up to August, 2013. Storing rice seeds with 12% seed moisture in coalter coated earthen pot performed better than with 10% seed moisture content. The moisture content of seed during storing was the critical factor on which the time of storage was dependent with regard to seed viability. Higher the moisture contents of seed at storage, higher the rapidity of viability loss.

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Introduction

CHAPTER I
INTRODUCTION

Rice is life for thousands of millions of people. Rice (*Oryza sativa L*) is the staple food of about 135 million people of Bangladesh and it covers about 9.99 million hectares. The rice crop occupies a place in almost 98% of the existing number of cropping patterns of the country. It provides nearly 48% of rural employment, about two third of total calorie supply and one half of the total protein intake of an average person in Bangladesh. It is the grain with the second-highest worldwide production, after corn. Bangladesh is the fourth highest rice (*Oryza sativa* L.) producing country in the world (FAO, 2013). Rice is grown on about 11.56 million hectares which has remained almost stable over the past three decades. About 76.71% of the total cropped area is planted to rice in the year 2012-13. The country is now producing about 34.00 million tons to feed her 149.69 million people (Mondal and Choudhury, 2014).

Storage of food grain as seed for next season is practiced from the era of very beginning of civilization and it is important in order to ensure constant food supply for every season.Successful storage of seed is the primary importance to the seed industry. Grain storage occupies a vital place in the economies of developed and developing countries (Ellis *et al*. 1992).Among the total seeds requirement in the country, only 10% quality seeds are available to the farmers and the 90% of the requirement are met up by the farmers saved seeds (Fakir *et al*. 2002). About 85% own preserved seeds were used by the farmers in Bangladesh for different rice seasons. Most of the Bangladeshi farmers preserve their rice seed for the next crop seasons, which is subjected to insect and disease infestation. Farmers usually grow rice for consumption or for commercial purpose and save a portion as seed. To the farmers, for satisfaction crop production, a quality seed is not only desirable but is also a satisfactory requirement in developed countries. It is so important to store rice grain as seed as it is the only propagation material from which farmer can get the crop. Farmers usually preserve their own seed following traditional method using bamboo made dole, gunny bag, earthen pot, jar etc. as storing containers.

Ensure the quality of seeds for sowingis one of the potential means of enhancing rice productivity. A good quality seeds are often free from diseases and posses high germinability and vigor.Moisture content has an important influence on several aspects of rice quality. Its primary effect is on the keeping properties of rice during storage. Under practical storage conditions moisture is generally the factor most responsible for controlling the rate of deterioration (Webb, 1985). Farmers with very little knowledge can hardly maintain required moisture level for better seed health. They usually store seeds using their own experience, thus fail to maintain the quality of the seed which further subjected to damage by various biotic and abiotic factors. The biotic factors includes fungi, mites, mould, insect, rodent, lizards, birds etc. and the abiotic factors includes temperature, moisture content, relative humidity, thermal properties of grain and storage structure, natural calamities like heavy rain and floods, etc. Storage fungi operate best at relative humidity of around 85% but the activity of fungi falls off below 75% effective humidity (Schroeder & Calderwood, 1972).Traditional storing accounts 70-80% of total rural produce. Rice grain is highly hygroscopic and thus the grain moisture content stored in gunny bag or earthen pot will automatically increase in the rainy season to an unsafe levels. Therefore, long term storage in tropical climate is crucial to prevent re-wetting of grain by humid air. Temperature and moisture content are crucial factors limiting the distribution and abundance of insects, mites and storage fungi that contaminate and destroy stored rice (Ullah & Abedin, 1991). During the last few years, rice farmers increasingly complained about rapid loss of seed viability in storage. This accordingly was attributed to the type of packaging materials now a day. Earthen pots, which were commonly used for rice seed storage, have been replaced gradually by gunny bags, then polythene and polysack bags. Therefore, it is important to investigate the value of earthen pot as it is cheap than others. The deterioration rate depends on storage condition that is temperature, relative humidity, seed moisture contents, storage container types etc. In addition to the general condition, rice seed viability is known to be preserved under low temperature; humidity and moisture levels. Types of container also regulate temperature, humidity and moisture content of stored seed. The threshold level of moisture should be 8% in rice seed for its viability. Nishiyama (1977) found that rice seeds of 10-14% moisture content can be stored in good conditions at 18^0C for more than 2 years. When rice seed with 12% moisture content was stored in baby food container, seed viability remained up to 352 days. When rice is dried to moisture content of 16% only or even a higher moisture percentage, the period of safe storage is shortened to a few weeks (Michael, 1978). Alam *et al*. (2007) found in their studies that the farmers got lost of their rice were about 2.33% in their storage containers. However, a very little work has been done on the locally available packing materials and their effect on viability of rice seed. With the concern about our farmer's economic condition, weather and climate, it is very important to improve storage practices and store seed at safe moisture level with traditional containers to sustain seed health. However, research works regarding the storability of rice seed under different moisture levels in earthen pot are scarce in Bangladesh. Therefore, a research work has been undertaken with following objectives:

i. To find out the suitable moisture content for traditional storage
ii. To find out the suitable earthen pot for traditional storage at small farm level.
iii. To know the suitable storage duration in earthen pot till when seed remain vigour.
iv. To find out the suitable combination of moisture and pot for safe storage.

Chapter II

Review of literature

CHAPTER II
REVIEW OF LITERATURE

Seed quality is the pre-condition that affects the germination and yield of rice. This pre-condition is directly related with the factors of moisture content of seed, drying temperature and relative humidity around seed storage, types of storage container and storage period. Scientists in different countries have conducted a good number of research works on various aspects for its successful result.

2.1. Effect of storage containers

Among the factors that are responsible for maintaining seed quality in stored condition, storage container is very important, especially for the storage of rice seed. Some information regarding the effect of storage container on rice seed viability is reviewed.

Hussain *et al*. (2013) experimented that at the Seed Pathology Center (SPC), Department of Plant Pathology, Bangladesh Agricultural University (BAU), Mymensing. The aim of the experiment was to determine the seed quality, germination category and rate of germination index of farmers' saved seeds after 45, 90 and 120 days of seed storing in different containers. Three containers viz. kerosene tin, polyethylene bag and gunny were used for seed preservation. Seed samples of rice (var. BR 1) were collected from four upazillas of Bogra districts. In case of seed quality, the highest percentages of discolored and spotted seeds were found in polyethylene bag and it was 2.98-3.72% and 79.51-80.08% respectively. Significantly higher number of normal seedling (77.35%) was recorded when seeds of kerosene tin were tested and higher number of abnormal seedling (4.44%), diseased seedling (12.06%) and dead seed (15.88%) were found in seeds of gunny bag. The rate of germination index in the seeds of kerosene tin, polyethylene bag and gunny bag ranged 95.11-97.68%, 93.74-96.17% and 92.07-94.35% respectively.

Khalequzzaman *et al.* (2012) conducted an experiment to know effect of abiotic and biotic factors, storage periods and storage containers on the seed quality of French bean. Tin container showed the highest germination, normal seedlings and vigor index which were followed by polythene bag, where Gunny bag showed the lowest germination, normal seedlings and vigor index up to 60 days after storage. The highest 1000-seed weight, moisture content, abnormal seedlings, seed rot and incidence of the *Fusarium oxysporum* were recorded in Gunny bag, where the lowest of these parameters were recorded in Tin container. Moisture content, 1000-seed weight, abnormal seedlings, seed rot, fungi association were increased, but germination and normal seedlings were decreased with the increase of storage periods. Among the three containers, Tin container was the best and the Gunny bag was the worst storage containers up to 60 days of storage for French bean seed.

Monira *et al.* (2012) studied on the effect of storage containers on the quality of Soybean seed. The experiment was conducted at Bangabandhu Sheikh Mujibur Rahman Agricultural University using three types of containers such tin container, poly bag and cloth bag stored at room condition. She reported that the moisture content increased with advanced of storage period but the increasing rate was higher in the seeds of cloth bag. The initial germination percentage of seeds in tin container, polythene bag and cloth bag was 91.32%, 89.15% and 88.40% respectively but after storage it was declined. So, cloth bag is not safe for soybean seed storage for long time than tin container and polythene bag. It is because the rate of moisture absorbance was higher in cloth bag than tin container and polythene bag.

Sawant *et al.* (2012) conducted an experiment on the storage performance of wheat for long term storage using GIC silos, CAP storage and Godown methods at the Department of Agricultural Process Engineering, CAET, Dapoli, (M. S.) India. The grain moisture content in the silo increased from 11.20% to 17.08% wet basis (w.b.), in bag storage increased from 11.20% to 17.25%, and in CAP storage increased from 11.20% to 17.19% wet basis (w.b.) during the storage period from April 06 to November 06 and it then slightly decreased during the storage period from November 06 to April 07. The temperature of the grain inside silo increased from 29.30℃ to 42.90℃. The grain temperature inside Godown storage increased from 29.300C to 32.31℃ and in CAP storage was 29.10℃ and it increased to 39.94℃ at the end of the storage period. The germination percentage of grain inside the silo was decreased from 86.70% to 78.60%, in Godown storage it decreased from 86.70% to 53.30%, and in CAP storage it decreased from 86.70% to 46.60% during the storage period from April to September.

Raza *et al*. (2010) conducted a study to investigate the changes in wheat grain quality that may occur during storage in different types of containers commonly used in Pakistan i.e. earthen pots, tin containers, cotton bags, jute bags and polypropylene bags. Freshly harvested grains of three different wheat varieties were stored in these containers for 12 months in two consecutive years i.e. 2003-04 and 2004-05, at existing environmental conditions at Food Quality & Nutrition Program of National Agricultural Research Centre, Islamabad. Samples were analyzed before storage and after every 4 months for different quality parameters i.e. moisture content, test weight, flour yield, falling number and fat acidity. Results of both years showed an increase in moisture content during storage that was least in cotton bags and earthen pots resulting in higher test weights and flour yield. Tin containers performed better in retaining low fat acidity values. Storage duration of 12 months generally increased moisture and fat acidity while decreased test weight and flour yield in both years. Falling number also increased in all containers during storage, but remained within the limits usually required for baking purposes. However, the pattern was not uniform within both the years under study.

Alam *et al.* (2009) studied the performance of alternate storage devices on seed quality of boro rice. Different storage devices used in this study were: T1 = Organic Cocoon, T2 = Rexin Cocoon, T3 = Polythene bag, T4 = Poly + Gunny bag , and T5 = Gunny bag. He found that germination percentage of Boro seeds stored in organic cocoon was significantly the highest (91%) compared to that of rexin cocoon (87%), Polythene bag (80%), polythene in Gunny bag (79.667) and Gunny bag (68%). Seeds stored in an organic cocoon performed better in maintaining higher germination due to lower moisture content (12.10%) below the critical level (14%), reduced oxygen level (4.9%) and higher proportion of dead insects (97%) caused by reduced oxygen.

Alam *et.al* (2009) studied seed quality of aman rice as affected by some alternate storage devices. Different storage devices used in this study were: (T1 = Organic Cocoon, T2 = Germax Cocoon, T3 = IRRI made storage bag, T4 = Rexin Cocoon, T5 = Polythene bag, T6 = Thick Poly bag, T7= Poly + Gunny bag, T8 = Gunny bag). USA organic cocoon, Germax cocoon, IRRI made storage bag, rexin cocoon and thick poly bag maintained lower moisture content below the critical level (14%) compared to polythene and gunny bag. USA organic cocoon, IRRI made storage bag and Germax cocoon were able to reduce oxygen level significantly (3.7, 7 and 12.23%) and killed more than 90% insects of the stored seeds compared to polythene type of bags, rexin cocoon and gunny bag. Highest 1000-seed weight was observed in seeds of gunny bag (26 g) and the lowest range (23.4-23.6 g) was in USA organic cocoon, Germax cocoon and IRRI made bag due to higher moisture content (15.27%) in gunny bag and lower moisture content (<12%) in latter devices. USA organic cocoon, Germax cocoon and IRRI made bag maintained an excellent germination rate (>90%) when Aman seeds were stored in this devices. Seed vigor, shoot and root growth were significantly affected when Aman seeds were stored in polythene type of bags and rexin cocoon though these devices were able to maintain a fair germination range of 82-87%.

Barua *et al.* (2009) conducted an experiment to study effect of storage containers environment at different storage period on the quality of chilli seed. He found that the seed moisture, abnormal seedling and dead seed were increased with increasing of storage time in Tin container, Polythene bag and Cloth bag and it was higher in seeds of Cloth bag (from 9.70% m.c to 12.83% m.c ,abnormal seedling from 3.15% to 10.25% after 2 months of storage). On the other hand, germination, root, shoot length and, root and shoot dry matter after storage was declined. The decline rate was higher in seed of Cloth bags container (germination percentage from 62.10% to 55.54%, root and shoot length from 8.93 cm & 7.83 cm to 6.15 cm & 6.15 cm and root & shoot dry matter from 0.74 mg & 0.88 mg to 0.64 mg & 0.63 mg).

Malaker *et al.* (2008) conducted an experiment to determine the prevalence of black point and percentages of germination, moisture content and different fungi associated with wheat seeds during storage in different types of container. Five types of storage containers viz., ‘dole’ (made of bamboo), earthen pitcher, tin container, polyethylene bag and refrigerator were used in this study. Dole, earthen pitcher and tin container were coated with paint before use. The seed moisture content and black point severity were found highest in dole resulting in the lowest percentage of seed germination. The highest germination percentage was observed under storage in refrigerator followed by polyethylene bag, tin container and earthen pitcher. The moisture content and black point infection increased and seed germination decreased with the increase of storage period. Seed germination decreased from 95% to 75% after 10 months and storage fungi viz., Aspergillus, Chaetomium, Nigrospora, Penicillium and Rhizopus increased with the progress of storage period.

Thilakarathna *et al.* (2006) studied quality change and mass loss of paddy during airtight storage in a Ferro-cement bin in Sri Lanka. An airtight storage system, based on a Ferro-cement bin, was developed. The objective of this study was to evaluate the storage system in terms of paddy quality and mass loss. Samples were drawn before and after storage from this bin and a control to analyze moisture content, thousand-grain mass, insect infestation, mould, germination rate and head rice yield. Germination rate, however, decreased from 85% to 0% in the airtight bin, whereas it was still 38% in the control. The study showed that airtight Ferro-cement bins provided a safe and convenient method for farmers in the tropics to preserve their harvest for later sale at a higher price. Further work is necessary to develop strategies for avoiding the decrease in germination capacity.

Zhang *et al*. (2005) opined that seed vigor will decline to low levels prior to planting, even for seed lots with acceptable germination. Low vigor seed may result in poor field stands, especially if planted in less than ideal field conditions.

Garg and Chandra (2005) said that there is an effect of storage place, packaging material, duration of storage and kind of seed on the viability during storage and the choice of a packaging material in a given climatic condition would depend upon kind of seed and the duration of storage.

Gupta *et al.* (2006) found that the moisture content of paddy decreased initially up to 150 days of storage, beyond which it increased due to increase in relative humidity of the atmosphere. The temperature of stored paddy increased initially up to 120 days and thereafter decreased. The highest germination loss of 78.5% was recorded in bamboo storage structure lined with polyethylene in the inner surface and painted black on the outer surface whereas the lowest germination loss was recorded in bamboo storage structure plastered with cement in the inner and outer surfaces.

Appreciable damage of stored paddy due to insects was also observed over a period of seven months.

Jolli and Ekbote (2005) reported that seeds of moth bean (*Vigna aconitfolia*) treated with insecticides and fungicides, alone and in combinations, were stored in cloth bags and 700 gauge polythene bags and stored at ambient condition for 18 months. Irrespective of the treatments, including the control, seeds stored in polythene bags maintained germination above the minimum seed certification standard level, whereas in cloth bags, it was inhibited in accordance to the level of infestation.

Muangkaeoa *et al.* (2005) conducted a research to study the effects of packaging materials and storage time on rice seed viability and chemical component changes during storage. Seed of rice dried to 9.65% moisture (MC) and stored in 4 different types of plastic bag i.e. Polyamide (PA), Polyethylene (PE), Metallized Polyethylene Terepthalate (MPET) and Woven Polypropylene (WP) bags for a period of 5 months under controlled temperature (160C) and relative humidity (65%).Seeds in WP bag were highly changed and gave a higher moisture content percentage (10.40%) than seeds in PA (9.81%), PE (9.83%) and MPET (9.89%) bags throughout storage periods. All treatment showed that rice seeds could maintain their germinability average 95% after 5 months. Rice seeds vigor showed that germination investigated by accelerated aging technique was decreased and the electrical conductivity from seed exudates was increased after 5 months storage (average 92% and 35.55 μ mhos cm-1 g-1). It was concluded that rice seeds stored in PA bag which prevented water vapor and oxygen transmission could delay seed quality deteriorate followed by PE, MPET and WP bags during 5 months storage.

In an experiment conducted on soybean, Agha *et al*. (2004) reported that, field emergence was significantly different for storage containers. Seed emergence was greater in seed stored in containers. Further data demonstrated that storage containers were significantly affected the percentage of healthy seedlings. The seed stored in containers 51.6% healthy seedlings.

Anuja and Aneja (2004) found that vigor and viability cannot always be differentiated in storage environments, especially in seed lots that are rapidly deteriorating. This progressive weakening with age continues until all the seeds became nonviable.

Mettananda *et al.* (2001) studied on effect of storage environment, packaging material and seed moisture content on storability of maize seed. Seeds were sun dried to 12% and 8% moisture content. Seeds with 12% moisture were packed in Poly-sacks, White polythene (gauge 500) and in clear polythene (gauge 500) and seeds with 8% moisture packed in clear polythene (gauge 500). Longest storability was recorded in cold room with all packaging used and at both moisture levels. Storage in Poly-sacks was good only under cold room condition. Seed stored in polythene at both 12% and 8% moisture levels were superior in storability compared to those stored in Poly-sacks in maintaining the germination level in all the environment tested.

Patra *et al*. (2000) found that with increase in storage period, viability of seeds decreased while pathogen activities, moisture content and sugar content in seeds increased gradually.

Krishnappan *et al*. (1998) experimented that groundnut seeds were stored in different containers (gunny bags, tar coated bags, polythene lined gunny bags, high density polyvinyl bags and Kraft paper bags). At about 70% moisture content in ambient conditions, the polyvinyl bags gave the greatest percentage germination and seed vigour after 16 months, but differences at earlier stages were not significant. All containers maintained the minimum certification standard of 70% germination for 12 months, and polyvinyl bags maintained this standard for 14 months.

Lewis *et al*. (1998) said that although many factors are known to influence the storability of seeds, it is generally accepted that storability may be improved by controlling the storage environment. 'Safe' storage conditions were defined as those which maintain seed quality without loss of vigor for three years.

Seeds of five soybean cultivars were packed in gunny bags or gunny bags lined with polyethylene. Moisture content and germination of the seeds stored in the unlined gunny bags were significantly decreased over the four months. Germination of the seeds stored in the lined bags was only slightly reduced (Sharma et al., 1998).

In another experiment, harvested seeds of groundnut were stored in a gunny bag, a plastic silo or a polyethylene-lined gunny bag containing 25 g anhydrous calcium chloride for between 120 and 360 days. Seed viability was significantly higher in both the plastic silo and the polyethylene-lined gunny bag with CaCl2 than in the ordinary gunny bag (Patra *et al.* 1996).

Dornbos (1994) defined seed viability as the capacity of the seed to germinate and produce a normal seedling. Germination capacity is the most practical indicator of seed viability and vigour. The seeds having low vigor values cannot germinate well under adverse field condition. The vigour of seeds at the time of storage is an important factor that affects their storage life.

Charjan and Tarar (1992) reported that *Helianthus annuus* seed stored in polyethylene bags germinated better and had less fungal contamination than that stored in cloth or jute bags. A direct correlation was found between the total mycoflora of the seed and germination tests after 6, 12 and, 18 months' storage. With the advance of the storage period, field fungi declined and storage fungi increased rapidly.

From a storage study, Eshwarappa*et al*. (1991) found that the germination of rice grains stored in gunny bags under ambient conditions decreased from 85% in August to 48% in March while germination of grains stored in a coal tar drum or plywood bean was 80-90% and 84-95%, respectively throughout the storage period.

Karim and Amiruzzaman (1991) reported that maize seeds stored in polythene lined motka, improved tin, polythene lined jute bag, traditional tin and polythene lined Dole showed lowest insect infestation rate of 0.46, 0.91, 1.14, 3.02 and 3.38 percent, respectively. The containers were opened once after 13 months. The rate of insect infestation trend was more or less similar, that is 0.23, 1.85, 2.10, 2.34 and 2.37 percent infestation were obtained from the seed stored in polythene lined motka, polythene lined jute bag, improved tin, polythene lined dole and traditional tin, respectively. In terms of viability of seeds, polythene lined motka and improved tin gave highest germination rate of 76.67 and 73.33 percent, respectively. The present moisture of the maize seed increased in all treatments from initial 10.47 to 13.44% but this moisture level did not affect the germination of seeds.

Boland *et al*. (1990) said that transparent plastic bags are versatile containers for seed storage and suitable for many species and storage conditions. Plastic bags or containers should be filled completely so that as little air as possible is stored with the seed Vacuum packing or storing in CO2 in plastic bags practically removes all air and makes the seed samples easy to handle.

Chowdhury *et al*. (1990) reported that the different storage techniques did not produce significant effect on the protein and starch of the lentil grain produced.

Storage in open containers at ambient temperature may be applicable for short term storage of some species, even where moisture content does increase. For example, Omram *et al*. (1989) found that seeds of *Casuarina glauca* and *C. cunninghamiana* could be stored in unsealed bags at room temperature for 8 months without significant loss of viability, albeit their moisture content increased from 5-6% to approx. 8 % during the period. The seeds lost viability in 20 months.

Rahman *et al*. (1985) reported that seed absorbed moisture and reduced germinability when it was stored in indigenous (not air-tight) container.

In an experiment to study the viability range, Nizersail and BR 11 rice seeds grown during the Aman season were dried to 12% moisture and then stored in polyethylene tubes, closed metal ware and gunny bags. In the case of Nizersail seed, germination percentage was equally high in the three containers up to 300 days of storage. But in BR11 seeds, those stored in sealed polyethylene tubes the germination percentage remained high at this stage but seeds stored in metal ware and gunny bags lost seed viability considerably only after 110 days storage and after 240 days they lost seeds viability completely (BRRI, 1985).

Willan (1985) and Doran *et al*. (1983) said that although most non-hard-coated orthodox seeds easily deteriorate under natural conditions, they have a long storage potential and can often maintain viability for many years when stored under optimal conditions.

Mali *et al.* (1983) reported that increasing rate of abnormal seedling was higher in seeds of gunny bag, because it was due to high moisture and fungal activities.

Haque and Harron (1983) found that among three rice varieties harvested in Boro season; seed viability range was the highest when seeds were stored in closed container but when stored in gunny bags, seed viability deteriorated very rapidly. The poor germination was probably due to response to storage environment for rapid viability loss.

Khandakar and Bradbeer (1983) reported a wide gap between laboratory test and field germination. Decline in vigour and death of seeds can be considered from two aspects: (i) loss of viability or death of a seed lot, i.e. a small or large quantity of seed or (ii) death of an individual seed. The germination percentage of a seed lot is the proportion of individual seed capable of producing normal plants.

Basnet and Jindal (1982) reported the changes of quality in terms of moisture content, bulk density, percent germination, milling yield and breakage strength of stored paddy in traditional bamboo bin and two ferro-cement bins of conical and cylindrical shape. The bamboo bin was reported to be superior in maintaining an overall better quality of paddy during the four months storage period.

Singh and Singh (1981) studied the effects of methods and duration of storage on seed germination and seedling vigor in papaya (*Carica papaya* L.). They found that cold stored papaya seeds maintained significantly higher germination and better seedling vigor than the room stored seeds. With the increase in the duration of storage, seed germination decreased after 20 months at room temperature whereas it declined marginally during the same period when kept in the cold storage. Irrespective of the storage conditions, seeds kept in sealed polythene bags or plastic bottles had better germination and seedling vigor than in paper and cloth bags.

Prabhakar and Mukherjee (1977) studied the extent storage of seeds at low temperature (10℃ to 15℃) and also maintained seed moisture at a favorable level (10%) and there by germination potential at a high level for a considerable period

(270 days). Room temperature (26°C) or high temperature (32°C or 35°C) resulted in the decline environment delayed the decline in germination potential of the storage.

Bass and Clark (1975) postulated that materials containing foil provided good moisture and germination protection.

Delouche et al. (l973) observed that such safe conditions are indeed favorable, but not always economically justified as they do not naturally occur except for small quantities of genetically valuable seed or very costly seed of vegetables, ornamental or forest species.

Bhattacharyya and Dutta (1972) recommended double plastic bags for seed storage. Canode (1972) found that the length of time that grass seed might be stored without serious reduction in germination depends on the species and storage condition.

Heydecker (1972) observed that the seeds having lower vigor values cannot germinate well under tightly condition and do not help in better crop establishment. Low vigor in seed may be due to genetic, physiological, morphological, cytological, mechanical and microbial factors.

Bhatnagar (1969) reported a replicated study on the Punjab Agricultural University (PAU) steel bins, indigenous mud bins and polythene lined mud bins for storage of wheat seed for a year. The grain stored in mud bins displayed higher moisture level, higher incidence of infestation and lower germination values.

Helmer and Delouche (1964) reported that at seed moisture contents of 8.9, 10.3, and 11.0 percent, tin cans, polyethylene-aluminium inserts, and heat sealed polyethylene bags were superior to sewn polyethylene bags and cloth bags in maintaining rice seed quality during oceanic shipment and storage in Costa Rica. An initial seed moisture content of 12.2, 13.3, and 14.3 seed deterioration was very rapid in all packaging materials. They recommended that to avoid deterioration, rice seed should be packaged in sealed moisture proof containers at 10.3 percent moisture or less for oceanic shipments and storage in tropical environments.

Ali (1963) showed that seeds stored in gunny bag and in earthen pots lost viability much earlier than seeds stored in closed tin and in glass bottles.

Seeds should be stored carefully by placing envelopes inside large glass jars with a bag of silica or powdered milk. These products absorb excess moisture. Alternatively, a tiny package of powdered milk is made by pouring a pile into the center of a piece of breathable fabric or tissue paper. Corners are pulled together and closed it up with a piece of string or elastic to create a sachet. The best jars for storage are wide mouth mason jars used for canning. They have the proper airtight seal that is essential for long term storage. If the jars are stored in a cool, dark place the seeds should last from a year to a few years, depending on the type. Ali (1963) recommended tin cans for seed storage. While, Anon. (1985) indicated the possibility of involvement of storage fungi in reducing the germination of gram seeds during storage in the containers.

2.2. Effect of seed moisture level

Seed moisture content is the most important factor that regulates the longevity of seed in storage. Higher moisture content in the seed enhances seed deterioration, which reduces the quality of seed. The moisture content of a sample is the loss in weight when it is dried in accordance with the rules. Some reviews on the effect of storage moisture content are as follows:

Mersal et al. (2006) found that prolonging storage period and high seed moisture content reduced germinability (as measured by germination percentage, germination index and germination rate), seedling vigor (plumule, radical lengths, seedling dry weight and its vigor index) and accelerated seed aging. Meanwhile, increasing storage period and high seed moisture content increased mean germination time, electrical conductivity and dry weight losses of the seed.

Extending the storability of seed by storing under reduced moisture content was reported in onion, tomato and carrot (Padma and Reddy, 2004), but they found that reducing the seed moisture beyond a critical level had not improved the storability of seed.

In an investigation by Nakayama et al. (2004) dry seeds of nine soyabean cultivars were soaked in water for 48 h and the effects of soaking (flooding stress) on the plant growth were studied in relation to initial seed moisture content. Both seedling emergence and subsequent growth were suppressed by soaking. Sensitivity to flooding stress was greatly influenced by the initial seed moisture content. Soaking of 6.50% moisture content seeds in water resulted in a marked reduction in dry matter accumulation in emerged seedlings from 0.5 to 54% of that in the non-soaked control. However, seeds with high moisture content were less sensitive to flooding. In the seeds containing 14.5% moisture and soaked in water, the dry matter accumulation in the emerged seedlings was 65 to 97% of that in the non-soaked control.

The protective effect of increasing the initial seed moisture on flooding stress was observed in all cultivars although the effect varied with the cultivar. Storability of vegetable seeds could be extended by reducing seed moisture content before storage (Padma and Reddy, 2004).

McGill et al. (2002) reported that, the conditions required to maintain seed viability during storage are not well understood and there are conflicting reports as to whether the seed will retain viability in storage. The decline in seed viability at relatively low seed moisture content is typical of oil storage seeds and consistent with orthodox seed behavior.

In an experiment, Vieira et al. (2001) observed that storing of high moisture seeds at 5^{0}C slightly extended the storage life, however viability loss was observed within one year.

Mettananda et al. (2001) studied on effect of storage environment, packaging material and seed moisture content on storability of maize seed. Seeds were sun dried to 12% and 8% moisture content. Seeds with 12% moisture were packed in Poly-sacks, White polythene (gauge 500) and in clear polythene (gauge 500) and seeds with 8% moisture packed in clear polythene (gauge 500). Longest storability was recorded in cold room with all packaging used and at both moisture levels. Storage in Poly-sacks was good only under cold room condition. Seed stored in polythene at both 12% and 8% moisture levels were superior in storability compared to those stored in Poly-sacks in maintaining the germination level in all the environment tested.

Padma and Reddy (2000) found large differences in the retention of viability of onion seed stored in different moisture pervious and moisture impervious containers at 7.15 and 5.30% seed moisture content. They reported that in storage studies with okra seed significant differences were observed in germination potential due to storage containers, moisture levels and their interactions. Seed stored in cloth bag at 10.0 and 7.14% seed moisture recorded germination over certification standard (65%) up to 22 and 26 months while it could safely be stored up to 50 months in polythene bag irrespective of moisture levels studied. Reducing the seed moisture beyond certification standard did not show any beneficial effect on seed longevity (except for cloth bag storage) under subtropical climate of Rajnagar.

Rathi et al. (2000) found that increased moisture content caused seeds to respire at faster rate and decreased the germination.

Bankole et al. (1999) stored melon seeds in jute and polyethylene bags for 12 months and determined moisture content (mc) monthly. The mc increased from 6.1 to 6.7% in jute and 6.2 to 6.5% in polyethylene bags after 12 months in storage. The germination percentage decreased from 96.3% to 28.7% and 45.3% in jute and polyethylene bags, respectively.

Lin (1999) observed that cucumber seed with 12% initial moisture content were stored at 70% RH and 20oC for up to 10 months and germination percentage remained high throughout the storage period, while vigour decreased and electrolyte leakage increased from 6 months of storage.

Sivritepe and Dourado (1995) found that pea seeds with high viability and high moisture content, high viability and low moisture content. Low viability and high moisture content or low viability and low moisture content were soaked in distilled water for l, 2,4,9 or 12 h or not soaked. Low viability seeds lost viability more rapidly during soaking than high viability seeds at both high moisture and low moisture. High viability low moisture seeds lost viability more rapidly than high moisture seeds.

Bewley and Black (1994) found that reduction of O2 pressure, e.g. by replacing oxygen with N2 or CO2 had little effect on seed longevity as long as temperature and moisture content were stored low.

A comparative study was conducted by Miah and Douglass (1992) to investigate the influence of storage structures and storage periods on the viability of high moisture wheat seeds. Laboratory studies showed that moisture content of seed for sealed clay bins remained approximately constant throughout the six week period but in the other structures it decreased. For re-wetted seed grain with 23% moisture content the viability fell rapidly after 2, 4 and 6 weeks storage in the different structures.

Huda (1992) observed that higher moisture content was negatively correlated with germination percentage and positively with insect infestation.

Gras and Bason (1990) opined that controlled atmosphere storage might have minor effects on the germination and physic-chemical properties of rice, maize, wheat and barley.

Trigo-Stockli and Pedersen (1991) conducted an experiment to study the effect of moisture content and length of storage on the quality of rough rice with 14,18,22 and 26 % moisture content for 5,10,15,20,25 and 30 days in insulated container. They found that rough rice stored at high moisture contents had greater percentage of discolored kernels, lower milling yield and lower germination percentage. The percentage of kernels invaded with storage fungi was higher on rough rice stored at high moisture, except at 26% m.c.

Clements (1988) reported that moisture content of seed was higher and seed germination was lower in earthen container than in polyethylene bag and tin container, irrespective of length of storage period and storage conditions.
Abeysiriwardena (1985) reported that packing seed paddy with 12% moisture content in polythene will enable the seeds to be used as seed paddy even after one season of

storage without any damage. Seed 2 ½ month old and 95% viable seed with 12 and 14% moisture content at packing in polythene could retain not less than 80% of its viability for a period about 27 and 12 weeks respectively.

Khandakar (1983) found that the higher is the seed moisture content; the lower is the seed longevity.

Ellis et al. (l9892) said that high seed moisture content is known to be detrimental to seed storage of many species.

Khandakar (1980) reported that the factors like moisture, temperature, proportion of infected seeds in storage, presence of foreign materials, activity of insects in seed lot, availability of oxygen to seed and associated micro flora and fauna were related to the seed viability in storage.

King and Roberts (1979) said that where storage cannot be avoided, storage conditions must be carefully balanced between reducing metabolism by reducing temperature and moisture contents, without hampering viability by too drastic a decrease in these factors. Storage conditions should basically aim at the following: prevent desiccation; control microbial contamination; prevent germination and maintain adequate oxygen supply.

Nishiyama (1977) found that rice seeds of 10-14% moisture content can be stored in good conditions at 18^0 C for more than two years.

Heydecker (1972) and Harrington (1972) also reported that seed deterioration increased as moisture content increased which resulted in loss of viability and poor germination.

Christensen and Lopez (1965) reported on rice stored at 15.5% m.c that invasion of rice by storage fungi seemed to result in slower loss of germination compared with sorghum, wheat, maize and barley.

Christensen and Kaufmann (1965) clearly demonstrated the increase in moisture content and storage fungi and decrease in germination and field fungi of stored grains during storage.

Christensen and Kaufmann (1964) observed that in the range of moisture content between 14.0 and 15.5% in wheat, a difference of only 0.2% may make a great difference in the rate of invasion of the grain by storage fungi and in the damage caused to the grain.

Henderson and Christensen (1961) observed that most of the stored product insects cease feeding and become inactive between 50C and 100C. Some species of mites reproduce at 50C or even lower, but only if the moisture content of the seed is above 12%. They also stated that the upper limits generally considered safe for long time storage under average condition are 13% for beans, peas and cereal grains including corn 12.5% for soybeans, 10.5% for flax seed and somewhat lower for most vegetables seeds and peanuts. This generalization of moisture limit is probably for temperate regions, it may be lower in case of tropical region.

Bass (1953) found that the loss of viability of freshly harvested Kentucky bluegrass seed was correlated with the moisture content of the seed and length of time held at a given temperature.

Chapter III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The laboratory experiment was conducted during the period from June to December, 2013 to study the storability of rice seed affected by storage containers under varied seed moisture levels. The materials and methods those were used for conducting the experiment have been presented in this chapter. It includes a short description of the experimental site, climatic condition, materials used for the experiment, experimental design, data collection and data analysis procedure.

3.1. Experimental site

The experiment was set at Agronomy farm laboratory in Sher-e-Bangla Agricultural University (SAU), Dhaka- 1207, Bangladesh. The lab was located in the eastern corner of the university.

3.2. Climatic condition of the experimental site

Experimental area is situated in the sub-tropical climate zone, which is characterized by heavy rainfall during the months of June to December and scanty rainfall during the rest period of the year. Details of the weather data in respect of temperature (^{0}C), rainfall (cm), and relative humidity (%) for the study period was collected from mini weather station, Sher-e-Bangla Agricultural University,Dhaka-1207(Appendix I).

3.3. Experimental material

The variety BRRI dhan 28 was used as seed material. The seed were collected from Rangpur district which were grown in the cropping season of 2013. After collection of seed they were dried up to 5 days to make their moisture level different from 10%-16%. After that the seed were stored in 36 different containers at June, 2013 as per treatment of the experiment. From all containers, 12 were coated with coalter and 12 were filled with polythene bag. The rest pots were kept as they were before.

3.4. Treatments of the experiment

This experiment consisted of two factors as mentioned below:

Factor A: Storage container (3 containers)

i Coalter coated earthen pot (C_1)

ii. Traditional earthen pot (C_2)

iii. Polythene bag in traditional earthen pot (C_3)

Factor B: Seed Moisture level (4 levels)

i. 10% moisture (M_1)
ii. 12% moisture (M_2)
iii. 14% moisture (M_3)
iv. 16% moisture (M_4)

There were 12 (3×4) treatment combinations.

The seed were sundried to make their moisture level as 16% first, and then they were also dried for 5 days to decrease their moisture levels like 14%, 12% and finally 10%. The moisture level was measured by a moisture meter.

3.5. Experimental design

The experiment was laid out in the ambient condition of the laboratory considering in a Completely Randomized Design (CRD) and the treatments were replicated three (3) times for each.

3.6. Storage of rice seeds

The healthy and uniform sized seeds were kept in different container as per treatment. Total 2 kg seed were stored in each container. After that the containers were made air tight by using earthen cover with masking tape and stored in clean and dry place in the laboratory. The stored containers kept under keen observation for 6 months in air tight condition.

3.7. Sampling and data collection

Three sampling of stored grains were taken at 2 months interval starting from August after storage in different containers for measuring the quality of rice seeds. So, data were collected at the month of August, October and December after storage of rice seeds.

3.8. Data collection

The following data were recorded:

1. Moisture percentage (%)
2. Germination percentage (%)
3. Seed Vigor test
   - Vigor index
   - Electrical conductivity test
4. Seedling vigor test
   - Seedlings root length (cm)
   - Seedlings shoot length (cm)
   - Seedlings fresh weight (g)
   - Seedlings dry weight (g)
   - Normal seedling (no.)

3.9 Procedure of data collection

3.9.1. Moisture percentage

Seed moisture content was determined following low constant temperature oven method and done as soon as the seed were removed from the container. An aluminum container was taken with cover and weighed (M_1). Some (about 100 g) rice seed sample was taken in the container and weighed the seed with cover (M_2). The container was placed on its cover and dried in an oven maintained at a temperature of 103 ± 2^oC for 17±1 hours. The drying period begins at the time the oven returns to the required temperature. After 17±1 hours the door of the oven was opened and the transferring tray with seeds was taken out. The container was closed immediately with its cover and was stored in the desiccators. After cooling (about 30 minutes) the container was weighed with their covers and the weight was recorded as M_3 to three decimals. The moisture content of rice seeds was determined using the following formula indicated by ISTA (1987). In this process moisture percentage was taken at the month of August, October and December after storage of rice seeds.

$$\% \, MC = \frac{M_2 - M_3}{M_2 - M_1} \times 100$$

Where,

M_1 = Weight of container + cover

M_2 = Weight of container + cover + seed before drying

M_3 = Weight of container + cover + seed after drying

3.9.2. Germination percentage (%)

Sand was used as germination media which was collected, washed and dried. Then the petridishes were filled with sand leaving 2cm from the top. Adequate moisture level was maintained in the germination media. Germination test for each storage container was carried out taking 100 seeds at every sampling in three replications. Germination percentage was calculated using the following formula (Krishnasamy and Seshu, 1990).

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

3.9.3. Vigour Index

The daily record of germination of seeds was kept starting from 4th day upto 14th day after placement of seed for germination. It was done over blotting paper on petridish. Vigor index (VI) was calculated by the following formula:

$$VI = \frac{\text{No of seeds germinated at final count}}{\text{Days required to first count}} + \ldots\ldots\ldots\ldots\ldots\ldots + \frac{\text{No of seeds germinated at first count}}{\text{Days required to final count}}$$

3.9.4. Electrical conductivity test

Electrical Conductivity test was done to quantify the leakage of electrolytes from the seed coat with respect to age, storage life and other factors i.e. temperature, humidity, soil and water stress etc. A sample of 50 seeds was taken from each treatment, placed in a 250 ml flask and 200 ml of distilled water was added into it. The flask was stirred to remove air bubbles as well as floating seeds and then covered with aluminum foil to store at 35^{0}C for 24 hours. After incubating the said time, water of the beaker containing seeds was decanted to separate the seeds. The electrical conductivity of the decanted water containing seed leachate was measured with a conductivity meter (Model-CM-30ET). Three replicates of measurements were made for each sample of seed. Conductivity was expressed on a weight bases in Micro Siemens cm^{-1} g^{-1} of seed ($\mu Scm^{-1}g^{-1}$). Lower the value of EC greater is the seed vigour.

3.9. (5, 6). Seedlings shoot and root length

After counting the number of seedlings for germination test, randomly selected 10 seedlings were carefully taken in such a way that no root parts were damaged and then they were washed in tap water properly. By separating the root portion of the seedling carefully, the length of shoot and root was measured by a centimetre scale and mean value of both shoot and root were recorded in cm.

3.9. (7, 8). Seedlings shoot and root dry weight

The shoot and root samples were kept separately in paper bags and dried in an electric oven maintaining 72°C temperature for 36 hours. After drying, the root and shoot dry weights were recorded by an electric balance and mean value were recorded in gram (g).

3.9.9. Normal seedling counting

100 seeds of each sample were kept on petridish in sand media. After 14 days, germinated seedlings were counted. Seedlings which have atleast 4cm height were termed as normal seedling. Then normal seedlings were separated and counted.

3.9.10. Statistical analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference of different containers and moisture contents. The mean values of all the characters were calculated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment means were estimated by the Least Significant difference (LSD) test at 5% level of significance.

Chapter IV

Results and Discussion

CHAPTER IV

RESULTS AND DISSCUSSION

This chapter comprises presentation and discussion of the results obtained from the study to investigate the planting value/quality of rice seed stored under different conditioned earthen pots (storage containers) with different seed moisture levels (contents). The results of seed moisture content, germination percentage (%), seedling vigour (seedling shoot length, seedling root length, seedling fresh weight, seedling dry weight and normal seedling), and seed vigour (vigour index and electrical conductivity test) have been presented and discussed in this chapter under separate heads and sub-heads as follows:

4.1. Seed moisture percentage

Seed moisture percentage varied significantly due to the influence of storage containers as revealed from the moisture determination test done in the month of August, October and December of 2013.

4.1.1 Effect of storage containers

It reveals from the Fig.01 that rice seed moisture percentage in every storage container gradually increased over the period of storage. From Fig. 01,it is shown that in coalter coated earthen pot (C_1) the moisture content was 12.15% after two months of storage i.e. in August, while, it was 14.76% after 6 months of storage i.e. on December. The corresponding moisture percentage in simple earthen pot (C_2) was 12.18% and 16.18% while the same in polybag contained in anearthen pot (C_3) was 12.34% and 15.40%. From the results, it is evident that, the moisture percentage in storage container of simple earthen pot (C_2) maintained the highest percentage of moisture in every storage period except in the month of August at which the moisture percentage of polybag contained in earthen pot (C_3) was statistically similar to it. The findings are in agreement with the findings of Bhatnagar (1969), Clements (1988) and Malakar *et al*. (2008), who stated that seeds stored in earthen containers displayed higher moisture level, higher incidence of infestation and lower germination. Of course, the moisture percentage below the critical level (14.0% for rice) was only found in October i.e. after four months of storage in coalter coated earthen pot (C_1) and in polybag in earthen pot (C_3) containers.

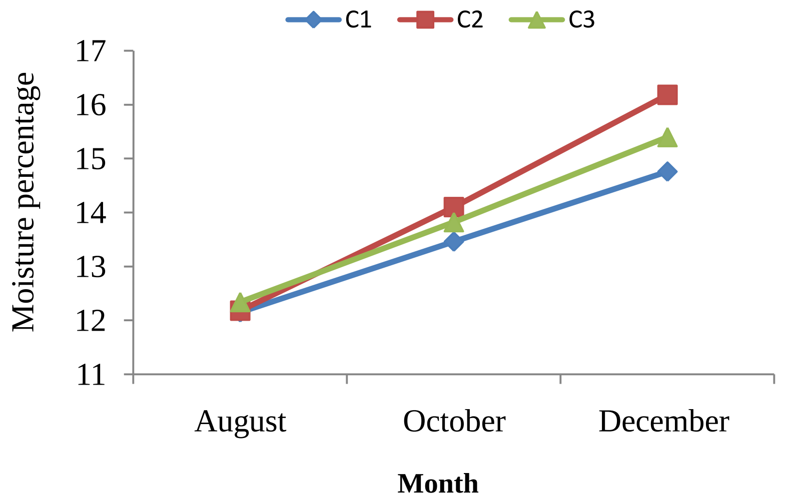

Figure 01. Effect of storage container on moisture percentage of rice seed (LSD $_{(0.05)}$ = 0.35, 0.34 and 0.42 at August, October and December, respectively)

C_1= Coalter coated earthen pot, C_2= traditional earthen pot and C_3= polybag in earthen pot

4.1.2. Effect of storage seed moisture content

The moisture percentage in seed stored under 4 different moisture levels varied significantly (fig.02) from each other. Seed moisture percentage of the seeds stored under different moisture levels also increased gradually from the initial storage period to the end of the storage period i.e. from June 2013 to December 2013 in all the seed moisture levels (fig.02). The rate of increase of moisture on seeds stored under 4 different moisture levels was more or less same and as such, the highest moisture percentage (18.68%) was found in the highest seed moisture level M_4 (16.0%) and the lowest moisture percentage (13.95%) was found in the lowest moisture level M_1 (10.0%) at the end of the storage period.

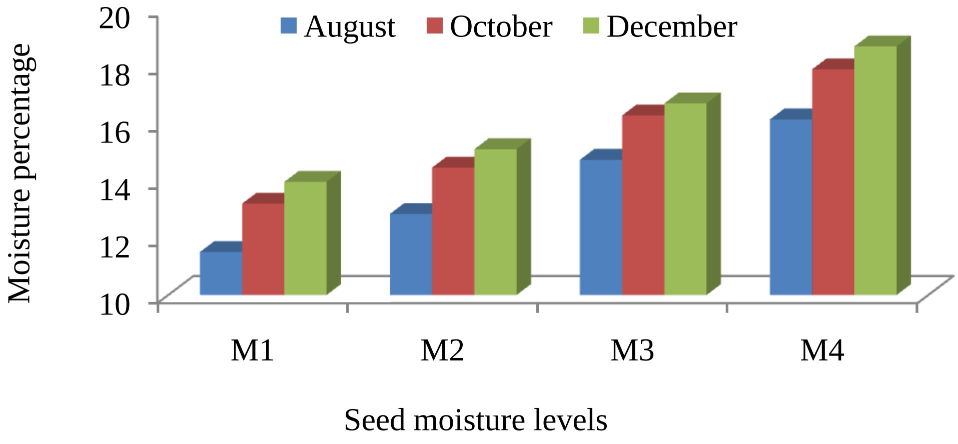

Figure.02 Effect of different seed moisture levels on moisture percentage of rice seed (LSD $_{(0.05)}$ = 0.40, 0.39 and 0.48 at August, October and December, respectively)

M_1=10% moisture, M_2=12% moisture, M_3=14% moisture, M_4=16% moisture

4.1.3. Interaction effect of storage containers and different moisture content in seeds

From the interaction Table 01, it reveals that the interaction effect of simple earthen pot and 16% seed moisture level (C_2M_4) maintained significantly the highest moisture percentage in seed as 18.40% and 19.23% in October and December test but at August test C_2M_4 (16.49%) was statistically similar to C_3M_4 (16.02%) and C_1M_4 (15.88%). The moisture levels of 16% (M_4) in combination with coalter coated earthen pot (C_1) or polythene bag in earthen pot (C_3) maintained the second highest moisture % in the stored rice seeds. The other moisture levels 10% (M_1) and 12 % (M_2) in combination with coalter coated earthen pot (C_1) or polybag in earthen pot (C_3) contained comparatively low moisture % in the seed of storage. Similar observations were reported by Abeysiriwardena (1985).

Table 01. Interaction effect of earthen pot and moisture levels on moisture percentage of rice seed

Treatment Combinations	Moisture percentage		
	August	October	December
C_1M_1	10.88 f	11.60 i	12.12 g
C_1M_2	12.62 cd	13.65 gh	14.10 f
C_1M_3	14.48 b	15.82 de	16.04 d
C_1M_4	15.88 a	17.96 ab	18.31 b
C_2M_1	12.01 de	14.51 f	15.24 e
C_2M_2	12.85 c	15.26 ef	16.00 d
C_2M_3	15.06 b	16.57 cd	17.57 c
C_2M_4	16.49 a	18.40 a	19.23 a
C_3M_1	11.61 e	13.45 h	14.50 f
C_3M_2	13.04 c	14.45 fg	15.17 e
C_3M_3	14.62 b	16.42 d	16.47 d
C_3M_4	16.02 a	17.29 bc	18.48 b
LSD $_{(0.05)}$	**0.68**	**0.83**	**0.59**
CV (%)	**2.93**	**3.21**	**2.16**

C_1= Coalter coated earthen pot, C_2= traditional earthen pot and C_3= polybag in earthen pot
M_1=10% moisture, M_2=12% moisture, M_3=14% moisture and M_4=16% moisture

4.2. Germination percentage

Seed germination is the indication of its ability to remain viable and to grow and develop into a normal seedling under favourable environment. So the determination of the germination percentage of seeds is invariably used to test the quality of seeds.

4.2.1. Effect of storage containers

In the determination of germination percentage of the rice seeds stored under different conditioned earthen pots (storage containers), the variation in earthen pots significantly affected the germination percentage of rice seeds (fig. 03) in August and December test. In October test, the variation in germination percentage of rice seeds under different conditioned earthen pots (storage containers) was insignificant.

Coalter coated earthen pot (C_1) showed significantly the highest germination percentages in December test. In August germination test (fig.03) 95.25% germination obtained by coalter coated earthen pot (C_1) was statistically similar to 94.50% obtained by polybag contained in earthen pot (C_3) while 93.17% germination obtained by simple earthen pot (C_2) was the lowest. In December germination test after 6 months of storage only the C_1 was found to maintain the standard germination percentage of rice seeds as 81.0% while the sub-standard germination percentage as 78.33% was found in C_3 and below standard as 75.75% was found in C_2 container. In other germination test i.e. in October, the variation was insignificant but the 3 storage containers were able to show the germination percentage upto the standard level as they were 89.83%, 88.42% and 89.63% respectively. The results indicate that out of the 3 storage containers only coalter coated earthen pot (C_1) could maintain the seed viability upto the next season. It is because the simple earthen pot (C_2) was porous, so there was the rise of moisture percent (%) in rice seeds which resulting the declination of seed viability. It is because the increased moisture content caused seeds to respire at a faster rate and decreased germination as reported by Rathi *et al* (2000). On the other hand, coalter coated earthen pot (C_1), the pores were blocked with coalter causing the prevention of moisture entry in the pot which resulted the less moisture rise in seeds contained in C_1. The observations are in conformity with the reports made by Singh and Singh (1981), Thilakarathna *et al* (2006) and Malakar *et al* (2008).

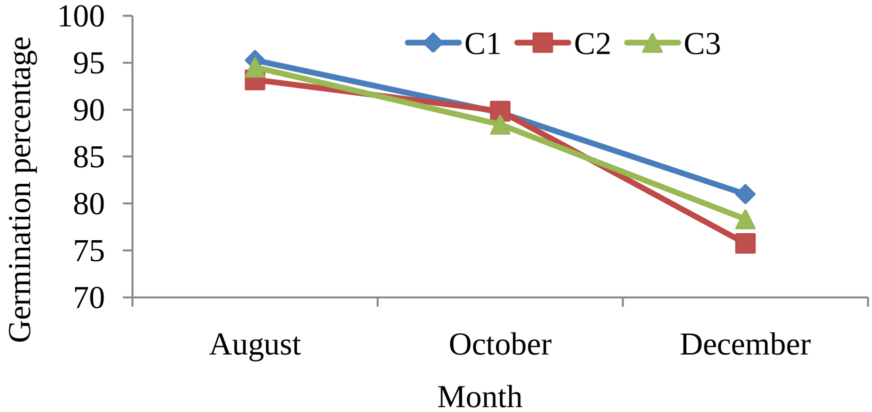

Figure. 03 Effect of storage container on germination percentage of rice seed (LSD $_{(0.05)}$ = 1.36, 2.12 and 1.91 at August, October and December, respectively)

C_1= Coalter coated earthen pot, C_2= traditional earthen pot and C_3= polybag in earthen pot

4.2.2. Effect of storage seed moisture content

Different seed moisture levels in storage caused significant variation in germination percentage of rice seeds (fig 04). No significant variation was observed in the germination percentage of rice seeds stored with 10% and 12% moisture content except in the month of October at which the germination percentage of 12% seed moisture content was significantly higher than that of 10% moisture. It reveals from the results that out of 4 seed moisture level M_1 (10.0% moisture) and M_2 (12.0% moisture) could maintain seed viability upto the next season, as they had germination percentage of 84.56% and 85.11% respectively. This finding corroborates with the finding of Abeysiriwardena (1985) where he observed that packing seed paddy with 12% moisture content in polythene enabled the seeds to be used as seed paddy even after one season of storage without any damage.Of course, the 4 seed moisture levels gave germination percentage of standard level upto October i.e.upto 4 months from the storage.

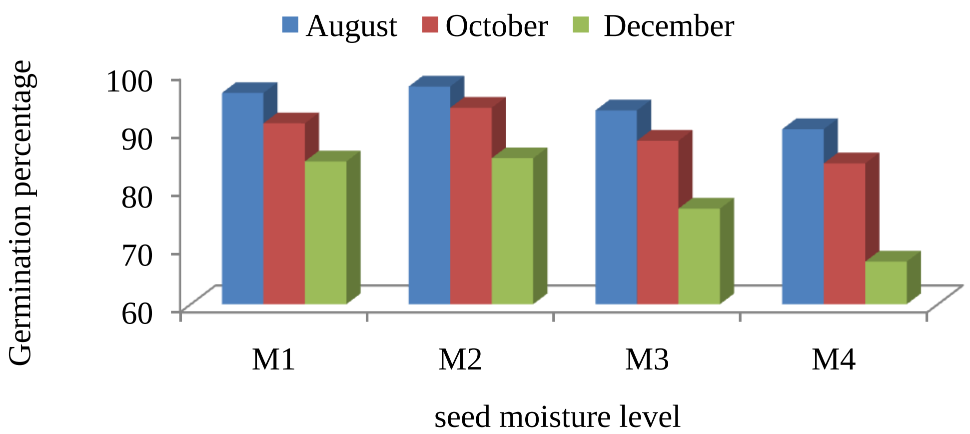

Figure 04. Effect of different moisture levels on Germination percentage (%) of rice seed (LSD $_{(0.05)}$ = 1.57, 2.44 and 2.2 at August, October and December, respectively)

M_1=10% moisture, M_2=12% moisture, M_3=14% moisture, M_4=16% moisture

4.2.3. Interaction effect of storage containers and different moisture content in seeds

Germination percentage showed significant variation due to the interaction effect of storage container and seed moisture level (Table 02). The seed moisture level M_1 (10.0%) and M_2 (12.0%) in interaction irrespective of the storage containers maintained the standard germination % upto the next cropping season. M_3 (14.0%) moisture level only with C_1 (coalter coated earthen pot) storage container as revealed from the results could maintain standard germination percentage upto the next cropping season. M_4 (16.0%) drastically failed, in interaction to maintain standard germination in December test. This result is in agreement with the findings of Mersal *et al*. (2006), who found that prolonging storage period with high seed moisture content reduced germinability.

Table 02. Interaction effect of earthen pot and moisture levels on germination percentage of rice seed

Treatment Combinations	Germination percentage		
	August	**October**	**December**
C_1M_1	98.33 a	94.00 ab	89.00 a
C_1M_2	97.00 a	91.00bc	83.67 b-d
C_1M_3	93.67 c	89.00 cd	80.00 d
C_1M_4	92.00 cd	84.67 ef	71.33 fg
C_2M_1	94.00 bc	89.33 cd	81.67 cd
C_2M_2	97.67 a	96.67 a	84.67 bc
C_2M_3	93.00 cd	88.67 c-e	73.67 ef
C_2M_4	88.00 e	84.67 ef	63.00 h
C_3M_1	96.67 ab	90.00 b-d	83.00 cd
C_3M_2	97.67 a	93.67ab	87.00 ab
C_3M_3	93.33c	86.67 d-f	75.67 e
C_3M_4	90.33 de	83.33 f	67.67 g
LSD $_{(0.05)}$	**2.723**	**4.232**	**3.81**
CV (%)	**1.71**	**2.81**	**2.89**

C_1= Coalter coated earthen pot, C_2= traditional earthen pot and C_3= polybag in earthen pot
M_1=10% moisture, M_2=12% moisture, M_3=14% moisture, M_4=16% moisture

4.3. Seed vigour test

4.3.1. Vigour index

4.3.1.1. Effect of storage containers

The vigour of the rice seeds stored under different storage containers was tested by vigour index and the results of the same as revealed from the fig. 05 indicate that the container C_1 and C_3 could maintain identical vigour of rice seeds upto the end of the storage period and the container C_2 was found to exhibit significantly lower vigour index of rice seeds stored in it.The underlying reason may be found in coalter coated earthen pot and in polybag in earthen pot. There was protective measure to prevent the entry of moisture and air which caused reduced oxygen and lower moisture content and thereby there was minimal maintenance, respiration and thus higher storage of carbohydrate reducing to higher vigour of seeds. This result is supported by Ali (1963) who reported that seeds stored in gunny bag and earthen pots lost viability much earlier than seeds stored in airtight containers. The highest vigour index as 14.45, 13.68 and 12.83 were shown by C_1while the lowest vigour index 13.52, 12.74 and 11.75 shown by C_2 for the period of August, October and December respectively.

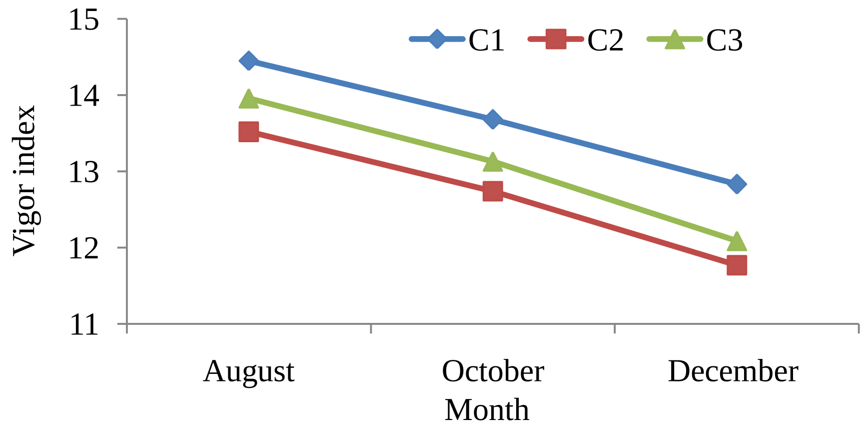

Figure.05 Effect of storage container on vigour index of rice seed (LSD $_{(0.05)}$ = 0.79, 0.81 and 0.83at August, October and December, respectively)

C_1= Coalter coated earthen pot, C_2= traditional earthen pot and C_3= polybag in earthen pot

4.3.1.2. Effect of storage seed moisture content

In respect of the influence of the seed moisture content of rice seeds in storage containers it is observed that the moisture level M_1 (10%) and M_2(12%) was found to be superior to that of M_3 (14%) and M_4 (16%) in maintaining the vigour of rice seeds (vigour index). Further it is observed that M_1 and M_2 were identical to each other in vigour index test but M_3 was always superior to M_4. The highest vigour index as 15.42, 14.72 and 13.49 was obtained respectively by the seed moisture level M_2 while corresponding vigour index as 12.49, 11.37 and 10.69 was obtained by the seed moisture level M_4 (16%).

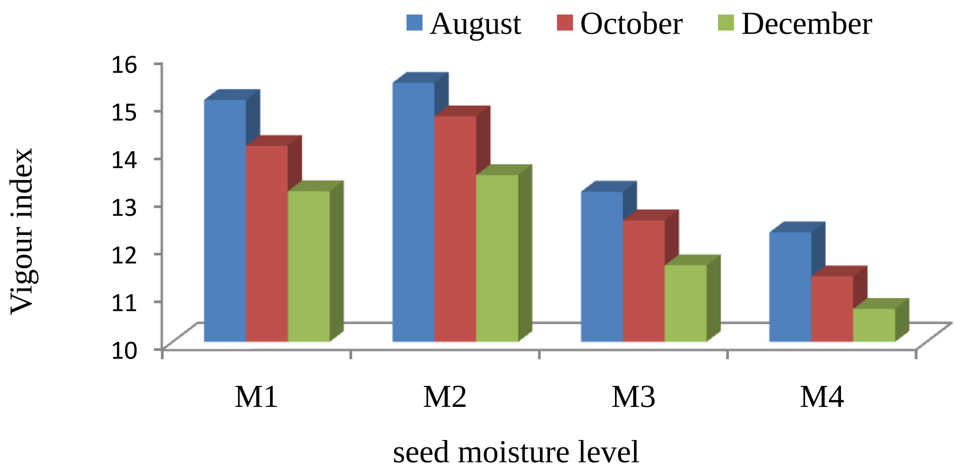

Figure 06. Effect of different moisture levels on vigour index of rice seed (LSD $_{(0.05)}$ = 0.91, 0.94 and 0.96 at August, October and December, respectively)

M_1=10% moisture, M_2=12% moisture, M_3=14% moisture, M_4=16% moisture

4.3.1.3. Interaction effect of storage containers and moisture contents in seed

In interaction between storage containers and moisture contents, towards the effect on vigour index of rice seeds (Table 03) it reveals that the seed moisture level M_1 (10%) throughout the storage period showed the higher vigour index irrespective of the storage containers. In contrast, the seed moisture level M_4 (16%) showed the lowest vigour index except the combination C_1M_4 at which M_4 did not hamper the vigour index of rice seeds so much as it would have been done in combination with other storage containers (C_2 and C_4). From the results it may be inferred here that the highest seed moisture content in the porous containers viz. C_2 and C_3 raised the seed moisture content in unsafe level which resulted the declination of seed vigour index. Similar findings were also reported by Alam *et al*. (2009a); Naguib *et al.* (2011) and Khalequzzaman *et al*. (2012).

Table 03. Interaction effect of earthen pot and moisture levels on vigour index of rice seed

Treatment Combinations	Vigour index		
	August	October	December
C_1M_1	14.85 a-c	14.04 ab	13.30 ab
C_1M_2	13.53 c-e	12.84 b-d	12.05 bc
C_1M_3	12.52 ef	11.68 c-e	10.98 cd
C_1M_4	13.96 b-e	13.00 b-d	12.17 a-c
C_2M_1	15.42 ab	14.87 a	13.42 ab
C_2M_2	12.80 d-f	12.07 c-e	11.31 cd
C_2M_3	11.92 f	11.00 e	10.20 d
C_2M_4	10.33 fg	9.10 f	8.5 e
C_3M_1	16.00 a	15.23 a	13.75 a
C_3M_2	13.10 d-f	12.72 b-d	11.45 cd
C_3M_3	12.42 ef	11.43 de	10.88 cd
C_3M_4	10.39 f	9.2 f	8.54 e
LSD $_{(0.05)}$	**1.571**	**1.679**	**1.65**
CV (%)	**6.67**	**7.33**	**8.01**

C_1= Coalter coated earthen pot, C_2= traditional earthen pot and C_3= polybag in earthen pot
M_1=10% moisture, M_2=12% moisture, M_3=14% moisture, M_4=16% moisture

4.3.2. Electrical conductivity

4.3.2.1. Effect of storage containers

Electrical conductivity test was done as per the procedure laid down in materials and methods and it was observed that the porous container C_2 (simple earthen pot) showed significantly the higher EC as 9.37, 32.90 and 40.57 µS cm^{-1} g^{-1} respectively in August, October and December test. In contrast, the non-porous container C_1 (coalter coated container) showed significantly the lowest EC as 29.93 and 37.44 µS cm^{-1} g^{-1} in October and December while that of August as 9.37µS cm^{-1} g^{-1} was statistically similar to 9.27µS cm^{-1} g^{-1} found in C_3 (polybag contained earthen pot). Here the porous seed containers have more EC than non-porous. It may be explained in such way that porous containers containing seeds have more leakage of electrolytes from seed coat which resulted its higher electrical conductivity.

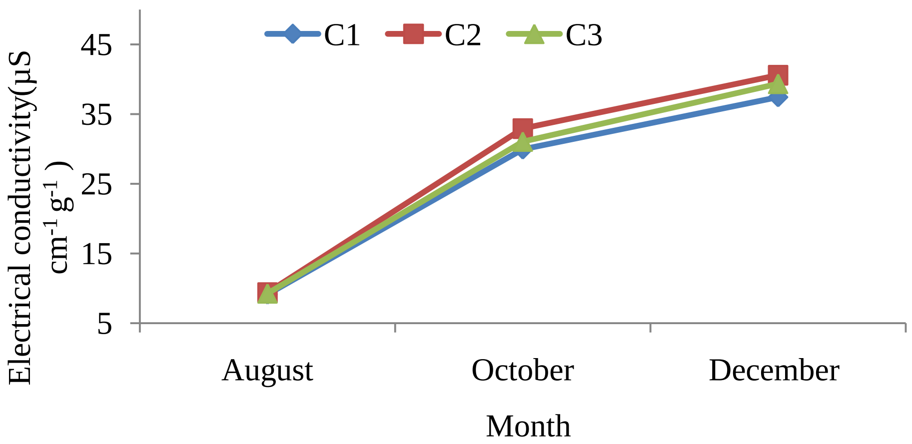

Figure 07. Effect of storage container on electrical conductivity of rice seed (LSD $_{(0.05)}$ =0.14, 1.18 and 0.81 at August, October and December, respectively)

C_1= Coalter coated earthen pot, C_2= traditional earthen pot and C_3= polybag in earthen pot

4.3.2.2 Effect of storage seed moisture content

As per characteristics of the electrical conductivity test, the seed moisture level M_4 (16%) possessing the highest moisture % gave significantly the highest EC as 9.61,37.54 and 46.74 µS cm^{-1} g^{-1}respectively in August, October and December test (fig.08). On the other hand seeds with the lowest moisture level M_1 (10%) showed significantly the lowest EC as 8.97, 28.30 and 34.84 µS cm^{-1} g^{-1}respectively in August, October and December test. With the advancement of storage period seed deterioration also proceeds and resultantly EC was also increased progressively in the results of each storage containers and each seed moisture levels.

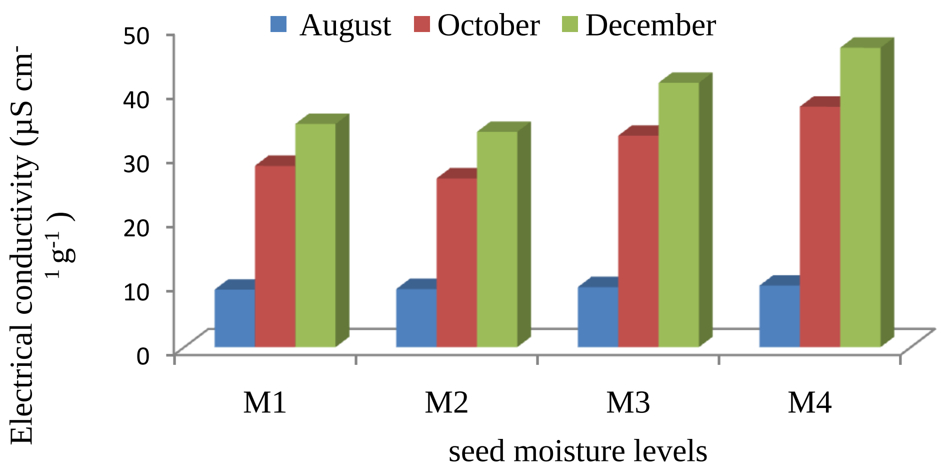

Figure 08. Effect of different moisture levels on electrical conductivity of rice seed (LSD $_{(0.05)}$ = 0.16, 1.36 and 0.93 at August, October and December, respectively)

M_1=10% moisture, M_2=12% moisture, M_3=14% moisture, M_4=16% moisture

4.3.2.3. Interaction effect of storage containers and moisture content in seed

In interaction, the combination of porous storage container (C_2) and high seed moisture level (M_4) i.e. C_2M_4 gave significantly the highest EC as 9.72, 38.12 and 48.98 µScm^{-1} g^{-1} respectively in August, October and December test while the non-porous storage container (C_1) or coalter coated earthen pot in combination with the lowest seed moisture level M_1 i.e. C_1M_1 showed significantly the lowest EC as 8.50, 25.05 and 31.20 µS cm^{-1} g^{-1} respectively in August, October and December test (Table 04).

Table 04. Interaction effect of earthen pot and moisture levels on electrical conductivity of rice seed

Treatment Combinations	Electrical conductivity (µS cm^{-1} g^{-1})		
	August	October	December
C_1M_1	8.50 g	25.05 e	31.20 i
C_1M_2	9.15 ef	27.07 de	35.30 g
C_1M_3	9.30 c-e	30.78 bc	38.90 e
C_1M_4	9.49 a-c	36.83 a	44.34 c
C_2M_1	9.25 c-e	30.51 bc	37.19 f
C_2M_2	9.11 ef	26.44 e	33.02 h
C_2M_3	9.43 b-d	36.52 a	43.10 cd
C_2M_4	9.72 a	38.12 a	48.98 a
C_3M_1	9.17 d-f	29.34 cd	36.12 fg
C_3M_2	8.93 f	25.51 e	32.50 hi
C_3M_3	9.37 b-e	31.74 b	41.82 d
C_3M_4	9.61 ab	37.66 a	46.89 b
LSD $_{(0.05)}$	**0.28**	**2.35**	**1.614**
CV (%)	**1.82**	**4.46**	**2.45**

C_1= Coalter coated earthen pot, C_2= traditional earthen pot and C_3= polybag in earthen pot
M_1=10% moisture, M_2=12% moisture, M_3=14% moisture, M_4=16% moisture

4.4. Seedling vigour test

4.4.1 Seedling root length

4.4.1.1. Effect of storage containers

Root length as observed from the seedling vigour test of rice seeds stored under different conditions varied significantly due to the variation of earthen pot containers (fig. 09). Seeds stored in coalter coated earthen pot (C_1) in August produced significantly the highest root length 7.52 cm. Both in October and December i.e. after 4 and 6 months of storage seeds in polybag contained in earthen pot (C_3) produced statistically the similar root length 6.39 cm and 5.40 cm with that produced on seeds of coalter coated earthen (C_1) pot as 6.59 cm and 5.64 cm. In 3 test period as in August, October and December, seeds stored in simple earthen pot (C_2) produced the root lengths as 7.16 cm, 6.18 cm and 5.25 cm which were respectively, statistically similar to 7.29 cm, 6.40 cm and 5.40 cm produced by the seeds stored in polybag contained in earthen pot (C_3). From the observation of the results it reveals that the root length produced by the seeds in simple earthen pot (C_2) always had the lowest value.

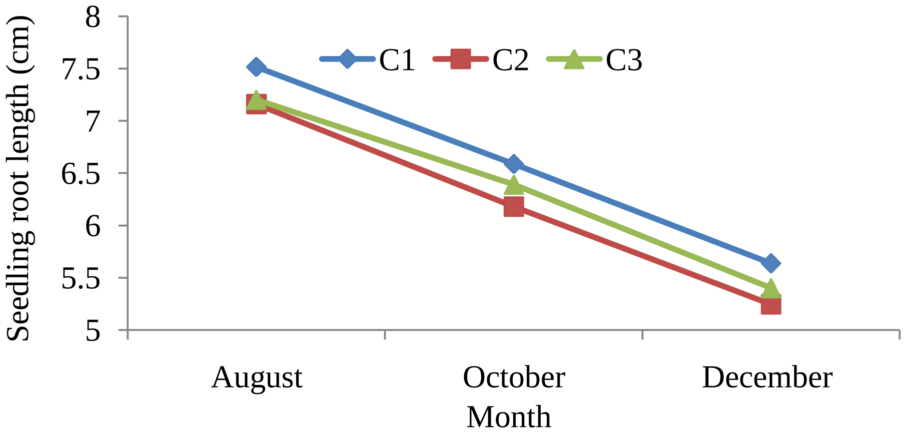

Figure 09. Effect of storage container on root length (cm) of rice seedling (LSD $_{(0.05)}$ = 0.180, 0.213 and 0.236 at August, October and December, respectively)

C_1= Coalter coated earthen pot, C_2= traditional earthen pot and C_3= polybag in earthen pot

4.4.1.2. Effect of storage seed moisture content

Root length also varied significantly due to the variation in seed moisture levels and it reveals from the fig.10that the root length produced by the seeds of seed moisture level M_1 (10.0%) and M_2 (12.0%) in the month of October and December was statistically similar to each other but in the month of August that of M_2 was statistically higher than that of M_1.In overall situation both M_1 and M_2 was significantly higher than M_3 and M_4 but M_3 was always higher than M_4. The highest root length in August, October and December was 8.15cm, 7.26cm and 6.21cm respectively produced by M_2 while the corresponding lowest was 6.45cm, 5.16cm and 4.41cm respectively produced by M_4.

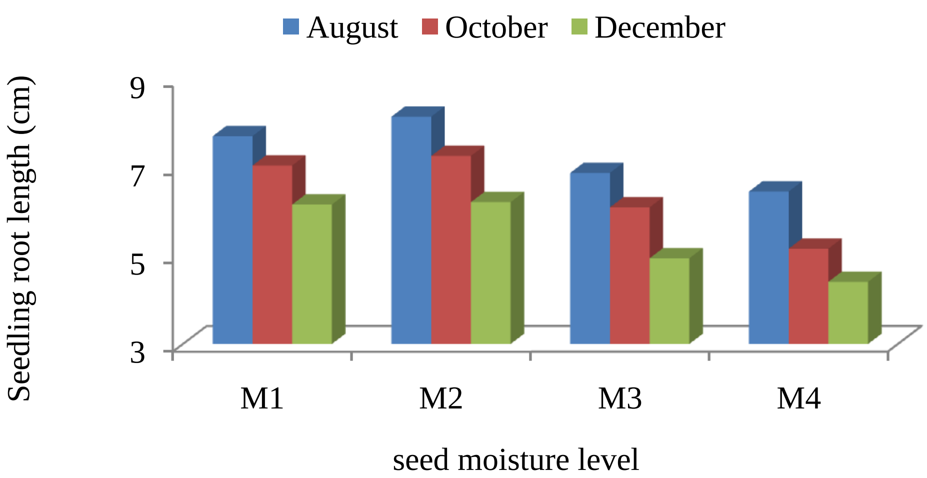

Figure 10. Effect of different moisture levels on root length (cm) of rice seedling (LSD $_{(0.05)}$ = 0.208, 0.246 and 0.273 August, October and December, respectively)

M_1=10% moisture, M_2=12% moisture, M_3=14% moisture, M_4=16% moisture

4.4.1.3. Interaction effect of storage containers and different moisture content on root length of rice seedling

Interaction effect of earthen pot and seed moisture level, treatment combinations showed significant variation in root length of rice seeds stored under different conditions. The treatment combination C_1M_1 (coalter coated earthen pot with seed moisture level of 10%) maintained higher root length than the rest treatment combinations in all the test periods. In August and October test period C_1M_1 produced the root length 8.67 cm and 7.75 cm which were statistically similar to the corresponding root length 8.36 cm and 7.45 cm produced by C_3M_2 but each of them was significantly higher than the corresponding root length produced by the rest treatment combinations. In December, of course, the treatment combination C_1M_1 produced significantly the higher root length (7 cm) than that of the rest treatment combinations including the treatment combination C_3M_2. Gradual declination of root length was observed from August to December. The highest root length 8.67 cm was found to come down at 7 cm in December. The lowest root length 6.33 cm showed by C_2M_4 in August came down to 4.10 cm in December. Similar results were also observed by Barua *et al*. (2009) where root length of 8.93 cm was found to decline to 6.15 cm after certain period of storage. Mersal *et al.* (2006) also reported similar observations. There was 19% declination of root length from August to December in C_1M_1 but at C_2M_4 it was 35%. So it was manifested that there was more declination of root length in the treatment combination of simple earthen pot with seed moisture level of 16% (C_2M_4).

Table 06. Interaction effect of earthen pot and moisture levels on root length (cm) of rice seedling

Treatment Combinations	Root length (cm)		
	August	October	December
C_1M_1	8.67 a	7.75 a	7.00 a
C_1M_2	7.80 c	6.90 b	5.85 c
C_1M_3	7.00 d-f	6.28 cd	5.10 d
C_1M_4	6.60 g-i	5.42 e	4.60 e
C_2M_1	7.25 d	6.65 bc	5.72 c
C_2M_2	8.28 b	7.42 a	6.35 b
C_2M_3	6.78 f-h	5.90 d	4.82 de
C_2M_4	6.33 i	4.75 f	4.10 f
C_3M_1	7.20 de	6.72 b	5.75 c
C_3M_2	8.36 ab	7.45 a	6.43 b
C_3M_3	6.84 e-g	6.10 d	4.90 de
C_3M_4	6.42 hi	5.30 e	4.52 ef
LSD $_{(0.05)}$	**0.36**	**0.43**	**0.48**
CV (%)	**2.93**	**3.97**	**5.19**

C_1= Coalter coated earthen pot, C_2= traditional earthen pot and C_3= polybag in earthen pot
M_1=10% moisture, M_2=12% moisture, M_3=14% moisture, M_4=16% moisture

4.4.2. Seedling shoot length

4.4.2.1. Effect of storage containers

Through seedling vigour test the shoot length of rice seedlings obtained from the rice seeds stored under different storage containers was determined. The shoot length was observed to vary significantly (fig.11) as influenced by the different conditions of the earthen pot containers. Seeds in C_1 container throughout the storage period produced higher shoot length than that of the containers C_2 and C_3. In August, October and December test (fig 13), seeds in C_1 container produced significantly the highest shoot length as 12.02 cm, 10.39 cm and 8.75 cm, respectively. The container C_3 (Polybag in earthen pot) as referred from figure 13 showed better performance than that of C_2 (simple earthen pot) in respect of producing shoot length. The corresponding shoot length of the rice seedlings obtained from the seeds stored in the container C_3 was11.72 cm, 9.82 cm and 7.93 cm, respectively. From the results, it appears that there was a gradual retardation of shoot length of the rice seedlings produced from the seeds stored under different conditioned earthen pots. The retardation was due to the progressive declination of seed vigour over the period of storage.

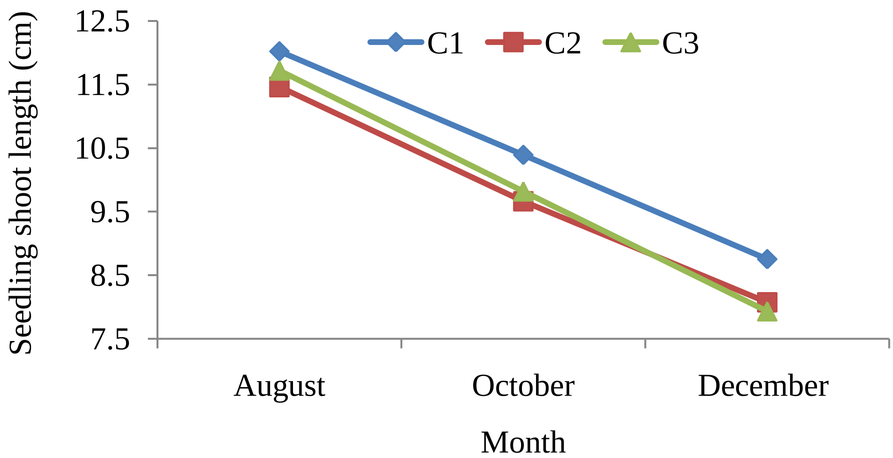

Figure 11. Effect of storage container on shoot length (cm) of rice seedlings (LSD $_{(0.05)}$ = 0.164, 0.148 and 0.519 at August, October and December, respectively)

C_1= Coalter coated earthen pot, C_2= traditional earthen pot and C_3= polybag in earthen pot

4.4.2.2. Effect of storage seed moisture content

Significant variation was also noticed in the shoot length of the rice seedlings obtained from the seeds stored under different seed moisture levels. The moisture level of 12% (M_2) was found to produce the tallest shoot of length 12.58 cm, 11.07 cm and 9.98 cm, respectively in August, October and December test. The highest shoot length 12.58 cm and 9.98 cm produced in August and December test by the seed moisture level 12% (M_2) was significantly higher than the corresponding shoot length produce by the seeds of the rest seed moisture levels. The highest shoot length 11.07 cm obtained by the seeds of seed moisture level 12% (M_2) in October was similar to the shoot length 10.90 cm produced by the seed of moisture level 10% (M_1). The lowest shoot length was noticed in the seeds of the highest seed moisture level of 16% (M_4).

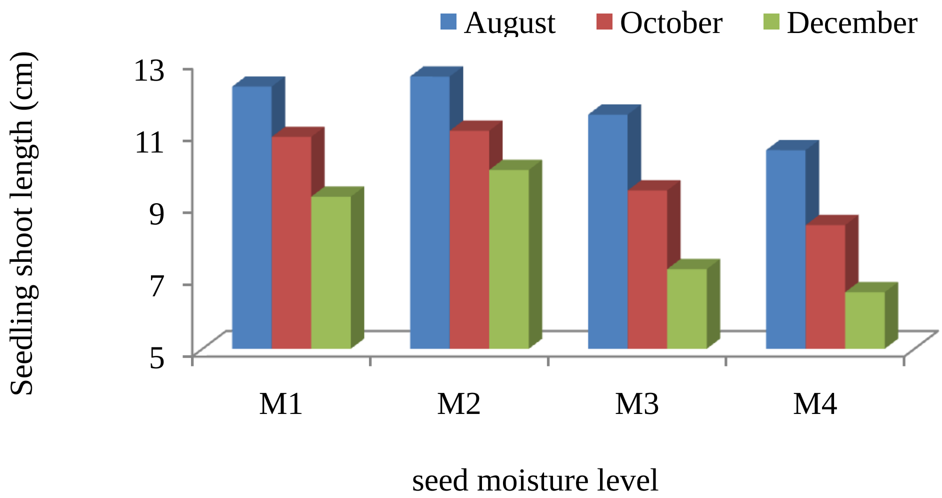

Figure 12. Effect of different moisture levels on shoot length (cm) of rice seedling (LSD $_{(0.05)}$ = 0.189, 0.171 and 0.599 at August, October and December, respectively)

M_1=10% moisture, M_2=12% moisture, M_3=14% moisture, M_4=16% moisture

4.4.2.3. Interaction effect of storage containers and moisture contents in seeds

In interaction effect the treatment combination of C_1M_1 (coalter coated earthen pot and 10% seed moisture level) produced the tallest shoot lengths of 13.22 cm, 11.83 cm and 10.50 cm, respectively in August, October and December test. The shoot length 13.22 cm and 10.50 cm produced by the interaction effect of C_1M_1 in August and December was similar to the corresponding shoot length 12.91 cm and 10.20 cm produced by the treatment combination C_3M_2 but in October the shoot length 11.83 cm produced by C_1M_1 was significantly higher than that of all other treatment combinations. The treatment combination C_2M_4 produced the lowest shoot lengths 10.24 cm and 6.22 cm in August and December respectively while C_3M_4 produced the lowest shoot length 8.13 cm in October. The shoot length retardation was highest in C_2M_4 combination and it was almost 39% while the lowest (20%) was in C_1M_1 combination. Barua *et al.* (2005) and Alam *et al.* (2009) reported that shoot length also decreased with the passage of time in storage with high moisture content and shoot length of 7.83 cm was found to decline to 6.15 cm. Mersal *et al*. (2006) also noticed similar happenings in the declination of shoot length.

Table 06. Interaction effect of earthen pot and moisture levels on shoot length (cm) of rice seedling

Treatment Combinations	**Shoot length (cm)**		
	August	**October**	**December**
C_1M_1	13.22 a	11.83 a	10.50 a
C_1M_2	12.18 c	10.83 c	9.60 ab
C_1M_3	11.82 de	10.15 d	7.94 cd
C_1M_4	10.85 g	8.743 fg	6.97 d-f
C_2M_1	11.53 ef	10.23 d	8.65 bc
C_2M_2	12.64 b	11.15 b	10.14 a
C_2M_3	11.42 f	8.82 f	7.28 de
C_2M_4	10.24 h	8.46 g	6.22 f
C_3M_1	12.15 cd	10.65 c	8.56 c
C_3M_2	12.91 ab	11.23 b	10.20 a
C_3M_3	11.31 f	9.26 e	6.44 ef
C_3M_4	10.50 h	8.13 h	6.54 ef
LSD $_{(0.05)}$	**0.33**	**0.30**	**1.04**
CV (%)	**1.67**	**1.77**	**2.36**

C_1= Coalter coated earthen pot, C_2= traditional earthen pot and C_3= polybag in earthen pot

M_1=10% moisture, M_2=12% moisture, M_3=14% moisture, M_4=16% moisture

4.4.3. Seedling fresh weight

4.4.3.1. Effect of storage containers

Fresh weight of rice seedlings obtained from the seeds stored under three different conditioned earthen pots was found to vary significantly (fig. 13) from each other. The seeds stored under the coalter coated earthen pot (C_1) recorded significantly the highest fresh weight as 1.10 g, 0.77 g and 0.66 g, respectively in August, October and December test. The result indicates that the C_1 was able to maintain the seed vigour higher than the seeds in other conditioned earthen pots. Fresh weight of seedling obtained from the seeds stored under the different earthen pot declined gradually. The rate of declination of fresh weight of seedling was varied from 40% to 42% only due to the effect of storage containers i.e. the difference of fresh weight variation was less from container to container.

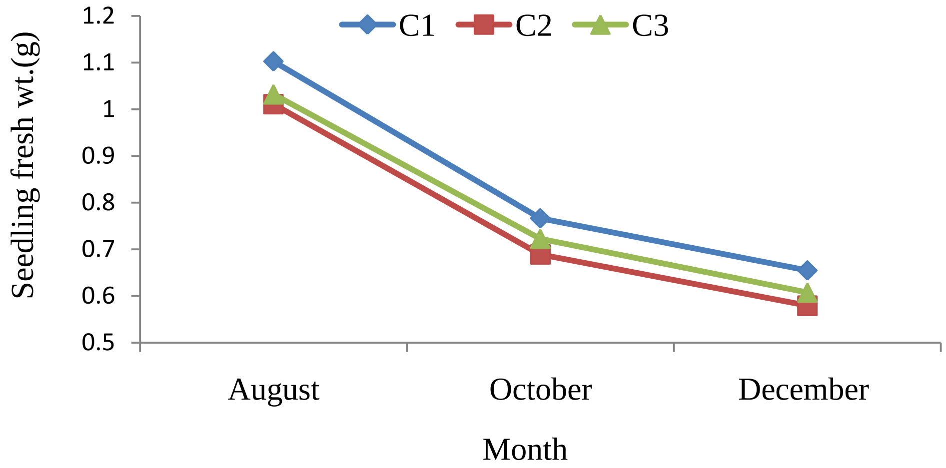

Figure 13. Effect of storage container on seedling fresh weight (g) of rice seedling (LSD $_{(0.05)}$ = 0.046, 0.037 and 0.026 at August, October and December, respectively)

C_1= Coalter coated earthen pot, C_2=traditional earthen pot and C_3= polybag in earthen pot

4.4.3.2. Effect of storage seed moisture content

Seed moisture content of different level significantly affected the fresh weight of rice seedling; the moisture level of 10% (M_1) and 12% (M_2) of rice seeds affected the fresh weight of rice seedling over the storage period in similar trend. Both these seed moisture level maintained significantly the higher fresh weight of rice seedling than that of the other two moisture levels. Seed moisture level 14% (M_3) performed better than that of 16% (M_4) in maintaining fresh weight of rice seedling and the lowest fresh weight of 0.44 g were observed in 16% (M_4) at the end of the storage.

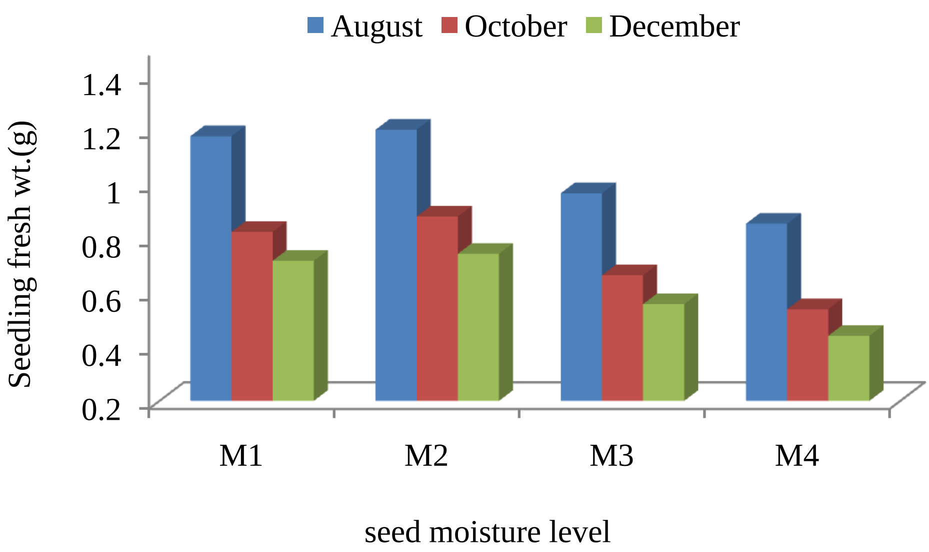

Figure 14. Effect of different moisture levels on seedling fresh weight (g) of rice seedling (LSD $_{(0.05)}$ = 0.053, 0.043 and 0.031 at August, October and December, respectively)

M_1=10% moisture, M_2=12% moisture, M_3=14% moisture, M_4=16% moisture

4.4.3.3 Interaction effect of earthen pot and storage seed moisture levels on fresh weight (g) of rice seedling

Significant variation was observed in the fresh weight of rice seedling due to the interaction effect of storage containers and seed moisture level (Table 08). In August and December test the treatment combination C_1M_1 (coalter coated earthen pot with 10% seed moisture level) obtained the seedling fresh weight as 1.35 g and 0.83 g which were significantly higher than the corresponding seedling fresh weight obtained by the rest treatment combinations but in October test the seedling fresh weight 0.94g obtained by C_1M_1 was statistically similar to 0.92 g and 0.87 g obtained by the treatment combination C_3M_2 and C_2M_2. In interaction effect though the highest seedling fresh weight was observed under the treatment combination of C_1M_1 but M_2 (seed moisture level 12%) in combination with any of the storage container performed better in maintaining the seed vigour through the storage period and M_4 (seed moisture level 16%) in combination with storage containers performed the worst.

Table 08. Interaction effect of earthen pot and moisture levels on seedling fresh weight (g) of rice seed

Treatment Combinations	seedling fresh wt.(g)		
	August	**October**	**December**
C_1M_1	1.35 a	0.94 a	0.83 a
C_1M_2	1.16 bc	0.85 bc	0.72 bc
C_1M_3	1.02 de	0.74 d	0.61 e
C_1M_4	0.89 fg	0.53 g	0.46 g
C_2M_1	1.08 cd	0.74 d	0.63 de
C_2M_2	1.20 b	0.87 abc	0.74 b
C_2M_3	0.92 fg	0.62 ef	0.52 f
C_2M_4	0.84 g	0.53 g	0.43 g
C_3M_1	1.10 cd	0.79 cd	0.68 cd
C_3M_2	1.24 b	0.92 ab	0.76 b
C_3M_3	0.95 ef	0.63 e	0.55 f
C_3M_4	0.83 g	0.55 fg	0.44 g
LSD $_{(0.05)}$	**0.09**	**0.08**	**0.05**
CV (%)	**5.16**	**6.28**	**4.9**

C_1= Coalter coated earthen pot, C_2= traditional earthen pot and C_3= polybag in earthen pot
M_1=10% moisture, M_2=12% moisture, M_3=14% moisture, M_4=16% moisture

4.4.4. Seedling dry weight

4.4.4.1. Effect of storage containers

Dry weight of rice seedling varied significantly due to the influence of different conditioned earthen pots. C_1 (coalter coated earthen pot) was observed to maintain significantly the highest dry weight of rice seedling as 0.57 g, 0.49 g and 0.36 g respectively in 3 different test period. Of the other two storage containers the performance of C_3 (polybag in earthen pot) was found to be better than that of C_2 (simple earthen pot) container. There was observed a gradual declination of seedling dry weight over time. The declination trend was more or less similar in C_1 and C_3 but it was a bit rapid in C_2. The declination was 36.8% in C_1 and 41% in C_2.

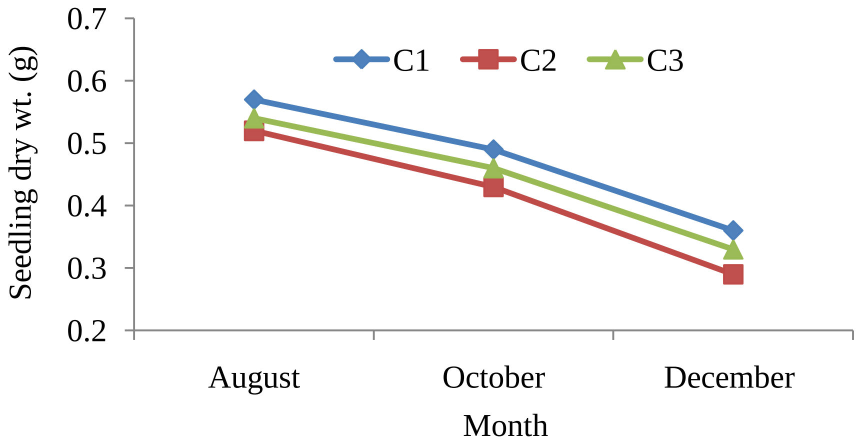

Figure 15. Effect of storage container on seedling dry weight (gm) of rice seed (LSD $_{(0.05)}$ = 0.026, 0.026, and 0.026 at August, October and December, respectively)

C_1= Coalter coated earthen pot, C_2= traditional earthen pot and C_3= polybag in earthen pot

4.4.4.2. Effect of storage seed moisture content

In respect of moisture level towards maintaining the dry weight of rice seedlings the seed moisture level of 10% and 12% showed similar effect throughout the storage period. The dry weight of rice seedlings as 0.63 g, 0.54 g and 0.42 g, respectively were obtained under the moisture level of 12% while those were under seed moisture level of 10% as 0.61 g, 0.52 g and 0.40 g, respectively in 3 different test periods. The moisture level of 16% performed the worst and the lowest dry weight of rice seedlings as 0.21 g under the same at the end of the storage period. The dry weight declination of rice seedling under 12% moisture levels was 33% and that was 50% under 16% moisture levels.

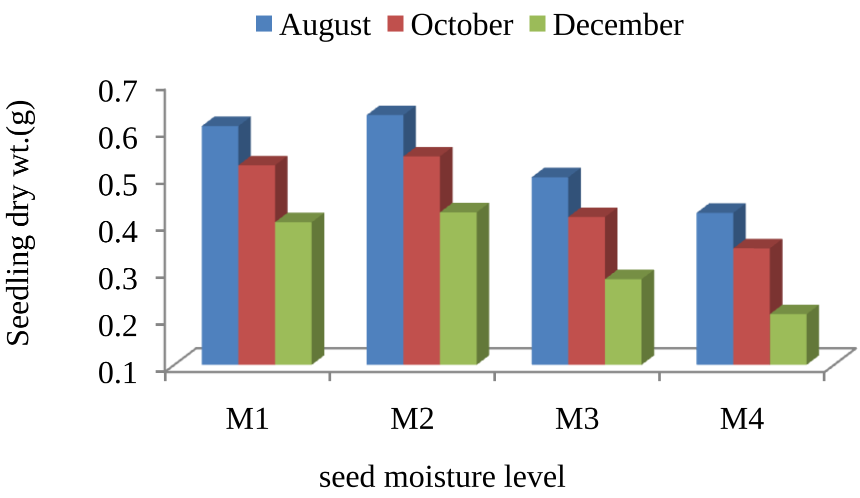

Figure 16. Effect of different moisture levels on dry weight (g) of rice seedling (LSD $_{(0.05)}$ = 0.030, 0.030 and 0.030 at August, October and December, respectively)

M_1=10% moisture, M_2=12% moisture, M_3=14% moisture, M_4=16% moisture

4.4.4.3. Interaction effect of storage containers and moisture contents on dry wt. of rice seedling

There was observed significant variation in dry weight of rice seedlings due to the interaction effect of different conditioned earthen pots and seed moisture levels (Table 08). The treatment combination of C_1 (coalter coated earthen pot) and M_1 (seed moisture level of 10%) recorded the seedling dry weight as 0.69 g, 0.61 g and 0.53 g respectively in August, October and December test period. Among them the dry weights 0.69 g and 0.61 g was statistically similar to the corresponding period dry weight 0.65 g and 0.57 g obtained by the treatment combination of C_3M_2. The dry weight of the other treatment combinations was significantly lower than that of the above mentioned dry weight.

Table 09. Interaction effect of earthen pot and moisture levels on dry weight (g) of rice seedling

Treatment Combinations	Seedling dry wt.(g)		
	August	October	December
C_1M_1	0.69 a	0.61 a	0.53 a
C_1M_2	0.61 bc	0.53 bc	0.40 cd
C_1M_3	0.52 ef	0.44 de	0.31 ef
C_1M_4	0.45 gh	0.36 f	0.22 g
C_2M_1	0.54 de	0.47 de	0.33 ef
C_2M_2	0.63 bc	0.53 bc	0.42 bc
C_2M_3	0.48 fg	0.37 f	0.24 g
C_2M_4	0.40 h	0.34 f	0.20 g
C_3M_1	0.59 cd	0.49 cd	0.35 de
C_3M_2	0.65 ab	0.57 ab	0.46 b
C_3M_3	0.49 efg	0.43 e	0.30 f
C_3M_4	0.42 h	0.34 f	0.21 g
LSD $_{(0.05)}$	**0.05**	**0.05**	**0.05**
CV (%)	**3.45**	**6.18**	**7.66**

C_1= Coalter coated earthen pot, C_2= traditional earthen pot and C_3= polybag in earthen pot

M_1=10% moisture, M_2=12% moisture, M_3=14% moisture, M_4=16% moisture

4.4.5. Normal seedling (no.)

4.4.5.1. Effect of storage containers

The percentage of normal seedling produced from the seeds stored under different storage conditions differed significantly due to variation (Fig.17) on storage containers. The seeds of storage container C_1 (coalter coated earthen pot) as revealed from the Fig. 17could only produce above 80% normal seedlings in December while in August and October normal seedling percentage was 88.92 and 86.17, respectively. The seeds of storage container C_2 (simple earthen pot) and C_3 (polybag contained in earthen pot) throughout the storage period produced statistically the similar normal seedling percentage but each of them was significantly lower than the percentage of normal seedlings produced by the seeds in storage container C_1 (coalter coated earthen pot). The findings were in conformity with those of Khalequzzaman *et al.* (2012) and Hussain *et al*. (2013) where they reported that seeds stored in non-porous containers produced significantly higher numbers of normal seedlings than those of porous containers. The percentage of normal seedlings produced by the seeds in C_2 (simple earthen pot) were 84.33, 81.08 and 76.50 in August, October and December, respectively while 85.25, 81.17 and 77.75 were the normal seedlings produced by the seeds in C_3 (polybag contained in earthen pot) container.

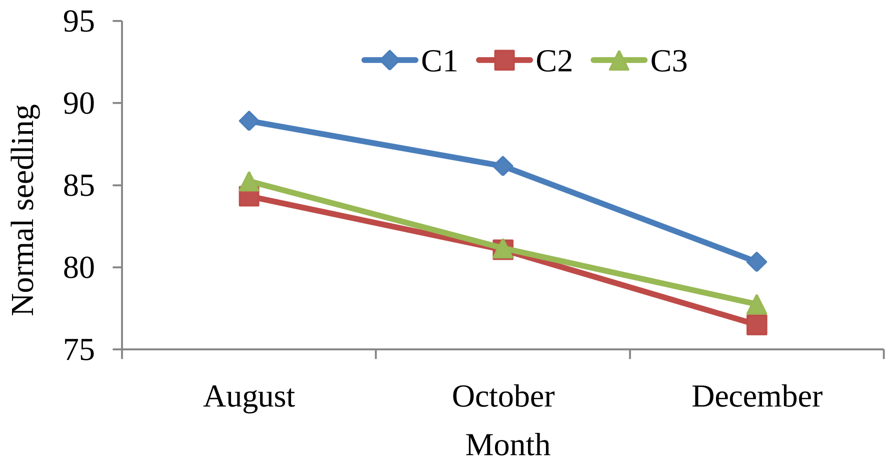

Figure 17. Effect of storage container on normal seedlings (no.) of rice seed (LSD $_{(0.05)}$ = 3.07, 2.741 and 2.21 at August, October, December respectively)

C_1= Coalter coated earthen pot, C_2= traditional earthen pot and C_3= polybag in earthen pot

4.4.5.2. Effect of seed moisture content

Percentage of normal seedlings showed significant variation due to the variation in seed moisture content in the storage. Of course, seeds with both seed moisture content M_1 (10%) and M_2 (12%) was able to produce above 80% normal seedlings upto the end of the storage period while M_3 (14%) was able to produce above 80% upto October and M_4 (16%) failed to produce 80% normal seedlings for any period after storage. Between the seed moisture level M_1 (10%) and M_2 (12%), the later showed better performance than the former as normal seedling percentage 89.22 and 84.22 produced by M_2 was significantly higher than that of 85.67 and 81.11 produced by M_1 on October and December test period and between M_3 (14%) and M_4 (16%), the former showed better performance than the later. Chattha *et al.* (2012) also observed that seeds packed with 16% moisture had the lowest performance in germination and in the production of normal seedlings.

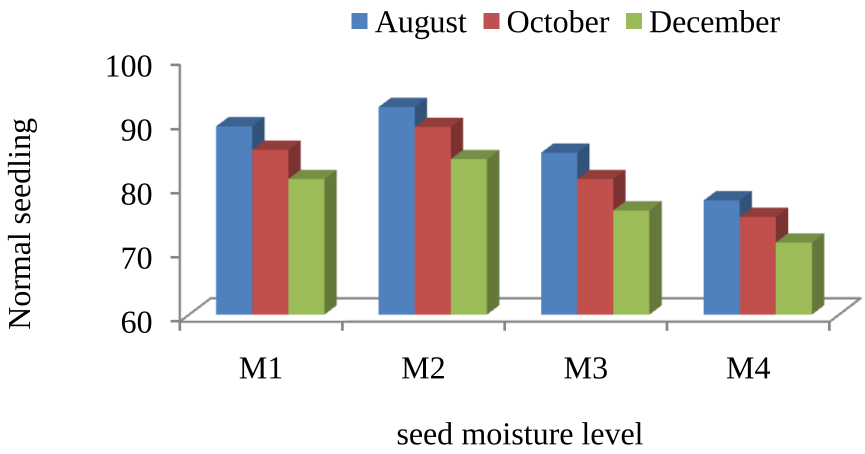

Figure 18. Effect of different moisture levels on normal seedlings (no.) of rice seed (LSD $_{(0.05)}$ = 3.544, 3.165 and 2.643 at August, October and December, respectively)

M_1=10% moisture, M_2=12% moisture, M_3=14% moisture, M_4=16% moisture

4.4.5.3 Interaction effect of storage containers and moisture contents in seeds

In August test, out of 12 treatment combinations, the number of normal seedlings produced by 10 treatment combinations was statistically similar to each other and each of them was statistically higher than the normal seedlings produced by the treatment combination C_2M_3 and C_3M_4. In October and December test, the treatment combinations comprising seed moisture level, M_2 (12%) with all the 3 storage containers (C_1, C_2 and C_3) produced statistically the similar number of normal seedlings which was also at par with that of the treatment combination C_1M_1. The number of normal seedlings produced by the rest treatment combinations was statistically lower than that of the above mentioned treatment combinations. From the results it is obvious that the treatment combinations comprising the seed moisture level, M_2 (12%) performed better than the combinations comprising seed moisture level M_1 (10%), though numerically the highest number of normal seedlings was obtained by the combination C_1M_1 in both October and December test.

Table 09. Interaction effect of earthen pot and moisture levels on normal seedlings (no.) of rice seed

Treatment Combinations	Normal seedlings (no.)		
	August	October	December
C_1M_1	93.33 ab	96.33 a	92.00 a
C_1M_2	97.33ab	91.33a-c	87.00 a-c
C_1M_3	95.67 ab	86.00 b-d	84.67 b-d
C_1M_4	92.67 ab	82.00 de	81.00 de
C_2M_1	95.33 ab	85.67 cd	82.67 cd
C_2M_2	97.33ab	92.00ab	89.00 ab
C_2M_3	92.33 b	85.33 cd	81.67 c-e
C_2M_4	92.67ab	74.33 f	71.00 g
C_3M_1	97.67 a	86.00 b-d	82.33 c-e
C_3M_2	97.67 a	93.67 a	91.67 a
C_3M_3	94.33 ab	84.33 d	77.00ef
C_3M_4	92.33 b	77.00ef	73.67 fg
LSD $_{(0.05)}$	**5.194**	**6.139**	**2.157**
CV (%)	**3.24**	**4.23**	**3.93**

C_1= Coalter coated earthen pot, C_2= traditional earthen pot and C_3= polybag in earthen pot
M_1=10% moisture, M_2=12% moisture, M_3=14% moisture, M_4=16% moisture

Chapter V

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Agronomy Farm Laboratory of Sher-e-Bangla Agricultural University, Dhaka-1207, during the period from June to December, 2013 to study the effect of different storage containers and seed moisture contents (levels) on the viability and vigour of the stored rice seeds.

The experiment comprised two factors; Factor A: storage containers (3 types): C_1: coalter coated earthen pot, C_2: earthen pot and C_3: polythene bag contained in earthen pot; Factor B: seed moisture levels (4 levels): M_1: 10% seed moisture level, M_2: 12% seed moisture level, M_3: 14% seed moisture level and M_4: 16% seed moisture level. The experiment was conducted in the ambient condition of the laboratory so it was laid out in a Completely Randomized Design (CRD) with three replications.

The variety BRRI dhan 28 was used as experimental materials. The healthy and uniform sized seeds were kept in different containers. After that the containers were closed using earthen cover with masking tape and stored in the clean and dry place in the laboratory for two to six months. Three samples of stored seed from each container were taken at two months interval starting from August for measuring the quality of the seeds and as such data were taken in August, October and December of 2013. The data collected were on seed moisture percentage, germination percentage, vigour index, electrical conductivity and seedling root length, seedling shoot length, seedling fresh weight, seedling dry weight and normal seedling percentage.

In respect of the effect of storage container on moisture percentage and germination percentage one was opposite to each other. For example, coalter coated earthen pot (C_1) recorded the highest germination percentage (81.00%) but the lowest moisture percentage (14.76%) while the traditional earthen pot (C_2) recorded the lowest germination percentage (75.75%) but the highest moisture percentage (16.18%) at the end of the storage , i.e. in December test. The storage container, polythene bag in earthen pot (C_3) recorded the values between C_1 and C_2.

In respect of the effect of seed moisture content on moisture percentage and germination percentage, the highest seed moisture level (M_4) had the highest moisture percentage (18.68%) but the lowest germination percentage (63.22%) at the end of the storage. Seed moisture content, M_1 and M_2 were statistically similar in effect except in October test and both maintained 80% or more germination percentage at the end. In October test, M_2 performed better than M_1. The storage containers C_2 and C_3 in combination with the seed moisture contents M_1 and M_2 could retain the seed viability upto the end of the storage but C_1 with M_3 also retained the viability.

In the vigour test, i.e.in the vigour index and electrical conductivity test, coalter coated earthen pot (C_1) along with seed moisture level M_1 (10%) showed the highest vigour index (13.30) and the lowest electrical conductivity (31.20 $\mu Scm^{-1} g^{-1}$). In contrast, the storage container, traditional earthen pot (C_2) along with the highest seed moisture level (M_4) showed the lowest vigour index (8.5) and the highest electrical conductivity (48.98 $\mu Scm^{-1} g^{-1}$).

In the measurement of root-shoot length and fresh-dry weight of rice seedlings, the seed container, coalter coated earthen pot (C_1) in all the tests recorded the highest values while the seed container, traditional earthen pot (C_2) recorded the lowest values and the seed container, polythene bag in earthen pot (C_3) in some of the tests recorded statistically the similar results with C_1.

Regarding the effect of the treatment seed moisture content on seedling vigour, it revealed that both M_1 (10%) and M_2 (12%), though in some test, the effect was similar but on the whole , M_2 was superior to M_1 and between M_3 and M_4, the former was superior to later.

The storage container C_1 was able to produce above 80% normal seedlings upto the end of the storage period whereas C_3 and C_2upto October. The seed moisture content of both M_1 and M_2 was able to produce normal seedlings upto the end of storage, M_3upto October but M_4 could not produce 80% normal seedling for any period i.e. in any test.

On the basis of above findings the conclusion may be drawn as follows:

i. Regarding the retention of good viability of seed paddy for a longer period in storage, moisture content of seed during storage should be selected according to the storage container used.

ii. Storing seed in porous containers like traditional earthen pot the time of storage that could retain 80% or more germination percentage is no longer dependent on the moisture content of seed during storing due to the ambient condition of the containers.

iii. High moisture content of seed during storing shorten the time of storage that could retain 80% germination even in non-porous container, coalter coated earthen pot time was shortened by 3 months.

iv. Rice seed with 12% moisture in traditional earthen pot in air tight condition may be suggested for use in the farmer’s level.

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Appendices

APPENDICES

Appendix I. Monthly average air temperature, rainfall and relative humidity of the experimental site during the period from June to December, 2013

Months	Air temperature (^0C)		Relative humidity (%)	Total rainfall (mm)
	Maximum	Minimum		
June	35.4	22.5	80	5.8
July	34.2	21.3	85	7.2
August	31.02	15.27	74.41	5.1
September	31.46	14.82	73.20	6.3
October	30.18	14.85	67.82	4.2
November	28.10	6.88	58.18	1.56
December	25.36	5.21	54.3	0.63

Source: Mini weather station, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka- 1207.

Appendix II. Analysis of variance of the data on moisture percentage of rice seed

Source of variation	df	Mean square of moisture percentage		
		August	October	December
Storage container (A)	2	0.12^{NS}	1.24*	6.12*
Seed moisture content(B)	3	47.56*	37.47*	38.14*
Storage container(A) X Seed moisture content (B)	6	0.62*	0.16*	1.24*
Error	24	0.17	0.16	0.25

*Significant at 5% level of significance
^{NS} Non significant

Appendix III. Analysis of variance of the data on germination percentage of rice seed

Source of variation August	df	Mean square of germination percentage		
		August	October	December
Storage container (A)	2	13.36*	7.19^{NS}	60.86*
Seed moisture content(B)	3	97.50*	151.58*	479.22*
Storage container (A) X Seed moisture content (B)	6	4.62*	14.19*	12.86*
Error	24	2.61	6.31	6.78

*Significant at 5% level of significance
^{NS} Non significant

Appendix IV. Analysis of variance of the data on vigour index of rice seed

Source of variation	df	Mean square of vigour index		
		August	October	December
Storage container (A)	2	1.92*	0.89*	0.48^{NS}
Seed moisture content(B)	3	7.54*	6.44*	8.88*
Storage container (A) X Seed moisture content (B)	6	0.39*	0.54*	0.30*
Error	24	0.28	0.18	0.28

*Significant at 5% level of significance
^{NS} Non significant

Appendix V. Analysis of variance of the data on electrical conductivity of rice seed

Source of variation	df	Mean square of electrical conductivity		
		August	**October**	**December**
Storage container (A)	12	0.22*	26.92*	29.93*
Seed moisture content(B)	3	0.76*	226.34*	334.31*
Storage container (A) X Seed moisture content (B)	6	0.13*	9.79*	12.47*
Error	24	0.03	1.95	0.92

*Significant at 5% level of significance
^{NS} Non significant

Appendix VI. Analysis of variance of the data on root length of rice seed

Source of variation	df	Mean square of root length (cm)		
		August	**October**	**December**
Storage container (A)	2	0.45*	0.50*	0.46*
Seed moisture content(B)	3	5.35*	8.35*	7.28*
Storage container (A) X Seed moisture content (B)	6	0.67*	0.47*	0.57*
Error	24	0.05	0.06	0.08

*Significant at 5% level of significance
^{NS} Non significant

Appendix VII. Analysis of variance of the data on shoot length of rice seed

Source of variation	df	Mean square of shoot length (cm)		
		August	October	December
Storage container (A)	2	0.95*	1.74*	2.31*
Seed moisture content(B)	3	7.56*	14.14*	23.48*
Storage container (A) X Seed moisture content (B)	6	0.72*	0.70*	1.25*
Error	24	0.04	0.03	0.04

*Significant at 5% level of significance
NS Non significant

Appendix VIII. Analysis of variance of the data on seedling fresh weight of rice seed

Source of variation	df	Mean square of seedling fresh weight (g)		
		August	October	December
Storage container (A)	2	0.03*	0.02*	0.02*
Seed moisture content(B)	3	0.25*	0.22*	0.18*
Storage container (A) X Seed moisture content (B)	6	0.02*	0.01*	0.01*
Error	24	0.003	0.002	0.002

*Significant at 5% level of significance
NS Non significant

Appendix IX. Analysis of variance of the data on seedling dry weight of rice seed

Source of variation	df	Mean square of seedling dry weight (g)		
		August	October	December
Storage container (A)	2	0.01*	0.01*	0.01*
Seed moisture content(B)	3	0.09*	0.08*	0.10*
Storage container (A) X Seed moisture content (B)	6	0.004*	0.01*	0.01*
Error	24	0.001	0.001	0.001

*Significant at 5% level of significance
NS Non significant

Appendix X. Analysis of variance of the data on normal seedling no. of rice seed

Source of variation	df	Mean square of normal seedling percentage		
		August	October	December
Storage container (A)	2	70.58*	101.69*	45.86*
Seed moisture content(B)	3	357.96*	329.21*	292.03*
Storage container (A) X Seed moisture content (B)	6	30.55*	43.44*	28.42*
Error	24	13.28	10.58	7.39

*Significant at 5% level of significance
NS Non significant

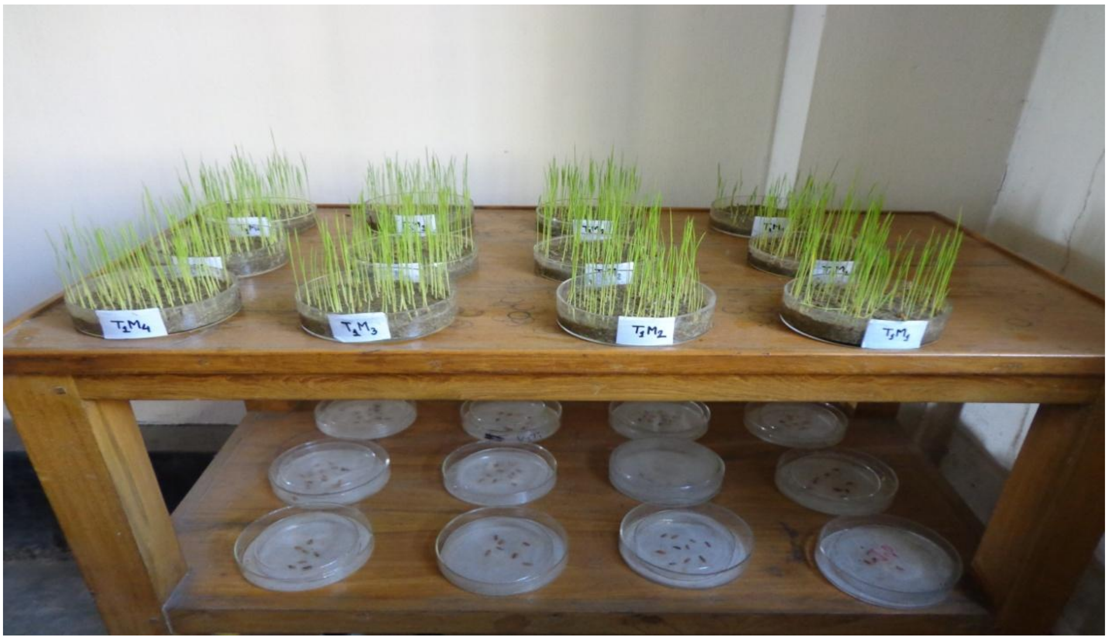
(A)

(B)

(C)

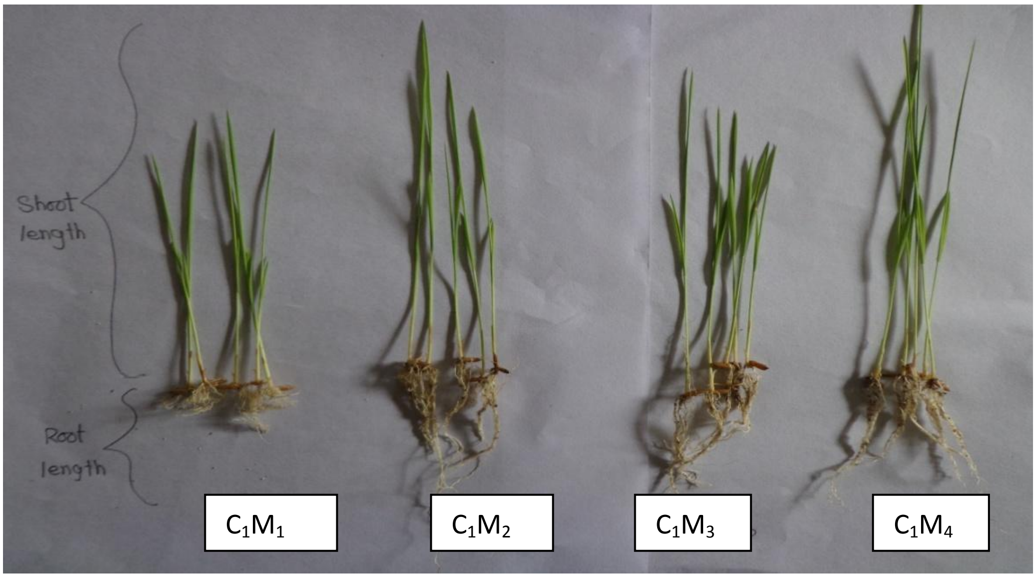
PLATE 01. Three types of earthen pot, (A) coalter coated earthen pot, (B) traditional earthen pot and (C) polythene bag in earthen pot.

(A) Earthen pots in Agronomy lab.



(B) Petri-dishes in Agronomy lab.

PLATE 02. Agronomy lab arrangement for experiment (A) Earthen pots in Agronomy lab and (B) Petri-dishes in Agronomy lab.



(A) Separated seedlings for root, shoot length measurement and fresh weight record

(B) Oven dried seedlings for dry weight record

PLATE 03. Separated seedlings for (A) root, shoot length measurement and fresh weight record and (B) Oven dried seedlings for dry weight record

(A) Soaked seed in bottles for electrical conductivity test

(B) Conductivity meter for recording data.

PLATE 04. Electrical conductivity test in BSMRAU .